Australian Orthodontic Journal

Volume 28 Number 2, November 2012

Contents

Editorial

Original articles

Case reports

Letters

General

Australian
Orthodontic Journal

The *Australian Orthodontic Journal* is published twice a year (May, November) for the Australian Society of Orthodontists Inc. The Journal welcomes articles that contribute to orthodontic knowledge from all sources. Material is accepted for publication on the understanding that it has not been submitted or published, in any format, elsewhere. Neither the Australian Society of Orthodontists Inc. nor the Editor, nor BPA Print accepts responsibility for the views or statements of the authors or the advertisers. For studies involving human subjects, or specimens, a brief statement that subjects' rights have been protected and informed consent was obtained is required. When laboratory animals have been used the appropriate animal use/ethics committee should be acknowledged. These may be given in the covering letter.

The Editor reserves the right to edit all contributions for clarity and style. If the Editor requests additional data forming the basis of the work the authors will make these data available for examination. All articles are peer reviewed. All authors of a manuscript accepted for publication must sign a covering letter assigning copyright to the Journal in the event that it is published. This letter should indicate that the work is original and has not been published (in any language or format) or is under consideration for publication elsewhere. It should also identify the corresponding author, and mention any financial support or relationships that may pose a conflict of interest. The latter statement has no bearing on the decision to publish an article.

Guidelines for contributors can be downloaded from the Journal website (www.aso.org.au/aoj) or obtained from the Journal office (aoj@netcon.net.au)

SUBSCRIPTIONS

The annual subscription rate for 2013 for non-member Individual and Institutional subscribers is A$200 (A$100 per issue), including postage and handling. GST is applicable for Australian subscribers. Postage is by airmail. The Australian Society of Orthodontists will not be responsible for journals that do not reach their destination.

Payment should be made in Australian dollars, by cheque or Australian bank draft payable to: The Subscription Manager, Australian Orthodontic Journal, P.O. Box 576, Crows Nest, NSW 1585, Australia, or by credit card.
Tel: (+61 2) 9431 8666 Fax: (+61 2) 9431 8677
Email: aso@apcaust.com.au

The subscription form can be downloaded from the Journal website: www.aso.org.au/aoj

The *Australian Orthodontic Journal* is indexed and abstracted by Science Citation Index Expanded (SciSearch) and Journal Citation Reports/Science Edition.

Editorial

Patients, clients or customers?

The age of political correctness is changing the way traditionally held values and concepts are viewed. This can be a welcome improvement as contemporary ideology tests entrenched concepts and attempts to initiate change. This is apparent, and also relevant to dentistry, as the medical profession wrestles with the concept of a 'patient' now being termed a 'client', particularly in the business and administrative circles of an institutional environment. Considerable opinion and discussion has appeared in the medical literature, most of which challenges and argues over any alteration in terminology which originally came about in psychiatry to avoid the stigma associated with mental illness.

Is a change in terminology valid in the orthodontic world? Is the recipient of orthodontic care a patient, a client or a customer? The noun 'patient' is derived from the latin word 'patiens', the present participle of the verb, patior, which translates to 'I am suffering'. A patient is literally 'one who is suffering' and is therefore someone who seeks health services because of a need. It could be considered that a patient has no choice and seeks care for the purposes of returning to health and wellbeing. Is it conceivable that a patient in a cardiac unit would enjoy being called a 'heart client'?

This is in contradistinction of a customer who visits a store in order to purchase a new television because their previous set does not meet contemporary technical standards. While it could be argued that the obsolete television has caused social and deprivation anxiety, the customer has the choice to shop around and purchase a modern television or an alternative electrical appliance to provide bargain entertainment. A legal client seeks the services of a lawyer because of a need which could be causing stress and a degree of depression. A legal client is not called a patient, then why should a patient be called a client? In this case, the definition of a client describes a person who engages the professional advice or services of another.

The title of 'patient' carries a degree of responsibility and an obligation to participate in the planned management of the health condition. The careful adherence to treatment instructions and associated compliance would be expected to lead to a successful outcome. The relationship between a health care provider and patient is special, unique and should be built on knowledge, trust and respect. These elements are detailed in health care codes of conduct. The term 'client' empowers the patient to a level of equality with the provider and, in some circles, is considered to diminish the doctor-patient relationship. However, the heart patient, on being told of their condition, is not likely to enter into negotiation and be asked what they would like to do about it; they would be told.

A client has a choice as to whether advice or a service is received. Being a client infers a business transaction from which a service receiver may choose to decline. There is often an expectation that the provider accepts all responsibility for the service or advice. There is little obligation on the part of the client who denies accountability. In orthodontics, there is an expectation on the part of the patient to assist in, and comply with, treatment instructions. The wearing of elastics, the care of the teeth and appropriate and regular attendance are requisites for success. Do orthodontists accept total responsibility and determine that patients bear none for their care? After all, the upsurge in non-compliant appliances, temporary anchorage devices and the placement of long-term bonded retention are perhaps examples of patient denial of responsibility or, at the very least, inadequate compliance and subsequent acceptance by the profession that the onus for success resides with the provider. In these circumstances, patients are receivers of care or a service for which a fee is paid and invites the appellation of client.

In a current society based on blame and the premise that personal misfortune can be attributed to others, a purely orthodontic business client/provider relationship would appear appropriate. The reason for an unsatisfactory and unaccepted orthodontic treatment result is the provider's fault. After all, the client has paid to have their teeth fixed!

However, the orthodontic profession expects that patients become actively involved in their dental care and take a high participatory role in treatment.

Almost certainly, a medical patient would willingly participate in their cancer treatment, take the prescribed course of antibiotics to completion and presumably follow the advice of their trained health care provider. A patient can ultimately be 'cured' but a client can continue to be treated. A rational patient would hardly discontinue treatment when not 'cured' and while their health problem persists.

In the end, the terminology applied to people receiving health care does matter and the type of service received delineates and defines the recipient. However, no profession, apart from health, uses the term patient as it embodies an entitlement of care. In an overarching sense, 'patient' describes 'clients' and 'customers'.

Rather than commodities, the receivers of orthodontic treatment are patients, are they not?

What do you think?

Quod scripsi scripsi

Craig Dreyer

The force-distance properties of attracting magnetic attachments for tooth movement in combination with clear sequential aligners

Angie Phelan,* Peter Petocz,* William Walsh† and M. Ali Darendeliler*

Discipline of Orthodontics, Faculty of Dentistry, University of Sydney* and Surgical and Orthopaedic Research Laboratories, University of New South Wales,† Sydney, Australia

Background: The demand for clear sequential aligner therapy has increased dramatically in recent years. An improved system utilising small neodymium-iron-boron (NdFeB) magnetic attachments has been proposed to enhance appliance capabilities.
Aim: The aim of the investigation was to analyse the force system diagrams produced by small attracting NdFeB magnets to determine, 1) whether the force levels were sufficient to induce tooth movement, 2) the effect of magnet morphology on force characteristics and, 3) the most appropriate magnet dimensions that could be utilised for this application.
Methods: Twenty-nine NdFeB rectangular magnets of varying dimensions were tested. A Mach-1 universal testing machine (Biosyntech Inc, Quebec, Canada) was used to measure the attractive force of pairs of magnets. Measurements commenced with a magnetic pair in contact and subsequently vertically separated a distance of 10 mm at a speed of 12 mm/minute. For all magnetic configurations four repeat measurements were performed on five magnetic pairs of the same size.
Results: The force-distance diagrams for all magnet configurations demonstrated a dramatic decrease in force with increasing magnet separation. Rather than a suggested inverse square law, the experimental data followed an inverse fourth law when an offset determined by a regression analysis was applied to the distance. For the majority of magnets, insignificant forces were attained beyond 2 mm of separation. Magnets with large pole face areas and longer magnetic axes provided the greatest force.
Conclusions: A select range of magnet configurations exhibited suitable and reliable attractive forces and therefore could be advocated for prescribed clinical application.
(Aust Orthod J 2012; 28: 159–169)

Received for publication: March 2012
Accepted: October 2012

Angie Phelan: angie.phelan@gmail.com; Peter Petocz: Peter.Petocz@mq.edu.au; William Walsh: W.Walsh@unsw.edu.au;
M. Ali Darendeliler: adarende@mail.usyd.edu.au

Introduction

The demand for aesthetic orthodontic appliances has increased dramatically in recent years. Consequently, clear sequential aligner therapy has become a popular alternative to fixed appliances. Clear aligner therapy refers to a sequence of clear thermoplastic appliances made on a series of casts with reset teeth, each incorporating small corrective tooth movements.[1] These appliances, which are marketed as practically 'invisible', are considered to be more aesthetically appealing, but despite this, clear aligners are less effective than fixed appliance therapy.[2] Aligners are effective in tooth tipping but have limited effectiveness with other types of movements such as bodily movement, rotations, extrusions and severe intrusion of teeth.[1,3,4]

In an attempt to overcome the movement limitations of aligners, resin attachments may be bonded to selected teeth.[5,6] These attachments increase dental undercuts and retention and therefore facilitate appliance purchase to achieve desired tooth movements.[5] The selection of the appropriate attachment size and shape is influenced by several factors related to dental morphology, the role of the attachment and

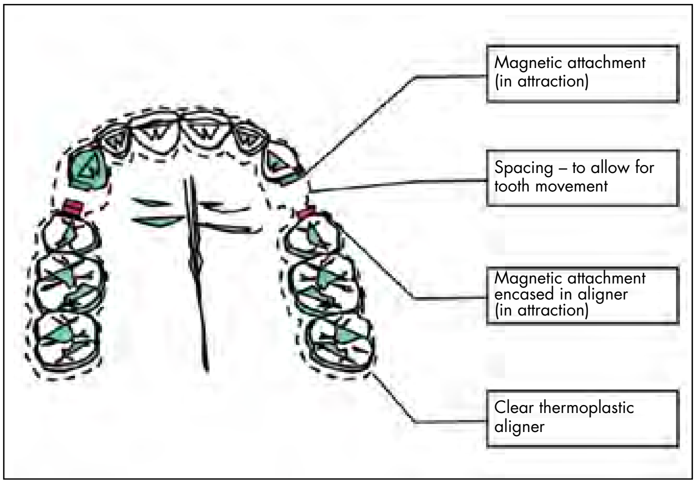


Figure 1. Schematic diagrammatic of the use of neodymium iron boron magnetic attachments for tooth movement in combination with clear sequential aligners.

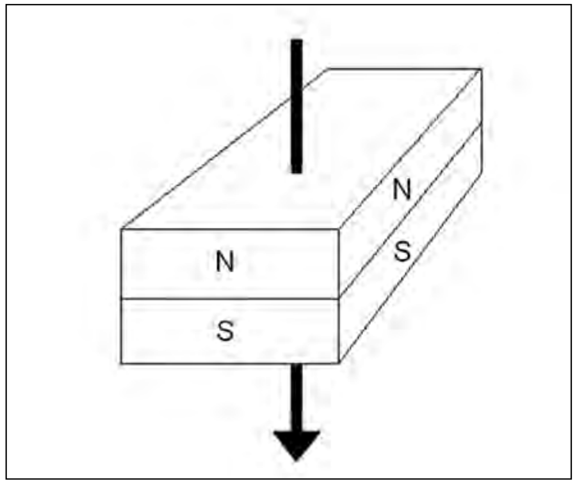


Figure 2. Magnet indicating direction of magnetisation and polarity of magnets used in this investigation.

the desired tooth movement.[5] Unfortunately, the use of attachments has been shown to only be partially effective.[4,6] Given the inherent limitations of clear appliances, they cannot be used routinely in severely crowded cases or as effectively in extraction cases.[7,8]

A system utilising small neodymium-iron-boron (NdFeB) magnetic attachments has been proposed to enhance the capabilities of clear aligners. In this system, a sequential aligning appliance is combined with at least one magnetic attachment positioned in an attractive or repulsive configuration and bonded to the surface of a tooth. A second magnet is encased in the thermoplastic material in the body of the appliance (Figure 1). NdFeB rare earth magnets are reported to provide the highest energy per unit volume of any commercially-available magnetic material.[9] Therefore the use of these magnetic attachments has the potential to create a force interaction that may theoretically make the movement of teeth, in any direction, possible and easier.

Magnetic forces have been used in orthodontics for tooth movement and orthopaedic correction with varying degrees of success.[10] Magnets have several advantages over traditional force delivery systems including a lack of friction, no material fatigue and the ability to produce predictable force levels over long periods of time.[9,10] However, the physical properties of magnets dictate that the attractive force reduces dramatically as the distance between the magnets increases.[11]

The present study aimed to examine the physical properties of attracting NdFeB magnets, used as attachments, to facilitate tooth movement in combination with clear sequential aligners. Specifically, the investigation was to analyse force system diagrams produced by small attracting NdFeB magnets to determine:

1. If the force levels were sufficient to induce tooth movement.
2. The effect of different magnet morphology on force characteristics.
3. The most appropriate dimensions of magnets that could be utilised.

Methods

NdFeB magnets

The magnets were fabricated from a neodymium-iron-boron alloy and were coated with nickel and copper (AMF Magnetics, Sydney, Australia). Commercially-available NdFeB permanent magnets are produced by a powder metallurgy process and are magnetised throughout their thickness (Figure 2).

A range of rectangular magnets of varying dimensions was selected, based on average tooth crown dimensions and the size of conventional rectangular resin attachments used by the Invisalign® system (Align Technology Inc, Santa Clara, CA, USA).[5,12] The dimensions of rectangular Invisalign® attachments vary in height (3, 4 and 5 mm), width (2 mm) and

Table I. The morphology of magnets used in this investigation.

Dimensions (mm)	Thickness				
	0.5	0.75	1	1.25	2
Width x length	1 x 4	0.75 x 5	0.75 x 4	0.75 x 3	3 x 3
	2 x 2	1 x 4	1 x 4	1 x 3	4 x 4
	2 x 3	1 x 5	1.5 x 4	1.5 x 3	
	2 x 4	1.5 x 5	2 x 3		
	2 x 5	2 x 2	2 x 4		
	3 x 3	2 x 3	3 x 3		
	3 x 4	2 x 4	3 x 4		
		2 x 5			
		3 x 3			
		3 x 4			

prominence (0.5 or 1 mm).[5] Twenty-nine different rectangular magnet dimensions were tested (Table I).

Apparatus

A Mach-1universal testing machine employing a 10 kg load cell (Biosyntech Inc, Quebec, Canada) was used to measure the attractive force of pairs of magnets. The lower component of the testing machine was immobile, while the upper component was attached to an electric motor that moved vertically. A customised non-magnetic mounting jig was constructed using aluminium (Figure 3). The base magnet was fixed with adhesive to an aluminium tab which screwed into the inferior component of the jig. The opposing magnet was placed, parallel and above, the base magnet. A small amount of adhesive (Loctite® Super Glue Gel Control™, Henkel, Düsseldorf, Germany) secured the superior magnet to its aluminium tab and the mobile upper jig component which was lowered until magnet to magnet contact was achieved. After five minutes, the upper component was raised to separate the magnetic pair and to confirm adherence. The load cell was calibrated at maximum separation of the equipment.

Measurement commenced with the magnetic pair in contact, following which the magnets were vertically separated to a distance of 10 mm at a speed of 12 mm/minute. There were no standardised instructions available for fixing the force-displacement curves of magnetic attachments (e.g. International Organisation for Standardisation [ISO] norms), consequently the measurement parameters were chosen with reference to previous studies.[13-16] The start position (0 μm) was determined as the position corresponding to the peak tensile force, otherwise known as the 'breakaway' load.[14] Force measurements at varying degrees of separation were recorded in grams and the results recorded electronically. Each measurement was repeated 4 times for every magnetic pair and 5 magnetic pairs were tested for every size. Therefore a total of 20 measurements was generated for each magnet size tested.

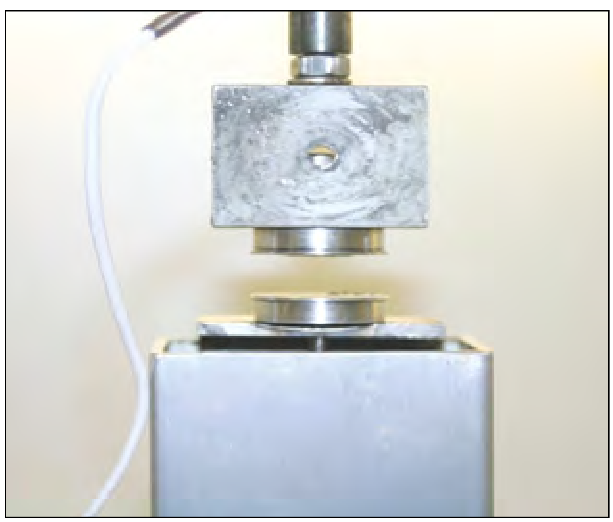


Figure 3. Mach-1 universal testing machine with customised mounting jig.

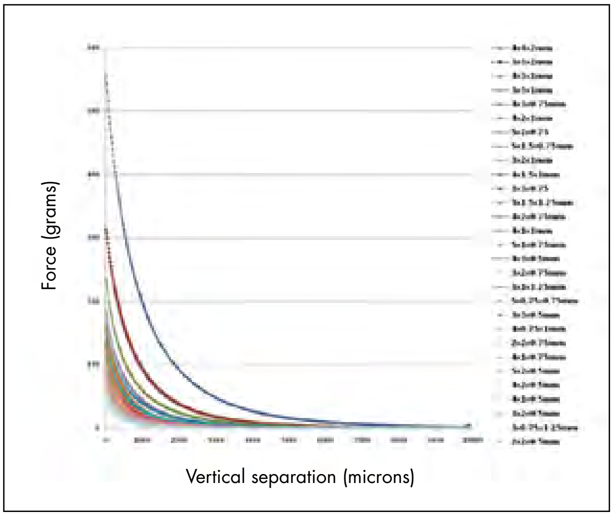


Figure 4. Force-displacement diagrams of the all tested NdFeB magnet configurations.

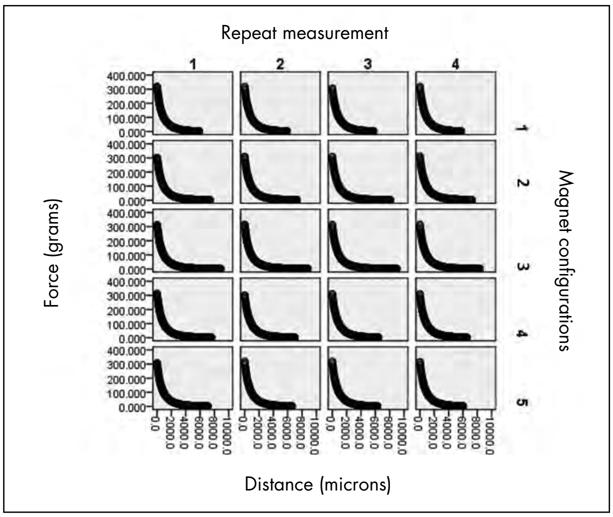


Figure 5. The force-distance diagrams of the 3 x 3 x 2 mm magnet demonstrating the outcomes for repeat measurements of the five magnetic pairs tested.

Measurement error

The presented force-displacement diagrams were constructed from the average of 20 measurements. One-way analysis of variance (ANOVA) for repeated measurements was performed on seven randomly selected magnet sizes. Both intra-magnet and inter-magnet measurement errors were analysed using the Statistical Package for Social Sciences (SPSS for Windows, version 16.0, Chicago, IL, USA).

Results

The average force-displacement diagrams of the 29 magnet configurations measured in the present investigation are depicted in Figure 4. All measurements indicated that the force decreased with increasing magnet separation. High forces were generated at small degrees of separation. The highest peak force of 555 g was produced by the 4 x 4 x 2 mm magnet, followed by the 3 x 3 x 2 mm magnet which produced a peak force of 312 grams. The lowest peak force of 44 g was generated by the 2 x 2 x 0.5 mm magnet (Table II).

Figure 5 demonstrates the force-distance diagrams generated for repeat measurements of one magnet

Table II. Results for the tested magnets with varying morphology.

			Clinically relevant force range	
Dimensions (l x w x h)	Maximum force (grams)	Activation range (microns)	Separation at MINIMUM force 15 g (microns)	Separation at MAXIMUM force 200 g (microns)
4 x 4 x 2	555.16	4181	5171	990
3 x 3 x 2	312.71	2924	3252	328
4 x 3 x 1	235.14	2542	2625	83
3 x 3 x 1	186.92	2072	2072	-
4 x 3 x 0.75	168.14	2020	2020	-
4 x 2 x 1	155.65	1575	1575	-
5 x 2 x 0.75	143.86	1458	1458	-
5 x 1.5 x 0.75	141.45	1285	1285	-
3 x 2 x 1	134.81	1440	1440	-
4 x 1.5 x 1	133.25	1257	1257	-
3 x 3 x 0.75	128.67	1558	1558	-
3 x 1.5 x 1.25	124.14	1315	1315	-
4 x 2 x 0.75	114.82	1218	1218	-
4 x 1 x 1	112.54	969	969	-
5 x 1 x 0.75	107.44	826	826	-
4 x 3 x 0.5	93.96	1127	1127	-
3 x 2 x 0.75	93.19	1066	1066	-
3 x 1 x 1.25	91.26	852	852	-
5 x 0.75 x 0.75	85.90	623	623	-
3 x 3 x 0.5	82.11	988	988	-
4 x 0.75 x 1	74.95	575	575	-
2 x 2 x 0.75	74.43	806	806	-
4 x 1 x 0.75	72.60	594	594	-
5 x 2 x 0.5	67.10	719	719	-
4 x 2 x 0.5	61.99	667	667	-
4 x 1 x 0.5	63.41	497	497	-
3 x 2 x 0.5	60.98	673	673	-
3 x 0.75 x 1.25	56.02	498	498	-
2 x 2 x 0.5	44.10	433	433	-

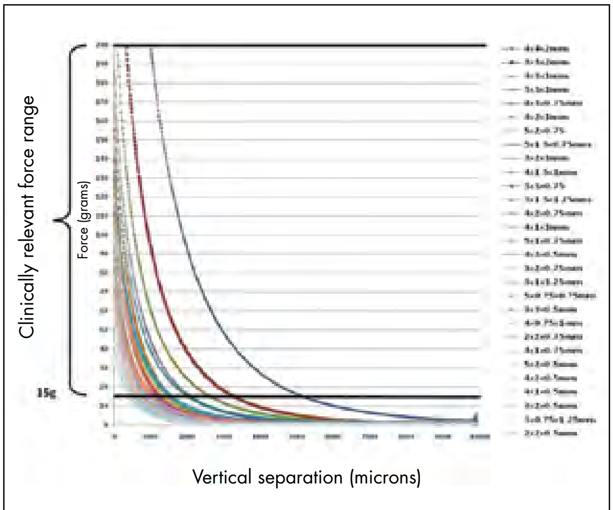


Figure 6. Force-displacement diagrams of the tested NdFeB magnet configurations indicating the clinically relevant force range.

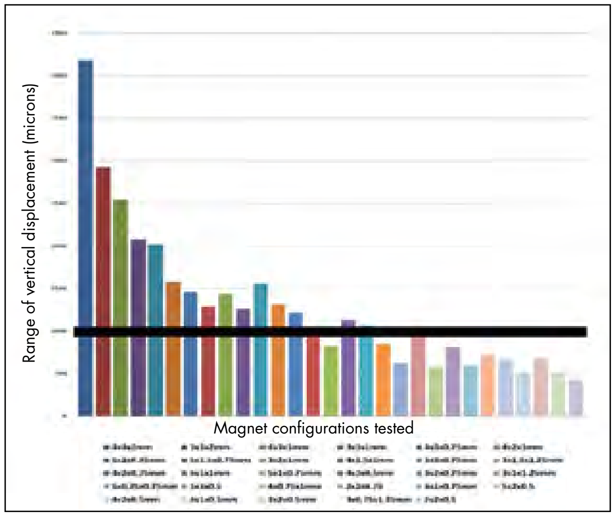


Figure 7. The activation range of each magnet configuration tested. The activation range refers to the range of vertical displacement in microns through which clinically relevant forces of 15-200 grams are generated.

Table III. Analysis of Variance of Repeat Measurements.

		One-way analysis of variance					
		Intra-magnet error			Inter-magnet error		
Magnet dimensions (mm)	Mean	Mean square error	Standard Deviation	% error	Mean square error	Standard Deviation	% error
3 x 3 x 2	312.72	23.53	4.85	1.55	52.41	7.24	2.32
3 x 3 x 1	186.92	12.51	3.54	1.89	307.04	17.52	9.37
2 x 2 x 0.5	44.10	1.88	1.37	3.10	6.35	2.52	5.72
5 x 1 x 0.75	107.44	1.86	1.36	1.27	63.95	7.99	7.44
4 x 2 x 1	155.65	7.42	2.73	1.75	16.84	4.10	2.64
4 x 1.5 x 1	133.25	5.66	2.38	1.79	16.93	4.12	3.09
4 x 4 x 2	555.16	13.67	3.70	0.67	377.76	19.44	3.50

configuration (3 x 3 x 2 mm). For all magnetic configurations, four repeat measurements were performed on five magnetic pairs of the same size. The variance of repeat measurements of an individual magnetic pair ranged from 0.67 - 3.1% of the mean value, while the variance between different magnetic pairs of the same size ranged from 2.32 - 9.37% of the mean value (Table III).

A range of 15-200 grams was chosen to represent clinically relevant force levels associated with tooth movement.[17] Figure 6 illustrates force-displacement curves for the tested magnet configurations and all, except for the three largest, generated peak force within the selected range. The larger magnet configurations of 4 x 4 x 2 mm, 3 x 3 x 2 mm and 4 x 3 x 1 mm, generated a maximum clinical force of 200 g at a vertical separation of 990 µm, 328 µm and 83 µm respectively. The majority of the magnets generated the minimum clinically significant force of 15 g at approximately 2 mm of separation or less. The three largest magnet configurations reached the minimum clinical force of 15 g at a vertical separation of 5171 µm, 3252 µm and 2625 µm respectively. Three magnet configurations, 3 x 0.75 x 1.25 mm, 4 x 1 x 0.5 mm and 2 x 2 x 0.5 mm, reached the minimum force of 15 g at 0.5 mm separation (Table II).

The range of vertical displacement over which clinically relevant forces were generated varied for all magnet configurations. The vertical displacement in microns through which clinically relevant forces

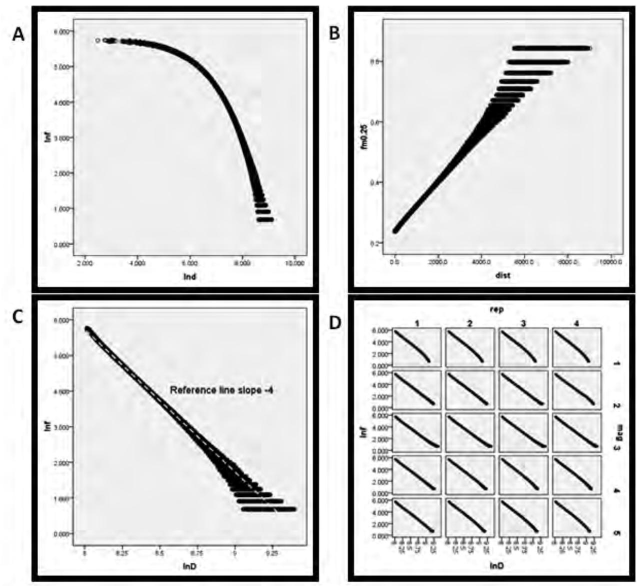


Figure 8. Functional relationship between force and displacement.
A. An exemplary plot of the logarithm of magnetic force against the logarithm of magnetic separation.
B. Standard plot of the logarithm of the inverse fourth root of the force (fm-0.25) against distance demonstrating an approximate linear relationship.
C. Typical plot of the log (force) against the log D (D = distance plus offset) follows a power law with coefficient of -4.
D. Typical plot of the log (force) against the log (distance plus offset) for individual measurements. The results of the 3 x 3 x 2 mm magnet are presented as an example of the typical outcomes.

were generated was deemed to be the activation range for each tested magnet (Table II). A comparison was conducted between the magnet configurations by noting the range of vertical displacement at which the desired force levels were reached (15-200 g, Figure 7). The 4 x 4 x 2 mm magnet had the greatest range of activation and the 2 x 2 x 0.5 mm magnet had the lowest range.

The relationship between force and magnet separation was evaluated by plotting the logarithm of magnetic force against the logarithm of distance. A typical log-log plot is shown in Figure 8A. A distinct curvature was evident in the log-log plot suggesting that the data did not obey the classic inverse square law. By applying a systematic data transformation approach to the results of this study, the inverse fourth root of the force ($fm^{-0.25}$) against distance was found to approximate a linear relationship (Figure 8B). The addition of an offset, obtained by fitting a linear regression of the transformed force variable ($fm^{-0.25}$) against distance (A/B), to the distance, suggested that force versus distance plus offset, follows an inverse fourth power law. Figure 8C demonstrates that the relationship for the log (force) against the log D (distance plus offset) follows a power law with a coefficient of -4. Figure 8D indicates that the relationship was consistent for repeat measurements of individual magnet configurations. The results of the 3 x 3 x 2 mm magnet are presented as an example of the typical outcomes (Figure 8).

Table IV summarises the offset values from the regression analysis for all magnetic configurations and the slope of the resulting plot of log force against log distance plus horizontal offset (D). The results were generally consistent and indicated an inverse fourth power law at small separations of 2 mm or less. The correlations between the offset and magnet dimensions – length (l), width (w), height (h), lw, lh or wh were analysed. The combination of height and cross-sectional area (lw) was highly significant ($p < 0.001$) and exhibited a correlation coefficient of 0.91. The regression on height alone was insignificant with a correlation coefficient of 0.44.

Discussion

The present laboratory-based study examined the force-displacement characteristics of attracting NdFeB magnets to assess if the force levels generated were sufficient to induce tooth movement. Most clinical strategies are based on the assumption that a force magnitude or a range of forces exist that, when applied to the periodontium, will yield an optimal rate of tooth movement.[1,18] The major factor that affects tooth movement is not force magnitude but the distribution of stress generated in the periodontium.[18-21] However, it is difficult to measure stresses and strains within the periodontal ligament and therefore force magnitudes have received significant attention in orthodontics.[19]

In the present investigation, a range of 15-200 grams was chosen to represent a clinically relevant force range. This force range was selected, based on previous investigations of the physical characteristics of magnets used for orthodontic tooth movement.[15,17] Mancini et al.[17] applied a clinically relevant force range of 15-200 g in an investigation of the physical characteristics of NdFeB magnets, whereas von Fraunhofer[15] and co-workers analysed samarium-cobalt magnets over an orthodontic force range of 75-150 grams. However, for comparative purposes, the larger force range of Mancini et al. was selected for this project.[17]

The larger magnet configurations 4 x 4 x 2 mm, 3 x 3 x 2 mm and 4 x 3 x 1 mm generated forces above the clinically accepted force range. High

Table IV. Summary of offset values from linear regression analysis for all magnetic configurations tested.

Magnet dimensions	A	B	Offset (A/B)	Slope	Standard error	Power value
4 x 4 x 2	0.21	0.000057	3667	-4.00	0.002	2.0
3 x 3 x 2	0.24	0.000083	2871	-3.98	0.002	2.0
4 x 3 x 1	0.26	0.000096	2719	-3.94	0.004	2.0
3 x 3 x 1	0.27	0.000116	2353	-4.01	0.003	2.0
4 x 3 x 0.75	0.29	0.000111	2568	-3.90	0.005	2.0
4 x 2 x 1	0.28	0.000157	1796	-4.24	0.014	2.0
5 x 2 x 0.75	0.29	0.000156	1853	-3.98	0.011	2.0
5 x 1.5 x 0.75	0.29	0.000179	1615	-4.08	0.010	2.0
3 x 2 x 1	0.29	0.000150	1960	-3.95	0.008	2.0
4 x 1.5 x 1	0.29	0.000173	1702	-4.04	0.010	2.0
3 x 3 x 0.75	0.30	0.000136	2197	-3.97	0.005	2.0
3 x 1.5 x 1.25	0.30	0.000162	1846	-3.97	0.008	2.0
4 x 2 x 0.75	0.31	0.000173	1763	-3.93	0.026	2.0
4 x 1 x 1	0.31	0.000207	1488	-3.83	0.013	2.0
5 x 1 x 0.75	0.31	0.000252	1224	-4.11	0.018	2.0
4 x 3 x 0.5	0.32	0.000169	1905	-3.94	0.013	2.0
3 x 2 x 0.75	0.32	0.000180	1783	-3.96	0.013	2.0
3 x 1 x 1.25	0.32	0.000220	1473	-3.93	0.007	2.0
5 x 0.75 x 0.75	0.33	0.000287	1143	-3.82	0.020	2.0
3 x 3 x 0.5	0.33	0.000171	1953	-3.82	0.011	2.0
4 x 0.75 x 1	0.34	0.000289	1176	-3.78	0.022	2.0
2 x 2 x 0.75	0.34	0.000222	1529	-4.02	0.016	2.0
4 x 1 x 0.75	0.34	0.000266	1179	-4.02	0.017	2.0
5 x 2 x 0.5	0.35	0.000218	1610	-3.88	0.011	2.0
4 x 2 x 0.5	0.36	0.000230	1552	-3.94	0.017	2.0
4 x 1 x 0.5	0.35	0.000334	1054	-4.13	0.017	2.0
3 x 2 x 0.5	0.36	0.000219	1642	-3.88	0.014	2.0
3 x 0.75 x 1.25	0.36	0.000288	1264	-3.93	0.014	2.0
2 x 2 x 0.5	0.39	0.000273	1422	-3.95	0.012	2.0

orthodontic forces are considered to be harmful due to the risk of high bone stress, root resorption, soft tissue dehiscences or loss of supporting bone.[16,22-24] Therefore, to avoid potential complications, the pole distance of these magnets would need to be clinically monitored.

The force-distance diagrams for all magnet configurations demonstrated a dramatic decrease in force with increasing magnet separation. This could equally be stated as an increasing force gradient as separation decreased, which is clinically applicable with the use of attractive magnets. Burstone[21] suggested that it might be biologically preferable to use an increasing gradient appliance. The rationale was that, as the periodontal ligament widened following orthodontic tooth movement, increasing forces might be required, as tooth mobility and vascularity had increased.

Table V. Dimensions of the magnets with the most clinically useful force characteristics and range.

Dimensions (mm)	Thickness		
	0.5	0.75	1
Width x length	3 x 4	1.5 x 5	1.5 x 4
		2 x 3	2 x 3
		2 x 5	2 x 4
		2 x 4	3 x 3
		3 x 3	
		3 x 4	

A range of magnets of varying configurations was examined. According to Vardimon et al.,[11] the performance of a magnetic system may be enhanced by increasing the length of the magnet which extends its magnetic axis. Alternatively, increasing the width of a magnet extends the pole surface area. The main factor in determining the maximum attractive force is the length of the magnetic axis representing the distance between the two magnetic poles. Increasing the width of the magnet affects the slope of the force-distance curve.[11] The present results support the conclusion that the largest pole face area and magnetic axis length generated the highest forces.

The inverse square law was not found to apply to the present experimental data. According to Coulomb's law, the force produced by any two magnets is inversely proportional to the square of the distance between them.[11,16,17,25,26] Although mention has been made of the application of the inverse square law in the dental literature,[11,16,17,25,26] many authors presented curves without comment on the functional relationship,[13,27,28] or reported that the law only 'approximately' applied.[16,25] Confusing alternate relationships have been previously documented, reporting that magnetic force, 'initially decreases as the square of the distance and subsequently, as the cube of the distance'[26] and an 'inverse square-root' relationship applied at small distances.[15]

The present study determined that an inverse fourth law operated when an offset was applied to the separation distance. The offset was obtained by fitting a linear regression of the transformed force variable (fm-0.25) against distance. The finding of a non-inverse square force-distance law is consistent with the results of Darvell and Dias[14,29] who found that an inverse square law did not apply for long thin magnets. Data demonstrated that the expected force-distance relationship approached an inverse fourth power law.[14,29] The rationale of Darvell and Dias considered that the commonly used elementary view of a simple dipole magnet was of little value in understanding the force-distance relationship at small distances.[14] It had previously been assumed that the surface of a magnet provided the appropriate reference plane for measuring distance and the variation in force was a simple distance function.[9,14] However, there is no known evidence which indicates that the functional pole resides at the magnet face.[14]

An offset, obtained by fitting a linear regression to the data, was added to the distance in order for the inverse fourth law relationship to apply. The offset adjusted the distance for differences in the physical size of the magnets and it was found that the offset increased with increasing height and cross-sectional area of the magnets ($p < 0.001$; correlation coefficient 0.91). Considering the offset was dependent on the physical characteristics of the magnet, as Darvell and Dias[14] suggested, it may represent the deviation of the apparent pole position from the end of the magnets.

Thermoplastic appliances can achieve 0.25 - 0.5 mm of tooth movement per aligner, therefore the proposed magnetic attachments must deliver clinically useful forces over this range to be of benefit.[1,5,30] The clinical use of magnets requires the application of a coating material applied to attach the magnet to the tooth surface and to prevent corrosion.[31,32] Therefore, the active range of a magnetic attachment should be greater than 1000 μm to account for the thickness of the coating material and the amount of tooth movement achievable by current thermoplastic appliances. It was intended that new magnetic attachments would be no larger than currently-used and commercially-available rectangular resin attachments. Based on the above criteria, eleven magnet configurations were deemed suitable for use as magnetic attachments in combination with clear sequential aligners (Table V).

The difference in force between individual magnet pairs was found to range from 2.32 – 9.37%. This compares favourably with the results of Bondmark and Kurol[16] who indicated a similar level of variation for repelling samarium-cobalt magnets. A variation of 6-9% was considered low and therefore the magnets

(a) (b)

Figure 9. Clinical example.
(a) Initial oral view. (b) Initial root angulation of central incisors.

(a) (b) (c)

Figure 10. Start of treatment.
(a) Magnetic attachments placed inter-proximally initially. (b) 0.8mm clear thermoplastic appliances with space for the desired tooth movement. (c) A stainless steel wire (016") was bonded to the lingual surfaces of the 13, 12, and 11 to prevent movement of these teeth, as the facial midline was coincident with the mesial surface of the 11.

could be routinely used without measuring the force of an individual pair.[16] Given that a similar variation was found in the present investigation, the conclusion of Bondmark and Kurol was supported.

The present study measured the force-displacement characteristics of a range of magnets in the vertical dimension with the magnet surfaces parallel to each other. If the magnets were applied clinically as attachments in combination with clear sequential aligners, it is unlikely that such conditions would be replicated and the magnets could be displaced in all three planes of space. Mancini et al.[17] found that horizontal displacements and angulations significantly reduced the pole face overlap, which directly affected the magnetic flux density and direction and therefore the force of attraction. Since both forces and moments work in all three planes, the effective force system acting on a tooth should be represented in three-dimensions.[33] While 3D forces and moments generated by magnetic devices have been previously measured,[11,33,34] a recommendation for future research is the characterisation of the three-dimensional force-displacement and moment-displacement diagrams of the most ideal magnetic attachments identified in the present investigation.

Clinical example

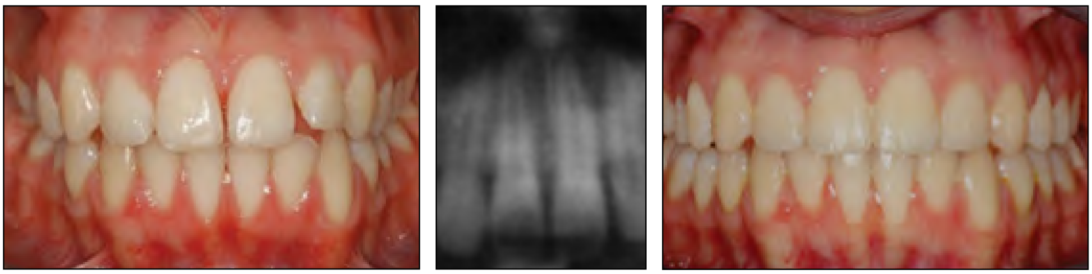
The following clinical example demonstrates the potential for magnetic attachments to expand the capabilities of clear sequential aligner therapy. A patient presented with a 5 mm diastema due to a broken upper fixed retainer which had debonded from tooth 22 (Figure 9). A desire to avoid retreatment with conventional fixed appliances was expressed.

NdFeB magnetic attachments (5 x 1.5 x 0.75 mm) were bonded indirectly to the central incisors using a conventional acid-etch technique. The magnetic attachments were initially placed on the mesial surfaces of the central incisors and then on the buccal surface as the space reduced. The magnets were plated with nickel and copper and coated with composite resin to provide an impermeable barrier. The barrier was designed to prevent ionic diffusion which would lead to corrosion, as well as facilitate the attachment of magnets to the teeth.[35]

A magnetic force was generated over a 3.72 mm range and reached a maximum of 141 grams. The theoretical maximum force was not reached as the resin coating material prevented full contact of the magnets. The patient was provided with 0.8 mm clear thermoplastic

(a) (b) (c)

Figure 11. Treatment progress.
(a) Three weeks in treatment. (b) Eight weeks in treatment. (c) Twelve weeks in treatment.



(a) (b) (c)

Figure 12. Treatment completion.
(a) Phase 1 diastema closed in 15 weeks. (b) Minimal tipping of central incisors. (c) Final oral view phase 2 with Invisalign treatment completed in 23 upper aligners and 28 lower aligners.

appliances (Erkodur, Erkodent®, Pfalzgrafenweiler, Germany) which incorporated space for the desired tooth movement (Figure 10). The patient was advised to wear the appliance full time except when oral hygiene was undertaken.

The objective of the initial phase of treatment using clear thermoplastic appliances in combination with magnetic attachments was confined to reduction of the diastema which closed in 15 weeks with minimal tooth tipping (Figures 11 and 12). Additional conventional sequential aligner therapy was directed at closing small residual spaces and achieving ideal alignment of the anterior teeth. This phase of treatment was completed using 23 upper aligners and 28 lower aligners (Figure 12c).

Conclusions

Based on the results of the present study the following conclusions may be drawn:

1. The neodymium-iron-boron magnet configurations examined displayed varying levels of clinical usefulness.
2. Magnet morphology affected clinical properties and performance.
3. A select range of magnet configurations exhibited suitable and reliable attractive forces and therefore could be advocated for clinical application as magnetic attachments in combination with clear sequential aligners.

Corresponding author

Professor M. Ali Darendeliler
Discipline of Orthodontics
Faculty of Dentistry
The University of Sydney
Level 2, 2 Chalmers Street
Surry Hills NSW 20120
Australian Society of Orthodontists

Email: adarende@mail.usyd.edu.au

References

1. Proffit WR, Fields HW, Sarver DM. Contemporary Orthodontics. 4 ed. St Louis: Mosby; 2007:402-7.
2. Djeu G, Shelton C, Maganzini A. Outcome assessment of Invisalign and traditional orthodontic treatment compared with the American

Board of Orthodontics objective grading system. Am J Orthod Dentofacial Orthop 2005;128:292-8.
3. Kravitz ND, Kusnoto B, BeGole E, Obrez A, Agran B. How well does Invisalign work? A prospective clinical study evaluating the efficacy of tooth movement with Invisalign. Am J Orthod Dentofacial Orthop 2009;135:27-35.
4. Joffe L. Invisalign: early experiences. J Orthod 2003;30:348-52.
5. Tuncay OC. The Invisalign System. London: Quintessence Publishing; 2006:112-113.
6. Kravitz ND, Kusnoto B, Agran B, Viana G. Influence of attachments and interproximal reduction on the accuracy of canine rotation with Invisalign. A prospective clinical study. Angle Orthod 2008;78:682-7.
7. Giancotti A, Greco M, Mampieri G. Extraction treatment using Invisalign Technique. Prog Orthod 2006;7:32-43.
8. Boyd RL. Complex orthodontic treatment using a new protocol for the Invisalign appliance. J Clin Orthod 2007;41:525-47.
9. Noar JH, Evans RD. Rare earth magnets in orthodontics: an overview. Br J Orthod 1999;26:29-37.
10. Darendeliler MA, Darendeliler A, Mandurino M. Clinical application of magnets in orthodontics and biological implications: a review. Eur J Orthod 1997;19:431-42.
11. Vardimon AD, Graber TM, Drescher D, Bourauel C. Rare earth magnets and impaction. Am J Orthod Dentofacial Orthop 1991;100:494-512.
12. Romaniuk K, Kruger BJ. Anatomy of the human skull, jaws, teeth and muscles of mastication. St. Lucia: Dept. of Oral Biology and Oral Surgery, University of Queensland; 1989:34-78.
13. Boeckler AF, Morton D, Ehring C, Setz JM. Mechanical properties of magnetic attachments for removable prostheses on teeth and implants. J Prosthodont 2008;17:608-15.
14. Darvell BW, Dias AP. Non-inverse-square force-distance law for long thin magnets. Dent Mater 2006;22:909-18.
15. von Fraunhofer JA, Bonds PW, Johnson BE. Force generation by orthodontic samarium-cobalt magnets. Angle Orthod 1992;62:191-4.
16. Bondemark L, Kurol J. Force-distance relation and properties of repelling Sm-Co5 magnets in orthodontic clinical use: an experimental model. Scand J Dent Res 1992;100:228-31.
17. Mancini GP, Noar JH, Evans RD. The physical characteristics of neodymium iron boron magnets for tooth extrusion. Eur J Orthod 1999;21:541-50.
18. Quinn RS, Yoshikawa DK. A reassessment of force magnitude in orthodontics. Am J Orthod 1985;88:252-60.
19. Ren Y, Maltha JC, Kuijpers-Jagtman AM. Optimum force magnitude for orthodontic tooth movement: a systematic literature review. Angle Orthod 2003;73:86-92.
20. Tanne K, Sakuda M, Burstone CJ. Three-dimensional finite element analysis for stress in the periodontal tissue by orthodontic forces. Am J Orthod Dentofacial Orthop 1987;92:499-505.
21. Burstone CJ. The biophysics of bone remodelling during orthodontics - optimal force considerations In: Norton LA, Burstone CJ, ed. The biology of tooth movement. Boca Raton: CRC Press; 1986: 321-33.
22. Bondemark L, Kurol J. Proximal alveolar bone level after orthodontic treatment with magnets, superelastic coils and straight-wire appliances. Angle Orthod 1997;67:7-14.
23. Brezniak N, Wasserstein A. Root resorption after orthodontic treatment: Part 2. Literature review. Am J Orthod Dentofacial Orthop 1993;103:138-46.
24. Chan E, Darendeliler MA. Physical properties of root cementum: Part 5. Volumetric analysis of root resorption craters after application of light and heavy orthodontic forces. Am J Orthod Dentofacial Orthop 2005;127:186-95.
25. Blechman AM. Magnetic force systems in orthodontics. Clinical results of a pilot study. Am J Orthod 1985;87:201-10.
26. Blechman AM, Smiley H. Magnetic force in orthodontics. Am J Orthod 1978;74:435-43.
27. Okuno O, Ishikawa S, Imuro FT, Kinouchi Y, Yamada Y, Nakano T, et al. Development of sealed cup yoke type dental magnetic attachment. Dent Mater J 1991;10:172-84.
28. Tegawa YY. Influences on attractive force in different clinical use of a cup yoke magnetic attachment. J Jpn Soc Mag Dent 1996;5:31-7.
29. Dias AP, Darvell BW. Physics, use and design of dental magnets. J Jpn Soc Mag Dent 1998;7:12-17.
30. Barbagallo LJ, Shen G, Jones AS, Swain MV, Petocz P, Darendeliler MA. A novel pressure film approach for determining the force imparted by clear removable thermoplastic appliances. Ann Biomed Eng 2008;36:335-41.
31. Bondemark L, Kurol J, Wennberg A. Biocompatibility of new, clinically used, and recycled orthodontic samarium-cobalt magnets. Am J Orthod Dentofacial Orthop 1994;105:568-74.
32. Kitsugi A, Okuno O, Nakano T, Hamanaka H, Kuroda T. The corrosion behavior of Nd2Fe14B and SmCo5 magnets. Dent Mater J 1992;11:119-29.
33. Drescher D, Bourauel C, Thier M. Application of the orthodontic measurement and simulation system (OMSS) in orthodontics. Eur J Orthod 1991;13:169-78.
34. Vardimon AD, Bourauel C, Drescher D, Schmuth GP. 3-D force and moment analysis of repulsive magnetic appliances to correct dentofacial vertical excess. J Dent Res 1994;73:67-74.
35. Sandler JP. An attractive solution to unerupted teeth. Am J Orthod Dentofacial Orthop 1991;100:489-93.

A qualitative investigation of specialist orthodontists in New Zealand: Part 2. Orthodontists' working lives and work-life balance

Kieran J. Soma,* W. Murray Thomson,† Kate C. Morgaine† and Winifred J. Harding†
Private practice, Mont Albert, Victoria, Australia* and Department of Oral Sciences, Sir John Walsh Research Institute, Faculty of Dentistry, The University of Otago, Dunedin, New Zealand†

Background: Orthodontics is the most widely practised form of specialist dentistry in New Zealand. To date, no known qualitative research has been published examining the work-life balance of practitioners. The aim of this study was to investigate the working lives and work-life balance of NZ orthodontists in order to generate an understanding of the reality of orthodontic specialist practice and its effects on orthodontists' professional and personal lives.
Methods: Semi-structured interviews were conducted involving 19 practising orthodontists (four females, 15 males; mean age 50 years) from throughout New Zealand and selected for maximum variation in the sample. Transcribed interviews were analysed for themes using an applied grounded theory approach.
Results: A core category of 'practising orthodontist' was derived, and related themes were grouped under the sub-categories of: (a) NZ orthodontic specialist practice; (b) NZ specialist orthodontists; and (c) Work-life balance. The present paper reports on the final sub-category. Themes emerging from the work-life sub-category were further divided into two sub-themes of 'work' and 'life'. Themes in the 'work' sub-group included time off, injuries and illness, regrets, personality traits, job stress and criticism, establishing a practice, peer support and contact, and success in orthodontics. Themes in the 'life' sub-group were personal development, family life, life balance and interests outside work, and financial security.
Conclusions: This was the first qualitative investigation of the orthodontic profession in New Zealand. The findings provided a valuable insight into the working lives of New Zealand orthodontists and effects on their day-to-day lives. It will be revealing and interesting to observe how the modernisation of orthodontic practice will affect the work-life balance of New Zealand orthodontists in the future.
(Aust Orthod J 2012; 28: 170–180)

Received for publication: February 2012
Accepted: June 2012

Kieran J. Soma: Kieran_soma@hotmail.com; W. Murray Thomson: murray.thomson@otago.ac.nz;
Kate C. Morgaine: kate.morgaine@otago.ac.nz; Winifred J. Harding: winfred@southnet.co.nz

Introduction

An adequate work-life balance and the appropriate management of job stressors are essential for career satisfaction and a healthy life.[1] Dentistry is accepted as a stressful profession,[2] and stress-related disorders are a common cause of early retirement.[3] However, there is a paucity of information on orthodontics.

Job satisfaction is defined as a pleasurable or positive emotional state resulting from the appraisal of one's job or job experiences, while occupational stress is defined as aspects of work which have (or threaten to have) negative effects.[4,5] Roth and co-workers investigated occupational satisfaction and stress among Canadian orthodontists using a conventional survey. It was found that 80% of participating orthodontists were satisfied overall with their job, but it was concluded that occupational stress in the orthodontic setting exists, is important and affects several facets of job satisfaction.[4] Moreover, effective time management was highlighted as an integral component in reducing occupational stress.[5] An early study of stress among

US dental professionals found that coronary heart disease was significantly higher in the disciplines judged to have the highest stress (general practice and oral surgery) than in those with the least stress (periodontics). Orthodontic respondents fell in between.[6] A more recent UK study among junior dentists reported stress levels comparable to those of restorative dentists and oral surgeons, but also showed less stress and 'burnout' among orthodontists.[7]

Qualitative studies have examined job satisfaction and job stressors in dentistry,[8,9] but none have been conducted of the orthodontic profession. It is likely that earlier quantitative investigations (surveys) have missed important facets of orthodontists' working and personal lives because inappropriate questions have been asked. Qualitative research offers the opportunity for in-depth exploration and exposition of the salient aspects of professional lives. The aim of this study was to investigate NZ orthodontists' work-life balance in order to generate an understanding of the reality of orthodontic specialist practice and its effects on the professional and personal lives of orthodontists.

Methods

A full description of the study approach was provided in an earlier paper.[10] In brief, semi-structured interviews were conducted with 19 practising specialist orthodontists (four females, 15 males; mean age 50 years) throughout New Zealand. Owing to the small number of orthodontists, all efforts were made to make the transcripts anonymous and preserve the privacy of participants prior to analysis. Excerpts used for reporting were referenced by identification numbers. The validity of the interview data was enhanced by member-checking, in which each transcript was emailed to the participating orthodontist for clarification and accuracy verification. Each participant was given the opportunity to edit or clarify the data, as necessary.

All transcribed interviews were analysed for themes using an applied grounded theory approach. A core category of 'practising orthodontists' was derived, and related themes were grouped under the sub-categories of: (a) NZ orthodontic specialist practice; (b) NZ specialist orthodontists; and (c) Work-life balance. The current paper reports on the latter.

Codes were used to identify data-driven themes, as outlined in Figure 1 in Part I.[10] A qualitative data analysis computer software package (NVivo software, Version 8) was used to organise and analyse the unstructured data, allowing the researcher to identify patterns and cross-examine information in a multitude of ways. Structured data relating to each theme were exported into a Microsoft Word document for further analysis.

Results

In keeping with the qualitative research approach, the following results (which pertain to orthodontists' work-life balance) are presented in a discursive format. Some general observations are made first, after which findings are presented and discussed under the two subthemes of 'work' and 'life'. Italicized direct quotes are for illustrative purposes.

There was (and perhaps still is) a perception that the practice of orthodontics is low in stress and allows for a good work-life balance. In reality, however, several respondents highlighted an unsatisfactory work-life balance, particularly at the start of their careers. For many, this was not corrected during their practising career, despite their best intentions.

> *As I get older, I would like to have more time to do the other things – I don't think, I didn't make the time when I was younger and came close to sort of burning out doing too much that had to do with work… (Interview 1)*
>
> *The job's the priority at the moment. My job's a priority. And I've been doing a lot of work on the practice management side and that's taken up a lot of time. (Interview 13)*

Those who were happier with their existing work-life balance tended to be older and have no financial interest in the running of the practice; alternatively, they had been able to compartmentalise their orthodontic career.

> *It's just a small part of my life. It's an important part, but it's not, I don't think, it's not who I am. I'm not my job… it's got a flexibility. If I can plan far enough ahead. If I need to plan, it gives me the flexibility to do what I want to. (Interview 12)*

The factors which affected clinicians and their perceived work-life balance were primarily age and experience, their utilisation of modern orthodontic technology, their use of auxiliaries, and their hours of work. Several practitioners identified long work hours (of between 10 and 12 hours a day), with additional evening hours spent in treatment planning and customising arch wires. It was not uncommon for practitioners to visit the practice during the weekend in order to plan treatment. Some were able to access their software from home and work from there.

It was even suggested that the ideal work-life balance was elusive. Unforeseen circumstances at home or work could upset the balance, and what was appropriate one week might not be the next. A reduction in office hours would assist but was not economically feasible, because staff still needed to be paid and facilities needed to be maintained. It was suggested that orthodontists could earn enough working three days a week, but, for reasons of best utilising staff and facilities, a reduction of working hours was seen as a waste of resources.

Orthodontics is generally a very flexible profession, as long as adequate planning takes place. It is very difficult to rebook 40 patients when the orthodontist is ill or needs a day off. Many patients travel considerable distances to be seen. Many orthodontists identified 'time off' as being the most difficult aspect of an orthodontic career.

Some orthodontists have adjusted well. This has been particularly helped by the reduction of clinical hours, and the implementation of orthodontic software. Technological advances in orthodontic materials have also made clinical practice more efficient.

> *It's certainly better than what it was…the hours I'm doing now are probably 10 hours a week less than what I was… getting rid of the Saturday was one of the best things I ever did. There's some real positive things come out which are going to help me, like…the Orthocad system with the computerisation of the models. (Interview 15)*

Maintaining a good work-life balance was shown to be important not only for personal health, but also for the people around them. A well-balanced 'boss' was able to work more efficiently, have better staff relations and have a happier home life. Some believe that the financial freedom that the job allows/compensates for the longer working hours, because it permits more expensive hobbies and other pastimes. No matter how hard some orthodontists tried to leave tasks at work or switch off, it was suggested that this was something that came with maturity in the profession. Life could sometimes get too hard and it was important to detect and manage this early.

> *You always feel like you maybe should be doing, dictating some letters or doing something. There's always a little bit of backlog lying around that you'd feel a whole lot better if it wasn't there. (Interview 2)*
>
> *I had to seek psychiatric help from a good friend for counselling, because I was getting really, really stressed with two young kids, building practice, busy, I could see that it was getting stressful. So I managed to nip the bud early. (Interview 4)*

It is suggested that there has to be a considerable and conscious effort to maintain or achieve the desired work-life balance. The following section presents the findings on work-life balance by separating out factors relating to work and home and discussing these in more detail.

Work

Several work-related factors relating to orthodontic practice and the orthodontic profession were noted to impact on orthodontists at a more personal level. These included time off, dealing with injuries and illness, regrets, personality traits, job stress, dealing with criticism, setting up practice, professional support, peer contact, and success in orthodontics.

Time off

Time off was considered to be the most difficult issue for orthodontists, due to an ongoing need for patient care. On average, most orthodontists took approximately 6 weeks off a year, including time off for conferences or work-related trips. A range of 4 to 10 weeks was noted, with generally a three-week break over the Christmas period (a time when a significant proportion of patients were also away). Practitioners with children would also often take time off during school holidays.

> *Orthodontics is difficult compared to, pretty much, the rest of the profession because you've got that ongoing group of people that need to be seen. So you just can't say "I'm going to take a month off", because you've got a whole lot of people in braces that you're going to need to see for their six or eight-weekly checks. They're getting breakages and then, you know, all that sort of stuff, so I'm kind of*

envious of people that can just shut their book for a month and disappear, but it's not an option for us. And there aren't locums around that you can just chuck in there and fill the gap. So that's certainly something that I think is difficult about orthodontics. You can't – it's hard to take a prolonged holiday. (Interview 14)

The duration of any extended holiday was limited to between 3 and 6 weeks at a time, depending on the orthodontist. This was also an issue with illness or injuries. It was highlighted that excessive time off would require a locum tenens to cover for the practice. Preferentially, most orthodontists did not do this because of locum scarcity, different working styles, and the substantial financial costs involved. Moreover, locum orthodontists are generally not available in New Zealand because of the small number of practitioners. Locums were considered to be expensive, difficult to find, and sometimes not compatible with the principal's working style. This was particularly apparent with overseas locums.

Arranging locums I imagine would be very difficult, given the workforce at the moment. It comes down to whether you are happy to leave your practice in the hands of someone even if you know them and trust them. And if you don't you probably won't. (Interview 11)

At the time of the study, there was one locum orthodontist available. The possibility of retired practitioners taking on locum work now also appears to be limited, because of recent changes in the requirements (most notably continuing professional development, CPD) for maintaining a current annual practising certificate. Most practitioners preferred to take short planned breaks rather than use a locum, and limited 'cover' would be arranged for patients, usually from colleagues nearby.

It was recognised that the problem of time off from orthodontics was not often perceived as an issue prior to specialisation. Time off was also seen as an important factor in a satisfactory work-life balance, and was routinely scheduled by either the orthodontist (or his/her partner) well in advance. Significant foresight and planning was required at least 6 weeks prior to any time off in order to accommodate the rescheduling of patients. Many orthodontists tried to fit in an overseas holiday at least once a year. A preference to split work holidays from personal holidays was evident, despite the potential tax benefits of the former.

…we decided to just keep the work and the holidays separate as much as possible from now on. Also, it means my wife goes with me and she's stuck with the kids for three or four days while I'm away at a study group, and it's no holiday for her. So she was kind of the driver behind that. People do different things. I know some people are just dead keen to go to the tropical islands and write it all off, and that's cool. (Interview 15)

Holidays are holidays. I try not to combine the two. Early on, I found that, when I tried to combine a holiday with a conference or a meeting somewhere, each would ruin the other. While I was on the course or programme, I'd be thinking of what I was going to be doing next week or what I was doing last week. And while I was on holiday, I'd be thinking of the meeting I'd just been to. So, I find it easier just to separate them completely. (Interview 17)

New practitioners setting up practice were perhaps the most affected, as a significant proportion of their time, energy and finances invested into the practice rather than considerations of relaxation. This was noted as a period of potential burn-out for orthodontists.

Time off could also be a family problem for childbirth or funerals. Childbirth required advance scheduling and/or the possible use of locums. Death and funerals were generally unforeseen, and so were very difficult to accommodate. Patients were also often less understanding than perhaps in the past.

I just dread, you know, when somebody's mother dies, I think oh, God, I've got to go to that funeral, how the hell am I going to get time to push patients aside. Where am I going to put them? … but you ring somebody from [out of town] or something who's coming in and they've arranged their whole family for that trip into [Practice Location] and you ring and say "can't see you today". They're not happy about that. Before they'd have understood if you mentioned the word 'funeral' but even so, some of them are not so graceful about it now. And that's the worst aspect of the whole thing. Probably that's the downside of the whole business. (Interview 21)

Injuries and illness

Injuries were common among orthodontists. Some were related to repetitive workplace tasks or posture, and others were attributed to events or activities outside orthodontics. Common strain injuries affected areas such as the neck, back and arms. Postural and strain injuries were considered to be no worse than those encountered in general dentistry. Participants also acknowledged the potential for allergies (to latex) and needle-sticks (from archwires).

Little injuries, little health problems, you know if you get a cold you put a mask on and two cotton rolls up your nose and you keep going whereas your staff stay at home for four days. It's just what you do when you're the boss and the more you're working the harder it is to take time off to be honest because there's just nowhere to put those patients. (Interview 1)

More significant health issues related to heart disease or a terminal illness when the individual or family was directly affected. Again, it was highlighted that the unavailability of specialist cover could be a concern at these times. Patients were also identified as being unsympathetic to such situations.

…I had quite a big [health scare] 10 or 11 years ago, and I'm conscious of the fact that at some stage I've got to get out of practice or die in practice, and it is just difficult for me to do, in that, if you die in practice, there's an awful lot of loose ends that someone's got to take over, and to get out of practice alive you've got to either find someone to take it over or you've got to wind it down, and once you start winding it down, the costs to income, the balance gets pretty mucked up. So it is a difficult decision to do. (Anonymous)

"…I think I probably saw the other side of that, [orthodontist with a terminal family member]…and we just said you've got to go, [they're] dying. And patients whinged about having to have their appointments changed. Or we took his book and just put them across into mine and we worked kind of early and late and through lunchtimes and stuff to see them, and people would say "oh, I don't want to come at that time. I have to come after school". And it was like, it's only once or twice. Yeah, that actually kind of opened my eyes as to how demanding they can be sometimes. (Anonymous)

Pain management was achieved with anti-inflammatory or steroid medication. The implementation of ergonomically friendly equipment (such as saddle chairs), non-latex gloves, delegation of work and a slower work rate helped improve workplace health. Several practitioners also remained active outside work or undertook Pilates training to maintain physical strength.

You need to invest a certain portion of your time into looking after yourself. You know, we spend a lot of money on brackets and wires; we should spend a few hundred bucks on ourselves… (Interview 11)

Sick days were extremely uncommon, and typified by some practitioners taking as few as 3-4 such days off in the previous ten years. Illness was not absent, but orthodontists chose to work through these periods in order to save inconvenience to their patients. A day off work was described as 'code red'.

Code red. They talk about code red. What happens with being a code red. It would be really disruptive. As in I see 60 or 70 patients, or maybe not, 50 to 70 patients a day, depending on what we're doing. So those patients have to go somewhere else…I really hate mucking people around. Because although patients understand, they don't really want to be mucked around too much. (Interview 19)

I haven't been sick, almost never. I've had two [major operations] and I had them both done in Christmas week. I had them done on the Monday and they kicked me out of hospital on the Thursday, the Friday, and then my normal three weeks holiday. (Anonymous)

Regrets

The choice of an orthodontic career was looked upon with no regret in hindsight. Any regrets related only to the timing of training, the choice of institution, and critical business or career decisions.

The one thing I suppose is that I should have not got involved with hospital orthodontics and cleft palate stuff. I should have got a practice set up so that I had financial security and then maybe as a more mature practitioner gone in… (Interview 17)

…I didn't do it early enough but then as I said I was probably too young to do it anyway. (Interview 4)

Several practitioners wished that they had started orthodontics much sooner. In contrast, many of those who had started at a younger age regretted that they had been unable to travel extensively prior to undertaking the course. All things considered, however, all were happy with their career choice.

Personality traits

The New Zealand orthodontic profession features a wide variety of personality traits. When asked what personality traits were significant and important for orthodontists, the following suggestions were offered: perfectionism; being an obsessive-compulsive; being strongly opinionated; being honest or of high moral integrity; being pragmatic; being scientifically or mechanically minded; and having a calm nature. The relative importance placed on each was unique to each orthodontist. There were no particular personality traits which were understood to be essential for the profession, and this was acknowledged by many of the members themselves.

> *…I don't know. Is there a special trait? No – I think it's a combination of your own personality and plus your workmanship. (Interview 9)*
>
> *…there are some personality traits an orthodontist would have in common, just perfectionist type of people, just attention to detail, that sort of thing, a little bit of obsessive compulsive, it's just an exaggeration of the things that make you a good dentist really. But within the orthodontic profession in New Zealand, the personality types are hugely, hugely different, very, very variable. (Interview 1)*

Job stress

Stress was related predominantly to time management, staffing, patient load, paperwork and difficulties in clinical practice. Stress affected clinicians differently, and each employed his/her own coping strategies. One participant believed that orthodontics was less stressful than general practice, but it was unclear whether this was a consensus view. Perhaps the greatest stress came from staff management. Disharmony among team members was difficult to manage delicately. Most practitioners preferred to avoid conflict wherever possible, and this was itself often an unforeseen and unneeded additional source of stress. Similar stresses were also related to associate orthodontists, succession planning and re-establishing a balance after the presence of a locum.

> *Probably the most stressful time was when I had an associate that left and that caused quite a few problems. (Interview 17)*

Double booking or over-booking to cope with breakages or time off was seen as an additional unwanted burden. This was made worse by the inflexibility associated with the job and the obligation to see patients through to treatment completion. In combination with the increase in paperwork relating to practice management and treatment planning, this often seemed overwhelming, particularly to newer practitioners.

> *If I was asked to get all my stressful situations and rank them, I would put staff at number one, setting up practice and wondering if it's actually going to work, and shelling out an obscene amount of money. That stressed me quite a bit, setting up. It shouldn't have, but it did. (Interview 16)*
>
> *I think probably the hardest thing I've found in my career as an orthodontist has actually been the business aspects of it. I don't think that physically lining teeth up and making them straight has been a huge issue but I think dealing with staff and sort of the management things are the things that create the most stress in the job to be honest. And if you could clone yourself and run everything that would kind of make life a lot easier sometimes. (Interview 13)*

Coping strategies ranged from physical exercise or talking about the problem, to structural changes in the workplace. These included reducing patient numbers or working days, or implementing systems for more efficient practice management.

Dealing with criticism

Within each orthodontist's practising career, there had been specific incidents and challenges which have been particularly difficult, both clinically and emotionally.

> *A low point was probably three years into owning my own practice, when there wasn't financially as much money coming through. And I started to see my retention checks from my first patients that I thought I'd treated so beautifully, and thinking "oh, God, I thought I had that right". That's low points. Or like recently for the first time in my practising career I had a patient complain about me. And it was like nine years since I treated her. And that was really, I thought "what the hell am I doing this for?" It was really nice at the end, really nice for the years out, and now she's got some gingival recession. That was pretty low. (Anonymous)*
>
> *…my biggest clinical disaster was I had some standard template letters…, I'd done a letter that hadn't been, it was sent out to a dentist who'd lost it, and it was, and my, the receptionist printed off, and it was a four fives letter I'd adapted to her case of three fives, she was an Asian girl who had a canine or something taken out in Taiwan, you know, and the receptionist printed off the standard four fives letter and left me with a, yes, it was a disaster because I hadn't, you know, it was somehow sitting in a computer somewhere or something like that. So she printed off the wrong letter with this girl's name on it and it ended up just as you can imagine being a clinical nightmare. And the thing about it, it wasn't a poor clinical decision, it was just not having administrative systems, administrative systems that were so poor that, there were no checks and balances involved in that. (Anonymous)*

Complaints from patients were viewed as personal attacks, and led to deep unrest for most orthodontists. However, it should be noted that negative feedback was relatively rare. With growing professional maturity, clinicians were better able to manage such issues. Maturity, however, did not ease the burden for the practitioner.

> *If a big complaint came in I'd take it pretty personally. I wear my heart on my sleeve, and it's a specialty, so you are the specialist and you're supposed to be very good at your job and I'd be questioning what went wrong. If something had gone wrong and it was due to me doing something wrong I'd take it pretty personally. (Interview 16)*

> *You don't sleep at nights for a long time. You worry about it, you self-analyse "where have I gone wrong", "where have I failed". It nearly always boils down to a patient whose expectations are unrealistic rather than something you've done wrong. If it is something that you've done wrong you just have to admit it, do what you can to put it right which is one of the great things about orthodontics – very little of what you do is permanent, and move on. (Interview 1)*

Confronting such an issue in an open, honest and calm manner was often enough to see resolution. If the issue was unable to be laid to rest through dialogue alone, a refund was often preferred to a formal disciplinary investigation.

> *You just sort of, the silly thing is you think about it and you think about it and when you actually get off your bum and confront it, the problem goes away 9 times out of 10 and you just think, why did I worry about that? (Interview 18)*

Challenges of setting up practice

Establishing a new practice was seen as the most difficult period in a clinician's career. The biggest decisions were selecting where to go, and whether to work alone or with others. Sometimes, the circumstances left no choice at all.

> *I'd say my low point would be…just the hassles of setting up practice. Where to go, what to do. I didn't really want to set up my own practice. I wanted to find an old chap who was about to retire and sort of work with him for a couple of years and then take it on. But I couldn't find that opportunity. And I didn't really want to start my own practice and I sort of fought that for a while. But then it became apparent that that was my only option really. And when I finally got that on board it was okay, but I guess that was probably my low point. Trying to decide what to do there. (Interview 11)*

Once a location was chosen, a practice location was required. Trying to get one close to schools or near transport links could be very difficult, and it was made more tedious by issues such as resource consent. It was also important to start meeting local dentists in order to create an awareness of the new orthodontist's presence. A timeline was required to try and co-ordinate everything.

The early years of practice were often challenging, especially financially. As a more constant workload developed, orthodontists were able to take on more staff and delegate work further.

> *A new practice is an evolving beast in a way. You have to make changes and adapt as you get busier… you have got to get to that point where you are financially viable and then you can heave a big sigh of relief - we're there now, which is good. I'm not worried about money on a daily basis. The first three to six months, you know, you're wondering, it's all about survival. (Interview 11)*

Orthodontists joining practice with older practitioners experienced significant difficulties, particularly with fee structures. It was financially untenable for younger orthodontists to survive off lower fees, due to their slower patient throughput or higher materials costs. Raising fees and justification for this increase presented a significant challenge for these practitioners. It was important for the new orthodontist to also establish his/her own identity and good standing within the community.

> *I think that's more being in a small provincial town, having, you know, when you're a new boy you've got to justify yourself, you know, the people, most of them know someone, someone's friend, some other kid at school who's dealt with you, and so they're coming with preconceived ideas about whether or not you know what you are talking about… (Interview 5)*

Undergraduate and postgraduate training was very limited in business education and many orthodontists felt under-prepared to manage their own practice. Most orthodontists relied on past knowledge and experience of running their own general dental practice, together with advice from colleagues, business management courses, and learning from first-hand experience. Several started by managing their own accounts, but, as they became busier, referred these on to their accountant.

> *I didn't even know how to order a paper towel when I started. I didn't know how anything worked but then there was no GST and everything was kept on a bit of paper in a book. Now everything's on a computer. (Interview 1)*
>
> *Yeah. I do. I think, as dentists we graduate with no business experience, and 90% of us are going to end up being businessmen. And then we go through a Masters training programme, and once again there's absolutely no business input. And, you know, so we come out being pretty good tooth-straighteners, but knowing very little about business, and there's very few of us that aren't going to end up running a business…I don't think I'd be lying in saying that it's running the business that's the stressful part of the job…because you've got to wear two hats in this job. (Interview 14)*

Professional support

New Zealand was seen to have a small community of close-knit orthodontists who were more than willing to lend a hand when required. However, there were always the odd exceptions. The New Zealand Association of Orthodontists (NZAO) as a professional body was recognised to be still in its infancy. Practitioners were in greatest need of professional support when starting out.

> *I think the course gears you up well for the orthodontics itself. My comment a year afterwards was they teach you the theory but there's not a lot of practice management. (Interview 16)*

The NZAO has formulated templates, a mentoring program and a practice accreditation program which includes practice management help. It was unclear whether all practitioners were aware of this assistance, or whether there was a desire for more. The NZAO accreditation (according to one clinician) was seen to be clinical "and I've already done three years of a Masters programme and I don't feel I need to answer to another orthodontist where I put my lower incisors" (Interview 11). Overall, the New Zealand community of orthodontists appeared to be otherwise very supportive.

> *With some, there's an elitist thing. You know, "I'm better than you, I do greater ops than you and more wonderful jobs". But there's also "the we're all doing the same thing, we're all trying to achieve the same thing and we may achieve it differently and that's okay". I still think the profession as a whole has got really good camaraderie. (Interview 19)*

Peer contact

Sole practitioners admitted that they were at the greatest risk of professional isolation. Several study groups and email networks had been established for discussing treatment and practice management. Study groups (in particular) were considered to be extremely valuable for professional development. Practitioners involved in associateships or group practices also benefited from this interaction.

> *…really good to go to a study group, ping the ideas off one another, "that's stupid", and nobody takes offence. "I think what you're doing is stupid…why don't you do it like this?"; "Oh, I hadn't thought of that". That's still really good. (Interview 19)*

Most practitioners found it easy to maintain peer contact, liaising with dentists, specialists and their peers at meetings and conferences whether regionally, nationally or internationally. Certain practitioners were also involved in publicly-funded positions, such as those in hospitals and at the School of Dentistry (University of Otago).

> *And being a solo practitioner I was aware of the isolation, so I took a job with [Local] Hospital, working in the cleft palate team and maxillo-facial team, and that multi-disciplinary approach of being able to bounce ideas off… other specialists… (Interview 16)*

Peer contact was also possible through committees associated with the NZAO. Some orthodontists preferred to visit other orthodontists in practice to observe both clinical and practice management systems.

Success in orthodontics

Participants perceived success very differently. Successful clinicians were seen as those who achieved a high standard of care, had a good patient rapport and were well respected among their peers, referring dentists and patients. Interestingly, financial success was either not at the forefront, or not mentioned at all. However, a sound business sense was acknowledged by some as a necessity for managing a successful orthodontic practice. Good communication was also important for staff management and harmony.

> *There are so many different types of successful orthodontists. Some people are very introverted, some people are people people. Some people are scientists, some people are pragmatists. Some people are marketers. I think that's one of the amazing things about orthodontics. That it actually can take all types. But I think what it does require is a straight, honest personality. Because those who are not get discovered early. (Interview 7)*

Life

Several orthodontists discussed the impact of their orthodontic career on family and home life.

Formulated subthemes included personal development, family life, interests outside work, and financial security.

Personal development

Orthodontics was shown to have affected several orthodontists in areas outside professional practice. The career was viewed by some as overwhelming on occasions.

> *Orthodontics has a big influence on my day-to-day life, because when I'm in [Orthodontic Practice Location] I feel it really dominates so much. It's a bit like a tiger you're riding that you can't get off. It's hard to control. Some people may be better organisers of their time and their responsibilities than I am. (Interview 17)*

Orthodontics has taught practitioners to be more rigorous and suspicious of anything new. It also made them more self-disciplined, structured and less introverted. However, when ideal treatment aims were not achievable, it could also be 'soul-destroying' (Interview 15).

> *I'm quite shy but with orthodontics you don't have that chance. You're with people all day, not only your staff but every single patient, every single parent. So that's probably changed me…probably would have been quite insular and isolated and kept to myself, but with orthodontics that would have changed my personality. (Interview 15)*

Family life

Family life was frequently affected by the demands of work. Several orthodontists reflected with regret upon the difficulties of allocating time for their children, especially during the early years of practice. The social responsibilities and pressure of maintaining the orthodontist role could sometimes affect other roles, such as in family life. This was more of an issue for females, particularly those running a full-time practice. It was particularly acute following the birth of children.

> *Like my daughter's friends, I've got braces on her friends and then we go to [sports] and the kids…next to her, I treat the kids. So I have to work quite hard to, you know, I am just mum. I remember saying to [Daughter] once, you know, if you stand up at my funeral and say my mum was a good orthodontist I'll be really upset. I want you to stand up and say I was a good mum. (Anonymous)*
>
> *I had a nanny. So I've always had a nanny. Yeah, it was like feeding a baby, the baby coming in at lunchtime for me to feed, and going away again. I used to rent a room so I could sit and breastfeed the baby. It wasn't, I wouldn't recommend it to anybody really. (Anonymous)*

Life partners were often involved in their own part- or full-time work, and their income was also essential during the initial years of establishing a practice. A few orthodontists had their partners working within the practice (many as practice manager). Others had partners within the wider dental profession. This provided partners with a unique insight into the day-to-day demands of the job, making them more sympathetic to the demands placed on the orthodontist. Partners and children were often the impetus in decisions to reconsider work commitments.

> *For me personally it's been great…it's wonderful having someone who understands about teeth. I don't know how I would get on with someone who didn't know what I was talking about. Obviously lots and lots of people out there do but for me it makes life very easy. (Interview 1)*
>
> *I guess the issues have been to weigh up cancelling patients versus your children's needs, your family's needs, and that I guess is a work-lifestyle balance which is not limited to orthodontics. It's just the, maybe because of the schedule it's a little more pressured. (Interview 7)*

Others preferred to keep work completely separate from home life. This also had the advantage of complete respite from the job outside the work environment.

> *…when I'm working here and I try to be on time, you know, and because I want my patients to be on time and I expect to be on time for them, when I get home, I don't want to be a day structured timetable, so it's more if we have to be somewhere we will be, but it tends to be I need some relief away from the structured, you know, clock off every five minutes. (Interview 5)*

Interests outside work

New Zealand orthodontists were consistent in their passion for outdoor pursuits and family bonding. Many orthodontists tried to balance their overwork by spending time with the family in weekends and holidays.

> *On my four days off, I'm mum. I'm the dropper-offer at school, the picker-upper and the house cleaner. (Anonymous)*

Personal time was used for gardening, reading, and more physical pursuits (which were very wide-ranging). Also prevalent were involvement in community organisations (such as Rotary), or active roles within the NZAO.

> *…I have a bunch of guys I go mountain biking with. I play golf with a whole lot of guys, do a bit of rugby coaching, play a bit of table tennis. I suppose mainly sporting sort of stuff….mentor a young kid as part of a mentoring program. (Anonymous)*

Financial security

Orthodontics was acknowledged as a career that afforded a comfortable lifestyle and was well remunerated. The extent of such comforts was individually dictated. A successful living was still attainable, for even the least efficient operator.

> *I didn't have a huge loan but I had nothing and I had to borrow money at 27% to buy a house, a car and a practice and I spent probably the first five years simply paying back interest on the loans. I didn't make any headway at all, so I was probably 40 before I started saving for my retirement. You don't think about that much in your 30s and then in your 40s you start thinking about the future and your retirement and oh I'd better put something away. But we live very simply – if we'd bought a $5 million house and wanted a boat and a Mercedes and those things then probably I'd feel a lot more stressed than I do but with [Partner] having a good income we haven't had any debt for a long time. Orthodontics provides you with a very, very comfortable living and you can choose to live to the hilt of your income and borrow and put yourself under stress that way, or you cannot, it's really a matter of your lifestyle choice. (Interview 1)*

A perception of orthodontics being a well-paid profession was present among the general public. The associated debt was less recognised, however.

> *I would rather be someone that the community trusted rather than being thought of as rich or whatever. Because we're not anyway, because we've got these huge debts. It's really funny, because that's what people think…people don't realise the costs of running a practice. (Interview 13)*

Conclusions

This report is the second of two which describe the experiences and working lives of New Zealand orthodontists, using the qualitative research approach. The first shed light on orthodontists and the practice of orthodontics in New Zealand, while the current report has concentrated upon orthodontists' working lives and how they balance the demands of work and life's other facets.

Respondents were aware of the need to achieve and maintain a satisfactory work-life balance, but there were various constraining influences. Taking time off was seen to be difficult because of the nature of orthodontics and the lack of viable options for covering the orthodontist's workload. This led to a degree of 'presenteeism' which carried further stress and health risks.[11] Other sources of stress were staffing problems, coping with criticism and complaints, and early-career difficulties of becoming established in practice (the issue of supporting younger practitioners has been recognised by the NZAO, and a mentoring program is in place). Despite these concerns, none regretted choosing to specialise in orthodontics, and the NZ specialty group's ethos of mutual support was welcomed.

Outside the workplace, other interests were vitally important. Those may relate to family, recreational pursuits (sports and hobbies) and involvement in community organisations. The financial security afforded by orthodontic practice meant that such pursuits were more within reach (although this was countered to some extent by difficulties in taking time off).

This was the first time that qualitative research has been used to investigate the orthodontic profession in New Zealand. This investigation provides valuable insight into the working lives of New Zealand orthodontists and the effects on their day-to-day lives. It will be informative and interesting to observe how the modernisation of orthodontic practice will affect the work-life balance of New Zealand orthodontists in the future.

Corresponding author

Professor W. Murray Thomson
Department of Oral Sciences
Sir John Walsh Research Institute
School of Dentistry
The University of Otago
PO Box 647
Dunedin
New Zealand

Email: murray.thomson@otago.ac.nz

References

1. Ayers KMS, Thomson WM, Newton JT, Rich AM. Job stressors of New Zealand dentists and their coping strategies. Occup Med 2008;58:275-81.
2. Newton JT, Allen CD, Coates J, Turner A, Prior J. How to reduce the stress of general dental practice: The need for research into the effectiveness of multifaceted interventions. Br Dent J 2006;200:437-40.
3. Freeman R, Main JRR, Burke FJT. Occupational stress and dentistry: Theory and practice. Part I Recognition. Br Dent J 1995;178:214-17.
4. Roth SF, Heo G, Varnhagen C, Glover KE, Major PW. Job satisfaction among Canadian orthodontists. Am J Dentofacial Orthop 2003;123:695-700.
5. Roth SF, Heo G, Varnhagen C, Glover KE, Major PW. Occupational stress among Canadian orthodontists. Angle Orthod 2003;73:43-50.
6. Russek H. Emotional stress and coronary heart disease in American physicians, dentists and lawyers. Am J Med Sci 1962;243:716-25.
7. Humphris G, Lilley J, Kaney S, Broomfield D. Burnout and stress-related factors among junior staff of three dental hospital specialties. Br Dent J 1997;183:15-21.
8. Turley M, Kinirons M, Freeman R. Occupational stress factors in hospital dentists. Br Dent J 1993;17:285-8.
9. Wells A, Winter PA. Influence of practice and personal characteristics on dental job satisfaction. J Dent Ed 1999;63:805-12.
10. Soma KJ, Thomson WM, Morgaine KC, Harding WC. A qualitative investigation of specialist orthodontists in New Zealand: Part 1. Orthodontists and orthodontic practice. Aust Orthod J 2012;28:2-16.
11. Dew K, Keefe V, Small K. 'Choosing' to work when sick: workplace presenteeism. Soc Sci Med 2005;60:2273-82.

Comparison of Australian and American orthodontic clinical approaches towards root resorption

Elaine Lim,* Glenn Sameshima,† Peter Petocz+ and Ali Darendeliler±

Private Practice, Melbourne, Australia,* University of Southern California, California, USA,† Macquarie University+ and University of Sydney,± Sydney, Australia

Aims: As part of The Rocky Mountain Travelling Fellowship, a pilot survey was conducted to assess current diagnostic and clinical approaches to the management of orthodontic patients in relation to root resorption.

Methods: Groups comprising Australians (Sydney, New South Wales) and North Americans (Los Angeles, California), in two stages of their orthodontic careers (post-graduate orthodontic students from the University of Sydney and University of Southern California and qualified practising orthodontists) were asked to complete a questionnaire. The questions examined diagnosis and management approaches related to root resorption used in their clinical practice.

Results: Replies demonstrated that there were differences in management depending on operator experience and the country of clinical practice. However, a summarised common approach to orthodontic root resorption comprised (1) the use of an orthopantomogram as a screening diagnostic tool, followed by periapical radiographs for those perceived as 'higher risk' patients, particularly individuals with a history of root resorption; (2) a six monthly radiographic review during treatment; (3) the use of light forces and/or rest periods (discontinuous forces) every two to three months; (4) the extraction of deciduous teeth if permanent successors were erupting ectopically and causing damage to adjacent root structures; and (5) the use of fixed retention after treatment.

Conclusion: This project was intended to initiate discussion and form a basis for further investigation into the clinical management of orthodontic root resorption.

(Aust Orthod J 2012; 28: 181–189)

Received for publication: April 2011
Accepted: July 2012

Elaine Lim: elim@yolandim.com.au; Glenn Sameshima: sameshim@usc.edu; Peter Petocz: peter.petocz@mq.edu.au;
Ali Darendeliler: adarende@mail.usyd.edu.au

Introduction

Root resorption resulting from orthodontic treatment is an unpredictable adverse sequela, involving transient inflammatory surface resorption.[1] The process is likely to be influenced by complex and multiple factors.[2]

Risk factors governing the incidence of root resorption have been reported to include: individual susceptibility, genetics, hormonal imbalance, an adverse medical history, nutritional imbalance, age, dental history, tooth type, the duration of orthodontic treatment, the amount of tooth movement, appliance type, the type of tooth movement and the magnitude of applied orthodontic force.[3]

Currently, there is no consensus regarding the prevention of root resorption. However, treatment strategies have been suggested in an attempt to minimise its impact. These include: limiting treatment duration,[4] using light intermittent forces,[5] the careful assessment of medical history and familial tendency,[6] the control of habits[7] and, if required, the cessation of treatment.[1]

Unwanted orthodontic related root resorption has direct implications for clinical practice. The identification of patients with increased susceptibility, their management during treatment, retention and follow-up protocol remains the responsibility of the orthodontist.[8] However, many general dentists and non-orthodontic specialists perceive that root resorption is avoidable and is under the control of the clinician through patient management. Furthermore, since dentists may be challenged by providing restorative options to post-orthodontic patients who have suffered root resorption,[9] a professional approach should ideally be universal, uniform and evidence-based.

No specific clinical approach to the orthodontic management root resorption has been established.[8,9] Even though there is a relatively high incidence of orthodontic root resorption, treatment options are generally case-dependent. Furthermore, there is a lack of high level evidence[9] and currently, the clinician's experience[10] and perception,[11] in conjunction with the evaluation of individual patient factors, determines the most suitable therapeutic approach.[12] It has been suggested that future research should aim to provide evidence for practitioners and patients which enables informed and improved decisions regarding appropriate management options.[9]

The aim of the present study was to assess current diagnostic and clinical approaches to the management of orthodontic patients in relation to root resorption. A pilot survey compared practitioners from two different countries (America and Australia) and in two different stages of their orthodontic careers (post-graduate orthodontic students and qualified practising orthodontists). It was anticipated that the survey responses would initiate discussion and identify a universal approach to the management of orthodontic root resorption and provide an evidence-based foundation for clinical practice.

Materials and methods

This cross-sectional study involved participants from the United States of America (Los Angeles, California) and Australia (Sydney, New South Wales). From each country, two professional groups representing different stages of orthodontic experience, post-graduate students (University of Southern California and University of Sydney) and registered specialist orthodontists from both countries, were sampled. The qualified orthodontists worked in hospital-based service or private practices and had past or current faculty involvement. All students who were enrolled in post-graduate programs in both countries were recruited.

The university orthodontic faculties were comparable. All students were enrolled in three-year full-time training programs. The universities were hospital-based and required the treatment of patients from the commencement of their respective courses. In addition, tutorial-based theory education was provided throughout the programs. Therefore, it was expected that all student participants would be able to answer the clinically-based survey questions.

A single part survey was designed with a series of fixed questions and responses selected from four to seven alternatives. Participants were able to choose more than one alternative to best describe their answer. In addition to the fixed responses, there was an option to add further information in seven of the sixteen questions. This critical incident questionnaire approach focussed participants onto a particular issue but provided an opportunity to express ideas, with minimal direction in order to establish their perspective.[13]

The surveys were distributed in person directly to participants. One survey per student was provided to the 17 American and the 12 Australian orthodontic post-graduate students. Orthodontists visiting the respective post-graduate training dental hospital and faculty departments over a 4-week period were given surveys. The majority completed the 30 minute-survey upon receipt. A covering letter accompanying each survey informed participants of the purpose of the survey and that data would remain anonymous and confidential. Consent to conduct the survey was granted by the respective heads of orthodontic departments.

Personal data from respondents was de-identified. Respondent numbers in each group were: University of Southern California post-graduate orthodontic students (American Students), N = 17 (27%) of total sample; University of Sydney post-graduate orthodontic students (Australian Students), N = 10 (16%); American orthodontists, N = 16 (25%); Australian orthodontists, N = 20 (32%), making a total of 63 participants.

The survey comprised questions relating to pre-orthodontic diagnosis of root resorption, management during orthodontics, including treatment planning options, and post-orthodontic retention (Figure 1).

Data for each item were analysed by determining frequency of distributions and percentages. Percentage

Please tick the appropriate box/boxes which best represent your response.

1. **Please indicate which best describes your current orthodontic position:**
   - ❑ The University of Sydney, Australia. Post-graduate orthodontic student (Specialist Training Program)
   - ❑ The University of Southern California, USA Post-graduate orthodontic student (Specialist Training Program)
   - ❑ Australian Private Practice
   - ❑ USA Private Practice
   - ❑ Australian Public/Hospital Practice
   - ❑ USA Public/Hospital Practice
   - ❑ Other. Please specify ....
2. **Years since graduation from orthodontic specialist training (if applicable)?**
   - ❑ <1 to 5 years
   - ❑ 5 to10 years
   - ❑ 10 to 20 years
   - ❑ >20 years
3. **What method(s) do you use in clinical practice to assess for risk of orthodontic root resorption?**
   - ❑ Previous dental history
   - ❑ Clinical examination
   - ❑ Orthopantomogram
   - ❑ Periapical radiograph
   - ❑ Computer Tomography imaging
   - ❑ Other. Please specify ....
4. **In what situations would you take additional precautions for a patient (where there is perceived increased risk of susceptibility to orthodontic root resorption)?**
   - ❑ History of trauma to dentition
   - ❑ Previous root resorption
   - ❑ Family history of root resorption
   - ❑ Transplanted tooth
   - ❑ Medical condition. Please specify ....
   - ❑ Other ....
5. **What method(s) do you use in clinical practice to screen for (detect) orthodontic root resorption?**
   - ❑ Clinical examination. Please specify ....
   - ❑ Orthopantomogram
   - ❑ Periapical radiograph
   - ❑ Computer Tomography imaging
   - ❑ Other. Please specify ....
6. **If orthodontic root resorption were noted, during initial consultation or any stage of treatment, what periodic follow-up assessment methods would you conduct?**
   - ❑ Orthopantomogram
   - ❑ Periapical radiograph
   - ❑ Computer Tomography imaging
   - ❑ Clinical examination (e.g. mobility, colour changes)
   - ❑ No follow-up
   - ❑ Other ....
7. **How often would you follow-up a case presenting with orthodontic root resorption once noted?**
   - ❑ Monthly
   - ❑ Three monthly
   - ❑ Six monthly
   - ❑ Yearly
   - ❑ Approximately half-way through treatment
   - ❑ End of treatment
   - ❑ No follow-up
   - ❑ Other. Please specify ....
8. **How do you classify orthodontic root resorption (what description method do you use to record the severity of root resorption for future comparison)?**
   - ❑ Loss of root in millimetres/inches
   - ❑ Loss of root in percentage
   - ❑ Description (mild/moderate/severe)
   - ❑ Diagram
   - ❑ Mobility
   - ❑ Other. Please specify ....
9. **Which best describes your clinical management of an orthodontic patient where there is generalised loss of one-third OR more than 4 mm of the tooth roots due to resorption?**
   - ❑ Finish your treatment immediately
   - ❑ Interrupt the treatment for a time, then continue at a later stage
   - ❑ Use very light wires/forces to finish the treatment
   - ❑ Other. Please specify ....
10. **If you note the presence of severe root resorption when would you inform the patient and/or parent(s)?**
    - ❑ Immediately
    - ❑ At the end of treatment
    - ❑ Only if it becomes worse
    - ❑ Never
11. **What is your choice of retainer where severe root resorption is present?**
    - ❑ Removable Hawley type
    - ❑ Removable Begg type
    - ❑ Thermoplastic retainer
    - ❑ Fixed wire retention
    - ❑ Other. Please specify ....
12. **Is the above retainer used the same as your routine/standard retention protocol?**
    - ❑ Yes
    - ❑ No
    - ❑ Other comments ....
13. **Which best describes your preferred management of a patient case where the erupting canines represent risk for lateral and/or central incisors?**
    - ❑ Extract the primary canines if present
    - ❑ Extract the permanent (secondary) canines
    - ❑ Expose the canine
    - ❑ Move the incisor(s) away
    - ❑ Wait and see (periodic monitoring)
    - ❑ Other comments ....
14. **Which best describes your preferred management of a patient case where the erupting canines have resorbed one-third of the root of the lateral and/or central incisor(s)?**
    - ❑ Extract the erupting canine
    - ❑ Expose the canine and monitor
    - ❑ Expose the canine and commence orthodontic traction
    - ❑ Orthodontics to move the incisor(s) away
    - ❑ Monitor
    - ❑ Other. Please specify ....
15. **Which best describes your management of a patient case where there is a need for extraction treatment and full-fixed orthodontic appliances, however generalised root resorption is present?**
    - ❑ Do not recommend treatment; advise against commencement of orthodontic treatment indefinitely
    - ❑ Do not recommend treatment for now; advise against commencement of orthodontic treatment, however, plan for future recall and reassessment for treatment at a later stage
    - ❑ Offer non-extraction orthodontic treatment and camouflage discrepancy where possible
    - ❑ Offer extraction treatment, but modify treatment approach by waiting for migration of the teeth following extractions, prior to application of orthodontic traction/force
    - ❑ Extract and continue as routine case
    - ❑ Other. Please describe ....
16. **Which best describes your management of a patient case where you have diagnosed severe root resorption and where there are remaining extraction sites to be closed?**
    - ❑ Stop treatment immediately and remove all appliances
    - ❑ Interrupt treatment for a period of time. Then continue
    - ❑ Continue, adapting to treatment mechanics to only involve 'light forces'
    - ❑ Continue, only to space closure and cease treatment thereafter

Figure 1. RMO Travelling Fellow Research Project. Questionnaire on orthodontic root resorption.

was based on the total number of responses for subjects within each group. Where descriptive responses were permitted, key themes were derived from comments and codes which noted similarities of responses were developed. To check the original responses for interpretive credibility, a blind thematic analysis was discussed with an orthodontist independent of the study. Validity was enhanced by not disclosing the orthodontic position or year since graduation of the subject making the comment.

Results

The analysis rate for the volunteers who returned the surveys was 100% for orthodontists and University of Southern California post-graduate orthodontic students and an 83% response rate for University of Sydney post-graduate orthodontic students. Of the sample, 57% were orthodontists. Over half of the American orthodontists had been in practice for at least 20 years, 18.8% for 10-20 years and 31% for 5-10 years. The largest proportion of the Australian orthodontist sample group had been practising for 5-10 years (40%). The remainder had been in practice 20 years (30%), 10-20 years (25%) and 1-5 years (5%), respectively.

All participants responded with more than one answer to the survey questions, although few used the option of further elaboration even when the 'other' response was chosen.

Responses relating to pretreatment diagnosis and treatment planning questions revealed that all groups would use periapical radiographs to assess the risk of a patient to root resorption. All Australian orthodontists and students indicated that a panoramic radiograph (OPG) would be used, whereas only 46.67% of the American orthodontists and 35.29% of the American students would use OPGs. More than 80% of Australian orthodontists and students would use previous dental history as the most frequent method of evaluation following OPG and periapical radiographs. In contrast, American students reported computer tomography (CT) as their preferred method for root resorption assessment in clinical practice (Figure 2).

The most favoured method to screen all patients for root resorption was an OPG for Australian orthodontists and students. The majority of American orthodontists and students would use periapical radiographs. A substantial proportion of American students (35%) cited computerised tomography as their assessment method method of choice, but only 5.88% of Australian students would employ this method.

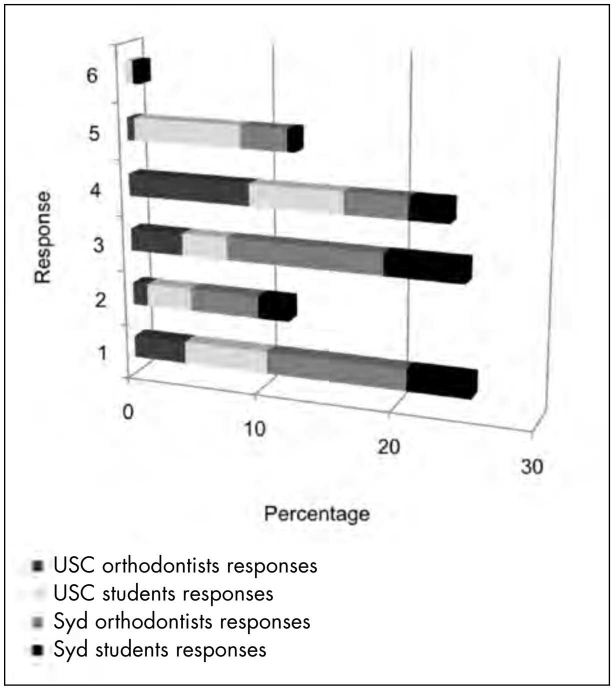


Figure 2. Methods used in clinical practice to assess risk of orthodontic root resorption.

Response answer 1: Previous history
Response answer 2: Clinical examination
Response answer 3: Orthopantogram
Response answer 4: Periapical radiograph
Response answer 5: Computer tomography
Response answer 6: Other

Clinical screening and investigation was used to confirm the pre-orthodontic presence of root resorption. In addition, situations arose in which there was a perceived increased risk of susceptibility. All respondents agreed that previous root resorption posed an increased risk and indicated that additional precautions would be required. The next most commonly perceived risk factors were a history of trauma to the dentition and a family history of root resorption.

If root resorption was noted, both American groups indicated that their preferred method of recording severity would be measurement of millimetre loss of root structure (students 40%, orthodontists 28.9%). The majority of Australian students (28.6%) and orthodontists (32.5%) used the written description of mild/moderate/severe; however, both American

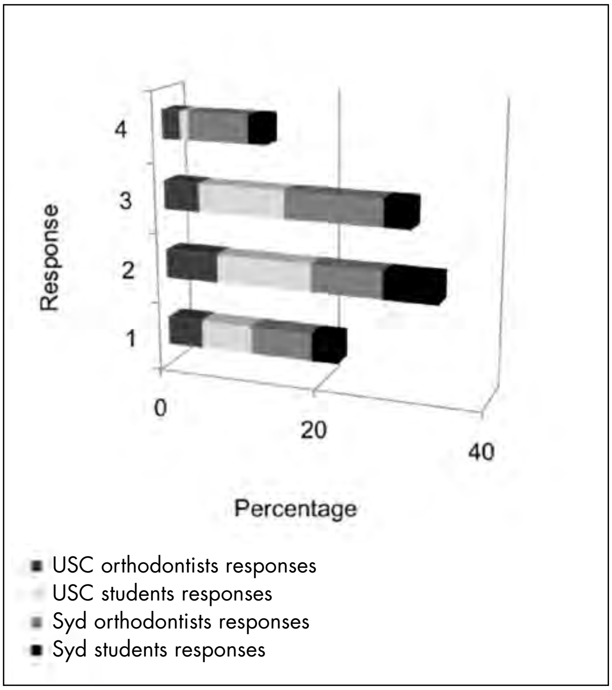


Figure 3. Approach to clinical management of orthodontic patients with generalised loss of one-third or four millimetres of tooth root loss due to resorption.

Response answer 1: Finish treatment immediately
Response answer 2: Interrupt treatment, continue later
Response answer 3: Use light wire/forces
Response answer 4: Other

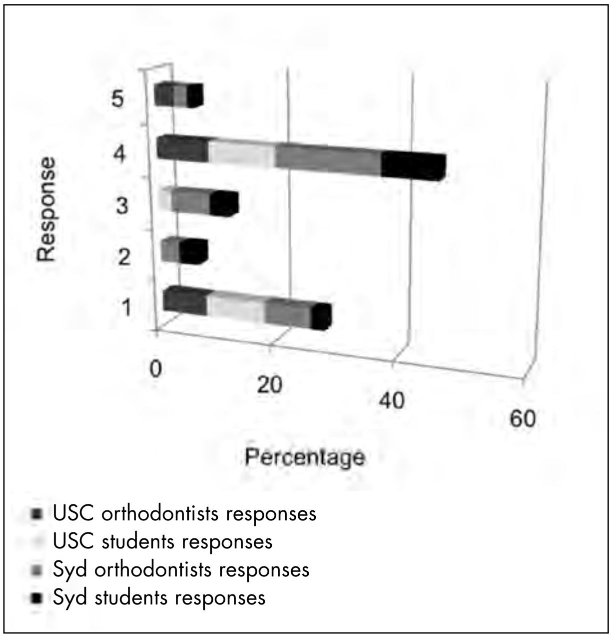


Figure 4. Retention method used for patients who have experienced root resorption during treatment.

Response answer 1: Removable Hawley type retainer
Response answer 2: Removable Begg type retainer
Response answer 3: Removable Thermoplastic retainer
Response answer 4: Fixed Wire retention
Response answer 5: Other

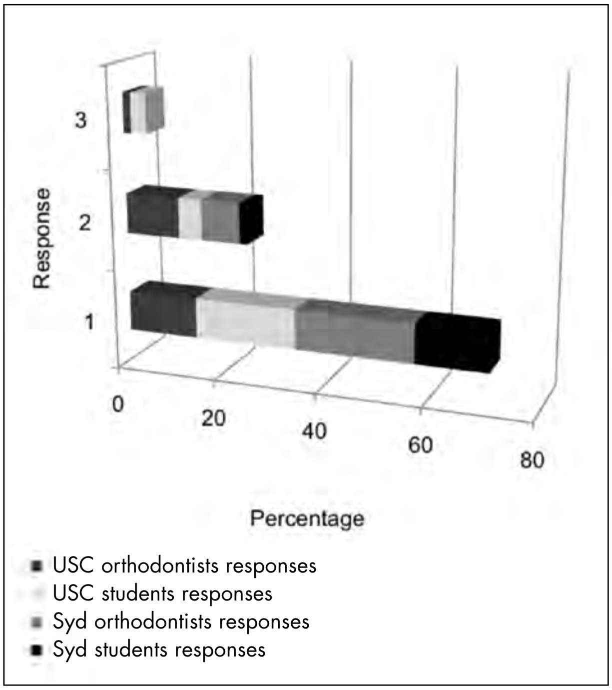


Figure 5. Comparison of retainer choice for routine vs root resorption cases.

Response answer 1: Yes, same retention
Response answer 2: No, different retention
Response answer 3: Other

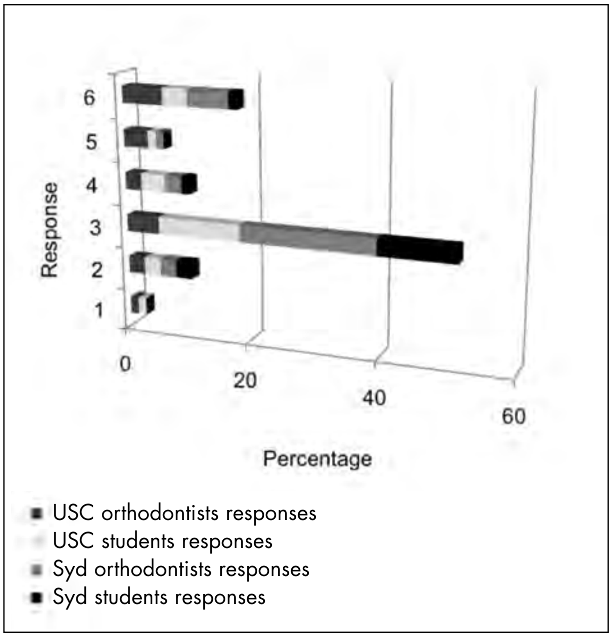


Figure 6. Preferred approach to management where erupting permanent canines have resorbed one-third of the incisor.

Response answer 1: Extract erupting canine
Response answer 2: Expose canine and monitor
Response answer 3: Expose canine and commence orthodontic traction
Response answer 4: Orthodontics to move incisor(s) away
Response answer 5: Monitor
Response answer 6: Other

(28.9%) and Australian students (28.6%) indicated that they would also use the percentage of root lost. A record of mobility and diagrams were the least favoured in all groups.

Once root resorption was noted, all groups indicated that they would continually monitor the case. Students would generally review more frequently (monthly, American Students 4.5%, Australian Students 9%) than orthodontists (monthly, 0%). However, the majority of all groups preferred a three to six monthly review regimen. A minority of Australian orthodontists would check the root resorption yearly (8%).

The preferred method of screening for root resorption was reflected in the periodic review of patients who were noted to have root resorption. American groups continued to prefer periapical radiographs (American students 46%, American orthodontists 61.5%), whereas the majority of Australians in each group said they would use OPGs (Australian students 40%, Australian orthodontists 36.7%), in preference to alternate methods. OPGs and periapical radiographs were preferred by all groups. Orthodontists also considered the use of CT; however, no students said they would use this method for reviewing root resorption.

Participants were asked which best described their clinical management of a patient with one-third (4 mm) or more of tooth root loss due to resorption (during treatment). The majority of Americans (orthodontists 37.5%, students 39.3%) and Australian students (42.9%) would temporarily suspend treatment. In contrast, most of the Australian orthodontists (33.3%) would continue using light wires and forces to finish (Figure 3). In terms of providing information to patients, all respondents stated that they would inform the individual involved immediately.

Following cessation or the completion of orthodontic treatment in patients with resorption, the preferred retention method of all groups was fixed wire retention (Figures 4 and 5). The next most popular retainer was a removable Hawley appliance. The retention protocol used was also the routine/standard protocol used for other patients for all clinicians.

Treatment scenarios were presented to assess the clinicians' approach to certain clinical problems. If the erupting permanent canines represented a risk to the incisors, the extraction of the primary canines was the management of choice. In circumstances in which a third of the incisor root has been lost as a result of resorption from an erupting canine, the exposure and commencement of orthodontic traction was the treatment of choice for the respondents in all groups (American students 50%, American orthodontists 23.5%, Australian students 69.2%, and Australian orthodontists 61.5%) (Figure 6).

The recommendations for patients with generalised resorption, in which there was a diagnostic need for extraction and full-fixed orthodontic treatment, differed between groups. The highest response from American orthodontists was to advise against the commencement of treatment (20%). In contrast, Australian orthodontists (37.9%) and students (30%) preferred to offer a non-extraction camouflage approach to management. A high number of students from America and Australia would modify their treatment approach by waiting for the migration of teeth following extraction before commencing active treatment. If an extraction case was already in treatment, but severe resorption was discovered, the majority in all groups would interrupt treatment for a period of time before continuing to completion.

Discussion

Approach to diagnosis

Diagnostic radiographic methods were used to assess root resorption. All respondents in the present study indicated that they would use periapical radiographs to assess the risk of root resorption in their orthodontic patients. This is in agreement with a previous study which compared Swedish and Greek orthodontists.[11] Panoramic radiographs were also a popular screening method. Convenience may be found in the routine use of this radiograph which is accepted for most orthodontic patient treatment planning. While radiation exposure is minimised with panoramic films, periapical radiographs offer greater clarity of root structure and features. However, OPGs may overestimate root loss by more than 20% when a comparison of pretreatment and post-treatment films is performed.[14]

Previous surveys and retrospective studies which have assessed clinical perception and guidelines governing root resorption did not question the use of CT.[10,11] CT may be superior to conventional film radiography for assessing root resorption risk associated with ectopically erupting canines[15] as it has been estimated that 50% more resorption is detected with CT.[16] In the current study, students indicated a higher use of this technology compared with orthodontists. The increased information must be balanced with the increased radiation dose[17] and whether the orthodontic treatment approach would be modified with the additional information.

Classification

The classification and record keeping of the amount of root loss was not standardised. In the present study, millimetre measurements were popular amongst American respondents, whereas Australians preferred the descriptors of mild/moderate/severe. Both methods have been used in the literature.[18] Consistency within individual clinics in order for temporal comparison would be ideal. If a universal approach within the orthodontic profession was agreed, the sharing of data may be made easier for future research in this field.

Risk factors

The most frequently cited perceived risk factor in the present study was a previous history of root resorption which supports previous research observations.[19] Patients at risk of severe resorption may be identified according to the amount of resorption during the initial stages following the commencement of treatment (within the first 6 months).[20] Additional risk factors mentioned in the present study were a history of trauma and a family history of root resorption. Previous trauma has been noted to indicate an increased risk; however, there have also been studies in which no evidence of root resorption has been reported following dental trauma.[5,21]

Genetic studies have supported the observation that a familial history may be an important clinical consideration when evaluating risk of root resorption. Evidence has been found of linkage disequilibrium of IL-1B polymorphism. The IL-1B gene is known to decrease the production of IL-1 cytokine which is associated with an increased risk of root resorption.[6]

Management of root resorption noted during treatment

Most orthodontists surveyed would likely review root resorption, once noted, in three to six months. This is in agreement with a retrospective study which found most clinicians took radiographs at six months.[10] A modification of the approach to care was indicated if root resorption was discovered during treatment. Lighter forces, periods of rest and reducing treatment time were noted as possible methods of management by all surveyed groups. Teeth moved with lighter forces experienced less and less severe root resorption.[5] Discontinuous forces have also been shown to be associated with reduced root loss.[22] Resting periods (of two to three months[23] and cessation of orthodontics have been prevention methods employed by practitioners to restrict the severity of resorption and these approaches are supported in the literature.[10] Other factors such as bracket type (self-ligating vs conventional and standard edgewise vs straightwire) or techniques (Begg, Tweed, Edgewise, Straightwire one-phase vs two-phase treatment plans) were considered unimportant, which agrees with published evidence.[5]

In the present study, the preferred treatment option for ectopically erupting permanent canines was the removal of their deciduous predecessors. This follows the recommendations of Ericson and Kurol.[24,25] Once erupting canines have caused damage to incisors, most participants would commence exposure and orthodontic traction.[26]

A modification to an extraction treatment option would be considered by surveyed respondents. If extraction treatment was required for orthodontic correction, Australian and American students preferred to compromise and camouflage the malocclusion without extractions. Premolar extraction cases have been found to experience more root resorption during treatment. It has therefore been suggested that consideration be given to avoiding extractions for overjet correction in cases which may require extended treatment time.[27]

Retention

A fixed wire retainer was the favoured retention method of those surveyed. Relapse could occur due to migration and fixed retention has been suggested if removable retention is inadequate.[28] Flexible retention allows limited physiologic movement between teeth; however, movement may contribute to fatigue and subsequent failure of the material.[28] A long term review using removable and twist-flex bonded retainers suggested that there were no differences between groups in relation to mobility.[29] Without root resorption considerations, there was still debate regarding a universally ideal and evidence-based approach to orthodontic retention in general.[30]

A combination of major themes expressed in the survey responses provides a summary of the general approach to orthodontic root resorption: (1) the use of the orthopantomogram as a screening diagnostic tool, followed-up by periapical radiographs for those perceived as 'higher risk' patients, particularly those with a history of root resorption, (2) six-monthly radiographic follow-up during treatment, (3) the use of light forces and/or rest periods (discontinuous forces) every two to three months, (4) the extraction of deciduous teeth if permanent successors were erupting ectopically and causing damage to adjacent roots and (5) the use of fixed retention after treatment. Although the survey indicated that there was no single agreement on a universal approach to aspects of diagnosis and management, there was commonality amongst practitioners, especially those from the same country of clinical practice. Similarity of responses also depended on career experience.

Conclusion

This pilot survey assessed the approach of practising orthodontists, represented by two groups of different professional levels and experience, as to their current diagnostic and clinical approaches to the management of root resorption. The responses demonstrated that there was no single universal approach amongst practitioners. However, there were common themes in responses, the majority of which related to the country of practice and stage of career. Approaches were based on scientific evidence; however the consensus in the literature reflected the various approaches in clinical practice. It is expected that this project will initiate discussion and form a basis for further investigation into the clinical approach for the management of orthodontic root resorption.

Acknowledgments

The authors are grateful for the funding provided by the Australian Society of Orthodontists Foundation for Research and Education and also to Rocky Mountain Orthodontics for their support.

Corresponding author

Dr Elaine Lim (Private Practice)
328 Jasper Road
Ormond Vic 3204
Australia

Email: elim@yolandim.com.au

References

1. Pizzo G, Licata M, Guiglia R, Guiliana G. Root resorption and orthodontic treatment. Review of the literature. Minerva Stomatol 2007;56:31-44.
2. Armstrong D, Kharbanda OP, Petocz P, Darendeliler A. Root resorption after orthodontic treatment. Aust Orthd J 2006;22:153-60.
3. Sameshima GT, Sinclair PM. Predicting and preventing root resorption: Part I. Diagnostic factors. Am J Orthod Dentofacial Orthop 2001;119:505-10.
4. Owman Moll P, Kurol J, Lundgren D. Repair of orthodontically induced root resorption in adolescents. Angle Orthod 1995;65:403-8.
5. Weltman B, Vig KW, Fields HW, Shanker S, Kaizar EE. Root resorption associated with orthodontic tooth movement: A systematic review. Am J Orthod Dentofacial Orthop 2010;137:462-76.
6. Al-Qawasmi RA, Hartsfield JK Jr, Everett ET, Flury L, Lui L, Foroud TM et al. Genetic predisposition to external apical root resorption. Am J Orthod Dentofacial Orthop 2003;123:242-52.
7. Odenrick L, Brattström V. Nailbiting: frequency and association with root resorption during orthodontic treatment. Br J Orthod 1985;12:78-81.
8. Lee KS, Straja SR. Tuncay OC. Perceived long-term prognosis of teeth with orthodontically resorbed roots. Orthod Craniofac Res2003;6:177-91.
9. Kokich V. Orthodontic and nonorthodontic root resorption: their impact on clinical dental practice. J Dent Educ 2008;72:895-902.
10. Makedonas D, Odman A, Hansen K. Management of root resorption in a large orthodontic clinic. Swed Dent J 2009;33:173-80.
11. Makedonas D, Hansen K. Diagnosis, screening and treatment of root resorption in orthodontic practices in Greece and Sweden. Angle Orthod 2008;78:248-53.
12. Ahangari ZN, Nasser M, Mahdian M, Fedorowicz Z, Marchesan MA. Interventions for the management of external root resorption. Cochrane Datanase Sust Rev 2010;June 16:CD008003.
13. Winning T, Lim E, Townsend G. Student experiences of assessment in two problem-based dental curricula: Adelaide and Dublin. Assessment and Evaluation in Higher Education 2005;30:489-505.
14. Sameshima GT, Asgarifar KO. Assessment of root resorption and root shape: periapical vs panoramic films. Angle Orthod 2001;71:185-9.
15. Albaker B, Wong R. Diagnosis and management of root resorption by erupting canines using cone-beam computed tomography and fixed palatal appliance: a case report. J Med Case Reports 2010;4:399.
16. Ericson S, Kurol J. Incisor root resorptions due to ectopic maxillary canines imaged by computerized tomography: a comparative study in extracted teeth. Angle Orthod 2000;70:276-83.
17. Drage N, Carmichael F, Brown J. Radiation protection: protection of patients undergoing cone beam computed tomography examinations. Dent Update 2010;37:542-4, 547-8.
18. Malmgren O, Goldson L, Hill C, Orwin A, Petrini L, Lundberg M. Root resorption after orthodontic treatment of traumatised teeth. Am J Orthod 1982;82:487-491.
19. Marques LS, Ramos-Jorge ML, Rey AC, Armond MC, Ruellas

AC. Severe root resorption in orthodontic patients treated with the edgewise method: prevalence and predictive factors. Am J Orthod Dentofacial Orthop 2010;137:384-8.
20. Artum J, Van't Hullenaar R, Doppel D, Kuijpers Jagtman AM. Identification of orthodontic patients at risk of severe apical root resorption. Am J Orthod Dentofacial Orthop 2009;135:448-55.
21. Mandall N, Lowe C, Worthington H, Sandler J, Derwent S, Abdi-Oskouei M et al. Which orthodontic archwire sequence? A randomised clinical trial. Eur J Orthod 2006;28:561-6.
22. Acar A, Canyürek U, Kocaaga M, Erverdi N. Continuous vs discontinuous force application and root resorption. Angle Orthod 1999;69:159-63.
23. Harris EF. Root resorption during orthodontic therapy. Semin Orthod 2000;6:183-94.
24. Ericson S, Kurol J. Early treatment of palatally erupting maxillary canines by extraction of the primary canines. Eur J Orthod 1988;10:283-95.
25. Ngan P, Hornbrook R, Weaver B. Early timely management of ectopically erupting maxillary canines. Semin Orthod 2005;11:152-63.
26. Ericson S, Kurol J. Incisor resorption caused by maxillary cuspids. A radiographic study. Angle Orthod 1987;57:332-46.
27. Sameshima GT, Sinclair PM. Predicting and preventing root resorption: Part II. Treatment factors. Am J Orthod Dentofacial Orthop 2001;119:511-15.
28. Williamson R. Retention of teeth with reduced root length through use of a resin-bonded splint: a case report. Quintessence Int 1995;26:237-42.
29. Levander E, Malmgren O. Long-term follow-up of maxillary incisors with severe apical root resorption. Eur J Orthod 2000;22:85-92.
30. Littlewood S, Millett D, Doublebay B, Bearn D, Worthington H. Retention procedures for stabilising tooth position after treatment with orthodontic braces. Cochrane Database Syst Rev 2006;Jan 25:CD002283.

An investigation of cephalometric and morphological predictors of successful Twin Block therapy

Padhraig S. Fleming,[*] Usman Qureshi,[*] Nikolaos Pandis,[†] Andrew DiBiase[+] and Robert T. Lee[+]
Institute of Dentistry, Queen Mary University of London, London, United Kingdom,[*] University of Bern, Switzerland[†] and East Kent Hospitals, United Kingdom[+]

Objective: To identify predictors of overjet reduction, changes in mandibular length (Co-Me) and antero-posterior changes in mandibular position (Pog-Vert) during Twin Block therapy.
Methods: Pre- and post-treatment cephalograms of 131 participants were analysed (Mean age 12.73 years ± 1) following Twin Block therapy.
Results: Mean annualised overjet reduction was 7.29 mm (± 2.99) with chin projection improving by 2.66 mm (± 5.37). The magnitude of the initial overjet was a strong predictor (95% CI: 0.30, 0.77, $p < 0.01$) of overjet reduction and change in chin position (95% CI: 0.08, 0.77, $p = 0.02$). Greater forward movement of Pogonion occurred if there was greater retrusion of Pogonion at the outset (95% CI: 0.15, 0.45, $p < 0.01$). No prognostic relationship was noted for other potential cephalometric predictors including pretreatment mandibular lower border morphology and Co-Go-Me angle.
Conclusion: No relationship between mandibular morphology, vertical skeletal pattern and favourable dentoalveolar and skeletal responses to Twin Block therapy could be found. These results require confirmation on an external sample.
(Aust Orthod J 2012; 28: 190–196)

Received for publication: March 2012
Accepted: July 2012

Padhraig Fleming: padhraig.fleming@gmail.com; Usman Qureshi: usman76@yahoo.co.uk; Nikolaos Pandis: npandis@yahoo.com; Andrew DiBiase: andrew.dibiase@ekht.nhs.uk; Robert Lee: r.t.lee@qmul.ac.uk

Introduction

Functional appliance therapy has successfully been used to address Class II malocclusions for almost a century. Nevertheless, considerable debate and comment has surrounded the impact of functional appliances on underlying skeletal deformity.[1] On the basis of well-designed prospective studies, it is reasonable to conclude that prolonged skeletal impact of functional appliance therapy is limited.[2-4]

Nevertheless, growth modification is instrumental in achieving successful overjet reduction in the short-term in subjects treated in early adolescence. In particular, 27% of overjet reduction has been attributed to skeletal changes including maxillary restraint and acceleration of mandibular growth.[5]

Factors contributing to the hard and soft tissue response to various functional appliances have previously been assessed. Baccetti et al.[6] have suggested that mandibular shape, specifically Co-Go-Me angulation, was predictive of both hard and soft tissue responses to headgear and Herbst appliance therapy.[6] In addition, skeletal dimensions including overall mandibular length, ramus height, ratio of posterior to anterior facial height, cranial base length and occlusal predictors, chiefly overbite depth, have variously been linked to successful therapy.[7,8]

The aim of the current research was to identify skeletal and occlusal predictors of favourable dental and skeletal response to Twin Block functional appliance therapy.

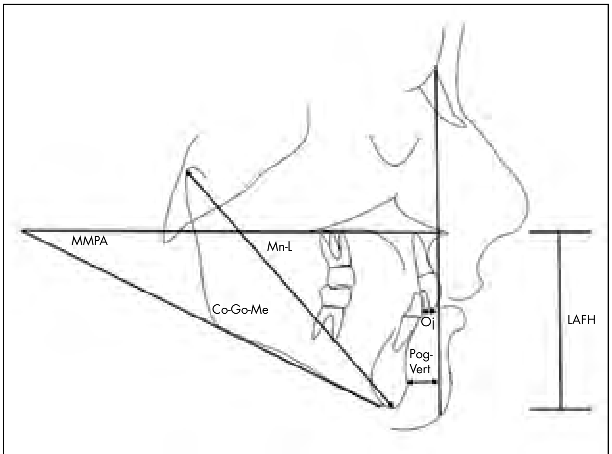


Figure 1. Cephalometric measurements obtained.
Mandibular length (Co-Me), lower anterior facial height (LAFH), Co-Go-Me angle, Maxillo-mandibular plane angle (MMPA), antero-posterior projection of chin point relative to the facial vertical though Nasion perpendicular to Frankfort plane (Pog-Vert)

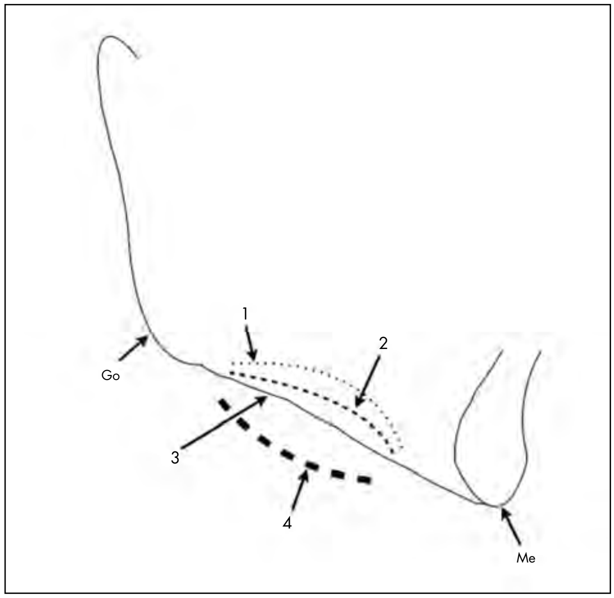


Figure 2. Assessment of lower mandibular border morphology.
1, Deeply convex superiorly; 2, Convex superiorly; 3, Straight; 4, Concave superiorly

Materials and methods

This retrospective cohort study was carried out in the Orthodontic Departments at The Royal London Dental Institute and East Kent Hospitals, UK between 2006 and 2010. Institutional approval for the project was obtained from East Kent Hospitals Research and Development Department. Based on previous research, a total of 123 patients was required to demonstrate a clinically meaningful difference of 1 mm in annualised mandibular length change with treatment (Mean = 5.1 mm, SD = 3.7 mm[6]) with a statistical power of 85% and alpha of 0.05.

Subjects included in the study were obtained from departmental clinical databases. The inclusion criteria were as follows: (1) patients aged between 10 and 14 years, (2) a skeletal II discrepancy (ANB > 4°), (3) an overjet in excess of 7 mm, (4) a pretreatment lateral cephalogram taken within 1 month of appliance placement and (5) an interval between repeated cephalograms not less than 9 months or in excess of 18 months. Subjects were excluded from the research if they had a cleft lip and/or palate or other craniofacial anomaly, or had undergone previous orthodontic treatment. A cohort of 131 subjects undergoing Twin Block therapy in the respective units was obtained from an initial sample of 198 patients after application of the selection criteria. The chief reasons for exclusion were incomplete or inappropriate records and inappropriate age.

Twin-block therapy was carried out by postdoctoral students under consultant supervision or directly by one of three consultants. Minor variations were likely in the general design; however, invariably, appliances involved clasping of all first premolars and first permanent molars with mandibular advancement to an edge-to-edge relationship from the outset. Participants were seen routinely at three-monthly intervals. Post-treatment cephalograms were taken following completion of the functional phase (T2) prior to commencement of fixed appliance therapy.

Data collection

Demographic characteristics including age and gender were obtained for each participant. Compiled cephalometric data included pretreatment skeletal characteristics describing mandibular length, lower anterior facial height, Co-Go-Me angle, maxillo-mandibular plane angle (MMPA) and antero-posterior projection of chin point relative to the facial vertical perpendicular to the Frankfort plane (Pog-Vert, Figure 1). Mandibular lower border morphology was also assessed by assigning a grade based on the degree of convexity or concavity (Figure 2). Pretreatment overjet and overbite were also recorded. On the post-treatment cephalogram, overjet, mandibular length, and the antero-posterior projection of chin point relative to

Table I. Demographic and pretreatment clinical characteristics (N =131).

Pretreatment clinical feature	Mean (SD)	N = (%)
Age (years)	12.73	100.00
Gender: Male	66.00	50.40
Gender: Female	65.00	49.60
Mandibular length (Co-Me, mm)	105.70	5.97
Overjet (mm)	9.94	1.81
Overbite (mm)	5.15	1.74
LAFH (mm)	56.13	6.56
MMPA (degrees)	25.19	4.83
Co-Go-Me (degrees)	124.60	5.43
Pog-Facial Vert (mm)	7.23	6.83
Lower border morphology (Grade: N =)	1 = 17	13.00
	2 = 75	57.00
	3 = 35	27.00
	4 = 4	3.00

Table II. Cephalometric variables (pre-, post- treatment and treatment-related changes)

Cephalometric variable	Pretreatment (T1)	Mean (SD)	Post-treatment (T2)	Mean (SD)	Annualised change (T1-T2)	Mean (SD)
Mandibular length (Co-Me, mm)	105.70	5.97	111.13	6.13	5.32	3.64
Overjet (mm)	9.94	1.81	2.69	2.50	7.29	2.99
Pog-Facial Vert (mm)	7.23	6.83	4.52	4.92	2.66	5.37

Table III. Uni- and multivariable linear regression assessing the effects of explanatory variables on overjet reduction.

Variable	Univariable			Multivariable		
		95% CIs	*p*-value		95% CIs	*p*-value
Overjet	0.58	0.35, 0.81	<0.01	0.53	0.30, 0.77	<0.01
Overbite	0.31	0.06, 0.56	0.02	0.17	-0.08, 0.42	0.18
Gender	0.23	-0.67, 1.13	0.62	0.13	-0.98, 0.72	0.76
Start age	0.35	-0.10, 0.79	0.13	0.25	-0.17, 0.67	0.24

the facial vertical (Pog-Vert) were calculated. Changes in linear dimensions were annualised and adjusted for cephalometric magnification. Measurements were repeated on 10 cephalograms at a two-week interval to assess intra-examiner repeatability.

Statistical methods

Descriptive statistics were used to summarise the demographics of the sample and to assess annualised changes in linear dimensions and overall change in angular measurements with Twin Block therapy. Inferential statistics were used to isolate variables which may predict overjet reduction, increases in mandibular length and improvement in sagittal mandibular projection (Pog-Vert). Observation of data curves confirmed that the data for overjet and sagittal mandibular projection were normally distributed, whereas data for mandibular length were appropriately transformed to follow a normal distribution, and a linear regression analysis was performed. A general linear model (GLM) was used allowing transformed data to be presented in the original scale. Possible predictors included: pretreatment mandibular length, lower anterior facial height, Co-Go-Me angle, maxillo-mandibular plane angle (MMPA), antero-posterior projection of chin point relative to the facial vertical (Pog-Vert), lower border morphology and overjet and overbite. The dependent variables were mandibular length, Pog-Vert and overjet. Variables found to be significant predictors ($p < 0.10$) were included in the multivariable model. Both bivariate assessment and backward elimination excluded the same variables at the 10% level of significance. Starting age and gender were included in the model as they were considered to be important outcome predictors *a priori*. Pretreatment values for outcome measures were also accounted for in the statistical model when correlation between T1 and T2 values exceeded r = *0.5*.

Acceptable levels of intra-observer agreement of continuous cephalometric measurements were demonstrated using Lin's concordance correlation coefficient (r = 0.89 - 0.98).[9] Similarly, excellent agreement between categorical measurement of lower border morphology was confirmed using a weighted kappa statistic (k = 0.83). Analyses were performed with the STATA® version 12.0 software (Stata Corporation, College Station, TX, USA) with a two-tailed p value of 0.05 considered statistically significant.

Results

From an initial sample of 198 participants, full data could be obtained on a total of 131 patients who satisfied the inclusion criteria. This cohort comprised 66 males (50.4%) and 65 females (49.6%), with an average age of 12.73 (± 1.00 years). All participants had a Class II division 1 incisor relationship. Mean pretreatment clinical characteristics are provided in Table I. The mean duration of treatment was slightly in excess of 1 year (1.02 years, SD = 0.18). The mean pretreatment overjet was 9.94 mm (SD = 1.81). Lower border morphology was slightly convex superiorly (Grade 2) in the majority of subjects (57.3%). The appliance-related annualised overjet reduction was in excess of 7 mm (7.29 mm, SD = 2.99). Annualised change in mandibular length was 5.57 mm (SD = 3.79) contributing to considerable improvement in relative chin point projection (2.66 mm, SD = 5.37; Table II).

The univariate analysis showed the pretreatment overjet value was the only significant predictor ($p < 0.10$) of overjet reduction. In the adjusted model, the magnitude of the initial overjet remained a strong outcome predictor (β = 0.23, 95% CI: -0.10, 0.56, $p < 0.01$); the larger the initial overjet, the greater the expected reduction during treatment. However, the variance explained by the multivariate model was low (Adjusted R^2 = 0.16) indicating that overjet reduction was influenced by other unidentified factors (Table III, Figure 3).

In the adjusted model, initial mandibular length and gender were found to be strong predictors of a change in mandibular length during treatment. Males underwent 0.48 mm more increase in mandibular

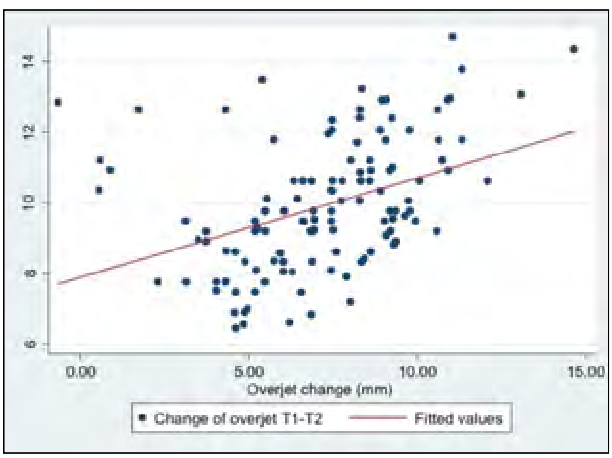


Figure 3. Plot of overjet reduction with increasing initial overjet.

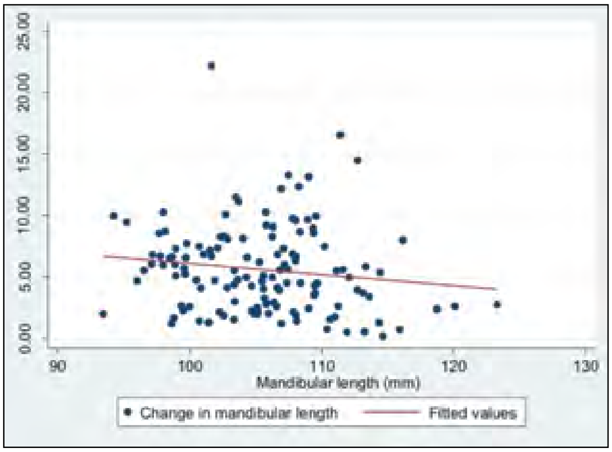


Figure 4. Inverse relationship between mandibular length change with treatment and increasing initial mandibular length.

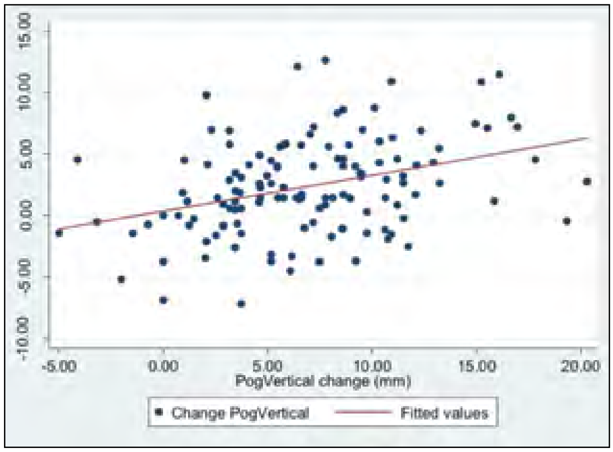


Figure 5. Greater sagittal mandibular projection occurs during treatment with greater initial mandibular retrusion.

Table IV. Uni- and multivariable linear regression analysis assessing the effects of explanatory variables on annualised change in mandibular length.

Variable	Univariable			Multivariable		
		95% CIs	*p*-value		95% CIs	*p*-value
LAFH	-0.01	-0.03, 0.00	0.09	-0.01	-0.03, 0.00	0.11
Overjet	0.06	-0.01, 0.13	0.10	0.05	-0.02, 0.12	0.14
Gender	0.33	0.08, 0.59	0.01	0.48	0.21, 0.75	<0.01
Start age	-0.02	-0.16, 0.11	0.73	-0.04	-0.16, 0.09	0.55
Initial mandibular length	-0.02	-0.04, 0.00	0.12	-0.03	-0.05, -0.00	0.03

Table V. Uni- and multivariable linear regression analysis assessing the effect of explanatory variables on annualised change in sagittal mandibular position (Pog-Vert).

Variable	Univariable			Multivariable		
		95% CIs	*p*-value		95% CIs	*p*-value
Co-Go-Me	0.18	0.01, 0.36	0.04	0.04	-0.11, 0.20	0.61
LAFH	0.13	-0.01, 0.28	0.07	0.03	-0.08, 0.15	0.55
Overjet	0.44	0.08, 0.80	0.02	0.42	0.08, 0.77	0.02
MMPA	0.20	0.01, 0.40	0.04	-0.09	-0.29, 0.12	0.39
Start Pog-Vert	0.29	0.16, 0.42	<0.01	0.30	0.15, 0.45	<0.01
Gender	1.46	-0.42, 3.34	0.13	0.43	-0.83, 1.69	0.50
Start age	-0.07	-1.02, 0.89	0.89	0.14	-0.49, 0.78	0.66

length than females (95% CI: 0.21, 0.75, $p < 0.01$) after adjusting for overjet and starting age. Changes in mandibular length reduced with increasing initial mandibular length (β = -0.03, 95% CI: -0.05, -0.00, p = 0.03). The variance explained by this multivariate model was also low (Adjusted R^2 = 0.09; Table IV, Figure 4).

Pretreatment Co-Go-Me angle, initial LAFH, overjet, MMPA and Pog-Vert values were all found to be significant predictors ($p < 0.10$) for Pog-Vert change during Twin Block therapy. However, in the adjusted model, only initial values for overjet and sagittal chin position (Pog-Vert) remained strong predictors. Greater forward projection of Pogonion was also noted with larger initial overjet values (β = 0.42, 95% CI: 0.08, 0.77, p = 0.02). The variance explained by this model was also low (Adjusted R^2 = 0.14; Table V, Figure 5).

Discussion

Various dento-alveolar and skeletal parameters may be used to assess the effectiveness of functional appliance therapy. The more common of these include overjet, mandibular length and a sagittal assessment of chin projection, such as Pog-Vert. In this retrospective study, the magnitude of overjet reduction during treatment was in excess of 7 mm. This figure is in keeping with prospective studies with O'Brien et al.[5] reporting a mean overjet reduction of 6.93 mm. Similarly, the mean increase in mandibular length was in excess of 5 mm; this compares favourably with both treated and untreated adolescent groups.[10] Given the retrospective nature of this study, the present study is likely to overstate the likely effectiveness of the appliance. Prospective studies, particularly randomised trials, are less susceptible to selection and performance bias, and other confounding issues. The advantage of randomisation is maintained throughout using an 'intention to treat' analysis. In the present study, unsuccessful cases were likely to have been omitted, as these individuals were less likely to have returned for follow-up radiographs. Consequently, the findings obtained may be considered a best-case scenario; the failure to identify significant predictors is therefore arguably more instructive.

Efforts were made to assess outcomes by relating the mandible to other structures (LAFH, MMPA, Pog-Vert) and by examining the mandible in isolation (Co-Go-Me, lower border morphology). While a previous study found a significant relationship between Co-Go-Me angulation and response to functional appliance therapy,[6] this relationship was not corroborated in the present study. The previous study was prospective in design and involved a phase of functional appliance therapy followed by refinement with fixed appliances; the present study investigated the duration of functional appliance therapy in isolation, with a shorter follow-up period. While it has been suggested that the Co-Go-Me angle may give an indication of mandibular morphology,[6] it is composed of only 3 points, and further elaboration of mandibular morphology would be of benefit. The present study therefore was the first to attempt to predict a response to functional appliance therapy on a purely morphological basis.

A grading system for lower border morphology was devised to permit more detailed analysis of the influence of mandibular shape in isolation on successful appliance therapy. The system devised was reproducible but failed to demonstrate a causal relationship. This outcome may reflect the absence of a clear relationship between a vertical growth pattern and the results of functional appliance therapy. Confirmation of a possible association may, however, have been hampered by the preponderance of subjects with straight or mildly convex lower border morphology. Additionally, morphological assessment was confined to a two-dimensional radiographic assessment. In the future, the application of three-dimensional imaging modalities including Cone-Beam Computed Tomography may permit more detailed morphological and volumetric assessment of the mandible[11,12] and therefore the outcome of growth modification treatment.

No relationship was demonstrated with respect to vertical dimensions and treatment outcome with appliance therapy in the present study. While this outcome may be slightly surprising, it is in keeping with previous prospective[6,8] and retrospective[7,13] research. The mean MMPA of participants was slightly reduced (25.2°) reflecting operator preferences and convictions. Significant vertical excess is likely to have been managed without recourse to the Twin Block in many cases due to concerns of increasing the vertical dimension further. Consequently, significant vertical discrepancy is likely to have been absent in this sample, making identification of significant relationships less likely. An assessment of the influence of a vertical discrepancy on the outcome of Twin Block therapy would therefore necessitate prospective follow-up, irrespective of the vertical skeletal pattern.

In the present study, overjet reduction and changes in mandibular projection were positively correlated with the extent of the initial discrepancy. Moreover, forward movement of the chin during Twin Block therapy was also found to be predicated on the initial overjet. Findings of this nature are common in orthodontic research; for example, the magnitude of transverse expansion has been shown to be related to the initial transverse dimension.[14] In this retrospective study, the final desired outcome was likely to be the elimination of the initial overjet during the functional appliance phase. Consequently, overjet reduction merely reflects the success of this treatment. However, given that the primary objective of treatment was typically overjet reduction rather than skeletal change, the relationship between mandibular retrognathia and treatment changes in the mandibular position may be of greater relevance. This finding is also in keeping with Baccetti et al.[10] who reported 2.7 mm of relative forward movement of Pogonion in their prospective study involving two-phased treatment commenced with bonded Herbst therapy.

The objective of the present study was not to assess the effectiveness of Twin Block appliances to an alternative as this objective would best be fulfilled with a randomised controlled trial, but was to identify parameters associated with successful outcomes. In epidemiological research, predictive models are best developed and piloted using observational designs. Potential relationships between dento-alveolar and skeletal parameters on both overjet reduction and change in mandibular position during Twin Block therapy have been identified; however, further research is necessary to confirm the validity of these results.[15,16] Specifically, given the relatively low strength of the relationships demonstrated, it is possible that important predictors may have been overlooked. Further analysis on an external sample is warranted to confirm these relationships. In particular, prospective follow-up research on a treated sample investigating sagittal skeletal responses with varying degrees of mandibular projection over a predefined treatment period would be of value.

Conclusions

No relationship between mandibular morphology and vertical skeletal pattern, and favourable dento-alveolar and skeletal responses to Twin Block therapy was found in this retrospective cohort study.

Corresponding author

Dr Padhraig Fleming
Senior Lecturer/Consultant, Institute of Dentistry
Queen Mary University of London
London E1 1BB
United Kingdom
Email: padhraig.fleming@gmail.com

References

1. Tulloch JF, Medland W, Tuncay OC. Methods used to evaluate growth modification in Class II malocclusion. Am J Orthod Dentofacial Orthop 1990;98:340-7.
2. O'Brien K, Wright J, Conboy F, Appelbe P, Davies L, Connolly I et al. Early treatment for Class II Division 1 malocclusion with the Twin-block appliance: a multi-center, randomized, controlled trial. Am J Orthod Dentofacial Orthop 2009;135:573-9.
3. Tulloch JF, Proffit WR, Phillips C. Outcomes in a 2-phase randomized clinical trial of early Class II treatment. Am J Orthod Dentofacial Orthop 2004;125:657-67.
4. Dolce C, McGorray SP, Brazeau L, King GJ, Wheeler TT. Timing of Class II treatment: skeletal changes comparing 1-phase and 2-phase treatment. Am J Orthod Dentofacial Orthop 2007;132:481-9.
5. O'Brien K, Wright J, Conboy F, Sanjie Y, Mandall N, Chadwick S et al. Effectiveness of early orthodontic treatment with the Twin-block appliance: a multicenter, randomized, controlled trial. Part 1: Dental and skeletal effects. Am J Orthod Dentofacial Orthop 2003;124:234-43.
6. Franchi L, Baccetti T. Prediction of individual mandibular changes induced by functional jaw orthopedics followed by fixed appliances in Class II patients. Angle Orthod 2006;76:950-4.
7. Patel HP, Moseley HC, Noar JH. Cephalometric determinants of successful functional appliance therapy. Angle Orthod 2002;72:410-17.
8. Caldwell S, Cook P. Predicting the outcome of twin block functional appliance treatment: a prospective study. Eur J Orthod 1999;21:533-9.
9. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement, Lancet 1986;1,8476;307-10.
10. Baccetti T, Franchi L, Stahl F. Comparison of 2 comprehensive Class II treatment protocols including the bonded Herbst and headgear appliances: a double-blind study of consecutively treated patients at puberty. Am J Orthod Dentofacial Orthop 2009;135:698.e1-10.
11. Ahn SJ, Kim JT, Nahm DS. Cephalometric markers to consider in the treatment of Class II Division 1 malocclusion with the bionator. Am J Orthod Dentofacial Orthop 2001;119:578-86.
12. Reynolds M, Reynolds M, Adeeb S, El-Bialy T. 3-d volumetric evaluation of human mandibular growth. Open Biomed Eng J 2011;5:83-9.
13. Ruf S, Pancherz H. The mechanism of Class II correction during Herbst therapy in relation to the vertical jaw base relationship: A cephaometric roentgenographic study. Angle Orthod 1997;67:271-6.
14. Fleming PS, DiBiase AT, Sarri G, Lee RT. Comparison of mandibular arch changes during alignment and leveling with 2 preadjusted edgewise appliances. Am J Orthod Dentofacial Orthop 2009;136:340-7.
15. Moons KG, Royston P, Vergouwe Y, Grobbee DE, Altman DG. Prognosis and prognostic research: what, why, and how? BMJ 2009;338:b375.
16. Altman DG, Vergouwe Y, Royston P, Moons KG. Prognosis and prognostic research: validating a prognostic model. BMJ 2009;338:b605

Occlusal bite force changes during 6 months of orthodontic treatment with fixed appliances

Sawsan A. Alomari and Elham S. Abu Alhaija
Department of Preventive Dentistry, Faculty of Dentistry, Jordan University of Science and Technology, Irbid, Jordan

Background: Occlusal bite force (OBF) is reported to change during fixed appliance orthodontic treatment.
Aims: The aim of the present study was to determine bite force changes during the first 6 months of fixed appliance orthodontic treatment and to investigate the relationship between patients' subjective pain levels and recorded changes in OBF.
Methods: Forty-seven subjects (34 females, 13 males) were recruited from the Dental Teaching Centre at the Jordan University of Science and Technology. The subject's ages ranged between 18 and 26 years (average 19.0 ± 3.36 years). Bite force was measured using a portable OBF gauge at nine time intervals (T0 - T8). At each OBF recording, subjects were asked to describe their subjective pain level using a visual analogue scale (VAS). A repeated-measures analysis of variance and a Bonferroni post-hoc comparison test were applied to determine differences at the various time intervals.
Results: Bite force significantly reduced during the first month of orthodontic treatment and approximately 50% of pretreatment OBF was lost by the end of the first week. However, bite force recovered to pretreatment levels by the end of the sixth month. Visual analogue pain scores were higher during the first 2 weeks of treatment and were positively correlated with the OBF loss.
Conclusion: OBF reduced during the first month of orthodontic treatment but, with time, recovered to pretreatment levels.
(Aust Orthod J 2012; 28: 197–203)

Received for publication: December 2011
Accepted: Accepted July 2012

Sawsan A. Alomari: saalomari@just.edu.jo; Elham S. Abu Alhaija: elham@just.edu.jo

Introduction

While many indicators have been used to assess the functional state of an occlusion, occlusal bite force (OBF) has been a key predictor of masticatory performance.[1] The number and size of occlusal contacts are considered the primary determinants of masticatory function for individuals with a complete dentition.[2] The nature of occlusal contacts has been shown to determine 10% to 20% of the variation of maximum bite force in adults.[3]

A reduced maximum bite force has been associated with a malocclusion.[4-6] Children with a unilateral posterior crossbite have been shown to have reduced maximum bite force and a reduced number of occlusal contacts compared with children possessing normal occlusions.[4] Sonnesen and Bakke[11] confirmed that bite force reduced immediately after the commencement of unilateral crossbite treatment but increased after retention and approached bite force levels in children with a normal occlusion. It was postulated that the fluctuation in bite force during crossbite correction was due to transient changes in occlusal contact and support.[11] In addition, Yawaka et al.[9] examined changes in the average occlusal bite force of patients with an anterior crossbite in the primary dentition and noted that bite force was lowest as the crossbite was treated but then gradually increased. Furthermore, Winocur et al.[10] found that occlusal bite force increased after orthodontic treatment compared with that measured prior to appliance removal and Henrikson et al.[7] revealed that females with normal occlusions had better masticatory performance than their Class II counterparts.

Maximum OBF has been shown to decrease during orthodontic treatment.[8-11] Thomas et al.[8] indicated that bite force decreased in patients scheduled for orthognathic surgery. However, unlike routine orthodontic treatment, presurgical treatment often increased the severity of a malocclusion by the decompensation process and a likely reduction in the number of occlusal contacts. In addition, pain is considered to be a modifying factor which limits the force of maximum bite due to reflex mechanisms.[12,13] Goldreich et al.[14] reported that pain had an effect on muscle activity even when it did not originate in the associated muscle or a related joint. Pain and discomfort of the orthodontic appliances and the induced malocclusion produced a reduction in occlusal bite force during and after presurgical orthodontics.[8]

While bite force changes have been shown to occur during routine orthodontic treatment,[9] research in this area has been minimal and mostly performed on surgical cases. Therefore, the aims of this study were to determine OBF changes during the first 6 months of fixed appliance orthodontic treatment and to investigate the relationship between patients' subjective pain levels and observed changes in OBF.

Materials and methods

Ethical approval for the present study was obtained from the Research Board of Jordan University of Science and Technology (JUST). All patients attending the orthodontic clinic at the Dental Teaching Centre during the period between October 2008 and June 2009 were screened. Of the 253 orthodontic patients, 47 (34 females, 13 males) patients who fulfilled the following criteria were included in this study:

1. No prior orthodontic treatment.
2. Adult Caucasian (>18 years).
3. Class I skeletal pattern (2° ≤ ANB ≤ 4°).
4. Average maxillomandibular plane angle (27 ± 5°).
5. No or mild crowding (0-4 mm).
6. No congenitally absent or missing permanent teeth.
7. No posterior crossbite.
8. No signs or symptoms of temporomandibular joint dysfunction.
9. No craniomandibular anomalies or systemic muscle or joint disorders.
10. No large carious lesions or restorations on upper or lower first permanent molars, and small carious lesions elsewhere restored prior to orthodontic treatment.
11. No periodontal disease.

The age of the subjects ranged between 18 and 26 years with a mean age of 19.0 ± 3.36 years. The average ANB angle for the sample was 3.60 ± 0.73 degrees, while the average maxillomandibular plane angle was 28.31 ± 2.85 degrees. Overjet was slightly increased and averaged 4.57 ± 0.29 millimeters. The average crowding was 2.39 ± 1.40 millimeters.

A control group comprising 47 dental students (34 females, 13 males) who possessed normal occlusions was selected and examined in order to provide comparative OBF levels over a period of six months. Occlusal bite force was recorded in these subjects on six separate occasions with an interval of one month between measurements. The OBF registration procedure was explained and written consent obtained from all subjects prior to the commencement of the study.

Orthodontic treatment involved the insertion of a preadjusted edgewise orthodontic appliance (Omni 0.022 inch Roth prescription, GAC International Inc., NY, USA) to the upper and lower arches. Upper and lower first and second permanent molars were banded in all treatment patients (GAC International Inc., NY, USA). Neither extra-oral appliances nor maxillary expansion devices were used for any patient. All patients were treated by the same consultant (EA) utilising a non-extraction treatment protocol. The archwire (3M Ltd, Unitek, Monrovia, CA, USA) sequence used during orthodontic treatment was the same for all patients (Table I). Occlusal bite force was recorded using a battery-operated portable type of OBF gauge (GM10, Nagano Keiki, Tokyo, Japan). The bite force gauge consisted of a hydraulic pressure gauge and a biting element made of a vinyl material encased in a polyethylene tube (disposable cap). The measured OBF force was calculated in Newtons (N) and displayed digitally.

OBF was bilaterally measured in the first permanent molar region. Before recording, each subject was instructed to sit upright, looking forward without head support and with the Frankfort plane parallel to the floor. Each subject was instructed to bite as hard as possible without moving their head. Three OBF measurements were recorded on each side with a 15 second rest between each bite. The maximum OBF measurement achieved on each side was recorded. The averaged maximum OBF was considered as the occlusal bite force (OBF) for that patient and included in the analysis. All measurements were carried out by the same investigator (SA) and OBF was recorded at the following time intervals:

Table I. Archwires sequence used during orthodontic treatment.

Recall visit	Archwire (Nickel-Titanium (Ni-Ti)), stainless steel (SS)
Bond-up visit	Upper and lower 0.014 Ni-Ti archwires
First month	Upper and lower 0.016 Ni-Ti archwires
Second month	Upper and lower 0.018 Ni-Ti archwires
Third month	Upper and lower 0.016 x 0.022 Ni-Ti archwires
Fourth month	Upper and lower 0.016 x 0.022 SS archwires
Fifth month	Upper and lower 0.017 x 0.025 SS archwires

1. Just prior to orthodontic elastic separator insertion (T0).
2. One week after the placement of orthodontic appliances (T1).
3. Two weeks after the placement of orthodontic appliances (T2).
4. One month and up to six months (T3-T8) after placement of orthodontic appliances and before the scheduled arch wire change for that visit.

At each OBF was recording, subjects were asked to describe their subjective pain level experienced at the time of their previous arch wire change using a 'Visual Analogue Scale' (VAS). The scale used a horizontal 10 cm baseline with two extremes representing 'no pain' extending to 'pain as bad as it could possibly be'. The patient was asked to indicate their subjective pain level relative to the two extremes and the distance from the low end of the scale to the patient's mark was measured to the nearest millimetre to represent the index of pain intensity. All measurements were made by the same investigator (SA) using the same stainless steel ruler. Subjective pain levels were then classified into three categories according to the VAS scores; mild pain if the VAS scores were between 0.1 cm and 3 cm, moderate pain if the VAS scores were between 3.1 cm and 6 cm and severe pain if the VAS scores were greater than 6 cm. OBF measurements for the control group were taken in a similar manner to the treatment group.

Statistical analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences computer software (SPSS 17.0, SPSS Inc., IL, USA). Shapiro-Wilks w-test revealed that OBF data were normally distributed. Descriptive statistics for OBF and VAS scores at the different time intervals were program calculated. The independent-sample student *t*-test was used to detect gender differences in OBF and VAS scores. A repeated measures analysis of variance (within-subjects ANOVA) test and a Bonferroni post-hoc comparison test were conducted to examine and define the differences between the OBF and VAS scores at the different time intervals before and during orthodontic treatment. Spearman correlation coefficients were calculated for OBF changes in relation to VAS pain scores. Statistical significance was predetermined at the $p \leq 0.05$ level.

Method error

The Dahlberg formula[15] was used to calculate the standard error of the method $S = \sqrt{\sum d2/2n}$. Houston's coefficient of reliability[16] was also calculated. Dahlberg error was 2.74 N and the coefficient of reliability was 89 per cent.

Results

The mean OBF, standard deviation and percentages of OBF loss and recovery during orthodontic treatment at the different time intervals for females, males and the total treatment group are shown in Table II. The patterns of OBF change during orthodontic treatment at different time intervals (T0 - T8) for females, males and the total treatment group are shown in Figures 1 and 2 respectively. Gender differences in OBF were not detected.

The mean OBF in the control group was 662.60 ± 246.37 N and 467.38 ± 173.99 N in the treatment

Table II. Mean OBF, SD and percentages of OBF loss and recovery at different time intervals.

Time interval	Control (N = 47)	Females (N = 34)			Males (N = 13)			Total treatment group (N = 47)		
	OBF (Mean ± SD)	OBF (Mean ± SD)	OBF loss %	OBF recovery %	OBF (Mean ± SD)	OBF loss %	OBF recovery %	OBF (Mean ± SD)	OBF loss %	OBF recovery %
Before Bond-up (T0)	-	418.91 ± 135.81	-	-	594.15 ± 203.13	-	-	467.38 ± 173.99	-	-
1st week (T1)	-	152.76 ± 109.45	63.53*	-	398.54 ± 201.28	32.92*	-	220.74 ± 177.52	52.71*	-
2nd week (T2)	-	212.82 ± 114.31	49.20*	22.57	442.54 ± 196.93	25.51*	22.49	276.36 ± 174.01	40.82*	22.55
1st month (T3)	662.60 ± 246.37	310.68 ± 142.06	25.84*	59.33	499.62 ± 186.66	15.91	51.68	362.94 ± 175.68	22.32*	57.65
2nd month (T4)	648.38 ± 245.99	359.94 ± 135.55	14.08	77.84	547.54 ± 192.34	7.85	76.71	411.83 ± 173.28	11.87	77.48
3rd month (T5)	647.32 ± 243.04	391.21 ± 129.32	6.61	89.59	611.62 ± 202.78	0	108.93	452.17 ± 180.71	3.25	93.83
4th month (T6)	644.08 ± 233.66	383.09 ± 135.52	8.55	86.54	587.69 ± 155.80	1.09	96.69	439.68 ± 167.53	5.91	88.77
5th month (T7)	640.52 ± 237.72	397.82 ± 126.78	5.03	92.08	617.15 ± 198.09	0	111.76	458.49 ± 177.77	1.90	96.39
6th month (T8)	640.52 ± 254.07	408.50 ± 123.83	2.49	96.09	623.31 ± 217.66	0	114.90	467.91 ± 181.09	-0.001	100.21

Minus sign donates that there is an increase rather than a decrease
* significant at the 0.05 level

Table III. Mean VAS scores and distribution of patients according to the severity of pain at different time intervals.

Time interval	Females						Males						Total treatment group					
	Mean (SD)	No Pain	Pain scores 0.1-3 cm	Pain scores 3.1-6 cm	Pain scores 6.1-10 cm	Pain total	Mean (SD)	No Pain	Pain scores 0.1-3 cm	Pain scores 3.1-6 cm	Pain scores 6.1-10 cm	Pain total	Mean (SD)	No Pain	Pain scores 0.1-3 cm	Pain scores 3.1-6 cm	Pain scores 6.1-10 cm	Pain total
T1	4.46 (2.67)	4 (12%)	7 (21%)	12 (35%)	11 (32%)	88%	2.66 (3.02)	4 (31%)	5 (39%)	2 (15%)	2 (15%)	69%	3.96 (2.86)	8 (17%)	12 (25.5%)	14 (29.8%)	13 (27.7%)	83%
T2	3.07 (2.46)	8 (24%)	11 (32%)	9 (26%)	6 (18%)	76%	0.79 (0.95)	6 (46%)	7 (54%)	0 (0%)	0 (0%)	54%	2.44 (2.37)	14 (29.8%)	18 (38.3%)	9 (19.2%)	6 (12.7%)	70.2%
T3	1.43 (1.91)	17 (50%)	12 (35%)	4 (12%)	1 (3%)	50%	0.97 (1.43)	8 (62%)	4 (31%)	1 (7%)	0 (0%)	38%	1.30 (1.79)	25 (53.2%)	16 (34%)	4 (8.5%)	2 (4.3%)	46.8%
T4	0.98 (1.60)	23 (68%)	5 (14%)	6 (18%)	0 (0%)	32%	1.51 (1.92)	7 (54%)	4 (31%)	2 (15%)	0 (0%)	36%	1.13 (1.69)	30 (63.8%)	9 (19.1%)	8 (17.1%)	0 (0%)	36.2%
T5	0.29 (1.12)	31 (91%)	2 (6%)	1 (3%)	0 (0%)	9%	0.54 (1.45)	11 (86%)	1 (7%)	1 (7%)	0 (0%)	14%	0.36 (1.21)	42 (89.4%)	3 (6.4%)	2 (4.2%)	0 (0%)	10.6%
T6	0.50 (1.24)	28 (82%)	4 (12%)	2 (6%)	0 (0%)	18%	0.77 (1.36)	9 (69%)	3 (24%)	1 (7%)	0 (0%)	31%	0.57 (1.26)	38 (80.9%)	6 (12.7%)	3 (6.4%)	0 (0%)	19.1%
T7	0.15 (0.70)	31 (91%)	2 (6%)	1 (3%)	0 (0%)	9%	0 (0.00)	13 (100%)	0 (0%)	0 (0%)	0 (0%)	0%	0.11 (0.60)	44 (93.6%)	2 (4.3%)	1 (2.1%)	0 (0%)	6.4%
T8	0.24 (0.82)	31 (91%)	2 (6%)	1 (3%)	0 (0%)	9%	0.31 (1.11)	12 (93%)	0 (0%)	1 (7%)	0 (0%)	7%	0.26 (0.90)	43 (91.5%)	4 (8.5%)	0 (0%)	0 (0%)	8.5%

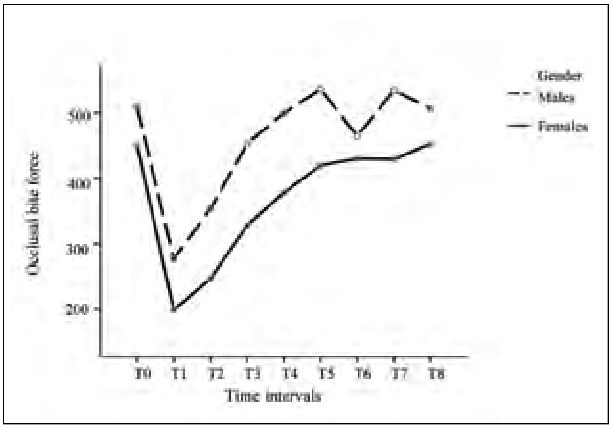


Figure 1. Pattern of maximum bite force change during fixed orthodontic treatment for females and males at different time intervals (T0 - T8).

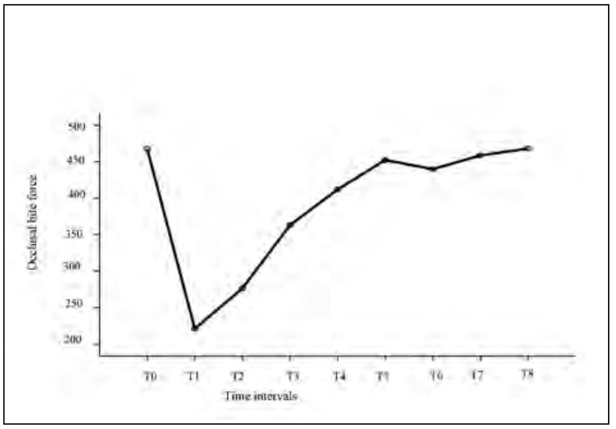


Figure 2. Pattern of occlusal bite force change during fixed orthodontic treatment at different time intervals (T0 - T8) for total treatment group.

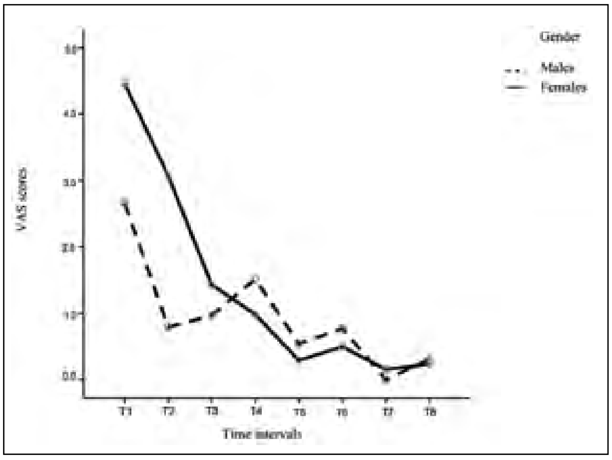


Figure 3. Pattern of VAS pain scores change during fixed orthodontic treatment for females and males at different time intervals (T1 - T8).

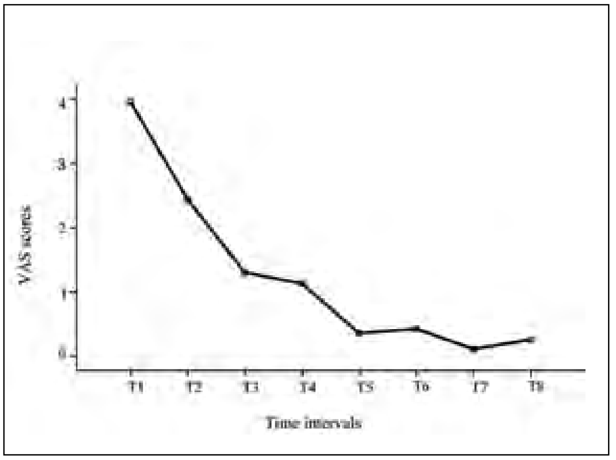


Figure 4. Pattern of VAS pain scores change during fixed orthodontic treatment at different time intervals (T1 - T8).

group ($p < 0.001$). No significant differences in OBF magnitude were found over the six month period in the control group ($p > 0.05$).

The mean VAS scores and the distribution of patients according to the severity of pain at different time intervals for females, males and the total treatment group are shown in Table III. Figures 3 and 4 represent the pattern of VAS score change during treatment at the different time intervals (T1 - T8) for females, males and the total treatment group respectively. Gender differences in VAS scores were not detected.

There was a significant difference in pain scores associated with the different time intervals ($p < 0.001$). The highest reported pain was at T1 and lowest was at T7. However, pain scores were only considered significant at T1, T2, T3 and T4 time intervals ($p < 0.001$). A significant positive correlation (at the 0.01 level) was observed between OBF loss and VAS scores at T1, T2 for the total treatment group; at T1 for females and at T2 for males.

Discussion

Few studies have addressed the issue of occlusal bite force changes during fixed appliance orthodontic treatment.[8-11] Previous reports have measured OBF before and after treatment but have not reported OBF during treatment.[8,9,11] In the present study, a control group was used to record OBF changes on a monthly basis in subjects with normal occlusion. As no significant changes in OBF values were found over six months, the changes in OBF measured during this study were considered a result of orthodontic treatment.

The present study employed a hydraulic pressure gauge with a biting element encased in plastic covering whose accuracy and reliability had been previously reported.[17] The visual analogue scale (VAS) to measure subjective pain was used due to its common acceptance as a pain measurement tool.[18] It was found superior to other pain scales in relation to reproducibility and ease of measurement.[19] However, the VAS scale did not allow subjects to differentiate between tooth or soft tissue sources of discomfort.[20]

All patients were selected to possess average anteroposterior and vertical skeletal relationships as occlusal bite force has been shown to vary in patients with different craniofacial morphological characteristics.[11,21,22] Subjects aged 18 years and above were recruited as previous evidence suggested that OBF increases with age to stabilise after the age of 14 years.[23] Varga et al.[24] found that there was minimal increase in bite force following the cessation of the pubertal growth spurt.

Malocclusions are often associated with reduced OBF.[4,5] In the present study, the OBF in the treatment group, each of which possessed a Class I malocclusion, exhibited lower OBF values prior to treatment, compared with a control group with normal Class I occlusions. This supports previous findings which reported that masticatory performance is highest in subjects with Class I occlusions followed by Class I, Class II and Class III malocclusions in descending order.[5,7]

Expectedly, a large reduction in OBF (50%) occurred at the end of the first week following the placement of fixed appliances. Bite force remained significantly reduced during the second week and in the first month. The results of the present study confirmed those of Thomas et al.[8] who reported a reduction in OBF during treatment. In addition, the present results were supported by Goldreich et al.[14] who suggested that orthodontic adjustments tended to reduce functional muscle activity. Sonnesen and Bakke[11] found that significant reductions in OBF occurred on the crossbite side rather than on the contralateral non-crossbite side immediately after treatment of a unilateral crossbite. This was explained by transient changes in occlusal support, periodontal mechanoreceptor effects and jaw elevator muscle reflexes.[25] The reduction in OBF observed in the present study may be due to changes in occlusal contacts which occurred during treatment, as it was previously reported that occlusal contacts determine 10% to 20% of the variation of maximum bite force in adults.[3]

A significant correlation was found between the amount of OBF loss and the subjective orthodontic pain experienced by the patient. This was in accord with Michelotti et al.[26] who indicated that the short-term occurrence of orthodontic pain was associated with motor and sensory changes of the masticatory muscles and represented by a decrease of the motor output and pressure pain thresholds of the jaw-closing muscles. Furthermore, pain is considered as an important modifying factor which tends to limit the maximum bite force due to reflex mechanisms.[12-13]

Contrary to some studies,[27,28] the current investigation determined no significant differences in the levels of perceived pain for males and females according to the VAS. Previous studies have also indicated that gender appears not to affect perceived pain during orthodontic treatment.[18,29] However, this finding may be affected by an unequal gender distribution in the present study.

Conclusions

1. 50% of pretreatment OBF was lost by the end of the first week.
2. OBF showed a tendency to return to pretreatment levels after the second month of orthodontic treatment.
3. VAS scores were high during the first 2 weeks of appliance treatment.
4. VAS scores positively correlated with the reduction of OBF.

Acknowledgment

The study was supported by grant number 52/2009 from the Deanship of Research/Jordan University of Science and Technology.

Corresponding author

Professor Elham S. J. Abu Alhaija
Preventive Dentistry Department
School of Dentistry
Jordan University of Science and Technology
P.O. Box 3030
Irbid
Jordan

Email: elham@just.edu.jo

References

1. Hatch J, Shinkai R, Sakai S, Rugh D, Paunovich E. Determinants of masticatory performance in dentate adults. Arch Oral Biol 2001;46 : 641-8.
2. Julien KC, Buschang PH, Throckmorton GS, Dechow PC. Normal masticatory performance in young adults and children. Arch Oral Biol 1996;41:69-75.
3. Bakke M. Bite force and occlusion. Semin Orthod 2006;12:120-6.
4. Sonnesen L, Bakke M, Solow B. Bite force in pre-orthodontic children with unilateral crossbite. Eur J Orthod 2001;23:741-9.
5. English JD, Buschang PH, Throckmorton GS. Does malocclusion affect masticatory performance. Angle Orthod 2002;72:21-7.
6. Tsai HH. Maximum bite force and related dental status in children with deciduous dentition. J Clin Pediatr Dent 2004;28:139-42.
7. Henrikson T, Ekberg EC, Nilner M. Masticatory efficiency and ability in relation to occlusion and mandibular dysfunction in girls. Int J Prosthodont 1998; 11:125-32.
8. Thomas G, Throckmorton G, Ellis E, Sinn DP. The effects of orthodontic treatment on isometric bite forces and mandibular motion in patients prior to orthognathic surgery. J Oral Maxillofac Surg 1995;53:673-87.
9. Yawaka Y, Hironaka S, Akiyama A, Matzuduka I, Takasaki C, Oguchi H. Changes in occlusal contact area and average bite pressure during treatment of anterior crossbite in primary dentition. J Clin Pediatr Dent 2003;28:75-9.
10. Winocur E, Davidov I, Gazit E, Brosh T, Vardimon A. Centric slide, bite force and muscle tenderness changes over 6 months following fixed orthodontic treatment. Angle Orthod 2007;77:254-9.
11. Sonnesen L, Bakke M. Bite force in children with unilateral crossbite before and after orthodontic treatment. A prospective longitudinal study. Eur J Orthod 2007;29:310-13.
12. Ahlberg J, Kovero O, Hurmerinta K, Zepa I, Nissinen M, Könönen M. Maximal bite force and its association with signs and symptoms of TMD, occlusion and body mass index in a cohort of young adults. Cranio 2003;21:248-52.
13. Hansdottir R, Bakke M. Joint tenderness, jaw opening, chewing velocity and bite force with tempromandibular joint pain and matched healthy control subjects. J Orofac pain 2004;18:108-13.
14. Goldreich H, Gazit E, Lieberman M, Rugh J. The effect of pain from orthodontic arch wire adjustment on masseter muscle electromyographic activity. Am J Orthod Dentofacial Orthop 1994;106:365-70.
15. Dahlberg G. Statistical methods for medical and biological students. Interscience Publications, New York: 1940;122-32.
16. Houston WJ. The analysis of errors in orthodontic measurements. Am J Orthod 1983;83:382-90.
17. Kamegai T, Tatsuki T, Nagano H, Mitsuhashi H, Kumeta J, Tatsuki Y et al. A determination of bite force in northern Japanese children. Eur J Orthod 2005;27:53-7.
18. Erdinç AM, Dinçer B. Perception of pain during orthodontic treatment with fixed appliances. Eur J Orthod 2004; 26:79-85.
19. Seymour R, Simpson J, Charlton J, Phillips M. An evaluation of length and end-phrase of visual analogue scales in dental pain. Pain 1985;21:177-85.
20. Scott P, Sherriff M, DiBiase A, Cobourne M. Perception of discomfort during initial orthodontic tooth alignment using a self-ligating or conventional bracket system: a randomized clinical trial. Eur J Orthod 2008;30:227-32.
21. Sondang P, Kumagai H, Tanaka E, Ozaki H, Nikawa H, Tanne K et al. Correlation between maximum bite force and craniofacial morphology of young adults in Indonesia. J Oral Rehabil 2003;30:1109-17.
22. Abu Alhaija E, Al Zo'ubi I, Al Rousan M, Hammad M. Maximum occlusal bite forces in Jordanian individuals with different dentofacial vertical skeletal patterns. Eur J Orthod 2010;32:71-7.
23. Braun S, Bantleon H, Hnat W, Freudenthaler J, Marcotte M, Johnson B. A study of bite force, part 1: relationship to various physical characteristics. Angle Orthod 1995;65:367-72.
24. Varga S, Spalj S, Varga M, Milosevic S, Mestrovic S, Slaj M. Maximum voluntary molar bite force in subjects with normal occlusion. Eur J Orthod 2011;33:427-33.
25. Sonnesen L, Bakke M. Molar bite force in relation to occlusion, craniofacial dimensions, and head posture in pre-orthodontic children. Eur J Orthod 2005;27:58-63.
26. Michelotti A, Farella M, Martina R. Sensory and motor changes of the human jaw muscles during induced orthodontic pain. Eur J Orthod 1999;21:397-404.
27. Scheurer P, Firestone A, Bürgin W. Perception of pain as a result of orthodontic treatment with fixed appliances. Eur J Orthod 1996;18:349-57.
28. Sonnesen L, Svensson P. Assessment of pain sensitivity in patients with deep bite and sex- and age- matched controls. J Orofac Pain 2011;25:15-24.
29. Fernandes L, Ogaard B, Skoglund L. Pain and discomfort experienced after placement of a conventional or a superelastic NiTi aligning archwire. A randomized clinical trial. J Orofac Orthop 1998;59: 331-9.

Bone density and miniscrew stability in orthodontic patients

Vilas Samrit,* Om Prakash Kharbanda,* Ritu Duggal,* Ashu Seith† and Varun Malhotra*

Division of Orthodontics and Dentofacial Deformities, Centre for Dental Education and Research* and Department of Radio-Diagnosis,† All India Institute of Medical Sciences, New Delhi, India

Objectives: The purpose of this study was to evaluate bone density in buccal inter-radicular bone between second premolars and first permanent molars and its association with the clinical stability of miniscrews used for en masse retraction of anterior teeth in extraction cases.

Materials and Methods: Thirty-eight miniscrews were placed in ten patients (8 females, 2 males: mean age, 18.9 ± 4.12 years) to provide indirect orthodontic anchorage. Twenty miniscrews were placed in the maxilla and eighteen were inserted in the mandible. All of the miniscrews were placed in the buccal inter-radicular bone between the second premolar and the first permanent molar. Bone density at each miniscrew site was recorded by computed tomography and recorded in Hounsfield units (HU) before miniscrew placement. Nickel-titanium closed-coil springs were used to apply an orthodontic force of 2N within one week following placement.

Results: Cortical bone density values ranged from 506.7 - 1705.6 HU (Mean, 929.27 ± 322.12 HU) in the maxilla and 503.8 - 1544.8 HU (Mean, 1116.2 ± 298.33 HU) in the mandible. Cancellous bone density values ranged from 185.9 - 930.8 HU (Mean, 450.09 ± 205.66 HU) in the maxilla and 197.3 - 803.6 HU (Mean, 561.87 ± 170.83 HU) in the mandible. There was no statistically significant difference between right and left sides. A bone density comparison between the maxilla and mandible revealed statistically significant higher values in mandibular cortical bone ($p = 0.008$), while no significant difference was found in cancellous bone values ($p = 0.097$). Clinically, the success rate of miniscrews in the maxilla was 100% but only 77.8% in the mandible. Miniscrew failures were associated with peri-implant inflammation and miniscrew proximity to dental roots. No relation was found between bone density and miniscrew stability.

Conclusion: The present study determined that no definitive association could be established between miniscrew success and bone density.

(Aust Orthod J 2012; 28: 204–212)

Received for publication: December 2011
Accepted: July 2012

Vilas Samrit: drsam_vilas@yahoo.co.in; Om Prakash Kharbanda: opk15@hotmail.com; Ritu Duggal: rituduggal@rediffmail.com;
Ashu Seith: ashubhalla1@yahoo.com; Varun Malhotra: drvarunmalhotra@gmail.com

Introduction

Clinical reports and experiments in recent years have shown that miniscrews can be used as absolute anchorage devices for en masse retraction of anterior teeth following the extraction of premolars in severe maxillary incisor protrusion[1,2,3] and in the treatment of other complex malocclusions such as skeletal deepbite,[4] skeletal openbite[5] and intrusion and distalisation of molars.[6-9]

Successful orthodontic treatment relies on primary miniscrew stability which is dependent on numerous factors classified as host related, implant related and surgical and technique related.[10-18] Host related factors include age, gender, type and amount of soft tissue and bone, and oral hygiene maintenance. Implant related factors involve the size, shape, length and type (predrilled or self-drilling) of the miniscrew. The angulation of the miniscrew, its proximity to dental roots, immediate, early or delayed loading, the amount of load applied, inflammation at insertion sites and the applied surgical procedures are other influencing factors associated with stability.

Bone quality has also been reported as an important factor affecting miniscrew stability and several classification systems and procedures have been proposed to assess bone and determine the prognosis of prosthetic implants.[19-22] Lekholm and Zarb[19] classified bone density radiographically into four types based on the amount of cortical versus trabecular bone. Misch[20] classified bone into five density categories based on a range of Hounsfield unit values; D1: greater than 1250HU, D2 850 - 1250HU, D3 350 - 850HU, D4 150 - 350HU and D5 less than 150HU. Norton and Gamble[21] and Shahlaie et al.[23] concluded that quantitative computerised tomography (CT) was a valuable supplement to the subjective assessment of bone density in the region of implant placement. This was based on a quantitative CT examination of prosthetic implant sites and a comparison of the Hounsfield unit value with subjective quality scores defined by Lekholm and Zarb.[19]

Histomorphometry of bone biopsies,[24,25] densitometry,[26] digital image analysis of microradiographs[27] and ultrasound[28] have been additional methods used for assessing bone quality which have proved reliable for quantitative measurement. However, routine use in clinical practice is impractical. Although cadaver studies[23,29] and clinical studies[21,30-35] assessing bone density are available, few studies examining proposed sites of orthodontic implants[36-40] exist in the literature.

Therefore, the present study aimed to evaluate bone density in the buccal inter-radicular bone between the second premolar and the first permanent molar regions in the maxilla and mandible. A secondary aim was to compare recorded bone density with the clinical stability of miniscrews in a group of orthodontic patients.

Materials and methods

The present study evaluated 38 miniscrew sites in 10 patients (8 females and 2 males) aged between 15 - 28 years (mean age, 18.9 ± 4.12 years) whose treatment required the extraction of at least, the upper first premolars. All patients were assessed to have high anchorage requirements represented by one Class II division 1 malocclusion and nine Class I patients characterised by bimaxillary protrusion. Twenty miniscrews (Absoanchor, Dentos Inc. Korea) were placed in maxillae and eighteen miniscrews were placed in mandibles. The study was sanctioned by the Institutional Ethics Committee and informed consent was obtained from all patients. Patients with systemic disease or those requiring long term medication likely to affect bone metabolism were excluded from the study.

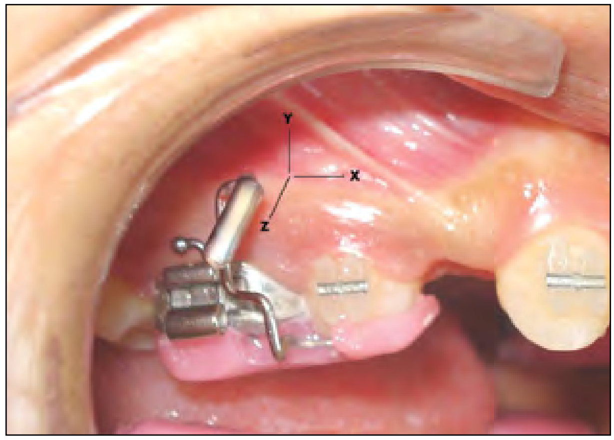


Figure 1. Implant guide in patient's mouth. The metal tube helped in orienting the miniscrew in X-, Y- and Z-axis. The miniscrew parallel to the metal tube will maintain the desired angulation with tooth surface.

All patients were treated with a preadjusted edgewise appliance of the Roth prescription (0.022 x 0.028 inch slot). A sequence of round wires was used for levelling and alignment until a 0.019 x 0.025 inch stainless steel archwire could be passively engaged.

After initial levelling and alignment, a customised implant guide was fabricated on a plaster model. The desired site for miniscrew placement was marked and a wire framework made from 0.8 mm stainless steel wire and stabilised occlusally with self-curing acrylic resin. A 5-6 mm section of metal tube (diameter approximately equal to that of the miniscrew) was soldered to the wire framework about 2 mm apical to the marked miniscrew site. The implant guide was checked in the patient's mouth and adjusted to indicate the path of miniscrew insertion and subsequently, cemented in place just before a CT scan was performed (Figure 1).

A multidetector CT machine MDCT (Sensation 40 Siemens, Erlangen, Germany) was used to assess the dentoaolveolar areas of each patient prior to miniscrew placement. The scanning conditions were standardised

Figure 2. The axial section parallel to occlusal plane and 5 - 8 mm apical to alveolar crest is used for determining the bone density.

at 120kV and 90mA. Axial images, taken parallel to the occlusal plane, were obtained and used as a guide for miniscrew placement. Acquisition slice thickness was 0.6 mm and images were reconstructed using a slice thickness of 3 millimetres. The reconstructed images were viewed in a bone window and areas 5 - 8 mm from the alveolar crest were selected for assessing bone density (Figure 2). The mean bone density in the region of interest was measured separately for cortical and cancellous bone (Figure 3a, Figure 3b) and recorded in Hounsfield Units (HU).

The implant guides were reinserted in the patient's mouth and, using the CT scan images, the position of the miniscrew in the x-axis was determined and the miniscrews placed in the identified sites. All subjects received oral anti-inflammatory drugs for five days following the surgical procedure and a strict oral hygiene program was prescribed. After one week, the miniscrews were connected to the first molars using 0.017 x 0.025 inch stainless steel wire. En masse retraction was applied using 9 mm nickel titanium closed-coil springs delivering a force of 2N between a molar hook and a hook soldered between the lateral incisor and canine on the main 0.019 x 0.025 inch stainless steel archwire (Figure 4). Miniscrew mobility was checked clinically with a hand instrument before loading to ensure good stability. Thereafter, miniscrew mobility was tested monthly. Pain and discomfort were evaluated with the help of a visual analogue scale on which patients marked their perceived level of pain. Signs of redness, swelling or bleeding on touching or

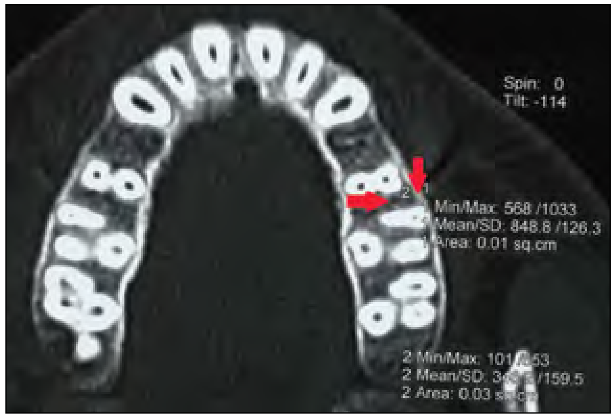


Figure 3. (a) Maxillary axial section with site markings for bone density determination (arrows).

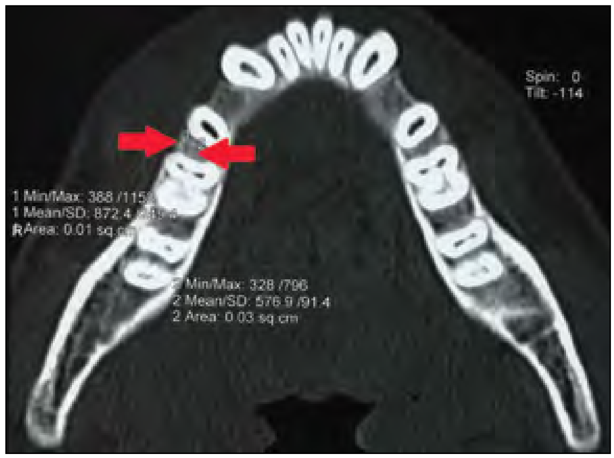


Figure 3. (b) Mandibular axial section with site markings for bone density determination (arrows).

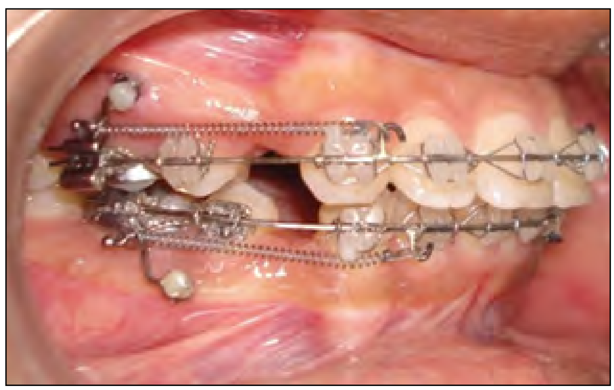


Figure 4. Miniscrews used as indirect anchorage saver for en masse retraction of anteriors. (Kharbanda OP, ed. Orthodontics: Diagnosis and Management of Malocclusion and Dentofacial Deformities. 2nd ed. India:Elsevier;2013. Chapter 47, Temporary anchorage devices. p.591 (Figure 47.13B). Cited with permission).

probing the peri-implant soft tissue were noted as the presence of inflammation. Pain and associated miniscrew mobility of 1 mm or more were considered signs of failure and the miniscrew was removed.[41] Patients were reviewed every two weeks.

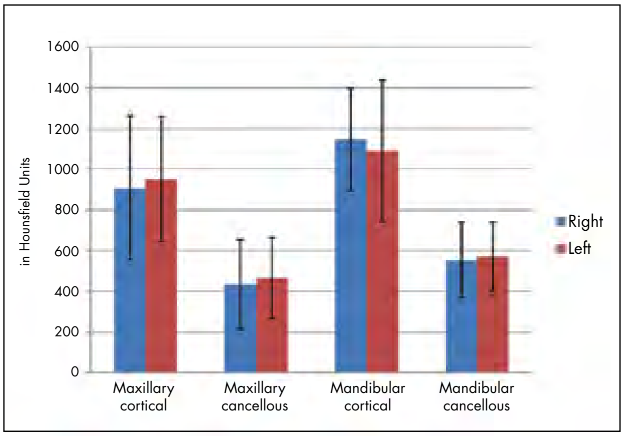


Figure 5. (a) Bone density values on left and right sides of maxilla and mandible.

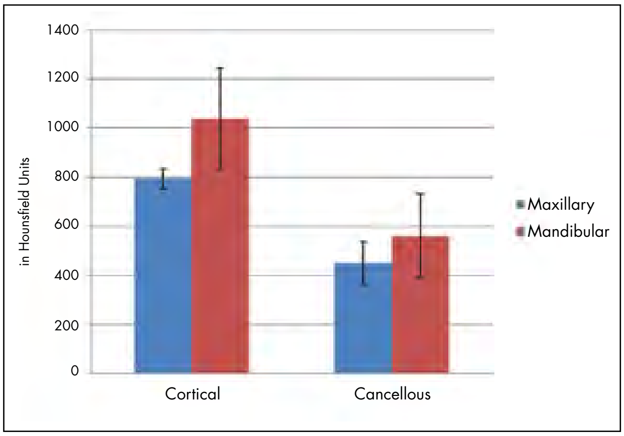


Figure 5. (b) Bone density values for cortical and cancellous region of maxilla and mandible.

All statistical analyses were performed using the SPSS version 15 software. The unpaired *t*-test and the Mann-Whitney test (wherever applicable) were used to compare bone densities on the left and right sides, bone densities of the maxilla and mandible and the association between bone density and miniscrew stability.

Results

The maxillary and mandibular bone density values for each patient are provided in Table I. The mean cortical and cancellous bone density in the maxilla was found to be 929.27 ± 322.12 HU and 450.09 ± 205.66 HU respectively (Table II). The mean cortical and cancellous bone density in the mandible was found to be 1116.2 ± 298.33 HU and 561.87 ± 170.83 HU respectively (Table III). There was no statistically significant difference in bone density between the right and left sides of either jaw. There was no statistically significant difference in cortical bone density values between the maxilla and mandible (p = 0.089). With the exception of two patients, all cases revealed cortical mandibular bone density values higher than those in the maxilla. If the two patients were excluded, a significant difference in bone density values between the maxilla and mandible became evident (p = 0.008). There was no statistically significant difference in cancellous bone densities of either jaw (p = 0.097) (Figure 5a, Figure 5b).

Of the ten patients, four experienced pain and discomfort. Two patients experienced mild pain on day one and increasing pain severity to day thirty-one at their mandibular sites. Two patients experienced discomfort during the initial period, one of whom reported mild pain on the first and seventh days while the other patient reported pain on the seventh day which resolved within a week.

Peri-implant inflammation was recorded at two mandibular sites in one patient on day seven. The inflammation persisted to day twenty-one. Inflammation was noted in another patient on day twenty-one. All other peri-implant sites remained healthy.

All miniscrews were stable on day one. Two miniscrew sites in each of two patients, showed grade I mobility on day seven, increasing to day twenty-one, at which time the four miniscrews were removed. The remaining miniscrews remained stable throughout complete retraction of the anterior teeth (average period of nine months). No significant association was found between bone density values and stability of the miniscrews as presented in Table IV.

Discussion

The site of miniscrew placement was located in the attached gingiva and buccal interradicular bone between the maxillary second premolar and first molar. This region in the maxilla and mandible has been shown to provide an optimal site for miniscrew placement,[36-38] as sufficient inter-radicular bone is present.[36-40] Deguchi et al.[37] quantitatively analysed bone thickness in the maxilla and mandible using three dimensional CT and stated that the best location for a miniscrew was mesial or distal to the first molar. Kuroda et al.[12] reported a high success rate of approximately 90% for miniscrews placed in the attached gingiva.

Table I. The maxillary and mandibular bone density values (in HU) for each patient included in the study.

Case No.	Cortical bone density				Cancellous bone density			
	Maxillary right Mean ± SD	Maxillary left Mean ± SD	Mandibular right Mean ± SD	Mandibular left Mean ± SD	Maxillary right Mean ± SD	Maxillary left Mean ± SD	Mandibular right Mean ± SD	Mandibular left Mean ± SD
1*	1203.6 ± 174.8	1474.2 ± 208.3	1020.4 ± 434.5	1132.8 ± 372.5	625.3 ± 193.1	453.2 ± 197.5	227.8 ± 191.1	220.3 ± 188.4
2	827.2 ± 285.1	855.4 ± 113.2	1027.0 ± 237.6	1094.4 ± 212.3	185.9 ± 102.7	280.5 ± 299.8	620.7 ± 178.7	702.0 ± 305.8
3	959.6 ± 192.3	814.3 ± 215.1	1076.1 ± 97.5	991.0 ± 127.1	293.4 ± 200.3	367.6 ± 109.6	444.9 ± 89.3	608.3 ± 169.5
4	935.0 ± 84.2	999.4 ± 109.2	1442.5 ± 112.4#	1511.4 ± 68.1#	903.9 ± 85.3	930.8 ± 154.3	803.6 ± 100.1#	688.6 ± 151.1#
5*	1705.6 ± 155.3	1503.4 ± 319.3	1544.8 ± 203.2	1526.0 ± 113.5	589.3 ± 145.0	552.6 ± 287.3	505.6 ± 253.6	673.3 ± 122.9
6	1012.9 ± 219.1	843.7 ± 188.3	1141.5 ± 304.3	943.4 ± 386.2	239.2 ± 144.2	312.7 ± 113.7	556.8 ± 181.3	543.0 ± 196.0
7	506.7 ± 33.3	740.3 ± 67.9	935.7 ± 78.9	905.4 ± 107.9	372.4 ± 62.2	662.6 ± 75.7	688.0 ± 74.7	669.6 ± 53.0
8	679.0 ± 77.7	877.8 ± 74.6	1149.6 ± 203.7	1088.6 ± 348.0	289.6 ± 161.4	403.8 ± 134.0	548.2 ± 189.2	547.1 ± 170.2
9	602.9 ± 129.2	848.8 ± 126.3	872.4 ± 249.4#	818.6 ± 86.9#	496.4 ± 119.3	346.2 ± 159.5	576.9 ± 91.4#	478.5 ± 96.2#
10	650.3 ± 117.9	545.4 ± 93.5	X	X	346.1 ± 56.1	350.4 ± 88.3	X	X

* Patients with higher maxillary bone density values than that of mandible
\# Sites at which miniscrew failure occurred
X Miniscrews not placed; hence, bone density not measured

Table II. Mean maxillary bone density (in HU).

	Maxillary cortical			Maxillary cancellous		
	Maximum	Minimum	Mean	Maximum	Minimum	Mean
Right	1109.9 ± 395.99	652.5 ± 350.51	908.28 ± 352.36	714.0 ± 217.85	201.0 ± 242.35	434.15 ± 220.36
Left	1134.3 ± 371.64	679.4 ± 285.68	950.20 ± 306.46	744.0 ± 185.94	198.7 ± 210.96	466.04 ± 200.42
Mean		929.27 ± 322.12			450.09 ± 205.66	

Table III. Mean mandibular bone density (in HU).

	Mandibular cortical			Mandibular cancellous		
	Maximum	Minimum	Mean	Maximum	Minimum	Mean
Right	1372.71 ± 264.79	818.43 ± 347.58	1145.55 ± 253.98	815.0 ± 189.75	287.43 ± 296.84	552.5 ± 185.23
Left	1298.75 ± 367.55	747.88 ± 478.68	1090.17 ± 347.96	838.38 ± 154.32	327.38 ± 234.10	570.07 ± 169.68
Mean		1116.2 ± 298.33			561.87 ± 170.83	

Table IV. Association between bone density and success of miniscrews (Two-sample Wilcoxon rank-sum [Mann-Whitney] test).

Miniscrew sites	No. of stable miniscrews	Bone density in HU (median)	No. of failed miniscrews	Bone density in HU (median)	*p* value
38 (cortical)	34	975.3	4	1157.45	0.6343 (NS)
38 (cancellous)	34	501.0	4	632.45	0.1280 (NS)

NS = Not Significant

The risk of failure of a miniscrew surrounded by non-keratinised mucosa has been reported to be higher than that for miniscrews surrounded by keratinised tissue.[10,16] Antoszewska et al.[17] also reported a higher success rate when miniscrews were placed in attached gingiva. In the present study, placement sites in attached mucosa provided an adequate area of bone in all patients. Furthermore, suitable and adequate indirect anchorage was provided by the connection of the miniscrew to the molar tube.

The current study measured bone density at the inter-radicular region between the second premolar and the first molar at 5 - 8 mm apical to the alveolar crest in both the jaws. Bone densities at these sites approximated values reported by Park et al.[31] and Choi et al.[35].

Numerous authors[21,23,29,30,34] have studied bone densities for the placement of dental implants for prosthetic purposes (Table V) and reported overall bone density values less than the present findings. The subjects in the earlier studies were older patients with edentulous areas. Combined densities of cortical and cancellous bone in edentulous ridge areas with thin cortices may have resulted in lower values. Santiago et al.[32] reported mean bone density value of 420.63HU in the maxillary posterior region of patients aged between 12.5 - 33 years. This is comparatively lower than the present findings. The combined measurements of cortical and cancellous bone density values have likely resulted in the lower previously reported average values.

A *t*-test comparison of the mean densities between the right and left sides of both jaws showed a difference which was statistically insignificant (p = 0.779, 0.734, 0.738 and 0.850). This finding is in contrast with the report by Santiago et al.[32] who found significantly greater maxillary bone density values on the right side. The present study found no significant difference between maxillary and mandibular cortical bone densities, although mandibular values were higher than the maxillary values in all but two patients. When these patients were excluded, the statistical analysis showed mandibular bone density values were significantly higher than those of the maxilla (p = 0.008) indicating that mandibular bone is more compact and dense than the maxillary bone. Individual variations, however, cannot be excluded. No statistically significant difference between the densities of cancellous bone in either jaw was found (p = 0.097) which supports the finding by Park et al.[31] In the present sample, greater variability in density was found in maxillary bone, whereas bone density values in the mandible were more consistent.

Inflammation is a factor affecting miniscrew stability.[10-12] Local inflammation around the miniscrew can worsen due to poor oral hygiene. In the present study, four mandibular miniscrews failed in two patients. Failure was likely due to peri-implant inflammation as food debris was consistently seen around the miniscrews in one affected patient. In addition, miniscrew failure could be attributed to the proximity of dental roots. Asscherickx et al.[18] suggested root contact as a major risk factor for failure due to the direct transfer of occlusal force to a miniscrew in contact with a tooth root. The second patient in whom a miniscrew failed, complained of discomfort and mild masticatory pain from the first day. The bone density values at the failed sites were within the normal range. Other patients experienced discomfort during the initial period which was attributed to irritation of the cheek mucosa. Resolution occurred within a week after smoothing the miniscrew head with composite resin.

Miniscrew failure in the present study occurred in the mandible only. Previous investigations assessing

Table V. Bone density of maxilla and mandible on prosthetic implant sites and miniscrew sites.

S No	Authors	Country	N	Sex	Age (Years)	Anterior maxilla	Posterior maxilla	Anterior mandible	Posterior mandible
Prostheric implant sites									
1	Norton and Gamble (2001)	United Kingdom	32	-	-	696 ± 244	417 ± 227	970 ± 269	669 ± 248
2	Shapurian et al (2006)	USA	101	65F, 36M	18 - 89	517 ± 177	333 ± 199	559 ± 208	321 ± 132
3	Turkyilmaz et al (2008)	Turkey	140	-	51 ± 11	708 ± 222	505 ± 274	927 ± 237	721 ± 291
Miniscrew implant sites									
4	Santiago et al (2009)	Brazil	15	7F, 8M	12.5 - 33	xx	420.63	xx	xx
						Maxillary cortical	Maxillary cancellous	Mandibular cortical	Mandibuar cancellous
5	Park et al (2008)	Korea	63	40F, 23M	F: 25.4 ± 7.0 M: 29.0 ± 10.4	810 - 940	280 - 500	810 - 1580	300 – 500
						Maxillary premolar and molar region		Mandibular premolar and molar region	
6	Choi et al (2009)	Korea	30	15F, 15M	24.7 (Mean)	467 to 1103 HU mean 719 - 802 HU between second premolar and first molar		721 to 1215 HU mean 988 - 1042 HU between second premolar and first molar	
7	AIIMS study (2012)	India	10	8F, 2M	18.90 ± 4.12	929.27 ± 322.12	450 ± 205.66	1116.2 ± 298.33	561.87 ± 170.83
						Between second premolar and first molar region			

xx Miniscrews not placed; hence, bone density not measured

success rates of miniscrew implants showed high failure rates in the posterior areas of the mandible. Park et al.[11] considered that failures might be caused by movable oral mucosa, excessive heat generated during placement because of thick and dense cortical bone, or irritation from food. It was possible that thick cortical bone and high bone density in the posterior mandible was traumatised by overheating during pilot hole preparation. In the present sample, miniscrews were placed in attached gingiva, without predrilling and bone density values at failure sites were not found to vary from the mean. Although the bone was of high density in one of the failure cases, stable miniscrews have been observed in high density bone in other patients. However, Chen et al.[14] reported greater failure in low density bone. It is likely that peri-implant inflammation and root proximity were more substantial explanations for the current failures. Mandibular posterior failures occurred within 2-3 weeks of placing the miniscrews which confirms the result of Miyawaki et al.[10] who reported miniscrew failure most frequently within the first two months following placement.

The limitations of the present study are sample size and the gender distribution of the subjects which need to be addressed in future investigations.

Conclusions

Mean bone density in the sample of subjects in this study was 927.27 ± 322.12 HU (cortical) and 450.09 ± 205.66 HU (cancellous) in the maxilla and 1116.2 ± 298.33 HU (cortical) and 561.87 ± 170.83 HU (cancellous) in the mandible.

Bone density values were not related to miniscrew stability when indirectly loading the miniscrews with a continuous force of 2N after the first week following placement.

From the present study, an association between miniscrew success and jaw bone density could not be established.

Corresponding author

Professor Om Prakash Kharbanda
Dvision of Orthodontics and Dentofacial Deformities
Centre for Dental Education and Research
All India Institute of Medical Sciences
New Delhi – 110029
India

Email: opk15@hotmail.com

References

1. Park HS, Bae SM, Kyung HM, Sung JH. Microimplant anchorage for treatment of skeletal Class I bialveolar protrusion. J Clin Orthod 2001;35:417-22.
2. Bae SM, Park HS, Kyung HM, Kwon OW, Sung JH. Clinical application of micro-implant anchorage. J Clin Orthod 2002;36:298-302.
3. Tanaka E, Nishi-Sasaki A, Hasegawa T, Nishio C, Kawai N, Tanne K. Skeletal anchorage for orthodontic correction of severe maxillary protrusion after previous orthodontic treatment. Angle Orthod 2008;78:181-8.
4. Kanomi R. Mini implant for orthodontic anchorage. J Clin Orthod 1997;31:763-7.
5. Sakai Y, Kuroda S, Murshid SA, Takano-Yamamoto T. Skeletal Class III severe openbite treatment using implant anchorage. Angle Orthod 2008;78:157-66.
6. Lin JC, Liou EJ, Yeh CL. Intrusion of overerupted maxillary molars with miniscrew anchorage. J Clin Orthod 2006;40:378-83.
7. Bae SM, Kyung HM. Mandibular molar intrusion with miniscrew anchorage. J Clin Orthod 2006;40:107-8.
8. Yamada K, Kuroda S, Deguchi T, Takano-Yamamoto T, Yamashiro T. Distal movement of maxillary molars using miniscrew anchorage in the buccal interradicular region. Angle Orthod 2009;79:78-84.
9. Kyung SH, Lee JY, Shin JW, Hong C, Dietz V, Gianelly AA. Distalization of the entire maxillary arch in an adult. Am J Orthod Dentofacial Orthop 2009;135:S123-32.
10. Miyawaki S, Koyama I, Inoue M, Mishima K, Sugahara T, Takano-Yamamoto T. Factors associated with the stability of titanium screws placed in the posterior region for orthodontic anchorage. Am J Orthod Dentofacial Orthop 2003;124:373-8.
11. Park HS, Jeong SH, Kwon OW. Factors affecting the clinical success of screw implants used as orthodontic anchorage. Am J Orthod Dentofacial Orthop 2006;130:18-25.
12. Kuroda S, Sugawara Y, Deguchi T, Kyung HM, Takano-Yamamoto T. Clinical use of miniscrew implants as orthodontic anchorage: success rates and postoperative discomfort. Am J Orthod Dentofacial Orthop 2007;131:9-15.
13. Baek SH, Kim BM, Kyung SH, Lim JK, Kim YH. Success rate and risk factors associated with mini-implants reinstalled in the maxilla. Angle Orthod 2008;78:895-901.
14. Chen YJ, Chang HH, Lin HY, Lai EH, Hung HC, Yao CC. Stability of miniplates and miniscrews used for orthodontic anchorage: experience with 492 temporary anchorage devices. Clin Oral Implants Res 2008;19:1188-96.
15. Moon CH, Lee DG, Lee HS, Im JS, Baek SH. Factors associated with the success rate of orthodontic miniscrews placed in the upper and lower posterior buccal region. Angle Orthod 2008;78:101-6.
16. Lim HJ, Eun CS, Cho JH, Lee KH, Hwang HS. Factors associated with initial stability of miniscrews for orthodontic treatment. Am J Orthod Dentofacial Orthop 2009;136:236-42.
17. Antoszewska J, Papadopoulos MA, Park HS, Ludwig B. Five year experience with orthodontic miniscrew implants: a retrospective investigation of factors influencing success rates. Am J Orthod Dentofacial Orthop 2009;136:158.e1-10.
18. Asscherickx K, Vande Vannet B, Wehrbein H, Sabzevar MM. Success rate of miniscrews relative to their position to adjacent roots. Eur J Orthod 2008;30:330-5.
19. Lekholm U, Zarb GA. Patient selection. In: Branemark PI, Zarb GA, Alberktsson T (eds). Tissue integrated prosthesis osseointegration in clinical density. Quintessence pub., Chicago; 1985:199-209.
20. Misch CE. Density of bone: Effect on treatment planning, surgical approach and healing. In: Misch CE, ed. Contemporary implant dentistry. Mosby Year Book, Inc., St Louis;1993:469-485.
21. Norton MR, Gamble C. Bone classification: an objective scale of bone density using the computerized tomography scan. Clin Oral Implants Res 2001;12:79-84.
22. Thruhlar RS, Orenstein IH, Morris HF, Ochi S. Distribution of bone quality in patients receiving endosseous dental implants. Int J Oral Maxillofac Surg 1997;55:38–45.
23. Shahlaie M, Gantes B, Schulz E, Riggs M, Crigger M. Bone density assessments of dental implant sites: 1. Quantitative computed tomography. Int J Oral Maxillofac Implants 2003;18:224-31.
24. Thomsen JS, Ebbesen EN, Mosekilde L. Relationships between static histomorphometry and bone strength measurements in human iliac crest bone biopsies. Bone 1998;22:153-63.
25. Trisi P, Rao W. Bone classification: clinical-histomorphometric comparison. Clin Oral Implants Res 1999;10:1-7.
26. Delvin H, Horner K, Ledgerton D. A comparison of maxillary and mandibular bone mineral densities. J Prosthet Dent 1998;79:323-7.
27. Jäger A, Radlanski RJ, Taufall D, Klein C, Steinhöfel N, Döler W. Quantitative determination of alveolar bone density using digital image analysis of microradiographs. Anat Anz 1990;170:171-9.
28. Hans D, Fuerst T, Uffmann M. Bone density and quality measurement using ultrasound. Curr Opin Rheumatol 1996;8:370-5.
29. Aranyarachkul P, Caruso J, Gantes B, Schulz E, Riggs M, Dus I, et al. Bone density assessments of dental implant sites: 2. Quantitative cone-beam computerized tomography. Int J Oral Maxillofac Implants 2005;20:416-24.
30. Turkyilmaz I, Ozan O, Yilmaz B, Ersoy AE. Determination of bone quality of 372 implant recipient sites using Hounsfield unit from computerized tomography. a clinical study. Clin Implant Dent Relat Res 2008;10:238-44.
31. Park HS, Lee YJ, Jeong SH, Kwon TG. Density of the alveolar and basal bones of the maxilla and the mandible. Am J Orthod Dentofacial Orthop 2008;133:30-7.

32. Santiago RC, de Paula FO, Fraga MR, Picorelli Assis NM, Vitral RW. Correlation between miniscrew stability and bone mineral density in orthodontic patients. Am J Orthod Dentofacial Orthop 2009;136:243-50.
33. Moon SH, Park SH, Lim WH, Chun YS. Palatal bone density in adult subjects: implications for mini-implant placement. Angle Orthod 2010;80:137-144.
34. Shapurian T, Damoulis P, Reiser GM, Griffin TJ, Rand WM. Quantitative evaluation of bone density using Hounsfield index. Int J Oral Maxillofac Implants 2006;21:290-7.
35. Choi JH, Park CH, Yi SW, Lim HJ, Hwang HS. Bone density measurement in interdental areas with simulated placement of orthodontic miniscrew implants. Am J Orthod Dentofacial Orthop 2009;136:766.e1-12.
36. Poggio PM, Incorvati C, Velo S, Carano A. "Safe zones": a guide for miniscrew positioning in the maxillary and mandibular arch. Angle Orthod 2006;76:191-7.
37. Deguchi T, Nasu M, Murakami K, Yabuuchi T, Kamioka H, Takano-Yamamoto T. Quantitative evaluation of cortical bone thickness with computed tomographic scanning for orthodontic implants. Am J Orthod Dentofacial Orthop 2006;129:721.e7-12.
38. Lee KJ, Joo E, Kim KD, Lee JS, Park YC, Yu HS. Computed tomographic analysis of tooth bearing alveolar bone for orthodontic miniscrew placement. Am J Orthod Dentofacial Orthop 2009;135:486-94.
39. Kim SH, Yoon HG, Choi YS, Hwang EH, Kook YA, Nelson G. Evaluation of interdental space of the maxillary posterior area for orthodontic mini-implants with cone-beam computed tomography. Am J Orthod Dentofacial Orthop 2009;135:635-41.
40. Park J, Cho HJ. Three-dimensional evaluation of interradicular spaces and cortical bone thickness for the placement and initial stability of microimplants in adults. Am J Orthod Dentofacial Orthop 2009;136:314.e1-12.
41. Sakka S, Coulthard P. Implant failure: etiology and complications. Med Oral Patol Oral Cir Bucal 2011;16:e42-4.

The effects of a vibrational appliance on tooth movement and patient discomfort: a prospective randomised clinical trial

Peter Miles,[*†] Heath Smith,[†] Robert Weyant[+] and Daniel J. Rinchuse[†]

Private Practice, Caloundra and University of Queensland Department of Orthodontics, Australia,[*] Seton Hill University Graduate Program in Orthodontics, Greensburg, Pennsylvania, USA[†] and Department of Dental Public Health and Information Management, School of Dental Medicine, University of Pittsburgh, Pittsburgh, Pennsylvania, USA[+]

Introduction: The aim of this study was to assess the rate of tooth movement and discomfort experienced by orthodontic patients using a vibrational appliance (Tooth Masseuse).

Methods: In this randomised controlled trial (RCT), 66 consecutive patients were assigned to a control or experimental group. The experimental group was instructed to use a vibrational appliance for a minimum of 20 minutes per day. All of the patients had the same fixed appliance and a 0.014 inch thermal NiTi wire during the 10 week study period. Impressions of the mandibular six anterior teeth were taken at 4 time points: at the start of treatment, 5 weeks, 8 weeks, and at 10 weeks after commencement. Little's Irregularity Index was used to record alignment and assess the rate of tooth movement. A discomfort score chart was used to evaluate patient pain levels at 5 time points.

Results: The experimental group showed a 65% reduction in irregularity at 10 weeks, while the control group showed a 69% reduction in irregularity over the same period. No significant differences in irregularity or pain levels were observed at any of the time points between the groups.

Conclusions: The results demonstrate that, for 20 minute use per day, there appears to be no clinical advantage in using the vibrational appliance for the early resolution of crowding or the alleviation of pain during initial alignment.

(Aust Orthod J 2012; 28: 213–218)

Received for publication: July 2012

Accepted: August 2012

Peter Miles: pmiles@beautifulsmiles.com.au; Daniel J. Rinchuse: drinchuse@setonhill.edu

Introduction

Orthodontists and patients would prefer the shortest treatment time possible. Treatment time is inherently dependent upon an individual's rate of tooth movement and so the possibility of accelerating the biological response of the PDL[1] and alveolar remodelling has potential beneficial effects.

Although the exact mechanism of alveolar remodelling is not completely understood, there are two main theories: (1) piezoelectricity generated in the alveolar bone, and (2) pressure-tension within the PDL.[2] Piezoelectricity proposes that orthodontic induced bending of alveolar bone generates an electrical charge, which, in turn, initiates an osteogenic response.[3] This was supported by Zengo et al.,[4] who demonstrated electronegative and electropositive properties of osteoblasts and osteoclasts, respectively. The pressure-tension theory involves alterations in blood flow through the PDL which activates cellular responses through chemical mediators.[2]

Based upon the piezoelectricity theory, Davidovitch et al.[5] suggested that applying exogenous electrical currents could accelerate tooth movement. These electrical potentials could simply be created by applying a force to bend alveolar bone and generate piezoelectric charges.[6] Shapiro et al.[6] stated that these forces should not be continuous as the piezoelectricity is only created when stress is applied and released.

Therefore, vibrational appliances could be effective in initiating stress-induced charges by applying intermittent forces at a rapid rate.

Kopher and Mao[7] found that applying cyclic forces to craniofacial bones in growing rabbits enhances sutural growth. This finding was further supported by an extension and continuation of the sutural study and additional work involving the cyclic loading of craniofacial bones in a postnatal rat model.[8,9]

A secondary mode of action of vibrational appliances may involve perturbations and the reduction of the stick-slip behaviour between wires and brackets. An in vitro study found that 'the reduction of frictional resistance was proportional to the magnitude of the perturbations'.[10] A further in vitro study evaluated an applied vibration frequency of 1.35 Hz when brackets were displaced by amounts of 0, 0.25, 0.5, and 1 mm to produce a resistance to sliding.[11] It was found that 0.16 mm of mesio-distal crown movement produced up to 85% reduction in sliding resistance. Liew et al.[12] showed a 60-85% reduction in friction was produced by vertical wire displacement as a result of 25-400 grams of applied force. However, recent literature[13] suggests that in vitro studies do not accurately reflect the clinical mode of archwire sliding. Intra-oral forces such as mastication, greatly reduce the frictional resistance between brackets and archwires, which has led to an 'overestimation of the clinical significance of friction.'[13]

Initial research involving vibrational appliances and orthodontic tooth movement was limited to animal models.[14-16] Nishimura et al.[14] has shown in Wistar rats that approximately 15% more tooth movement was achieved in 21 days by utilising resonance vibration for 8 minutes per day (on days 0, 7, and 14), when compared with a control group affected by only static forces. Loading a vibrational force in Macaca fuscata monkeys for 1.5 hours per day over three weeks was reported to provide 1.3 to 1.4 times greater tooth movement (~25-30% faster) than loading by a static force.[15] An increase in tooth movement of this magnitude achieved in humans would be considered clinically significant.

'Promising rates of tooth movement' were described in initial articles involving vibrational forces applied to human subjects for 20 minutes per day.[17,18] Approximately 2-3 mm of tooth movement per month in both arches was reported by measuring the reduction in Little's Irregularity Index;[19] however, these studies may be questioned because of inadequate sample sizes and controls.

In addition to faster orthodontic tooth movement, it has been proposed that vibratory stimulation can decrease pain following orthodontic adjustments. Ottoson et al.[20] found that applying vibration at 100 Hz to various points in the skull and facial region reduced pain in 30 of 33 patients suffering from dental pain of various types. Other research demonstrated a reduction in musculoskeletal pain in 69% of patients by using vibratory stimulation[21] while vibro-tactile stimulation was shown to reduce musculoskeletal pain by as much as 40 per cent.[22]

Currently there has not been a published randomised clinical trial (RCT) conducted on human subjects. Therefore, the purpose of the present RCT was to assess the rate of tooth movement and discomfort experienced following the use of a vibrational appliance on orthodontic patients.

Material and methods

Ninety-four consecutive orthodontic patients from the private practice of one author (PM) were invited to participate in the study. Subjects were selected based on the following inclusion criteria: children aged between 11-15, a non-extraction treatment plan in the lower arch, no impactions/unerupted teeth, fixed appliances bonded from first molar to first molar in both arches, and living locally to allow for additional appointments for impressions. Of the 94 patients, 28 did not meet the inclusion criteria or declined to participate, leaving a study cohort of 66. The CONSORT 2010 Statement[23] was used as a guide for the clinical trial. All patients and families were informed of the purpose and methodology of the study and consented to participate. Ethical approval was also obtained prior to the start of data collection from the Institutional Review Board at Seton Hill University, Greensburg, Pennsylvania, USA.

Patients who met the inclusion criteria (Figure 1) were randomly assigned in blocks of six to ensure even numbers in the control and experimental groups. The experimental group was instructed to use a vibrational appliance (Tooth Masseuse, Figure 2) which applied a vibrational frequency of 111 Hz and 0.06 N (~6.1 g) for 20 minutes per day, or more if desired. The first

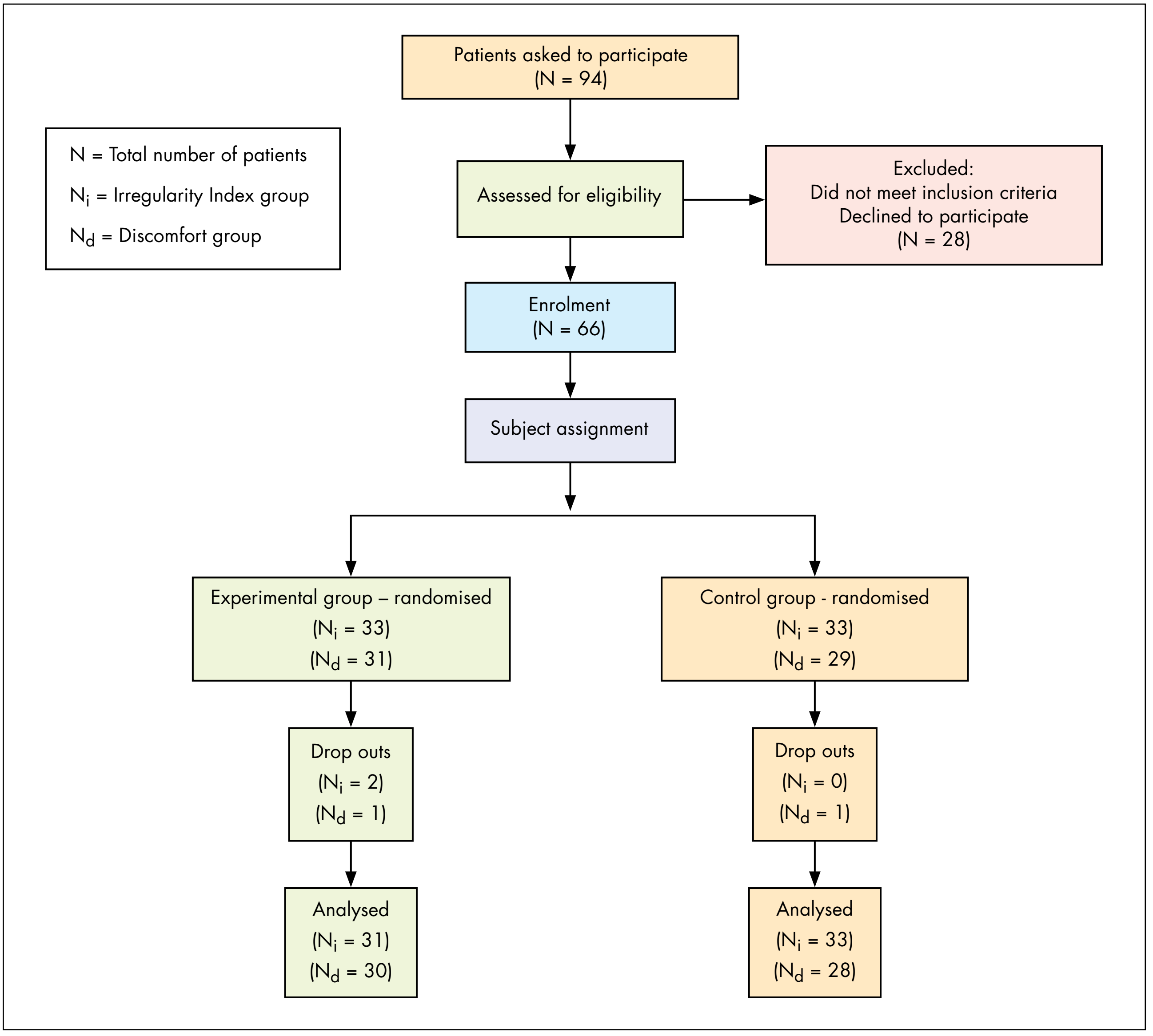


Figure 1. Consort diagram for patient participation.
Flow chart modelled after: Moher et al. Consort 2010 Explanation and Elaboration: updated guidelines for reporting parallel group randomised trials. BMJ 2010; 340:c869.

use was immediately after the initial wire was placed, to alleviate discomfort while patient instructions were being delivered. All patients were treated with conventional 0.018 inch slot, MBT prescription brackets (Victory Series, 3M Unitek, Monrovia, CA, USA). The arch wire in both groups was a 0.014 inch M5 Heaters™ thermal NiTi wire (G&H Wire Co., Franklin, IN, USA) which remained in place during the 10-week experimental time period. Alginate impressions of the lower anterior teeth were taken at 4 time points: at the start of treatment, at 5 weeks, 8 weeks, and at 10 weeks after commencement. The

Figure 2. Tooth Masseuse

Table I. Pretreatment demographics.

	Control group	Experimental group
Age, mean (standard error) in years	13.1 (0.18)	13.0 (0.18)
Number of Males	14	12
Number of Females	19	21

Table II. Irregularity index values.

Time point	Control group	Experimental group
T0 (initial), mean (SD) in mm	4.9 (2.5)	6.2 (3.7)
T1 (5 weeks), mean (SD) in mm	2.7 (1.4)	3.1 (2.1)
T2 (8 weeks), mean (SD) in mm	1.9 (1.0)	2.4 (1.3)
T3 (10 weeks), mean (SD) in mm	1.6 (0.9)	2.1 (1.1)

impression at 8 weeks was used to assess the possibility that initial alignment may occur 20% faster when using vibration, but no wire adjustment or retying was performed. The starting arch wire was retied at the 5-week appointment but no other adjustment was made during the 10-week study period. The clinician was blinded to the study participants at all appointments. Identification numbers were assigned to the models prior to measurement to ensure blinding. The irregularity index was measured by one of the authors (PM). After data collection was complete, the model numbers were matched back to the corresponding patients.

Little's Irregularity Index[24] was used to record irregularity at 4 time points: at the start of treatment, at 5 weeks, 8 weeks, and at 10 weeks. A discomfort score chart was used to evaluate the pain levels experienced by each patient. The patient was instructed to record the level of discomfort at 5 different time points by placing a mark on a 100 mm VAS (Visual Analogue Scale).[25] The 5 time points were: immediately after initial bracket and wire placement, 6-8 hours after appliances were placed, 1 day after, 3 days after, and 7 days after appliances were placed. Patients were asked to avoid analgesics containing ibuprofen, as the rate of tooth movement can potentially be affected.[26,27] A staff member who was blinded to the study groups and trained in the use of a micrometer measured the VAS data.

Statistical analysis

A power analysis based upon data from a previous study[28] demonstrated that for a clinically significant difference of 20% faster alignment/reduction in irregularity, a sample size of 59 would be required to achieve a 90% power at a significance level of 0.05. To allow for 10% dropout, a final sample of 66 subjects was chosen. The data from the various time points were compiled on a spreadsheet and submitted for statistical analysis using JMP® Version 7 (SAS Institute Inc., Cary, NC, USA 1989-2007). Means were calculated for irregularity and pain scores so that changes between the time points could be compared. A one-way ANOVA was used to determine if there was a statistically significant difference in age between groups and gender was evaluated by using a contingency analysis. A matched pairs *t*-test was used to determine differences in the irregularity indices and pain scores. Paired *t*-tests were used to evaluate the reliability of measures. A significance level of $p \leq 0.05$ was used for all tests.

Results

Sixty-six patients were enrolled in the study, of whom 64 patients reported for all 4 impression appointments. Pain scores were recorded by 60 patients, with 58 completing all 5 time points. Table I shows the pretreatment demographics of both groups. The age range for the study was 11.1 to 15.7 years with an average age of 13.1 years for the control group and 13.0 years for the experimental group. Table II shows the mean irregularity indices for both groups at the 4 time points. The initial irregularity means for the control and experimental groups were 4.9 mm and 6.2 mm, respectively. After 10 weeks of treatment, the control group had a mean irregularity index value of

Table III. Mean irregularity differences.

Time point	Control group	Experimental group
T0-T2, mean (SD) in mm	3.1 (2.4)	3.4 (2.7)
T0-T3, mean (SD) in mm	3.4 (2.4)	4.0 (3.3)

Table IV. VAS scores.

Time point	Control group	Experimental group
T0, mean (SD) in mm	8.1 (12.3)	12.4 (13.3)
T1, mean (SD) in mm	39.6 (25.8)	40.4 (20.8)
T2, mean (SD) in mm	47.6 (24.5)	41.5 (27.2)
T3, mean (SD) in mm	19.9 (15.5)	18.8 (18.5)
T4, mean (SD) in mm	5.5 (7.8)	4.0 (6.3)

1.6 mm, while the experimental group had a mean irregularity index value of 2.1 mm. Table III shows the mean irregularity difference for both groups at the 8 and 10 week time points. The irregularity difference between T0-T3 (10 weeks of treatment) was 3.4 mm for the control group and 4.0 mm for the experimental group. Table IV shows the mean VAS score for both groups at the 5 time points following appliance placement.

Discussion

The scheduled appointment for placement of the second archwire in PM's practice is routinely at 10 weeks.[29] If a vibrational device can cause a 20% increase in the rate of tooth movement, then hypothetically, the second wire could be placed at 8 weeks which relates to the extra appointment in the study protocol. At the 8-week time point, the appliance group irregularity reduced 3.4 mm while the control group irregularity reduced by 3.4 mm at the 10-week time point. This would imply that the appliance would achieve a 20% faster reduction in irregularity. However, despite the randomisation process, there were five outliers with an irregularity index greater than 10 mm which were all assigned to the experimental group and resulted in a higher initial irregularity in this group. Therefore, a comparison of the two groups required an account of the difference in baseline irregularity. The experimental group demonstrated a 55% (3.4/6.2) reduction in irregularity at 8 weeks, while the control group demonstrated a 63% (3.1/4.9) reduction in irregularity at 8 weeks. By 10 weeks the experimental group demonstrated a 65% (4.0/6.2) reduction in irregularity while the control group demonstrated a 69% (3.4/4.9) reduction in irregularity. Therefore, the results indicated no advantage in using the Tooth Masseuse for the early resolution of crowding. In addition, the results also indicated no significant benefit in using the appliance to reduce pain.

It is imperative that when clinicians evaluate the effectiveness of new appliances, there is an awareness of the potential for observational bias. For example, an enthusiastic clinician may decide to change to the next archwire at 8 weeks instead of 10 weeks; however, because of normal biological variation, some patients could have changed to the next wire at 8 weeks anyway. Therefore, positive results can be easily misconstrued by observational bias and the lack of controls can result in false conclusions.

Obviously the results of this study may not be generalised to other vibratory devices since we used a specific vibratory device (Tooth Masseuse), a particular vibratory frequency (111Hz), and force (0.06 N ~6.1 g). In addition, Rinchuse et al.[30] have argued that a protocol of consecutively treated patients may not provide a homogeneous sample that can be randomised into treatment and control groups. It would have been preferable to have the same baseline irregularities for both groups so that a stratification or minimisation strategy could have been employed.

Conclusions

The present results demonstrate no advantage in using the Tooth Masseuse for 20 minutes per day for the early resolution of crowding or the alleviation of pain.

Acknowledgment

We would like to thank Dr Shazia Naser-ud-Din (University of Queensland) for her help in assessing the vibration frequency of the Tooth Masseuse.

Corresponding author

Dr Peter Miles
10 Mayes Avenue
Caloundra, Queensland, 4551
Australia

Email: pmiles@beautifulsmiles.com.au

References

1. Krishnan V, Davidovitch Z. Cellular, molecular, and tissue-level reactions to orthodontic force. Am J Orthod Dentofacial Orthop 2006;129:469.e1-469.e32.
2. Proffit WR. Contemporary orthodontics. 4th ed. St Louis: Mosby; 2007. p. 331-8.
3. Grimm FM. Bone bending, a feature of orthodontic tooth movement, Am J Orthod 1972;62:384-93.
4. Zengo AN, Pawluk RJ, Bassett CAL. Stress-induced bioelectric potentials in the dentoalveolar complex. Am J Orthod 1973;64:17-7.
5. Davidovitch Z, Finkelson MD, Steigman S, Shanfield JL, Montgomery PC, Korostoff E. Electric currents, bone remodelling, and orthodontic tooth movement. II. Increase in rate of tooth movement and periodontal cyclic nucleotide levels by combined force and electric current. Am J Orthod 1980;77:14-32.
6. Shapiro E, Roeber FW, Klempner LS. Orthodontic movement using pulsating force-induced piezoelectricity. Am J Orthod 1979;76:59-66.
7. Kopher RA, Mao JJ. Suture growth modulated by the oscillatory component of micromechanical strain. J Bone Miner Res 2003;18:521-8.
8. Peptan AI, Lopez A, Kopher RA, Mao JJ. Responses of intramembranous bone and sutures upon in vivo cyclic tensile and compressive loading. Bone 2008;42:432-8.
9. Vij K, Mao JJ. Geometry and cell density of rat craniofacial sutures during early postnatal development and upon in vivo cyclic loading. Bone 2006;38:722-30.
10. Braun S, Bluestein M, Moore BK, Benson G. Friction in perspective. Am J Orthod Dentofacial Orthop 1999;115:619-27.
11. O'Reilly D, Dowling PA, Lagerstrom L, Swartz ML. An ex-vivo investigation into the effect of bracket displacement on the resistance to sliding. Br J Orthod 1999;26:219-27.
12. Liew CF, Brockhurst P, Freer TJ. Frictional resistance to sliding archwires with repeated displacement. Aust Orthod J 2002;18:71-5.
13. Swartz ML. Fact or friction: the clinical relevance of in vitro steady-state friction studies. J Clin Orthod 2007;41:427-32.
14. Nishimura M, Chiba M, Ohashi T, Sato M, Shimizu Y, Igarashi K et al. Periodontal tissue activation by vibration: intermittent stimulation by resonance vibration accelerates experimental tooth movement in rats. Am J Orthod Dentofacial Orthop 2008;133:572-83.
15. Shimizu Y. Movement of the lateral incisors of the Macaca fuscata as loaded by a vibrating force. Nihon Kyosei Shika Gakkai Zasshi 1986;45:56-72.
16. Darendeliler MA, Zea A, Shen G, Zoellner H. Effects of pulsed electromagnetic field vibration on tooth movment induced by magnetic and mechanical forces: a preliminary study. Aust Dent J 2007;52:282-7.
17. Kau CH. A novel device in orthodontics. Aesthetic dentistry today 2009; 3: 42-3.
18. AcceleDent System. http://www.acceledent.com
19. Kau CH, Nguyen JT, English JD. The clinical evaluation of a novel cyclical force generating device in orthodontics. Orthodontic Practice 2010:1.
20. Ottoson D, Ekblom A, Hansson P. Vibratory stimulation for the relief of pain of dental origin. Pain 1981;10:37-45.
21. Lundeberg T, Nordemar R, Ottoson D. Pain alleviation by vibratory stimulation. Pain 1984;20:25-44.
22. Staud R, Robinson ME, Goldman CT, Price DD. Attentuation of experimental pain by vibro-tactile stimulation in patients with chronic local or widespread musculoskeletal pain. Eur J Pain 2011;15:836-42.
23. Schulz KF, Altman DG, Moher D, for the CONSORT Group. CONSORT 2010 Statement: updated guidelines for reporting parallel group randomised trials. BMJ 2010;340:c332.
24. Little RM. The irregularity index: a quantitative score of mandibular anterior alignment. Am J Orthod 1975;68:554-63.
25. Duncan GH, Bushnell MC, Lavigne GJ. Comparison of verbal and visual analogue scales for measuring the intensity and unpleasantness of experimental pain. Pain 1989;37:295-303.
26. Kehoe MJ, Cohen SM, Zarrinnia K, Cowan A. The effect of acetaminophen, ibuprofen, and misoprostol on prostaglandin E2 synthesis and the degree and rate of orthodontic tooth movement. Angle Orthod 1996; 66: 339-49.
27. Southard KA. Reader's Forum: Ask Us. Am J Orthod Dentofacial Orthop 2004;125:18A.
28. Miles PG. SmartClip versus conventional twin brackets for initial alignment: is there a difference? Aust Orthod J 2005; 21:123-7.
29. Ong E, Ho C, Miles P. Alignment efficiency and discomfort of three orthodontic archwire sequences: a randomized clinical trial. J Orthod 2011;38:32-9.
30. Rinchuse DJ, Rinchuse DJ, Karam JR. Consecutive treatments and the 'random walk'. Am J Orthod Dentofacial Orthop 2008;133:792-5.

A pharmacodynamic investigation into the efficacy of osteoprotegerin during aseptic inflammation

Linda Curl, Christopher Barker, Craig Dreyer and Wayne Sampson
Orthodontic Unit, School of Dentistry, The University of Adelaide, Adelaide, South Australia, Australia

Background: Osteoprotegerin (OPG), as an osteoclast antagonist, limits mineralised tissue resorption under physiological conditions. Previous work investigating OPG in a rat periodontal ligament (PDL) ankylosis model found no inhibitory effect on osteoclasts when OPG was administered at a dosage of 2.5mg/kg.[1,2]
Aims: The object of this study was to determine whether dosages higher than 2.5 mg/kg of OPG were required to limit osteoclastic activity in an aseptic inflammatory model in rats.
Materials and methods: Dry ice was applied for 15 minutes to the upper right first molar crown of eighteen, 8-week-old, male Sprague-Dawley rats. Three groups of 3 were injected with OPG at dosages of 2.5, 5.0 and 7.5 mg/kg of body weight immediately following the thermal insult. After 7 days, the rats were sacrificed and each maxilla processed for histological examination and stained for osteoclastic activity using tartrate-resistant acid phosphatase (TRAP). Osteoclast population numbers were estimated via light microscopy and results were analysed using a comparative mixed model statistical analysis.
Results: Results showed OPG inhibited osteoclastic activity in a dose-dependent manner. From 2.5 mg/kg to 7.5 mg/kg, osteoclast populations were linearly reduced by 39.8% ($p < 0.05$). OPG did not appear to affect the inflammatory process and had varied efficacy in different regions of individual teeth.
Conclusion: Although osteoclastic activity reduced, it was not completely eliminated, perhaps because dosages were still inadequate, or additional factors might influence OPG and osteoclast activation in the aseptic inflammatory model.
(Aust Orthod J 2012; 28: 219–224)

Received for publication: June 2012
Accepted: September 2012

Linda Curl: curl80@hotmail.com; Christopher Barker: cwdbarker@yahoo.com; Craig Dreyer: craig.dreyer@adelaide.edu.au;
Wayne Sampson: wayne.sampson@adelaide.edu.au

Introduction

Orthodontic treatment aims to move teeth as efficiently as possible with the least amount of dental and periodontal damage. However, orthodontically induced inflammatory root resorption has been increasingly recognised as an iatrogenic consequence of treatment. Tooth movement relies on the interaction between osteoblasts and osteoclasts which govern bone apposition and resorption. Osteoclasts are recruited to specific resorptive sites while osteoblasts repair resorbed bone by the deposition of matrix and mineral in a coupled process. However, osteoclast-derived bone resorption required for orthodontic tooth movement often has the adverse consequence of external root resorption.[3]

The OPG/RANK/RANKL system has been considered a breakthrough in the understanding of bone biology.[4] It has been accepted that osteoclastic bone resorption precedes apposition by osteoblasts in the normal bone remodelling cycle.[5] Osteoclast differentiation is initiated through direct cell-to-cell communication between osteoblasts and osteoclast precursors. The initiating factors have been identified as the RANK ligand produced by osteoblasts and the RANK receptor on the osteoclast precursor.[6] Furthermore, OPG, as a protein produced by osteoblasts and stromal cells in the PDL,[7,8] has been identified as a decoy receptor for RANKL.[9,10] OPG competitively binds to RANKL, thereby inhibiting osteoclastogenesis and subsequent bone resorption. Fused or recombinant OPG (Fc-OPG) has been demonstrated to increase bone density and strength in rodents.[4,11] The administration of Fc-OPG is capable of compensating for a reduction of endogenous OPG in OPG-knockout animals.[12]

The inhibitory effects of OPG during external inflammatory root resorption have been previously investigated.[1] Results indicated that an OPG dosage of 2.5 mg/kg did not prevent root resorption in an aseptic inflammatory model. Therefore, the dosage required to completely inhibit osteoclastogenesis during pathological conditions is yet to be clarified and forms the basis of the present study.

Materials and methods

Experimental animals

Eighteen, 8-week-old, male Sprague-Dawley rats were divided into experimental groups of 6 and treated under ethical regulations for animal experiments as approved by the Ethics Committee of The University of Adelaide (M-4-2004). Each animal weighed between 250-300 g at the start of the experiment and increased in weight normally during the experimental timeline. Within each group of 6, rats were equally divided into experimental and control groups.

Experimental protocol

Each rat was anaesthetised with a combination of Hypnorm (fentanyl citrate 0.315 mg/ml and fluanisone 10 mg/mL) and Hypnovel (midazolam hydrochloride 5 mg/mL) in a 1:1 ratio with sterile water and administered at a dosage of 2.7 mL/kg of body weight. The anaesthetised rats were placed on a specially constructed rack which stretched the mouth open through the use of metal rings looped around both the upper and lower incisors. With cheek and tongue retraction, the upper right first molar was carefully frozen for a period of fifteen minutes by the application of customized pellets of dry ice (CO_2 at -81°C). Following the application of cold, the tissues were allowed to thaw slowly under anaesthesia and the animals recovered under a heat lamp to prevent hypothermia. The upper left first molar was left unfrozen and served as a control. Immediately following the experimental freezing, each group of experimental animals had single doses of OPG administered intramuscularly (IM), in concentrations of 2.5 mg/kg, 5.0 mg/kg or 7.5 mg/kg.

TRAP staining

Seven days after the thermal insult, all animals were sacrificed under anaesthesia via the intracardiac perfusion of 30 mL of 4% paraformaldehyde fixative. Each maxilla was dissected out and immersed in the same fixative for 24 hours, rinsed in phosphate-buffered saline (0.4M pH 7.4) for 24 hours and decalcified using 4% EDTA in phosphate buffer. Subsequently, the tissues were placed in 70% alcohol before processing through graded alcohols and paraffin wax impregnation in a Shandon Citadel 2000 automatic processor. Coronal plane wax sections of 5 µm were cut and mounted in sequential order on aminopropyltriethoxysilane (APT) coated slides.

For orientation purposes every tenth slide was stained with Mayer's haematoxylin and eosin (H&E) and viewed under a light microscope. The staining protocol for demonstrating TRAP activity in paraffin sections on adjacent slides was based on a modified technique of Goldberg and Barka[13] with basic fuchsin allowed to mature and characterised by a silver lining on the solution surface. A suitable staining solution displayed a dark rust-coloured precipitate. To allow comparison of variations of the technique, a rating was given to each slide based on the clarity of structures associated with the PDL and the intensity of the TRAP staining present.

Cell counts were conducted using a consistent grid, which subdivided the tooth roots into palatal, furcal and buccal columns via lines of best fit orientated through the long axis of the root. Totals for each column were recorded for each slide for further evaluation. Osteoclasts were identified by positive TRAP staining which appeared as an intense red colour on a green background. During cell counts, 50 slides were randomly revisited and recounted by one observer with blinding. Results were recorded and analysed for accuracy and consistency between

Figure 1. H and E staining of frozen tooth in 5.0 mg/kg OPG administered rat (Scale bar equals 200 μm). Arrows show areas of ankylosis.

P, Pulp; D, Dentine; PDL, Periodontal Ligament; AB, Alveolar Bone.

counts. Cell numbers for the 3 areas were recorded for control and test teeth and analysed statistically using a mixed model.

Results

Haematoxylin and Eosin

Histological stains showed marked differences between frozen (test) and unfrozen (control) teeth via the orientation of the odontoblasts in the pulpal cavities, regardless of the dosage of OPG given. The odontoblasts in the frozen test teeth were disorientated and obliterated, while, in the unfrozen control teeth, they showed parallel alignment close to the walls of the pulp chamber. Increased numbers of resorptive pits were seen on the root surface of frozen test teeth and necrosis of surrounding tissues was evident. Two rats in the 5.0 mg and 7.5 mg/kg groups exhibited ankylosis (Figure 1). This finding appeared incidental and no characteristic common to both and different from the remaining 16 animals was determined.

TRAP staining

The frozen test teeth exhibited higher average osteoclastic populations than the unfrozen control teeth regardless of the OPG dosage administered. The reductions in the osteoclastic populations are represented in Figure 2 (Dose vs osteoclastic population). From 2.5 mg/kg to 7.5 mg/kg, there was

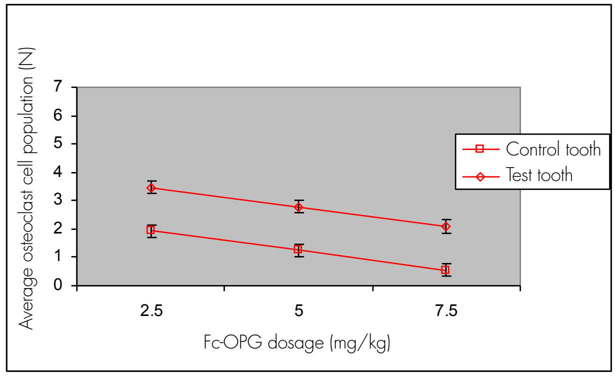
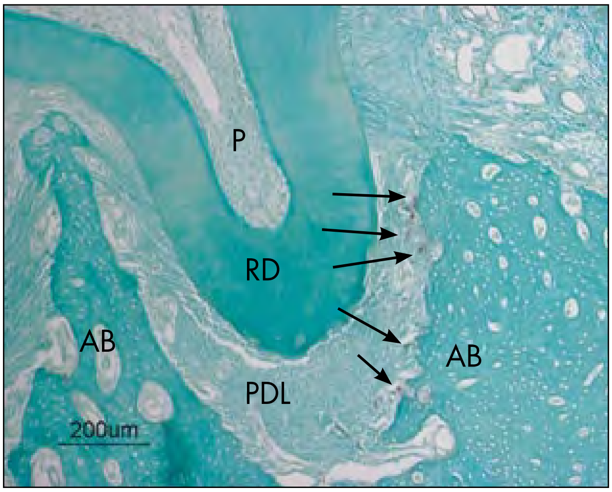


Figure 2. Dose vs osteoclastic population.

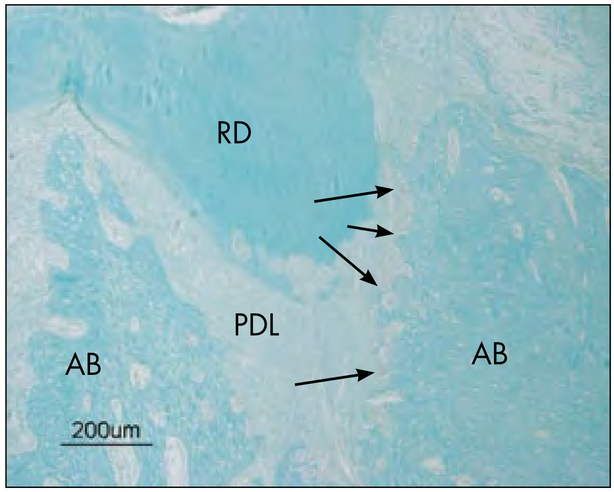
a linear reduction of 39.8% ($p < 0.05$). The osteoclastic populations present at 7.5 mg/kg dosage in frozen test teeth averaged 2.09 cells per slide (average osteoclastic cell population $p < 0.05$ compared to control teeth). The difference in the osteoclastic populations between test and control teeth was statistically insignificant ($p > 0.05$). The test teeth and control teeth parallelled each other during the linear decline of osteoclast populations as the single dose of Fc-OPG increased from 2.5 to 7.5 mg/kg (Figures 3 a-c). The osteoclastic cell populations are presented in Figure 4 (Dose vs. osteoclastic population per area). The reduction was greatest in the palatal region, followed by the furcation region and finally the buccal region. There was no obvious correlation observed between the areas.

Discussion

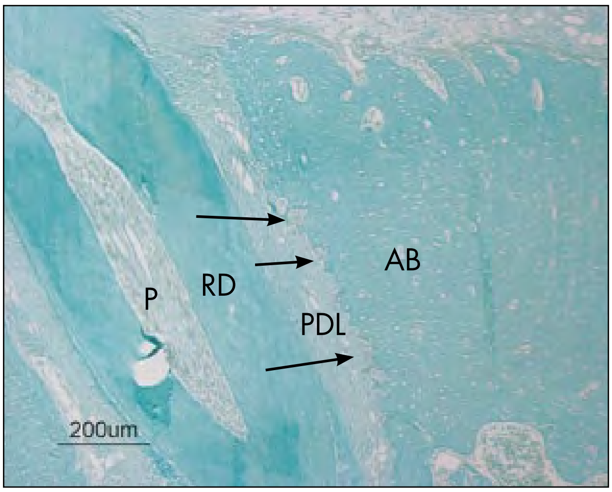
A frozen tooth model was used to produce aseptic necrosis and subsequent root resorption in an attempt to mimic inflammation caused by orthodontic tooth movement.[1] Previous dental studies using cryotherapy by Wesselink et al.[14] and Tal et al.[15] showed resorption of alveolar bone and cementum. In the present study, it was histologically evident that the application of cold to the rat molar crowns caused necrosis of the underlying pulpal and periodontal tissues. Osteoclast activity was apparent on the bone and cementum surfaces in areas affected by the freezing process. This model of tooth freezing was found to be safe, predictable and correlated with previously studied peak serum concentrations for Fc-OPG.[16] The use of endogenous OPG is difficult due to its limited availability. The use of the recombinant Fc-OPG has been advocated; however, there are structural differences between the endogenous and recombinant



(a)



(b)



(c)

Figure 3. (a) Histological TRAP stain of 2.5 mg/kg test tooth at 10x magnification (Scale bar equals 200 μm). Arrows show TRAP positive cells. AB, Alveolar Bone; RD, Dentine; P, Pulp; PDL, Periodontal Ligament

(b) Histological TRAP stain of 5.0 mg/kg test tooth at 10x magnification (Scale bar equals 200μm). Arrows show TRAP positive cells. AB, Alveolar Bone; PDL, Periodontal Ligament; RD, Root Dentine

(c) Histological TRAP stain of 7.5 mg/kg test tooth at 10x magnification (Scale bar equals 200μm). Arrows show TRAP positive cells. AB, Alveolar Bone; P, Pulp; PDL, Periodontal Ligament; RD, Root Dentine

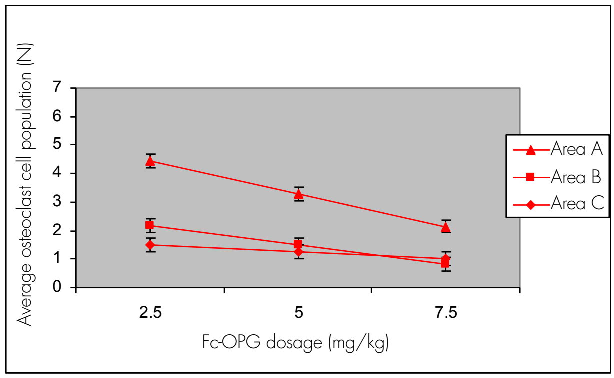


Figure 4. Summary graph of dose versus osteoclast population per area. Area A = Palatal root, Area B = Furcation region, Area C = Buccal root

types. The OPG used in this study consisted of a genetically engineered fusion molecule.

TRAP labelling enables the detection of tartrate-resistant acid phosphatase in multinucleate cells. Andersson and Marks considered the enzyme histochemistry of TRAP staining to be a useful marker of osteoclast ontogeny and function,[17,18] while Modderman et al. indicated that macrophages also attained TRAP properties, suggesting that the TRAP labelling in osteoclasts was not an exclusive marker.[19,20]

The analysis of cell numbers in specified areas was performed using a mixed model analysis. This proved satisfactory, although the use of appropriate statistical analysis in biological models is always open to debate. The raw data showed clusters of higher cell populations in distinct peaks interpreted as the areas in which roots were present. In the future, it may be beneficial to incorporate this observed variable into the analysis. The present study indicated that from 2.5 mg/kg to 7.5 mg/kg, the specific reduction of osteoclast cell populations occurred in a linear dose-dependent manner, with an average reduction of approximately 39.8%. This agrees with the results of other regimes involving single or multiple dosage protocols in both in vivo and in vitro models which have indicated that the principal pharmaco-dynamic action of OPG is the specific, rapid and sustained reduction of osteoclast numbers, along with other indices of bone resorption.[1,10,21,22] The observation of TRAP activity in resorption bays of the control unfrozen molars was an occasional finding and consistent with previous studies.[1] It is likely that this surface resorption was physiologic in nature and normal for these animals. It was considered that the experimental teeth were sensitive after the application of cold, and that the contralateral side was preferred for mastication. Hence, the stressed animal may have placed higher loads on control teeth, resulting in the unexpected resorption pattern with a short-term increase in osteoclast population.

The present study found that OPG did not appear to affect any tissues or cells associated with the PDL other than osteoclasts. This suggests that OPG is highly specific for RANKL which is in turn highly specific for osteoclasts.[4,23,24] Capparelli et al. found a rapid 24 hour reduction in osteoclast numbers on the surface of rat tibiae with numbers reaching a low at 5 days and a sustained inhibitory effect after the administration of 5 mg/kg of OPG.[25] Lane reported similar findings to indicate that a single dose of OPG had an inhibitory effect on total osteoclast numbers and on the recruitment of osteoclasts during orthodontic tooth movement.[26] Bekker et al. in a randomised, double-blind, placebo-controlled single dose study, used a 3 mg/kg dose of OPG on post-menopausal women and observed an 80% decrease in bone resorption assessed by biochemical markers, indicating that, in this model, the 3 mg/kg dose was effective in rapidly and profoundly reducing bone turnover.[27]

Bolon investigated the efficacy of OPG in adjuvant-induced arthritis (AIA) and found that, if given at the onset of disease, 4 mg/kg of Fc-OPG was sufficient to eliminate all osteoclastic activity.[28] Bolon also reported that Fc-OPG given at increasing dosages of 1-30 mg/kg at the peak of disease progression could eliminate all osteoclastic activity but there was no impact on bone integrity due to pre-existing bone loss. This indicated that OPG inhibited osteoclastic activity, but was both dose and schedule-dependent.[28] In addition, Bolon found that single adenoviral delivery of Fc-OPG dosages had an immediate effect within 24 hours and efficacy peaked after 4 days.[29] Previous studies using single doses of various forms of OPG indicated the principal efficacy of OPG is its rapid inhibition of osteoclastic activity.

Osteoclast populations were present at the 7.5 mg/kg dosage in test teeth (Average osteoclastic cell population = 2.09, $p > 0.05$), and in smaller population numbers in the control teeth at all doses. This unexpected finding may be explained by insufficient OPG available to neutralise the RANKL following extensive necrosis during inflammation, or other mechanisms possibly exist that directly stimulate osteoclastic activity. Atkins et al. demonstrated that OPG completely inhibits the formation of osteoclasts from precursors within osteolytic giant cell tumours at 50 ng/mL OPG with 50% inhibition observed at 6.25 ng/mL.[30] However, the move from in vitro work to in vivo models has not been as comprehensive. Transgenic models have confirmed the initial in vivo results, in so far as transgenic mice, which over express OPG, systemically developed osteopetrosis in association with a near total lack of osteoclasts.[4,31]

Bolon et al., after testing at dosages up to 30 mg/kg, suggested that a dosage of 2.5 mg/kg in the murine model may be insufficient to cause total osteoclast inhibition.[28] Whilst RANKL, RANK and OPG play a significant role in the activity of osteoclasts, other hormonal and inflammatory mediators have the potential to possibly influence the OPG/RANK/RANKL interaction.[2,26]

Conclusion

The reduction in mature osteoclastic population numbers from single doses of 2.5, 5.0 and 7.5 mg/kg OPG occurred in a dose-dependent manner. The three current dosage regimes were either insufficient for complete inhibition of osteoclast activity or other factors were involved in stimulating osteoclasts. The current investigation reported the reduced occurrence of osteoclasts at the 7.5 mg/kg dosage level without complete inhibition as originally hypothesised. By extrapolation of the data, if the reduction of osteoclast numbers continued to decrease in a linear dose-dependant manner, there should be complete inhibition of osteoclasts at 15 mg/kg in this model of aseptic inflammation. This hypothesis warrants further investigation and a study of osteoclastic responses at higher dosages, along with single or multiple dose regimes, would be valuable and critical in understanding the true efficacy of osteoprotegerin.

Acknowledgment

We are grateful for the funding provided by the Australian Society of Orthodontists Foundation for Research and Education.

Corresponding author

Professor Wayne Sampson
Begg Chair in Orthodontics
Orthodontic Unit
The University of Adelaide
Adelaide, South Australia 5005
Australia

Email: wayne.sampson@adelaide.edu.au

References

1. Dreyer CW. Thesis: Clast cell activity in a model of aseptic root resorption. Orthodontic Adelaide: The University of Adelaide, 2002.
2. Curl L, Sampson W. The presence of TNF-alpha and TNFR1 in aseptic root resorption; A preliminary study. Aust Orthod J 2011;27:102-9.
3. Brezniak N, Wasserstein A. Orthodontically induced inflammatory root resorption. Part I: The basic science aspects. Angle Orthod 2002;27:175-9.
4. Simonet WS, Lacey DL, Dunstan CR Kelley M, Chang MS, Lüthy R et al. Osteoprotegerin: a novel secreted protein involved in the regulation of bone density. Cell 1997;89:309-19.
5. Phan TC, Xu J, Zheng MH. Interaction between osteoblast and osteoclast: impact in bone disease. Histol Histopathol 2004;19:1325-44.
6. Takayanagi H. Mechanistic insight into osteoclast differentiation in osteoimmunology. J Mol Med 2005;83:170-9.
7. Wise GE, Yao S, Zhang Q, Ren Y. Inhibition of osteoclastogenesis by the secretion of osteoprotegerin in vitro by rat dental follicle cells and its implication for tooth eruption. Arch Oral Biol 2002;47:247-54.
8. Wada N, Maeda H, Yoshimine Y, Akamine A. Lipopolysaccharide stimulates expression of osteoprotegerin and receptor activator of NF-kappa B ligand in periodontal ligament fibroblasts through the induction of interleukin-1 beta and tumor necrosis factor-alpha. Bone 2004;35:629-35.
9. Yun TJ, Chaudhary PM, Shu GL, Frazer JK, Ewings MK, Schwartz SM et al. OPG/FDCR-1, a TNF receptor family member, is expressed in lymphoid cells and is up-regulated by ligating CD40. J Immunol 1998;161:6113-21.
10. Tsuda E, Goto M, Mochizuki S, Yano K, Kobayashi F, Morinaga T et al. Isolation of a novel cytokine from human fibroblasts that specifically inhibits osteoclastogenesis. Biochem Biophys Res Commun 1997;234:137-42
11. Ross AB, Bateman TA, Kostenuik P, Ferguson VL, Lacey DL, Dunstan CR et al. The effects of osteoprotegerin on the mechanical properties of rat bone. J Mater Sci Mater Med 2001;12:583-8.
12. Min H, Morony S, Sarosi I, Dunstan CR, Capparelli C, Scully S et al. Osteoprotegerin reverses osteoporosis by inhibiting endosteal osteoclasts and prevents vascular calcification by blocking a process resembling osteoclastogenesis. J Exp Med 2000;192:463-74.
13. Goldberg AF BT. Acid Phosphatase activity in human blood cells. Nature 1962:195-297.
14. Wesselink PR, Beertsen W, Everts V. Resorption of the mouse incisor after the application of cold to the periodontal attachment apparatus. Calcif Tissue Int 1986;39:11-21.
15. Tal H, Kozlovsky A, Pitaru S. Healing of sites within the dog periodontal ligament after application of cold to periodontal apparatus. J Clin Periodontol 1991;18:543-6.
16. Hill P. Bone Remodelling. Br J Orthod 1998;25:101-7.
17. Andersson GN, Marks SC. Tartrate-resistant acid ATPase as a cytochemical marker for osteoclasts. J Histochem Cytochem 1989;37:115-17.
18. Andersson GN, Lindunger A, Ek-Rylander B. Isolation and characterization of skeletal acid ATPase: a new osteoclast marker? Connect Tissue Res 1989;20:151-8.
19. Hattersley G, Chambers TJ. Generation of osteoclastic function in mouse bone marrow cultures: Multinuclearity and tartrate-resistant acid phosphatase are unreliable markers for ostoclast differentiation. Endocrinology 1989;124:1689-96.
20. Modderman WE, Tuinenburg-Bol Raap AC, Nijweide PJ. Tartrate-resistant acid phosphate is not an exclusive marker for mouse osteoblasts in cell cultures. Bone 1991;12:81-7.
21. Suda T, Takahashi N, Martin TJ. Modulation of osteoclast differentiation. Endocr Rev 1992;13:66-80.
22. Lacey DL, Timms E, Tan H, Kelley MJ, Dunstan CR, Burgess T et al. Osteoprotegerin ligand is a cytoskine that regulates osteoclast differentiation and activation. Cell 1998;93: 165-76.
23. Khosla S. Minireview: the OPG/RANKL/RANK system. Endocrinology 2001;142:5050-5.
24. Theoleyre S, Wittrant Y, Tat SK, Fortun Y, Redini F, Heymann D. The molecular triad OPG/RANK/RANKL: involvement in the orchestration of pathophysiological bone remodeling. Cytokine Growth Factor Rev 2004;15:457-75.
25. Capparelli C, Morony S, Warmington K, Adamu S, Lacey D, Dunstan CR et al. Sustained antiresorptive effects after a single treatment with human recombinant osteoprotegerin (OPG): a pharmacodynamic and pharmokinetic analysis in rats. J Bone Miner Res 2003;18:852-8.
26. Lane P. Thesis: A histomorphetric investigation into the dffects of osteoprotegerin on tooth movement in rats. Adelaide: Orthodontic Department, School of Dentistry, 2004.
27. Bekker PJ, Holloway D, Nakanishi A, Arrighi M, Leese PT, Dunstan CR. The effect of a single dose of osteoprotegerin in postmenopausal women. J Bone Miner Res 2001;16:348-60.
28. Bolon B, Campagnuolo G, Feige U. Duration of bone protection by a single osteoprotegerin injection in rats with adjuvant-induced arthritis. Cell Mol Life Sci 2002;59:1569-76.
29. Bolon BC, Carter C, Daris M, Morony S, Capparelli C, Hsieh A. Adenoviral delivery of osteoprotegerin ameilorates bone resportion in a mouse ovariectomy model of osteoporosis. Mol Ther 2001;3:197-205.
30. Atkins GJ, Boualexis S, Haynes D, Graves SE, Geary SM, Evdokiou A et al. Osteoprotegerin inhibits osteoclast formation and bone resorbing activity in giant cell tumors of bone. Bone 2001;28:370-7.
31. Romas E, Sims NA, Hards DK, Lindsay M, Quinn JW, Ryan PF et al. Osteoprotegerin reduces osteoclast numbers and prevents bone erosin in collagen-induced arthritis. Am J Pathol 2002;161:1419-27.

Subjective symptoms of RME patients treated with three different screw activation protocols: a randomised clinical trial

Koray Halıcıoğlu,* Ali Kiki† and İbrahim Yavuz+
Department Orthodontics, Faculty of Dentistry, Abant İzzet Baysal University, Bolu,* Department Orthodontics, Faculty of Dentistry, Atatürk University, Erzurum† and Department Orthodontics, Faculty of Dentistry, Erciyes University, Kayseri,+ Turkey

Aims: The purpose of the present study was to evaluate the subjective symptoms of patients during the active phase of rapid maxillary expansion (RME) treatment, and further, to assess the differences between three different RME activation protocols.
Materials and methods: The clinical sample consisted of 60 patients (mean age 13.5 years) with maxillary transverse deficiency requiring expansion. The subjects were randomly divided into three groups on which different expansion protocols were performed. An evaluation of the subjective symptoms was carried out by a Numerical Rating Scale (NRS). The patients completed questionnaires after the first, fifth, tenth, twentieth and final activations. A Shapiro-Wilk test was applied to evaluate homogenity; a Kruskall Wallis test was performed for gender-related differences and to compare the different activation schedules. The Wilcoxon test was used to compare the activations at the various time intervals.
Results: No gender-related differences were found. Ninety-eight percent of the patients reported pain during RME. There were no specific differences between groups except for the pain perceived at the twentieth activation. In all groups, pain, the sensation of pressure and its duration were highest at the fifth activation. Subjective symptoms tended to decrease after the fifth and tenth activations. Headache and dizziness were minimal.
Conclusion: Different activation protocols did not appear to alter subjective symptoms encountered during RME. The majority of the patients undergoing RME suffered pain and pressure sensations especially after the fifth activation.
(Aust Orthod J 2012; 28: 225–231)

Received for publication: January 2012
Accepted: October 2012

Koray Halıcıoğlu: korayhalicioglu@hotmail.com or koray.halicioglu@ibu.edu.tr; Ali Kiki: akiki25@hotmail.com;
İbrahim Yavuz: iyavuz@erciyes.edu.tr

Introduction

Rapid maxillary expansion (RME) is a common clinical procedure for the treatment of posterior crossbite and reduced maxillary width. It is reported that over 90% of orthodontists offer RME as a treatment option.[1] RME and the rapid elimination of arch constriction by opening the mid-palatal suture, occupies a unique place in contemporary orthodontics. By generating a force which exceeds the limits of orthodontic tooth movement, an expansion appliance compresses the periodontal ligament, bends alveolar processes, tips anchor teeth, and gradually affects the circummaxillary suture system but more specifically, the mid-palatal suture.[2] Maxillary changes are produced by separation of this facial bone from its craniofacial articulations.[3,4] Numerous studies have investigated the effects of the procedure and process on the skeletal and dental structures[5-10] as well as the surrounding soft tissues.[11-13]

Besides its primary indication in the management of skeletal maxillary constriction, the literature has shown favourable RME effects in individuals suffering sleep disturbances,[14] in children with conductive hearing loss,[15,16] in patients with nasal respiratory problems[17-19] and even in nocturnal enuresis cases.[20,21]

Table I. Pain assessment form.

Date: ____________________________

Expander Type:

- ❑ Memory Screw
- ❑ Hyrax two quarter turns/day
- ❑ Hyrax one quarter turn/day

Patient's Name: ____________________

Number: ___________________________

Activation (1st, 5th etc.): ______________

Please grade your degree of pain and/or pressure marking a place between 0 and 100.
Zero (0) means no discomfort, where as 100 corresponds to severe pain and/or pressure.

1. Did you feel pain when you turned the screw, if yes how severe?

❑ No
❑ Yes 0 | | | | 50 | | | | 100

2. Did you feel pressure sensation when you turn the screw if yes how severe?

❑ No
❑ Yes 0 | | | | 50 | | | | 100

3. How long did pressure sensation continue after the activation of the screw?

A. Less than one minute
B. 1 to 2 minutes
C. 2 to 3 minutes
D. 5 to 10 minutes
E. 10 to 30 minutes
F. 30 minutes to one hour
G. More than one hour

4. Did you experience headache when you turned screw, if yes how severe?

❑ No
❑ Yes 0 | | | | 50 | | | | 100

5. Did you experience dizziness when you turned screw, if yes how severe?

❑ No
❑ Yes 0 | | | | 50 | | | | 100

Although rarely reported, undesirable side effects of the RME procedure may be experienced. These include pain, oral ulceration, non-opening of the sutural articulations, extreme tooth tilting and bone and/or root resorption.[22-24] Among these, RME-associated pain is less reported. Although clinicians are aware that patients frequently report pain during the RME procedure, only two studies[25,26] have investigated its consequences.

The prevalence, timing and intensity of other subjective symptoms such as headache, dizziness, the sensation of pressure and its duration have not been documented. It is important for the clinician to inform his/her patients about likely experiences when undergoing treatment. The patient's psychological response and ability to cope might be improved with this pre-emptive guidance.[26,27]

The present study aimed to investigate the subjective symptoms of RME and to determine whether there were any differences between three screw activation protocols.

Materials and methods

The study was conducted in the Departments of Orthodontics, Faculties of Dentistry, Atatürk and Abant İzzet Baysal Universities and approved by the University Ethics Committee (2006/20). A power analysis indicated that 60 patients were required.

Seventy-five consecutive patients (45 female, 30 male) aged between 10 and 15 years and presenting with a bilateral posterior crossbite were included in the study. All of the subjects were in the permanent dentition with fully erupted first premolar teeth. Because analgesic drugs were consumed or patients incompletely completed the questionnaire, 15 subjects were excluded from the study. A final evaluation was performed on 60 patients (aged between 10.25 and 14.6 years with a mean of 13.5 years). All subjects were treated by one author (KH) and the questionnaires were prepared and evaluated by the other authors.

Informed consent for each patient and their parents was obtained. The subjects were randomly divided into

Figure 1. Occlusal photograph at the end of expansion of RME produced by the memory screw.

Figure 2. Occlusal photograph at the end of expansion of RME produced by the Hyrax screw.

three groups according to an expansion protocol to be applied. The first group (10 female, 8 male) received a nickel titanium rapid maxillary expansion screw - memory screw (Forestadent, Pforzheim, Germany) introduced by Wichelhaus et al.[28] It is a modified Hyrax screw comprised of nickel titanium open coil springs in the screw bed which aimed to reduce the expansion forces. The memory screw, combining intermittent and continuous force modules, was activated 6 quarter-turns a day. The second group (10 female, 10 male) received a conventional Hyrax appliance (Forestadent, Pforzheim, Germany) which was activated twice daily until the mid-palatal suture opened, after which, activation was reduced to one quarter-turn a day. The third group (13 female, 9 male) also received a conventional Hyrax screw which was activated two quarter-turns a day during the entire expansion phase. All of the devices were tooth-borne and cemented to the maxillary anchor teeth. Mid-palatal suture separation was verified by occlusal radiographs in all patients.

The patients were provided with questionnaires at the 1st, 5th, 10th, 20th and at the final activations (Table I). The subjects were asked to complete the forms soon after the cessation of pain and/or the other subjective symptoms and to avoid the use of analgesics during the active expansion phase. Statistical evaluation was provided by the Shapiro-Wilk test which determined that the distribution of data was non-homogeneous. The Kruskal-Wallis test was applied for gender-related differences and for the screw activation protocols. The differences between the 1st, 5th, 10th, 20th and the final activation were analysed by the Wilcoxon test.

Results

Gender differences

The Kruskal-Wallis test was applied separately to each of the three groups and revealed no gender-related differences, therefore female and male subjects were pooled in each group.

Comparison of the different activation schedules

The Kruskal-Wallis test further demonstrated that there were no differences between the three activation protocols regarding the subjective symptoms of the patients except for pain perceived at the 20th activation (Table II). This difference was at a level of confidence represented by $p < 0.5$ and may be considered as negligible. Thus, the groups were combined for the evaluation of the differences between the 1st, 5th, 10th, 20th and the final activation time points.

Comparison of the subjective symptoms perceived at different activation time points

The differences between the 1st, 5th, 10th, 20th and the final activations were determined by the Wilcoxon test and the results are shown in Table III.

Pain

Fifty-nine of the 60 subjects reported pain during RME. The perception of pain peaked at the 5th

Table II. Comparison of three different screw activation programs.

	First activation				Fifth activation				Tenth activation				Twentieth activation				Final activation			
	1	2	3	z	1	2	3	z	1	2	3	z	1	2	3	z	1	2	3	z
Pain	13.89	16.67	25.29	2.60	33.33	29.33	34.70	0.53	29.44	37.33	22.35	3.33	37.78	18.00	22.94	8.89*	18.33	19.33	18.82	0.19
Pressure	21.67	22.67	26.47	0.31	32.78	40.00	24.70	3.97	32.22	34.67	22.94	2.89	34.44	25.33	28.24	2.23	16.67	25.33	21.18	2.42
Duration	7.89	7.20	8.21	0.34	10.58	2.57	10.76	4.40	7.69	3.83	11.85	1.30	4.83	3.40	10.38	2.46	6.03	4.13	4.18	0.70
Headache	5.00	10.00	8.23	0.83	5.00	8.00	9.41	1.61	3.33	10.67	9.41	0.71	4.44	6.67	10.00	1.02	1.67	4.00	7.64	1.19
Dizziness	.00	.00	2.35	3.96	3.89	5.33	1.76	1.33	3.33	2.67	2.35	0.15	1.11	5.33	1.76	1.53	.56	4.00	1.17	0.04

*$p < 005$

Table III. Differences between the first, 5th, 10th, 20th and the final activations.

	Activations														
	First (I)	Fifth (II)	Tenth (III)	Twentieth (IV)	Final (V)	I-II	I-III	I-IV	I-V	II-III	II-IV	II-V	III-IV	III-V	IV-V
Pain	18.60	32.60	29.40	26.80	18.80	-3.39***	-2.57**	-1.99*	-0.11	-1.32	-1.69	-3.14*	-0.73	-3.06*	-2.39
Pressure	23.60	32.20	29.80	29.60	20.80	-2.39*	-1.40	-1.38	-1.16	-0.72	-1.19	-3.21***	-0.11	-2.89*	-3.49***
Duration	7.79	8.24	7.95	6.29	4.83	-0.77	-1.15	-1.02	-1.75	-0.22	-2.34*	-1.18	-2.31*	-2.25*	-1.48
Headache	7.60	7.40	7.60	7.00	4.40	-0.24	-0.05	-0.04	-1.23	-0.16	-0.28	-1.29	-0.26	-1.68	-1.52
Dizziness	0.80	3.60	2.80	2.60	1.80	-1.88	-1.63	-1.38	-0.54	-1.03	-0.79	-1.25	-0.37	-0.78	-1.63

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

activation and lessened thereafter. There was no difference in pain perception between the first and the last activations. However, there were significant differences between the 1st and the 5th ($p < 0.001$), the 1st and the 10th ($p < 0.01$), and the 1st and the 20th activations ($p < 0.05$). Statistically significant differences were also observed between the 5th and the final activations ($p < 0.05$) and between the 10th and the final activations ($p < 0.05$).

Sensation of pressure

In keeping with the experience of pain, pressure perception reached its highest level at the 5th activation and diminished thereafter. There were significant differences between the 5th and the 20th activations ($p < 0.001$) and between the 20th and the final activations ($p < 0.001$). In addition, the 1st and the 5th activations, and also the 10th and the final activations were different at the $p < 0.05$ significance level.

Duration of pressure

The duration of pressure was longest at the 5th activation. There were significant differences between the 5th and the 20th ($p < 0.05$), the 10th and the 20th ($p < 0.05$) and between the 10th and the final activations ($p < 0.05$).

Headache

To a mild degree, patients who were treated with RME appliances experienced headache. However, discomfort had reduced by the last activation. No statistically significant difference was observed between the activations.

Dizziness

RME patients reported slight dizziness during the procedure, but there was no significant difference between activations.

Discussion

The clinical monitoring of RME treatment often uses pain as a guide, and the correct interpretation of pain is of paramount importance.[3] Although numerous RME reports have investigated patient discomfort, there have been few studies regarding subjective symptoms. Early investigations[1,22,29] cited pain among the side effects and, more recently, it has been revealed that the vast majority of patients undergoing RME, report pain.[25] De Felippe et al.[26] indicated that 93.9% of respondents experienced pain and discomfort from their palatal expanders (Hyrax, Haas, banded and quad-helix).

Needleman et al.[25] evaluated pain perceptions in children undergoing RME by using Visual Analogue Scale scores. However, the study evaluated and compared pain arising from two different RME protocols. It was reported that during the first 10 activating turns, patients whose rate of expansion was two turns per day were more likely to experience pain compared with children whose rate of expansion was less frequent. As twice daily activation is the most commonly applied program, it is recommended that the preferred protocol be twice daily for the first four to five days, followed by one activation per day throughout the remainder of the expansion process.[30] The present study aimed to compare the activation protocols with a memory screw which was activated six times a day. Wichelhaus et al.[28] postulated that the memory expansion screw, which generates lighter forces compared with conventional screws, produced maxillary expansion over a shorter period of time, was more effective and caused minimal patient discomfort.

The present study found that the subjects wearing the memory Hyrax appliance (6 activations/day) reported more pain than those in the other two groups at the 20th activation. In all other respects, there was no statistically significant difference between groups. This effect could possibly be explained by an accumulation of residual forces. Since expansion of 20 quarter turns in the memory screw group was achieved by the fourth day, residual loads might not have dissipated over the short time frame. Importantly, the 20th activation in the second and third groups took place on the 15th and 10th days respectively, which allowed more time for residual forces to dissipate. At the final activation, pain scores were similar in all groups.

The duration of pressure sensation, the severity of headache and dizziness were statistically similar between the groups. As there was no difference (except for the pain score at the 20th activation), the groups were pooled and the differences between the 1st, 5th, 10th, 20th and the final activations assessed.

The overall pattern indicated that pain reached a maximum at the 5th activation and thereafter gradually decreased by the 10th and the 20th activations. At the final activation, the pain score recorded was similar to that experienced at the first activation. This finding is in agreement with those of Needleman et al.,[25] who found the highest levels of pain during the first 10 turns with the greatest intensity during the first 6 turns. This is likely explained by the mid-palatal suture starting to react at that time. Timms[3] cited rigidity of the facial skeleton and mechanical interlocking and synostosis of the mid-palatal suture as reasons for pain during RME. Furthermore, histological studies[31-33] have demonstrated the presence of an inflammatory reaction with concommitant pain in the suture during RME.[34] However, a recent animal study by Joviliano et al.[35] concluded that RME-induced neural activation in the same nociception-related structures that were also activated during tooth movement. Therefore compression of the periodontal ligament of the anchor teeth may contribute to the pain experienced during RME.

The inflammatory reaction during sutural disruption may account for the source of pain in the early phase of RME, but the presence of high pain scores after sutural opening may infer that other factors are involved. These may be residual forces accumulating at the circummaxillary articulations as well as periodontal pain.

Pressure sensation scores showed a similar pattern to those of pain. A zenith was reached at the 5th activation which steadily decreased thereafter. This may be explained by the close proximity of pain and pressure receptors and also the difficulty that children might have in distinguishing pain from pressure. The duration of the pressure sensation was reported to be 7.76 minutes on average at the 1st activation and 8.24 minutes by the 5th activation, thereafter it decreased. It was clear that the demonstrated duration of the pressure sensations matched those of pain and followed a similar progress. Headache and dizziness were minimal and were not significantly different at any observation point.

In the present study, there was no gender-related difference in any of the parameters. Although it is known that mechanical pain thresholds are similar between the genders,[36] it is believed that females are more sensitive to pain while males are more stoic.[37] Conflicting results have been reported on this issue. While earlier reports have indicated that females experience more pain during fixed appliance therapy,[38,39] others recorded no gender difference.[40] In accordance with the present results, Needleman et al.[25] found that the gender of the patient was not a significant factor in predicting RME pain.

In a histological study, Persson and Thilander[41] found that the earliest loss of sutural responsiveness was in a 15-year-old subject. Therefore, the present study did not incorporate subjects older than 15 years. In addition, there was the assumption that maxillary expansion generated more pain in older adolescents.[3] However, there are differing reports regarding pain and its association with age. It is known that resistance to maxillary expansion increases with age, but at the same time, pain threshold levels also increase from 5 to the age of 25 years.[42] Moreover, studies[25,26] evaluating pain during RME did not find any difference between older and younger age groups. Nevertheless, the present study confined the age of the subjects to a narrow band (10.25 - 14.6 years).

The numerical rating scale (NRS) is one of the common methods of assessing pain in orthodontics,[37] and so it was used with confidence to provide a quantitative assessment of RME pain. However, as it is recognised that pain is a complex perceptual phenomenon and a subjective experience, it is impossible to precisely evaluate the pain of others.[37]

Conclusions

The majority of patients undergoing RME suffered a degree of pain and a sensation of pressure.

Headache and symptoms of dizziness were relatively mild and rare.

Except for reported pain at the 20th activation, the memory screw produced similar responses to the other Hyrax groups in relation to pain, pressure sensation, duration of pressure, headache and dizziness at all of the evaluation time points. Therefore, the completion the active expansion phase in approximately one week by using a memory screw, activated 6 times a day, did not cause an increase in subjective symptoms.

When all subjects in the study were taken collectively, subjective symptoms were seen to peak during the first 10 activations, especially at the 5th activation, and decrease thereafter.

The data may be utilised in patient information and education processes.

Corresponding author

Dr Koray Halıcıoğlu
Abant Izzet Baysal University
Faculty of Dentistry
Department of Orthodontics
14300-Bolu
Turkey

Email: korayhalicioglu@hotmail.com
or koray.halicioglu@ibu.edu.tr

References

1. Korbmacher H, Huck L, Kerkle T, Kahl-Nieke B. Clinical profile of rapid maxillary expansion - outcome of a national inquiry. J Orofac Orthop 2005;66:455-68.
2. Haas AJ. Rapid expansion of the maxillary dental arch and nasal cavity by opening the midpalatal suture. Angle Orthod 1961;31:73-89.
3. Timms DJ. Rapid maxillary expansion. Chicago: IIIiniosis Quintessence Publishing Co. Inc 1981;27-57.
4. Bishara SE, Staley RN. Maxillary expansion: clinical implications. Am J Orthod Dentofacial Orthop 1987;91:3-14.
5. Wertz RA. Skeletal and dental changes accompanying rapid midpalatal suture opening. Am J Orthod 1970;58:41-66.
6. Halıcıoğlu K, Kiki A, Yavuz İ. Maxillary expansion with the memory screw: a preliminary investigation Korean J Orthod 2012;42:73-9.
7. Sandikcioglu M, Hazar S. Skeletal and dental changes after maxillary expansion in the mixed dentition. Am J Orthod Dentofacial Orthop 1997;111:321-7.
8. Cameron CG, Franchi L, Baccetti T, McNamara J. Long-term effects of rapid maxillary expansion: a posteroanterior cephalometric evaluation. Am J Orthod Dentofacial Orthop 2002;121:129-135; quiz 193.
9. Usumez M, Uzel I. A comparison of rapid maxillary expansion and Quad-Helix applications in the late mixed dentition. Turkish J Orthod 2008;21:187-95.
10. Halıcıoğlu K, Yavuz İ. Comparison of the effects of rapid maxillary expansion caused by treatment with either a memory screw or a Hyrax screw on the dentofacial structures. Eur J Orthod 2011;Aug 29: (Epub ahead of print).
11. Karaman AI, Basciftci FA, Gelgor IE, Demir A. Examination of soft tissue changes after rapid maxillary expansion. World J Orthod 2002;3:217-22.
12. Kılıc N, Kiki A, Oktay H, Erdem A. Effects of rapid maxillary expansion on Holdaway soft tissue measurements. Eur J Orthod 2008;30:239-43.
13. Berger JL, Pangrazio-Kulbersh V, Thomas BW, Kaczynski R. Photographic analysis of facial changes associated with maxillary expansion. Am J Orthod Dentofac Orthop 1999;116:563-71.
14. Cistulli PA, Palmisano RG, Poole MD. Treatment of obstructive sleep apnea syndrome by rapid maxillary expansion. Sleep 1998;15:831-5.
15. Ceylan I, Oktay H, Demirci M. The effect of rapid maxillary expansion on conductive hearing loss. Angle Orthod 1996;66:301-7.
16. Kılıc N, Kiki A, Oktay H, Selimoglu E. Effects of rapid maxillary expansion on conductive hearing loss. Angle Orthod 2008;78:409-14.
17. Halıcıoğlu K, Kılıc N, Yavuz İ, Aktan B. Effects of rapid maxillary expansion with memory palatal split screw on the morphology of maxillary dental arch and nasal airway resistance. Eur J Orthod 2010;32:716-20.
18. Doruk C, Sokucu O, Sezer H, Canbay EI. Evaluation of nasal

airway resistance during rapid maxillary expansion using acoustic rhinometry. Eur J Orthod 2004;26:397-401.
19. Bicakci AA, Agar U, Sokucu O, Babacan H, Doruk C. Nasal airway changes due to rapid maxillary expansion timing. Angle Orthod 2005;75:1-6.
20. Usumez S, Iseri H, Orhan M, Basciftci FA. Effect of rapid maxillary expansion on nocturnal enuresis. Angle Orthod 2003;73:532-8.
21. Schutz-Fransson U, Kurol J. Rapid maxillary expansion effects on nocturnal enuresis in children: a follow-up study. Angle Orthod 2008;78:201-8.
22. Schuster G, Borel-Scherf I, Schopf PM. Frequency of and complications in the use of RPE appliances - results of a survey in the Federal State of Hesse, Germany. J Orofac Orthop 2005;66:148-61.
23. Erverdi N, Okar I, Kucukkeles N, Arbak S. A comparison of two different rapid palatal expansion techniques from the point of root resorption. Am J Orthod Dentofacial Orthop 1994;106:47-51.
24. Langford SR, Sims MR. Root surface resorption, repair, and periodontal attachment following rapid maxillary expansion in man. Am J Orthod 1982;81:108-15.
25. Needleman HL, Hoang CD, Allred E, Hertzberg J, Berde C. Reports of pain by children undergoing rapid palatal expansion. Pediatr Dent 2000;22:221-6.
26. De Felippe NL, Da Silveira AC, Viana G, Smith B. Influence of palatal expanders on oral comfort, speech, and mastication. Am J Orthod Dentofacial Orthop 2010;137:48-53.
27. Sergl HG, Klages U, Zentner A. Functional and social discomfort during orthodontic treatment - effects on compliance and prediction of patients' adaptation by personality variables. Eur J Orthod 2000;22:307-15.
28. Wichelhaus A, Geserick M, Ball J. A new nickel titanium rapid maxillary expansion screw. J Clin Orthod 2004;38:677-80; quiz 671-2.
29. Handelman CS, Wang L, BeGole EA, Haas AJ. Nonsurgical rapid maxillary expansion in adults: report on 47 cases using the Haas expander. Angle Orthod 2000;70:129-44.
30. Zimring JF, Isaacson RJ. Forces produced by rapid maxillary expansion. 3. Forces present during retention. Angle Orthod 1965;35:178-86.
31. Cleall JF, Bayne DI, Posen JM, Subtelny JD. Expansion of the Midpalatal Suture in the Monkey. Angle Orthod 1965;35:23-35.
32. Ten Cate AR, Freeman E, Dickinson JB. Sutural development: structure and its response to rapid expansion. Am J Orthod 1977;71:622-36.
33. Murray JM, Cleall JF. Early tissue response to rapid maxillary expansion in the midpalatal suture of the rhesus monkey. J Dent Res 1971;50:1654-60.
34. Krishnan V. Orthodontic pain: from causes to management - a review. Eur J Orthod 2007;29:170-9.
35. Joviliano P, Junqueira AA, Stabile AC, Leite-Panissi CR, Rocha MJ. Rapid maxillary expansion causes neuronal activation in brain structures of rats. Brain Res Bull 2008;76:396-401.
36. Hogeweg JA, Kuis W, Oostendorp RA, Helders PJ. The influence of site of stimulation, age, and gender on pain threshold in healthy children. Phys Ther 1996;76:1331-9.
37. Bergius M, Broberg AG, Hakeberg M, Berggren U. Prediction of prolonged pain experiences during orthodontic treatment. Am J Orthod Dentofacial Orthop 2008;133:339.e1-8.
38. Erdinç AM, Dinçer B. Perception of pain during orthodontic treatment with fixed appliances. Eur J Orthod 2004;26:79-85.
39. Ngan P, Kess B, Wilson S. Perception of discomfort by patients undergoing orthodontic treatment. Am J Orthod Dentofac Orthop 1989;96:47-53.
40. Jones M, Chan C. The pain and discomfort experienced during orthodontic treatment: a randomized controlled clinical trial of two initial aligning arch wires. Am J Orthod Dentofacial Orthop 1992;102:373-81.
41. Persson M, Thilander B. Palatal suture closure in man from 15 to 35 years of age. Am J Orthod 1977;72:42-52.
42. Tucker MA, Andrew MF, Ogle SJ, Davison JG. Age-associated change in pain threshold measured by transcutaneous neuronal electrical stimulation. Age Ageing 1989;18:241-6.

Measurements from conventional, digital and CT-derived cephalograms: a comparative study

Ahmed Ghoneima,*† Sahar Albarakati,+ Asli Baysal,± Tancan Uysal± and Katherine Kula†

Department of Orthodontics, Faculty of Dental Medicine, Al-Azhar University, Cairo, Egypt,* Department of Orthodontics and Oral Facial Genetics, Indiana University School of Dentistry, Indianapolis, USA,† Department of Pediatric Dentistry and Orthodontics, College of Dentistry, King Saud University, Riyadh, Saudi Arabia+ and Department of Orthodontics, Faculty of Dentistry, Izmir Katip Celebi University, Izmir, Turkey±

Objective: The purpose of this retrospective radiographic study was to determine the reliability and reproducibility of skeletal and dental measurements of lateral cephalograms created from a computerised tomography (CT) scan compared with conventional and digital lateral cephalograms.

Methods: CT and conventional lateral cephalograms of the same patients were obtained from university archives. The lateral cephalometric radiographs of 30 patients were manually traced. The radiographs were subsequently scanned and traced using Dolphin Imaging software version 11 (Dolphin Imaging, Chatsworth, CA, USA). The CT-created lateral cephalograms were also traced using the same software. Sixteen (10 angular and 6 linear) measurements were performed. Cephalometric measurements obtained from conventional, digital and CT-created cephalograms were statistically compared using repeated measures analysis of variance (ANOVA). Statistical significance was set at the $p < 0.05$ level of confidence.

Results: The intra-rater reliability test for each method showed high values ($r > 0.90$) except for mandibular length which had a correlation of 0.82 for the CT-created cephalogram. Five measurements (N-A-Pog, N-S, ANS-PNS, Co-ANS and Co-Gn) were found to be significantly different between the CT-created and conventional cephalograms and three measurements (SNB, ANB, and /1-MP) were found to be significantly different between the CT-created and digital cephalograms.

Conclusions: There are statistically-significant differences in measurements produced using a traditional manual analysis, a direct digital analysis or a 3D CT-derived cephalometric analysis of orthodontic patients. These differences are, on average, small but because of individual variation, may be of considerable clinical significance in some patients.

(Aust Orthod J 2012; 28: 232–239)

Received for publication: January 2012
Accepted: October 2012

Ahmed Ghoneima: aghoneim@iupui.edu; Sahar AlBarakati: salbarakati@gmail.com; Asli Baysal: baysalasli@hotmail.com; Tancan Uysal: tancanuysal@yahoo.com; Katherine Kula: kkula@iupui.edu

Introduction

Cephalometry has been a valuable tool for clinical evaluation and research purposes in orthodontics. Two techniques may be used for cephalometric analysis; manual or computer aided. The manual technique involves landmark identification and a tracing performed on acetate paper, which is placed over the cephalometric radiograph. Difficulties with landmark identification[1-4] and measurement error are disadvantages.[5] Computer-aided techniques also require manual landmark identification using a mouse driven cursor on digital images. Software completes the analysis which reportedly reduces errors of tracing and measuring.[6]

Two-dimensional (2D) cephalograms have been used to interpret the three-dimensional (3D) craniofacial complex but suffer from limitations arising from distortion and the differential magnification of structures.[7] Advances in imaging technology have made the 3D evaluation of the craniofacial structures possible. While 3D analysis undergoes clinical validation,[7] cephalometric analyses generated from 2D cephalograms are still used by many clinicians to determine the relationship of dentofacial structures.[8-10]

Computerised tomography (CT) makes comprehensive and accurate evaluation of dental and skeletal structures possible.[11] CT scans allow fast and precise acquisition of multiple thin slices to produce multiplanar 3D reconstructions which enhance the utility of CT as a diagnostic tool.[11] CT technology has become an acceptable, accurate and readily accessible aid in clinical practice to strengthen orthodontic diagnosis and treatment planning.[11]

The purpose of this retrospective radiographic study was to determine the reliability and reproducibility of skeletal and dental measurements of lateral cephalograms created from CT scans compared with conventional and digital lateral cephalograms. The null hypothesis was that there were no differences in the comparative measurements generated using the three methods.

Materials and methods

Cephalograms were retrospectively gathered from the archives of the outpatient clinic of the Orthodontic Department, Al-Azhar University, Cairo, Egypt, of patients who had undergone spiral CT as a part of a previously conducted study.[12] The present study was approved by the Ethics Committee of the Faculty of Dental Medicine. The lateral cephalograms were taken with the same x-ray machine and a multi-planar spiral CT scanner (X vision EX, General Electric 'GE' Corporation Medical Systems Company, NY, USA) was used to obtain pretreatment CTs for all subjects. The patients' ages ranged from 8 to 15 years (mean 12.3 ± 1.9 years) and after applying the exclusion criteria, an original sample of 69 cephalograms was reduced to 30. Cephalometric records were excluded if the cephalogram showed gross asymmetry or that the patient was not properly positioned as shown by ear rod markers. In addition, records were excluded if landmarks could not be identified because of motion, resolution or lack of contrast; the cephalogram showed craniofacial deformity or excess soft tissues that could interfere with landmark location; or showed bilateral anatomical structures which did not allow accurate mid-sagittal superimpositions.

All cephalograms were taken with subjects positioned in the cephalostat with the sagittal plane perpendicular to the path of the x-rays, Frankfort plane parallel to the floor, the teeth in centric occlusion and the lips lightly together. The conventional and digital tracings as well as all the measurements were performed by one investigator (AG). The manual tracing was performed on fine grain 0.003 inch transparent acetate papers using a 0.3 mm lead pencil. The tracing process was conducted in a darkened room using a screen-viewing box. The selected landmarks were traced with bilateral structures averaged to make a single structure or landmark. All measurements were carried out manually and entered into an Excel spreadsheet (Microsoft, Seattle, WA, USA) for statistical evaluation.

The radiographs were subsequently scanned (Epson Perfection V700 Photo, Long Beach, CA, USA) with an accompanying Dolphin ruler (100 mm) into a JPEG digital format at 300 dpi resolution and an eight-bit grey scale. Once captured, software calibration of the actual size of the image in millimeters was based on a

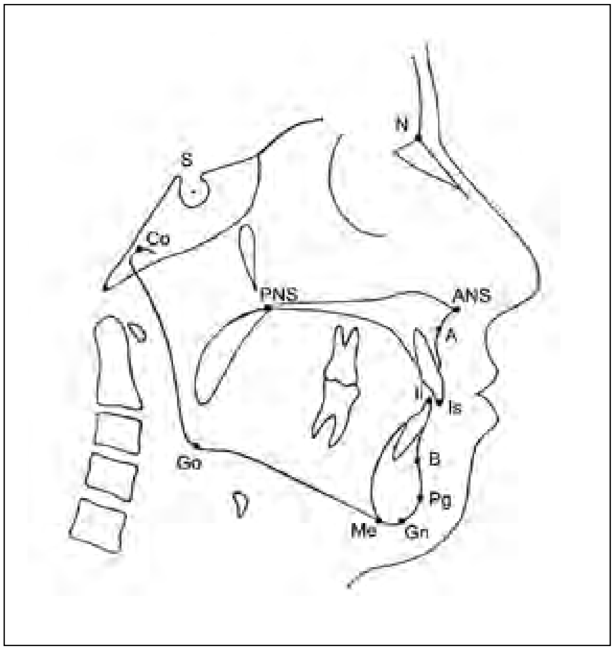


Figure 1. Cephalometric reference points and landmarks.

S: Sella
N: Nasion
ANS: Anterior nasal spine
PNS: Posterior nasal spine
Point-A (subnasal)
Is: Incisor superius
Ii: Incisor inferius
Point-B (supramental)
Pg: Pogonion
Gn: Gnathion
Me: Menton
Go: Gonion
Co: Condylion

Table I. Definition of cephalometric skeletal and dental measurements used in the study.

Skeletal angular measurements (degrees)	
SNA	Anteroposterior position of the maxilla relative to the anterior cranial base
SNB	Anteroposterior position of the mandible relative to the anterior cranial base
ANB	The difference between SNA and SNB angles, and defines the relationship, in the sagittal plane of the maxillary and mandibular bases
Angle of convexity	The angle formed by the intersection of the N-A-point to A-point – pogonion. It reveals the convexity (or concavity) of the skeletal profile
SN-MP	The angle formed between the SN plane and the mandibular plane
SN-PP	The angle formed between the SN plane and the Palatal plane
PP-MP	The angle formed between the palatal plane and the mandibular plane
Gonial angle	The angle between mandibular plane and ramal plane
Dental angular measurements (degrees):	
Upper incisor to SN (1/-SN)	The angle formed between the long axis of upper central incisor and the anterior cranial base (SN plane)
Lower incisor to mandibulare plane (/1-MP)	The angle formed between long axis of lower central incisor and the mandibular plane
Skeletal linear measurements (mm):	
Anterior cranial base(N-S)	The linear distance from sella turcica and most anterior point of the frontonasal suture
Mandibular body length (Go-Gn)	Linear distance from gonion and gnathion
Maxillary length (ANS-PNS)	Linear distance from ANS to PNS
Co-ANS	The linear distance from condylion (Co) to anterior nasal spine. It represents the effective midfacial length
Co-Gn	The linear distance from condylion (Co) to the gnathion (Gn). It represents the effective mandibular length
LAFH(ANS-Me)	The lower anterior facial height, linear distance from ANS to Menton

S, Sella; N, Nasion; ANS, anterior nasal spine; PNS, posterior nasal spine; MP, mandibular plane; PP, palatal plane; Go, gonion; Gn, gnathion; Co, condylion; Me, menton; LAFH, lower anterior facial height

known distance between 2 points on the screen ruler. The digital tracing was performed using Dolphin Imaging software version 11 (Dolphin Imaging, Chatsworth, CA, USA). Landmark identification was carried out manually on the digital images using a mouse-driven cursor and data was stored in the Dolphin Imaging archive.

Patient CT scans were obtained at 120 kV and 20 mA (low dose), with a scanning time of 2 sec/section and voxel size 0.49. The machine's perpendicular light beams were used to standardise head position in all three planes. The scans were taken with the patients in the supine position with the palatal plane perpendicular to the floor. Each subject was positioned so that the longitudinal light beam passed through the center of glabella and the philtrum, and the transverse light beam passed through the lateral canthi of the eyes. Processing of the DICOM (digital imaging and communications in medicine) images, the creation of the lateral cephalograms with 100 mm bar (ruler), and the tracing and digitisation of cephalograms were carried out using Dolphin Imaging software.

Thirteen landmarks were defined on each cephalogram (Figure 1) and 16 selected skeletal and dental parameters were measured (Table I and Figure

Table II. Mean differences, standard deviation (SD) and intra-examiner reliability expressed as Pearson's correlation coefficient for repeated measurements of conventional, digital cephalograms and computed tomography.

Measurements	Conventional cephalogram		Digital cephalogram		Computed tomography scanogram	
	Difference (Mean ± SD)	r	Difference (Mean ± SD)	r	Difference (Mean ± SD)	r
Angular (degrees)						
SNA	-0.03 ± 0.7	0.98	0.6 ± 1.6	0.93	0.1 ± 1.2	0.95
SNB	-0.4 ± 1.2	0.94	0.1 ± 0.9	0.97	0.4 ± 1.4	0.93
ANB	0.4 ± 1.4	0.92	0.5 ± 1.3	0.91	0.4 ± 1.5	0.88
Angle of convexity (N-A-Pog)	-0.04 ± 0.7	0.99	-0.0007 ± 1.1	0.99	0.3 ± 0.9	0.99
SN-MP	-0.2 ± 0.8	0.99	0.07 ± 0.5	0.99	0.5 ± 2.1	0.95
SN-PP	0.7 ± 0.9	0.98	-0.6 ± 1.3	0.96	0.2 ± 1.3	0.95
PP-MP	-0.3 ± 0.8	0.99	0.01 ± 0.4	0.99	0.3 ± 1.9	0.95
Gonial angle	-0.1 ± 0.7	0.99	0.007 ± 0.4	0.99	0.3 ± 1.8	0.96
1/-SN	-0.2 ± 0.9	0.99	-0.1 ± 0.9	0.99	0.2 ± 1.3	0.98
/1-MP	0.4 ± 1.3	0.99	-0.2 ± 0.8	0.99	0.7 ± 1.7	0.97
Linear (mm)						
N-S	0.3 ± 0.9	0.97	-0.1 ± 0.7	0.98	0.6 ± 1.4	0.95
Go-Gn	-1.3 ± 1.6	0.94	1.7 ± 1.9	0.94	0.3 ± 3.6	0.82
ANS-PNS	0.6 ± 2.5	0.82	-1 ± 2.1	0.91	0.5 ± 1.4	0.94
Co-ANS	1.3 ± 1.5	0.96	-0.8 ± 1.3	0.96	0.6 ± 1.5	0.93
Co-Gn	0.6 ± 1.2	0.98	-0.7 ± 1.0	0.99	0.2 ± 1.4	0.98
LAFH	0.1 ± 0.7	0.99	-0.4 ± 1.3	0.98	0.5 ± 1.3	0.98

r (Pearson's correlation coefficient): $r > 0.8$ = strong; $0.5 \le r \le 0.8$ = moderate; $r < 0.5$ = weak

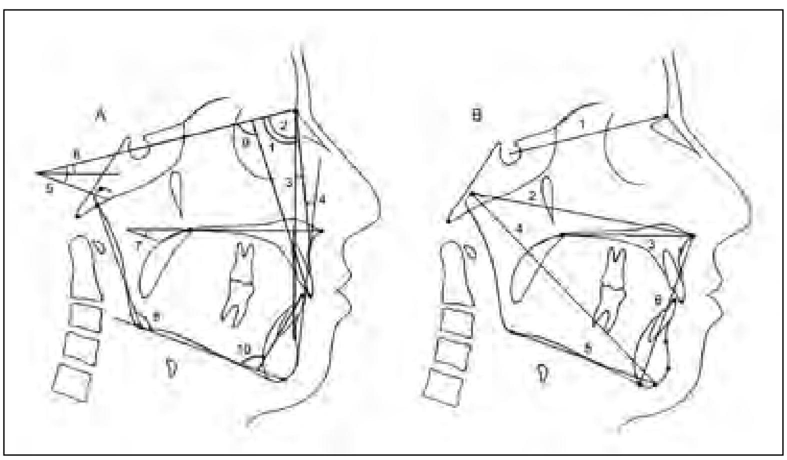


Figure 2. Cephalometric measurements.

A. Skeletal and dental angular measurements: 1, SNA; 2, SNB; 3, ANB; 4, angle of convexity; 5, SN-MP; 6, SN-PP; 7, PP-MP; 8, gonial angle; 9, 1/-SN; 10, /1-Mp

B. Skeletal linear measurements: 1, N-S; 2, Co-ANS; 3, ANS-PNS; 4, Co-Gn; 5, Go-Gn; 6, ANS-Me

2). All 30 radiographs were retraced manually and digitally (scanned cephalograms and CT created cephalograms) within a six-week interval to assess examiner reliability (intra-examiner error) and the reproducibility of the manual and digital methods. The scanned images and constructed images were analysed together to avoid introducing additional errors in scanning and orientation. Linear and angular parameters were measured to the nearest 0.1 mm and 0.1 degree respectively.

All statistical analyses were performed with the Statistical Package for the Social Sciences (SPSS), 16.0 (SPSS Inc, Chicago, IL, USA). Shapiro-Wilks normality test and Levene's variance homogeneity test were applied to the data. Because data were found to be normally distributed and there was homogeneity of variance between the groups, the statistical evaluations were performed using parametric tests. The results of the comparison between the angular and linear measurements of the conventional, digital and CT techniques were calculated by repeated measures analysis of variance (one-way ANOVA) and Tukey Honestly Significant Difference (HSD) test. Statistical significance was tested at alpha level of 0.05.

Results

Intra-examiner reliability of repeated measurements, the mean differences, standard deviations and correlation coefficients (r) for each of the 16 measurements of conventional, digital and computed tomography techniques are presented in Table II. The greatest difference between the first and second tracings within each technique was 1.3 mm and 0.7 degrees (Co-ANS, SN-PP) for the conventional, 1.7 mm and 0.6 degrees (Go-Gn, SNA) for the digital and 0.6 mm and 0.7 degrees (N-S, /1-MP) for the CT techniques, respectively. The correlation coefficients (r) of all measurements for the three methods were above 0.90 (strong correlation) except for maxillary length which had a correlation of 0.82 for the conventional cephalogram, ANB angle (r = 0.88) and mandibular length (r = 0.82) for the CT. Overall, reliability was good and intra-examiner error was small.

The results of the statistical analysis are summarised in Table III. Significant differences between the three techniques were observed for nearly all of the angular and linear measurements. Only two out of the ten angular measurements [SN-MP (p = 0.112) and 1/-SN (p = 0.084)], and only one out of six linear measurements [LAFH (p = 0.290)] showed no statistically significant difference between the groups.

Discussion

The present study compared the reliability and reproducibility of cephalometric measurements on CT-created cephalograms with conventional and digital lateral cephalograms. According to Richardson[13] and Sandler,[14] manual tracing methods compare favourably with the results obtained from digitised radiographs. Gravely and Benzies[15] reported that, if landmark identification was performed manually, measurement errors were no different from those produced via digital means. In the current study, statistically significant differences were found between manual and computer-aided techniques. These results matched those of Chen et al.[16] who showed significant differences for all measurements derived from conventional radiographs and digitised cephalograms. Although statistically significant differences were found between the measurements performed on conventional and digital cephalograms, Baumrind et al. suggested that the clinical significance should be evaluated based on the standard deviations.[17] The small differences in the averages generated from the three sets of measurements might be of little clinical significance but, because of large standard deviations, differences for individual patients may be of considerable importance.

The diagnostic value of cephalometric analysis has been shown to be associated with accurate and reproducible landmark identification.[18,19] However, this is also believed to be the main source of analysis error.[20-22] The variability of the patient's hard and soft tissues, radiographic quality and the experience of the clinician, affects the accurate identification of landmarks.[23] While Chen et al.[16] expected digitised image processing would assist landmark identification on poorly defined structures, Macri and Wenzel reported that landmark reliability in lower quality digitised radiographs was not shown to improve with digital processing.[24]

The quality of a digital image relies on the number of pixels and gray levels. The reliability of landmark identification on a digital cephalogram with a pixel size of 0.003 mm has been shown to be better than a landmark identified on an original radiograph.[25] In

Table III. Mean, standard deviation (SD) and the significant differences between conventional, digital cephalogams and computed tomography as expressed by *p* value.

Measurements	Conventional cephalogram	Digital cephalogram	Computed tomography scanogram	*p* value	Multiple comparison		
	Mean ± SD	Mean ± SD	Mean ± SD		Digital/ manual	CT/manual	CT/digital
Angular (degrees)							
SNA	78.3 ± 3.3	79.3 ± 3.6	78.8 ± 3.9	0.001*	0.000	0.428	0.153
SNB	76.2 ± 3.6	77.4 ± 3.6	76.0 ± 3.8	0.001*	0.000	1.000	0.007
ANB	2.1 ± 3.4	1.9 ± 3.2	2.8 ± 2.6	0.023*	1.000	0.135	0.043
Angle of convexity (N-A-Pog)	4.1 ± 6.0	4.5 ± 6.3	4.9 ± 6.3	0.007*	0.020	0.014	0.747
SN-MP	41.8 ± 6.5	42.4 ± 6.3	42.6 ± 6.9	0.112			
SN-PP	8.3 ± 3.9	7.4 ± 3.8	7.9 ± 4.3	0.021*	0.000	0.615	0.471
PP-MP	34.6 ± 6.6	35.7 ± 6.5	35.6 ± 5.8	0.038*	0.000	0.167	1.000
Gonial angle	131.6 ± 6.3	132.5 ± 7.0	131.5 ± 6.4	0.048*	0.009	1.000	0.150
1/-SN	103.9 ± 7.4	104.5 ± 7.0	103.7 ± 7.4	0.084			
/1-MP	84.7 ± 7.8	84.1 ± 7.9	85.8 ± 7.5	0.001*	0.140	0.390	0.002
Linear (mm)							
N-S	70.3 ± 4.3	70.1 ± 4.5	69.3 ± 4.6	0.002*	1.000	0.011	0.052
Go-Gn	77.7 ± 4.5	80.0 ± 4.8	78.5 ± 5.9	0.001*	0.000	0.376	0.090
ANS-PNS	50.9 ± 3.6	49.8 ± 4.0	48.6 ± 4.5	0.000*	0.033	0.001	0.134
Co-ANS	87.9 ± 4.8	85.0 ± 4.7	85.0 ± 4.2	0.000*	0.000	0.000	1.000
Co-Gn	118.8 ± 6.8	116.5 ± 7.3	117.1 ± 7.6	0.000*	0.000	0.001	0.777
LAFH	74.1 ± 7.5	74.0 ± 7.1	74.6 ± 7.0	0.290			

*Significant at $p < 0.05$

the present study, the image resolution was set at 300 dpi with 8 bit grey levels for improved visualisation, even though the software manufacturer recommended a resolution of 150 dpi. Using high resolution, good quality radiographs with the assistance of software manipulation, clear visualisation of anatomic structures and the accuracy of landmark identification may approximate those obtained using quality CT cephalograms. The present study determined that the fewest number of differences were found between the CT-synthesised cephalograms and the digital cephalograms which was attributed to the high quality of the images.

According to Cevidanes et al., landmarks like condylion, porion and gonion have greater margins for error.[26] Superimposition of middle ear and temporal fossa structures make the identification of anatomical porion difficult[7] and Chen et al.[27] showed significant variability in the localisation of gonion. Bruntz et al.[28] confirmed the unreliability of landmarks like porion, articulare, posterior nasal spine and the upper molar while Sekiguchi and Savara[29] stated that nasion was difficult to identify if the naso-frontal suture was obscure. This might explain the statistically significant differences found in measurements which involved nasion, gonion, posterior nasal spine and condylion in the present study. However, 1/SN and

SN-MP measurements, which include nasion, did not statistically vary between the three methods.

It has been considered that 3D CT cephalometry is highly accurate and reliable.[30,31] According to the results of the present study, cephalometric measurements performed on CT-created cephalograms may be assumed to be comparable with conventional and digitised cephalograms. However, greater differences were found between the conventional and digital cephalometric measurement methods.

The threshold for a clinically meaningful difference was suggested as ± 2 mm or ± 2 degrees.[32,33] Olmez et al.[34] compared direct skull measurements with 3D computer-assisted measurements and showed good reliability of the computer-assisted measurements. However, greater differences were found in comparing direct skull measurements with cephalometric measurements. These differences were attributed to divergence of the x-ray beam and related magnification.[34] Structures at any distance from the central x-ray beam were magnified but structures farther from the film were magnified more.[34]

The three-dimensional representation of structures is diagnostically important in the craniofacial area. Moreover, resorption, hyperplastic growth, displacement, shape anomalies of condyles and morphological differences between left and right sides may be detected with CT scans.[7] These capabilities make the CT a valuable diagnostic tool but as new 3D techniques emerge, there is a need for reliable 3D normative data.[7] Weighing the advantages and disadvantages of CT acquisition, radiation exposure and cost still restrain routine use in orthodontics.

Conclusions

From the results of this study, the following conclusions may be drawn:

1. Statistically-significant differences in measurements were identified when comparing traditional manual analysis, direct digital analysis or 3D CT-derived cephalometric analysis of orthodontic patients.
2. These differences may be small but, because of individual variation, may be of considerable clinical significance in selected patients.
3. The relevance of these differences will vary according to the aims and objectives set by assessing clinicians.

Corresponding author

Dr Ahmed Ghoneima
Department of Orthodontics and Oral Facial Genetics
Indiana University School of Dentistry
1121 West Michigan Street
Indianapolis, IN 46202
U.S.A.

Email: aghoneim@iupui.edu

References

1. Baumrind S, Frantz RC. The reliability of head film measurements. 1. Landmark identification. Am J Orthod 1971;60:111-27.
2. Midgård J, Björk G, Linder-Aronson S. Reproducibility of cephalometric landmarks and errors of measurements of cephalometric cranial distances. Angle Orthod 1974;44:56-61.
3. Houston WJ. The analysis of errors in orthodontic measurements. Am J Orthod 1983;83:382-90.
4. Houston WJ, Maher RE, McElroy D, Sherriff M. Sources of error in measurements from cephalometric radiographs. Eur J Orthod 1986;8:149-51.
5. Onkosuwito EM, Katsaros C, van't Hof MA, Bodegom JC, Kuipers-Jagtman AM. The reproducibility of cephalometric measurements: a comparison of analogue and digital methods. Eur J Orthod 2002;24:655-65.
6. Liu JK, Chen YT, Cheng KS. Accuracy of computerized automatic identification of cephalometric landmarks. *Am J Orthod Dentofac Orthop*. 2000;118:535–540.
7. Cevidanes LH, Styner MA, Proffit WR. Image analysis and superimposition of 3-dimensional cone-beam computed tomography models. Am J Orthod Dentofac Orthop 2006;129:611-18.
8. Halazonetis DJ. From 2-dimensional cephalograms to 3-dimensional computed tomography scans. Am J Orthod Dentofacial Orthop 2005;127:627-37.
9. Hatcher DC, Aboudara CL. Diagnosis goes digital. Am J Orthod Dentofacial Orthop 2004;125:512-15.
10. Mah J, Hatcher DC. Three-dimensional craniofacial imaging. Am J Orthod Dentofacial Orthop 2004;126:308-9.
11. Ghoneima A, Abdel-Fattah E, Eraso F, Fardo D, Kula K, Hartsfield J. Skeletal and dental changes after rapid maxillary expansion: a computed tomography study. Aust Orthod J 2010;26:141-8.
12. Ghoneima A, Abdel-Fattah E, Hartsfield J, El-Bedwehi A, Kamel A, Kula K. Effects of rapid maxillary expansion on the cranial and circummaxillary sutures. Am J Orthod Dentofacial Orthop 2011;140:510-19.
13. Richardson A. A comparison of traditional and computerized methods of cephalometric analysis. Eur J Orthod 1981;3:15-20.
14. Sandler PJ. Reproducibility of cephalometric measurements. Br J Orthod 1988;15:105-10.
15. Gravely JF, Benzies PM. The clinical significance of tracing error in cephalometry. Br J Orthod 1974;1:95-101.
16. Chen YJ, Chen SK, Yao JC, Chang HF. The effects of differences in landmark identification on the cephalometric measurements in traditional versus digitized cephalometry. Angle Orthod 2004;74:155-161.
17. Baumrind S, Frantz RC. The reliability of head film measurements. 2. Conventional angular and linear measures. Am J Orthod 1971;60:505-17.
18. Kamoen A, Dermaut L, Verbeeck R. The clinical significance of error measurement in the interpretation of treatment results. Eur J Orthod 2001;23:569-78.

19. Stabrun AE, Danielsen K. Precision in cephalometric landmark identification. Eur J Orthod 1982;4:185-96.
20. Perillo MA, Beideman RW, Shofer FS, Jacobsson-Hunt U, Higgins-Barber K, Laster LL, Ghafari JG. Effect of landmark identification on cephalometric measurements: guidelines for cephalometric analyses. Clin Orthod 2000;3:29-36.
21. Broch J, Slagsvold O, Rosler M. Error in landmark identification in lateral radiographic headplates. Eur J Orthod 1981;3:9-13.
22. Major PW, Johnson DE, Hesse KL, Glover KE. Effect of head orientation on posterior anterior cephalometric landmark identification. Angle Orthod 1996;66:51-60.
23. Kazandjian S, Kiliaridis S, Mavropoulos A. Validity and reliability of a new edge-based computerized method for identification of cephalometric landmarks. Angle Orthod 2006;76:619-24.
24. Macri V, Wenzel A. Reliability of landmark recording on film and digital lateral cephalograms. Eur J Orthod 1993;15:137-48.
25. Cohen AM, Linney AD. A low cost system for computer-based cephalometric analysis. Br J Orthod 1986;13:105-8.
26. Cevidanes LHS Franco AA, Gerig G, Proffit WR, Slice DE, Enlow DH, et al. Comparison of relative mandibular growth vectors using high resolution 3-dimensional imaging. Am J Orthod Dentofac Orthop 2005;128:27-34.
27. Chen YJ, Chen SK, Chang HF, Chen KC. Comparison of landmark identification in traditional versus computer-aided digital cephalometry. Angle Orthod 2000;70:387-92.
28. Bruntz LQ, Palomo JM, Baden S, Hans MG. A comparison of scanned lateral cephalograms with corresponding original radiographs. Am J Orthod Dentofac Orthop 2006;130:340-8.
29. Sekiguchi T, Savara BS. Variability of cephalometric landmarks used for face growth studies. Am J Orthod 1972;61:603-18.
30. Swennen GR, Barth EL, Schutyser F, De Groeve P, Lemaitre A. Three-dimensional (3-D) cephalometry. The basics for virtual planning. J Cranio Maxillofac Surg 2004;32:(Suppl 1)135.
31. Swennen GR, Schutyser F, Barth EL, De Groeve P, De Mey A. A new method of 3-D cephalometry. Part I: the anatomic cartesian 3-D reference system. J Craniofac Surg 2006;17:314-25.
32. Cavalcanti MG, Hailer JW, Vannier MW. Three-dimensional computed tomography landmark measurement in craniofacial surgical planning: experimental validation in vitro. J Oral Maxillofac Surg 1999;57:690-4.
33. Kumar V, Ludlow J, Cevidanes LH, Mol A. In vivo comparison of conventional and cone beam CT synthesized cephalograms. Angle Orthod 2008;78:873-9.
34. Olmez H, Gorgulu S,Akin E, Bengi AO, Tekdemir I, Ors F. Measurement accuracy of a computer-assisted three-dimensional analysis and a conventional two-dimensional method. Angle Orthod 2011;81:375-82.

Qualitative and quantitative evaluation of enamel after various post-stripping polishing methods: an in vitro study

Priyanka Gupta,* Nitin Gupta,† Nirav Patel,+ Ravi Gupta,‡ Gurinderpal Singh Sandhu± and Charudatta Naik‡

Private Practice, Panchkula,* Department of ENT, Government Medical College and Hospital-32, Chandigarh,† Ahmedabad Dental College, Ahmedabad,+ Department of Orthodontics, Dr D.Y. Patil Dental College and Hospital, Maheshnagnar, Pimpri, Pune‡ and Bhojia Dental College and Hospital, Baddi, Distt. Solan±

Aim: The purpose of this study was to evaluate the ultramorphology and surface roughness of permanent tooth enamel after various post-stripping polishing methods.

Methods: Sixty extracted, permanent lower incisors were randomly assigned to two groups (Group A and Group B). Group A was morphologically assessed by a scanning electron microscopy (SEM) and Group B was assessed by a stylus profilometer which applied a surface roughness test. Each group was divided into five subgroups of six incisors. Four of the subgroups were subjected to interpoximal enamel reduction, followed by various polishing methods; the fifth subgroup served as a control. The polishing methods comprised; Subgroup 1, diamond disk followed by a fine Sof-lex disc; Subgroup 2, diamond disk and fine diamond bur; Subgroup 3, diamond disk and fine tungsten carbide bur; Subgroup 4, diamond disk and chemical stripping using 37% orthophosphoric acid in conjunction with a fine 3M finishing strip and Subgroup 5 (control), no stripping nor polishing. Qualitative (scanning electron microscopy) and quantitative (surface roughness test) assessments were performed. Surface roughness values (Ra) for permanent enamel were evaluated using the Welch analysis of variance (ANOVA).

Results: Subgroup 1 (diamond disk and fine Sof-lex disc) produced the smoothest enamel surface and Subgroup 4 (chemical stripping) produced the roughest enamel surface.

Conclusions: All proximal stripping and polishing methods significantly roughened the enamel surfaces. The best results were obtained when the stripped enamel surfaces were polished and finished with fine Sof-lex discs.

(Aust Orthod J 2012; 28: 240–244)

Received for publication: May 2012
Accepted: October 2012

Priyanka Gupta: drguptapriyanka@gmail.com; Nitin Gupta: nitinent123@gmail.com; Nirav patel: niravpatel001@gmail.com
Ravi Gupta: smileperfect@rediffmail.com; Gurinderpal Singh Sandhu: drsandhugary@gmail.com; Charudatta Naik: drcrnaik@yahoo.co.in

Introduction

In 1944, Ballard[1] described interproximal tooth reduction for the first time. The main indications for the procedure included the management of late lower incisor crowding following orthodontic treatment, addressing Bolton's discrepancies,[2] treating mild to moderate crowding, reshaping of approximal contacts,[3] stabilising the dental arch,[4] correction of tooth shape deviation and the elimination of unaesthetic black triangles.[5] The technique for interproximal enamel reduction in the posterior area is referred to as air-rotor stripping (ARS) and appears to be an acceptable alternative to extraction or expansion procedures in cases of mild-to-moderate crowding.[6,7]

The beneficial outcomes of interproximal reduction have been well documented.[5,8] Nevertheless, possible detrimental effects on enamel have also been a subject of debate. While there are varying reports regarding the extent of enamel reduction, it is generally recommended that less than half of the enamel thickness on any tooth surface may be reduced.[8] The loss of surface enamel and associated exposure of enamel prism endings to the oral environment results in a decrease in the resistance of the tooth surface to organic acids produced in plaque, therefore making teeth more prone to decalcification.[9] It is reportedly difficult to produce an enamel surface free of furrows that result from the initial reduction abrasion.[10] The residual furrows may predispose the tooth to periodontal pathology and caries as more retentive sites for debris, plaque and bacterial attachment are produced.[10,11] However, previous studies have failed to establish a significant relationship between enamel stripping and caries susceptibility, as enamel reduction and demineralisation are generally followed by spontaneous remineralisation of hard tissues.[12,13]

Claims have been made that stripped enamel could be adequately finished by polishing with carbide finishing burs, diamond finishing burs, polishing disks, hand held finishing strips or mechano-chemical techniques.[15,17] The purpose of this study was to evaluate the ultramorphology and surface roughness of permanent tooth enamel after various post-stripping polishing methods.

Materials and methods

The present study was conducted in the Department of Orthodontics at a premier Dental College and Hospital in India. Sixty extracted, human mandibular incisors were obtained. Teeth with enamel defects or treated with chemical agents were excluded while the remainder were stored in de-ionised water prior to use. Immediately before use, the teeth were cleaned and polished with pumice and rubber cups and randomly assigned to two groups (Group A and Group B) of 30 samples each for a qualitative (SEM) or a quantitative assessment (surface roughness test) of enamel after proximal stripping and polishing employing various methods.

SEM evaluation (Group A)

The 30 teeth of Group A were randomly divided into five subgroups, each of six teeth. Each subgroup was aligned in an arch form and mounted in plaster. Four of the subgroups were subjected to interproximal enamel reduction using one of the following stripping and polishing methods; the fifth subgroup remained as a control.

Subgroup 1. Teeth were proximally stripped with six strokes of a diamond disk and were polished with fine Sof-lex discs (3M ESPE) (20 passes) under wet conditions to mimic the clinical situation.

Subgroup 2. Teeth were proximally stripped with six strokes of a diamond disk and were polished with fine diamond burs (Swiss Diameds) (20 passes) under wet conditions.

Subgroup 3. Teeth were proximally stripped with six strokes of a diamond disk and were polished with a fine tungsten carbide bur (SS white) (20 passes) under wet conditions.

Subgroup 4. Teeth were proximally stripped with six strokes of a diamond disk and were polished with a fine 3M finishing strip with 37% orthophosphoric acid (3M-ESPE) gel (20 passes). After the procedure, the acid was rinsed thoroughly with an air-water spray.

Subgroup 5 (control). No proximal stripping and polishing was performed.

After proximal stripping and polishing, the teeth were removed from the plaster, thoroughly rinsed with water and dehydrated in ascending concentrations of alcohol.

Each specimen was mounted on a metallic support and gold coated (Fine coat-Ion Sputter JFC-1100[JOEL]) to a thickness 30 nanometers over a time period of 2 minutes under a current of 25 mA) for observation under a scanning electron microscope (JSM 6100) at 20 kV of accelerating voltage. Images were acquired and taken at x500 and x1500 magnification.

Surface roughness test (Group B)

The 30 teeth in Group B were randomly divided into five subgroups, each of six teeth. The teeth in each subgroup were aligned in an arch form and mounted in plaster. Four of the subgroups were subjected to interproximal enamel reduction following one of the stripping and polishing methods described above; the fifth subgroup remained as a control. After stripping and polishing, the teeth were removed from the plaster, thoroughly rinsed with running water and cleaned with a soft brush. Tooth surface parameters were assessed with a contact stylus profilometer (Mitutoyo SJ 201P), an instrument used to measure surface profile, in order to quantify its roughness. The technical specifications of the profilometer dictated operation under a 1 mm transverse length and 0.25

Figures 1 to 5. SEM micrographs of enamel surfaces following various stripping and polishing methods.

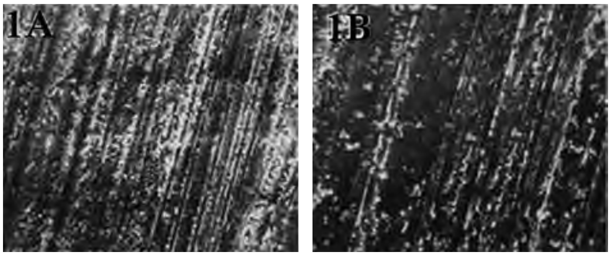


Figure 1. Enamel surface after stripping and polishing with a diamond disc and a fine sof-lex disc. A = x500, B = x1500

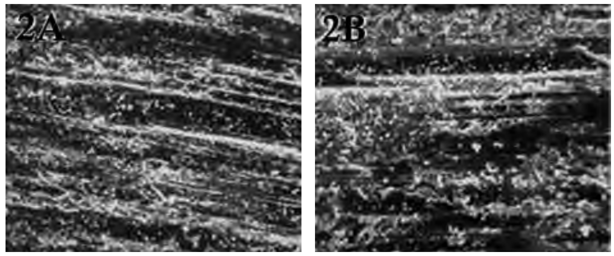


Figure 2. Enamel surface after stripping and polishing with a diamond disc and a fine diamond burs. A = x500, B = x1500

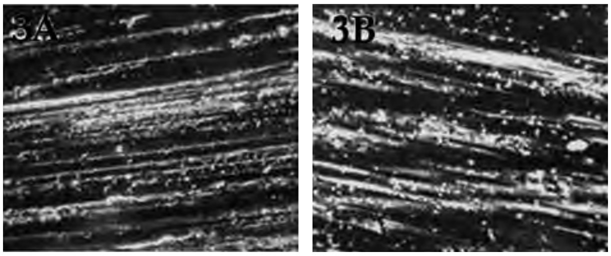


Figure 3. Enamel surface after stripping and polishing with a diamond disc and a fine tungsten carbide bur. A = x500, B = x1500

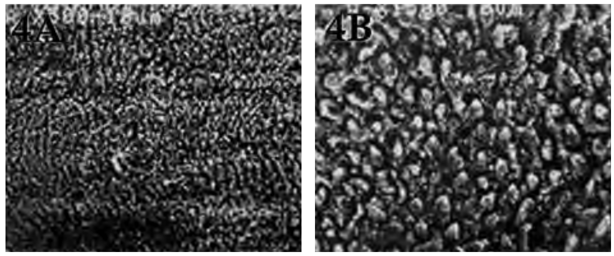


Figure 4. Enamel surface after stripping and polishing with a diamond disc and a fine 3M finishing strip with 37% orthophosphoric acid gel. A = x500, B = x1500

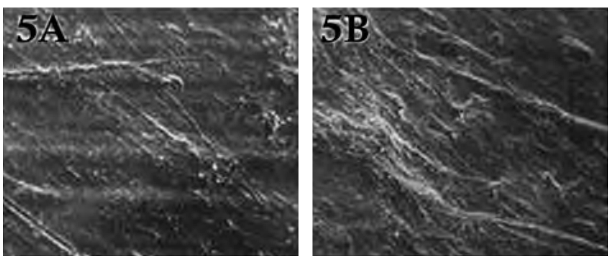


Figure 5. Intact enamel (x500). A = x500, B = x1500

mm cut-off length. The profilometer had a tip radius of 2 µm, a mass of 18 grams and applied a force of 0.75 milli Newtons over a measuring range of -200 µm to +150 µm. For each specimen, two perpendicular topographical recordings were made and the stylus registration results averaged.

Statistical analysis

The surface roughness values (Ra) of each group were compared with the Welch analysis of variance (ANOVA).

Results

SEM images indicated that all proximal stripping protocols resulted in roughened and grooved enamel surfaces at x500 and x1500 magnification (Figures 1-5). After proximal stripping with a diamond disk and polishing with a fine Sof-Lex disc (Subgroup 1), the enamel surface appeared smooth, although furrows could still be seen (Figure 1). By using a diamond disk and polishing with fine diamond burs (Subgroup 2), the surface exhibited deeper furrows and altered morphologic features (Figure 2). With fine tungsten carbide burs (Subgroup 3), the surface appeared finely roughened with grooves (Figure 3). The grooves produced as a result of the use of a diamond disk almost completely disappeared and the heads of the enamel prisms were evident on the surface following polishing with fine 3M finishing strip in conjunction with 37% orthophosphoric acid gel (Subgroup 4) (Figure 4). The descriptive statistics for the various surface roughness data are shown in Table I. The statistical comparisons of surface roughness values in all subgroups are shown in Table II.

The surface enamel roughness values generated from all tested proximal stripping methods were significantly greater than those of unstripped enamel (Subgroup 5) (Table I, Figure 5). Subgroup 1 showed the lowest mean surface roughness of 0.59 ± 0.16 µm (Table I) compared with the other experimental subgroups. Surface roughness values of Subgroup 1 were significantly different and better than the surface roughness values of Subgroup 2 and Subgroup 4 (Table II). Subgroup 2 showed a mean surface

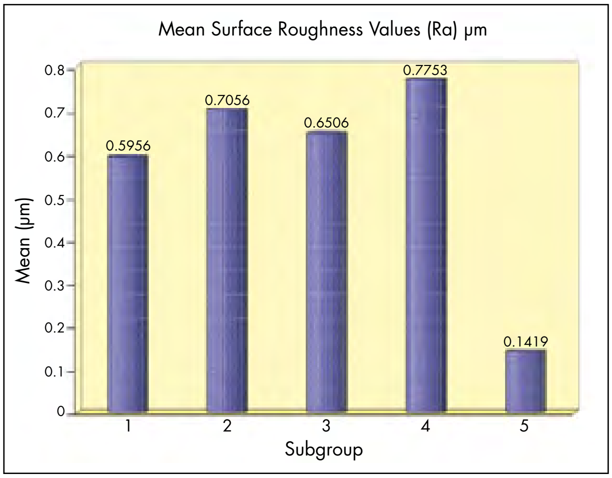


Figure 6. Comparison of surface roughness of Subgroups 1, 2, 3, 4 and 5.

roughness of 0.70 ± 0 .022 µm (Table I). Subgroup 3 showed a mean surface roughness of 0.65 ± 0.15 µm (Table I). Subgroup 4 showed the highest mean surface roughness of 0.77 ± 0.11 µm (Table I, Figure 6). Surface roughness values for Subgroup 4 were significantly different and worse than the surface roughness values for Subgroup 1 and Subgroup 3 (Table II). Figure 6 shows a bar diagram comparing the mean surface roughness of the five subgroups.

Discussion

The present study evaluated various polishing methods following proximal stripping using a diamond disk. Single-sided disks were used exclusively to keep initial dental contact as minimal as possible and ensure that only one tooth was cut at a time.

Extracted human mandibular incisors were subjected to conservative reduction with a diamond stripping disk, followed by various polishing methods. Mandibular incisors were assessed because proximal stripping procedures are most commonly performed on these teeth.

The SEM analysis showed that enamel reduction followed by the various polishing methods significantly affected the enamel surface by producing furrows and grooves which altered the morphological characteristics of the previously intact enamel. However, the smoothest enamel surfaces were obtained using fine Sof-Lex polishing discs after proximal stripping (Subgroup 1) and the roughest enamel surfaces were produced after finishing with 3M polishing strips and 37% phosphoric acid (Subgroup 4). Finishing with 3M polishing strips and 37% phosphoric acid (a combined mechanical and chemical technique, as advocated by Joseph and colleagues[14]) appeared inappropriate as the roughest enamel surfaces were obtained. Piacentini and Sfondrini[15] and Zhong et al.[16] also recommended Sof-Lex disc smoothing after enamel reduction with tungsten carbide burs and diamond-coated discs respectively. Ayca Arman et al.[17] recommended Sof-Lex discs after proximal stripping with a stripping disk or diamond coated metal strip. Changes in enamel morphology due to other proximal stripping methods have been previously reported;[10,14,15] however, several studies have revealed that proximal stripping produces deep furrows and scratches, which can be improved by polishing.[15,16] Alternatively, Zhong et al. stated that more than 90% of proximally stripped surfaces were well polished and appeared smoother than those of

Table I. Descriptive statistics of surface roughness values (Ra) of permanent and deciduous tooth enamels.

Subgroup	Mean (µm)	N	SD
1	0.5956	12	0.16263
2	0.7056	12	0.02249
3	0.6506	12	0.15298
4	0.7753	12	0.11865
5	0.1419	12	0.02120
Total	0.5738	60	0.25122

ANOVA result: $p = 0.000$

Table II. Multiple subgroup comparisons of surface roughness values (Ra).

Between	*p* value
1 and 2	0.030
1 and 3	0.403
1 and 4	0.005
1 and 5	0.000
2 and 3	0.231
2 and 4	0.058
2 and 5	0.000
3 and 4	0.036
3 and 5	0.000
4 and 5	0.000

untreated enamel.[16] Moreover, surfaces which stayed less perfectly polished were no more plaque retentive than untreated enamel.

To date, most studies which have examined the surface characteristics of enamel by proximal stripping procedures have been limited to qualitative evaluations using SEM.[10,14,15] The main disadvantage of this method is observer subjectivity, as not all grooves and surface roughness may be adequately assessed and measured. Therefore, as SEM provides only supportive visualisation, the present study employed surface profilometry to generate quantitative data. The present data supplied convincing evidence that the use of fine Sof-Lex discs after proximal stripping produced the smoothest enamel surface, and is therefore recommended for clinical use.

Conclusion

Within the experimental conditions and limitations of the study, the following conclusions have been drawn:

Quantitative measurements of surface roughness were consistent with SEM results.

All proximal stripping methods significantly roughened the enamel surfaces.

Chemical stripping resulted in the roughest enamel surfaces.

The best and preferable results were obtained when proximally-stripped tooth surfaces were polished with fine Sof-Lex discs.

Acknowledgment

I owe my gratitude and sincere thanks to Dr O. P. Kharbanda, Head and Professor, Division of Orthodontics, CDER, AIIMS, for his constant guidance and encouragement. It was his penchant for hard work, sincerity and constructive criticism that helped me improve upon the quality of my work. Thank you, Sir.

Corresponding author

Dr Priyanka Gupta
House no-341/A
Panchkula
India

Email: drguptapriyanka@gmail.com

References

1. Ballard ML. Asymmetry in tooth size, a factor in the etiology, diagnosis, and treatment of malocclusion. Angle Orthod 1944;14:67-70.
2. Peck H, Peck S. An index for assessing tooth shape deviations as applied to the mandibular incisors. Am J Orthod 1972;61:384-401.
3. Tuverson DL. Anterior interocclusal relations. Part I. Am J Orthod 1980;78:361-70.
4. Rossouw PE, Tortorella A. Enamel reduction procedures in orthodontic treatment. J Can Dent Assoc 2003;69:378-83.
5. Zachrisson BU. Interdental papilla reconstruction in adult orthodontics. World J Orthod 2004;5:67-73.
6. Sheridan JJ. Air-rotor stripping. J Clin Orthod 1985;19:43-59.
7. Sheridan JJ. Air-rotor stripping update. J Clin Orthod 1987;21:781-8.
8. Boese LR. Fiberotomy and Reproximation without lower retention, nine years in retrospect. Part I. Angle Orthod 1980;50:88-97.
9. Ogaard B. Oral microbiological changes, long-term enamel alterations due to decalcification and caries prophylactic aspects. In: Brantley WA, Eliades T (eds). Orthodontic Materials: Scientific and Clinical Aspects. Stuttgart: Thieme, 2000: 124-40.
10. Radlanski RJ, Jager A, Schwestka R, Bertzbach F. Plaque accumulations caused by interdental stripping. Am J Orthod Dentofacial Orthop 1988;94:416-20.
11. Twesme DA, Firestone AR, Heaven TJ, Feagin FF, Jacobson A. Air-rotor stripping and enamel demineralization in vitro. Am J Orthod Dentofacial Orthop 1994;105:142-52.
12. Crain G, Sheridan JJ. Susceptibility to caries and periodontal disease after posterior air-rotor stripping. J Clin Orthod 1990;24:84-5.
13. El-Mangoury NH, Moussa MM, Mostafa YA, Girgis AS. In-vivo remineralization after air-rotor stripping. J Clin Orthod 1991;25:75-8.
14. Joseph V.P. Orthodontic microabrasive reproximation. Am. J Orthod Dentofacial Orthop 1992;102:351-9.
15. Piacentini C, Sfondrini G. A scanning electron microscopy comparison of enamel polishing methods after air-rotor stripping. Am J Orthod Dentofacial Orthop 1996;109:57-63.
16. Zhong M, Jost-Brinkmann PG, Zellmann M, Zellmann S, Radlanski RJ. Clinical evaluation of a new technique for interdental enamel reduction. J Orofac Orthop 2000;61:432-9.
17. Arman A, Cehreli SB, Ozel E, Arhun N, Cetinşahin A, Soyman M. Qualitative and quantitative evaluation of enamel after various stripping methods. Am J Orthod Dentofacial Orthop 2006;130:131.e7-14.

Correction of severe tooth rotations using clear aligners: a case report

Gianluigi Frongia and Tommaso Castroflorio
Private practice, Turin, Italy

Background: The present adult patient case report shows the correction of a crossbite malocclusion and severe tooth rotations treated with the Invisalign system.
Methods: A 27-year-old female with a dental crossbite (24, 34), severe rotations of two lower incisors (more than 40°) and malalignment of the upper and lower arches is described. The Invisalign system was treatment planned to correct the malocclusion.
Results: The treatment goals of crossbite, rotation and malalignment correction were achieved after 12 months of active aligner therapy. The overbite improved (2.5 mm before treatment, 1 mm at the end); the dental crossbite, the crowding and the severe tooth rotations (with a mean of 2° of improvement per aligner) were corrected.
Conclusions: After treatment, the dental alignment was considered excellent. The presented case indicates that the Invisalign system can be a useful appliance to correct a dental malocclusion involving severe rotations.
(Aust Orthod J 2012; 28: 245–249)

Received for publication: September 2011
Accepted: July 2012

Gianluigi Frongia: gianluigi_frongia@msn.com; Tommaso Castroflorio: tcastroflorio@libero.it

Introduction

In recent years, increasing numbers of adult patients have sought orthodontic treatment[1] and expressed a desire for aesthetic alternatives to conventional fixed appliances.[2] The possibility of using clear overlay appliances to achieve an orthodontic result was introduced in 1946, when Kesling[3] devised the concept of using a series of thermoplastic tooth positioners to progressively move malaligned teeth to impoved positions.

In 1997, Align Technology (Santa Clara, CA, USA) adapted and incorporated modern technologies to introduce the Invisalign system which made Kesling's concept a feasible, efficent and effective orthodontic treatment option. In 2000, Boyd et al.[4] published the first case report on the use of clear aligners and indicated that the primary benefit of the Invisalign appliance was the superior aesthetics during treatment, compared with metal braces.

The Invisalign system[5,6] is based on a clear sequential appliance (aligners) made from a translucent thermoplastic material, which is worn for at least 20 hours per day. According to current protocols, the appliances are replaced on a bi-weekly regimen which incorporates a progressive alignment of up to 0.25 mm translation or up to 2 degrees of rotation per tooth per aligner.

Malocclusions treated with the Invisalign system initially involved only mild crowding of 3-6 millimetres.[7] Recent data has expanded the use of this appliance to incorporate molar distalisation,[8] extraction cases,[9] the treatment of open bites,[10] crossbites,[7] deep bites,[11] Class II[8] and Class III corrections[12] and orthodontic-periodontic problems.[13]

Rotation is an orthodontic movement reported to be difficult to achieve and control with the Invisalign system. Previous studies[14,15] have demonstrated that aligners were not able to control the rotation of canines requiring rotational movements greater

Figure 1. Intra-oral photos at the beginning of the treatment.

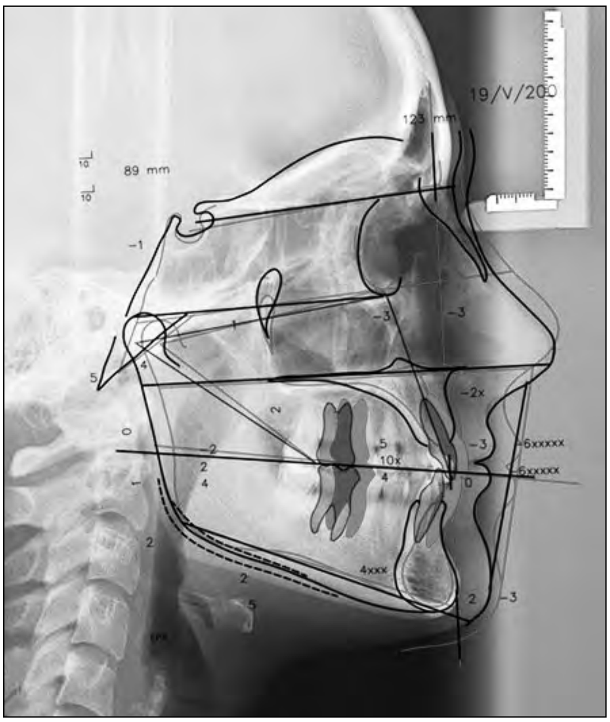


Figure 2. Teleradiography and superimposition of the latero-lateral cephalometry. Dark grey represents the Bolton Standard chart and light grey represents the cephalometry of the patient.

than 15 degrees, which underlined the fact that the effectiveness of canine derotation was questionable.

Recently, many new biomechanical features have been promoted by Align Technology to improve the predictability of aligner treatment. In particular, the G3 and G4 platforms introduced a collection of newly engineered attachments to improve control of desired tooth movements, including dental rotation and root tipping. The present case report describes an adult patient in whom the correction of a crossbite malocclusion with severe tooth rotations was successfully achieved with the Invisalign system.

Case report

A 27-year-old female patient with a dental crossbite (24, 34), severe rotations of two lower incisors (more than 40°) and malalignment of the upper and lower arches presented for orthodontic treatment (Figure 1). Informed consent was obtained from the patient who underwent examination and record taking. This involved clinical, orthodontic and temporomandibular disorder (TMD) evaluations,[16] a radiographic assessment (panoramic), lateral cephalometry (Figure 2), stone casts, intra-oral (Figure 1) and extra-oral photos, and upper and lower arch impressions to generate a ClinCheck® assessment.

The clinical examination revealed a molar and canine Class I relationship, an overjet of 1 mm, an overbite of 2.5 mm, a crossbite between teeth 24 and 34, upper and lower crowding, and severe rotations of lower incisors (32 rotated 45° and 42 rotated 44°). The assessment of the temporomandibular joints[17] revealed no signs and/or symptoms of TMD.

Cephalometric analysis

Cephalometric analysis showed a skeletal Class I-III relationship according to Steiner[17,18] with an ANB angle of -1 degree (mean of 2° ± 2°), a hypodivergent craniofacial form indicated by a SN-GoGn angle of 27 degrees (mean of 32° ± 4°), an interincisal angle of

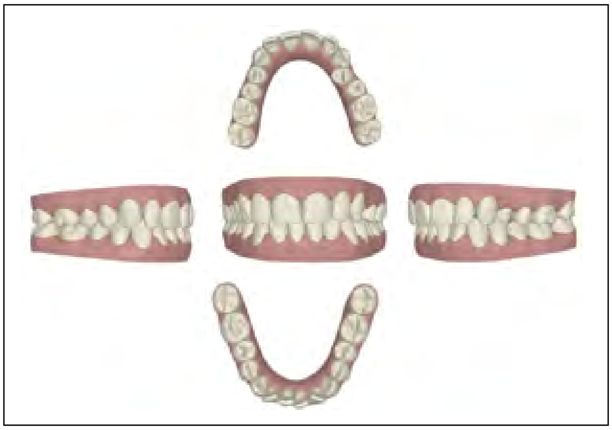


Figure 3. Initial stage of the ClinCheck®.

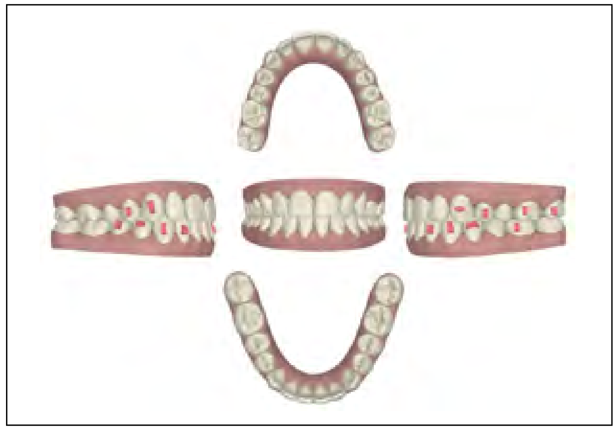


Figure 4. Final predicted stage of the ClinCheck®.

Figure 5. Intra-oral photos at the end of treatment.

145 degrees (mean of 135° ± 5°), a counterclockwise growth rotation according to Siriwat and Jarabak,[19] with a PostHt/AntHt ratio of 72% (mean of 60-64%) and a counterclockwise growth rotation according to Bjork[20] of 387 degrees (mean of 396° ± 6°).

ClinCheck® and aligners

Invisalign treatment was planned to correct the dental crossbite, the severe rotations of 32 and 42 and the upper and lower malalignment. The final ClinCheck® (version 2.9, Align Technology Inc., Santa Clara, CA, USA) provided 17 aligners for the upper arch and 23 aligners for the lower arch (Figures 3 and 4). The duration of therapy was assessed to require approximately 12 months. Each aligner was to be worn for two weeks. No inter-proximal reduction (IPR) was indicated for the correction of the crowding. Retention attachments were planned on several upper teeth (13, 14, 23, 24, 26, 27) and on several lower teeth (32, 33, 34, 36, 42, 43, 44, 45).

Treatment progress was checked every 4 weeks (2 aligners every month) using the ClinCheck® analysis to evaluate changes, patient compliance and bonded attachment stability. A new aligner was inserted at each appointment. The precise relationship and connection between the attachments, the aligner and the teeth, provided an indication of the positive progress of treatment. As compliance is critical in all orthodontic therapy, the patient was instructed to wear the aligners full time, except for eating and tooth brushing. The aligners were worn for a minimum of 20 hours per day.

Results and Discussion

A patient with a dental crossbite, severe rotations of lower incisors and malalignment of the upper and

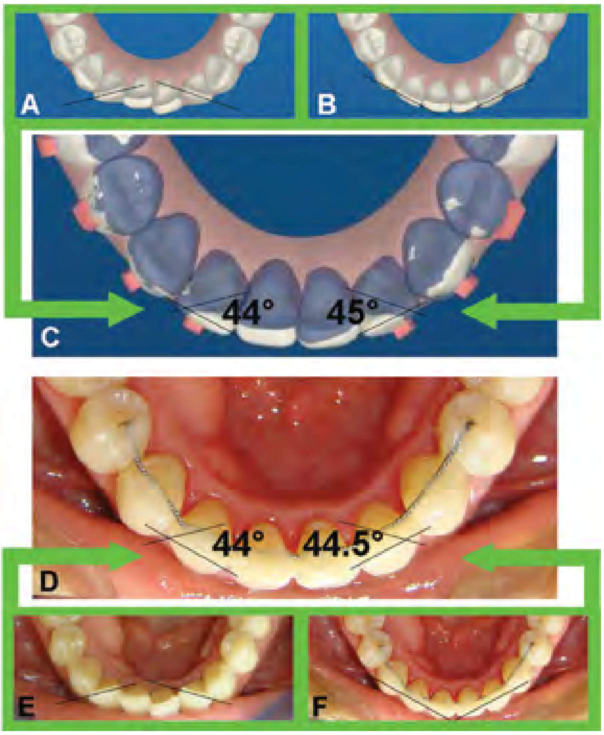


Figure 6. (A) Initial ClinCheck®, (B) final ClinCheck® and (C) superimposition of A and B. The ClinCheck® simulation shows the degrees of correction of the rotations. (E) Initial intra-oral photo on the lower arch, (F) final intra-oral photo on the lower arch and (D) summary of changes of (E) and (F). The correction of the rotations on the ClinCheck® and on the photos are similar.

lower arches was treated with the Invisalign appliance. Patient compliance was high throughout treatment and excellent oral hygiene was maintained. The molar and canine Class I relationships were maintained, as well as the overjet. The overbite improved (2.5 mm pretreatment, 1 mm post-treatment); the dental crossbite, the crowding (Figure 5) and the severe tooth rotations (with a mean of 2° of correction per aligner) were corrected (Figure 6). No obvious root resorption was radiographically evident at the end of therapy (Figure 7). A lower fixed retainer was bonded from the right first premolar to left first premolar to maintain lower incisor alignment. Retention in the upper arch was provided by the last aligner used as a nocturnal removable retainer.

In 2003, Joffe[21] defined the criteria for selecting Invisalign patients and emphasised that caution should be taken in specific malocclusions involving severe tooth rotations (more than 20°). In the presented case, a correction of 45 degrees and 44 degrees for teeth 32 and 42 respectively, was achieved with 23

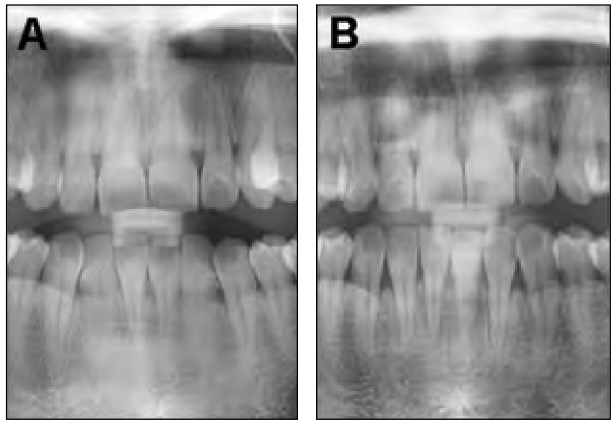


Figure 7. (A) Initial and (B) final panoramic x-ray (anterior region only). No obvious root resorption is present after treatment.

lower aligners, using accepted treatment protocols. The rotated incisors were derotated approximately 2 degrees per aligner and the final result was achieved in 12 months. This result may be due to the recent significant improvement in Invisalign technology which has allowed the treatment of more difficult malocclusions over a shorter time. The introduction of the G3 and G4 platforms with new smart force features has also potentially allowed more predictable tooth movement.

Conclusion

The Invisalign system can be a useful therapeutic tool to correct a dental malocclusion involving severe rotations. The presented case confirmed that:

1. The correction of a crossbite in an adult patient is possible with clear aligners.

2. Severe tooth rotations of lower incisors (up to 45°) can be corrected with clear aligners.

Acknowledgment

The logistical support of Equipe Dentale Srl was greatly appreciated.

Corresponding author

Dr Gianluigi Frongia
Corso Vittorio Emanuele II, 170,
10138 Torino
Italy

Email: gianluigi_frongia@msn.com

References

1. Melsen B. Northcroft Lecture: how has the spectrum of orthodontics over the past decades? J Orthod 2011;38:134-43.
2. Rosvall MD, Fields HW, Ziuchkovski J, Rosenstiel SF, Johnston WM. Attractiveness, acceptability, and value of orthodontic appliances. Am J Orthod Dentofacial Orthop 2009;135:276.e1-12; discussion 276-7.
3. Kesling HD. Coordinating the predetermined pattern and tooth positioner with conventional treatment. Am J Orthod Oral Surg 1946;32:285-93.
4. Boyd RL, Miller RJ, Vlaskalic V. The Invisalign system in adult orthodontics: mild crowding and space closure cases. J Clin Orthod 2000;34:203-12.
5. Kuo E, Miller RJ. Automated custom-manufacturing technology in orthodontics. Am J Orthod Dentofacial Orthop 2003;123:578-81.
6. Boyd R, Vlaskalic V. Three-dimensional diagnosis and orthodontic treatment of complex malocclusions with the Invisalign appliance. Semin Orthod 2001;7:274-93.
7. Vlaskalic V, Boyd R. Orthodontic treatment of a mildly crowded malocclusion using the Invisalign System. Aust Orthod J 2001;17:41-6.
8. Schupp W, Haubrich J, Neumann I. Class II correction with the Invisalign system. J Clin Orthod 2010;44:28-35.
9. Womack WR. Four-premolar extraction treatment with Invisalign. J Clin Orthod 2006;40:493-500.
10. Schupp W, Haubrich J, Neumann I. Treatment of anterior open bite with the Invisalign system. J Clin Orthod 2010;44:501-7.
11. Giancotti A, Mampieri G, Greco M. Correction of deep bite in adults using Invisalign system. J Clin Orthod 2008;42:719-26.
12. Boyd RL. Surgical-orthodontic treatment of two skeletal Class III patients with Invisalign and fixed appliances. J Clin Orthod 2005;39:245-58.
13. Turatti G, Womack R, Bracco P. Incisor intrusion with Invisalign treatment of an adult periodontal patient. J Clin Orthod 2006;40:171-4.
14. Kravitz ND, Kusnoto B, Agran B, Viana G. Influence of attachments and interproximal reduction on the accuracy of canine rotation with Invisalign. A prospective clinical study. Angle Orthod 2008;78:682-7.
15. Kravitz ND, Kusnoto B, BeGole, Obrez A, Agran B. How well does Invisalign work? A prospective clinical study evaluating the efficacy of tooth movement with Invisalign. Am J Orthod Dentofacial Orthop 2009;135:27-35.
16. Seligman DA. Occlusal risk factors in CMD: recommendations for diagnostic examination and treatment. Paper presented at: The 1994 meeting of the European Academy of Craniomandibular Disorders, Hamburg. 1994; Sept 22-25.
17. Steiner CC. Cephalometrics for you and me. Am J Orthod 1953;39:729-55.
18. Steiner CC. The use of cephalometrics as an aid to planning and assessing orthodontic treatment. Am J Orthod 1960;46:721-35.
19. Siriwat PP, Jarabak JR. Malocclusion and facial morphology is there a relationship? An epidemiologic study. Angle Orthod 1985;55:127-38.
20. Bjork A. Prediction of mandibular growth rotation. Am J Orthod 1969;55:585-99.
21. Joffe L. Invisalign: early experiences. J Orthod 2003;30:348-52.

Skeletal Class III malocclusion with thin symphyseal bone: a case report

Eriko Hikida* and Chihiro Tanikawa†
Private Practice, Osaka* and Department of Orthodontics and Dentofacial Orthopedics, Osaka University, Osaka,† Japan

Aim: To describe the management of a severe skeletal Class III patient with thin symphyseal bone and alveolar bone covering the mandibular incisors.
Method: A 24 year-old female presented with a skeletal Class III malocclusion characterised by thin alveolar bone in a mildly crowded, mandibular incisor region. Computerised tomography (CT) assisted in the determination of possible tooth movement within the anterior mandibular alveolar bone. The finalised treatment plan aimed to align the maxillary and mandibular dental arches following the extraction of the maxillary right first premolar and the mandibular right permanent lateral incisor. The surgical repositioning of the maxilla and mandible with a LeFort I osteotomy and a bilateral sagittal split osteotomy (BSSO) would follow.
Results: After treatment, an acceptable facial profile and a solid intercuspation of the teeth were obtained. Significant root resorption was not observed. The occlusion remained stable with normal overjet and overbite after two years of retention.
Conclusion: CT examination provided an assessment of the three-dimensional morphological characteristics of anterior alveolar bone which enabled an evaluation of possible tooth movement.
(Aust Orthod J 2012; 28: 250–257)

Received for publication: March 2011
Accepted: October 2012

Eriko Hikida: tetete9@gmail.com; Chihiro Tanikawa: ctanika@dent.osaka-u.ac.jp

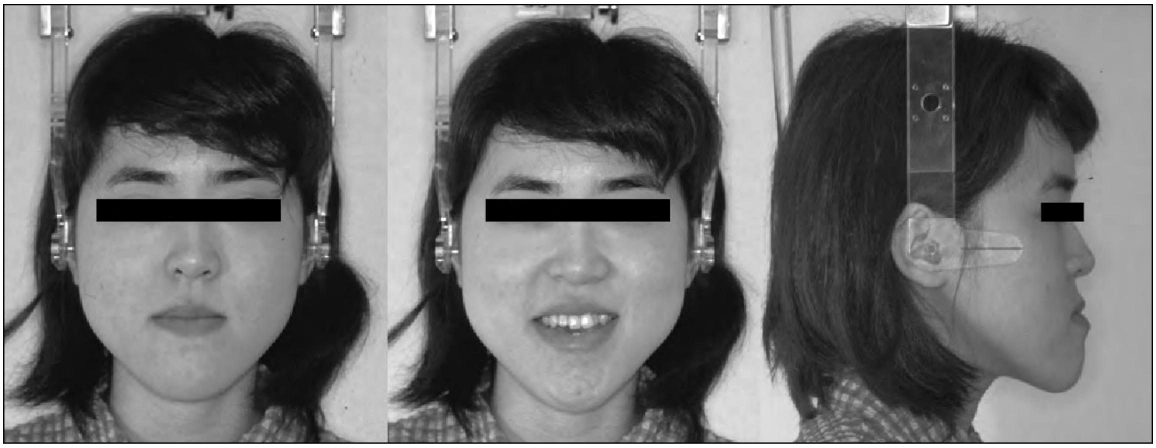
Introduction

Patients with skeletal mandibular prognathism who need treatment via orthognathic surgery, often have retroclined mandibular incisors.[1–3] One of the objectives of presurgical orthodontic treatment is dental decompensation and the proclination of the mandibular incisors to facilitate a more favourable postoperative angulation and interdigitation of the teeth.[2,3] However, often, the extent of possible orthodontic anteroposterior movement of the incisors is limited[4] and dictated by insufficient anteroposterior width of the symphysis and alveolar bone in the mandibular incisor region.[1,2] If the root apices of the mandibular incisors contact the lingual cortical plate, further tooth movement may be impeded and continuued orthodontic force may lead to root resorption and/or lingual bony perforation.[5,6] Therefore, it is important to determine the limits of alveolar bone in adult surgery patients who present with skeletal Class III traits. Computerised tomography (CT) has become a valuable tool to assess the 3-dimensional (3D) nature of dentofacial structures and, in the present case, the mandibular incisor region.[4]

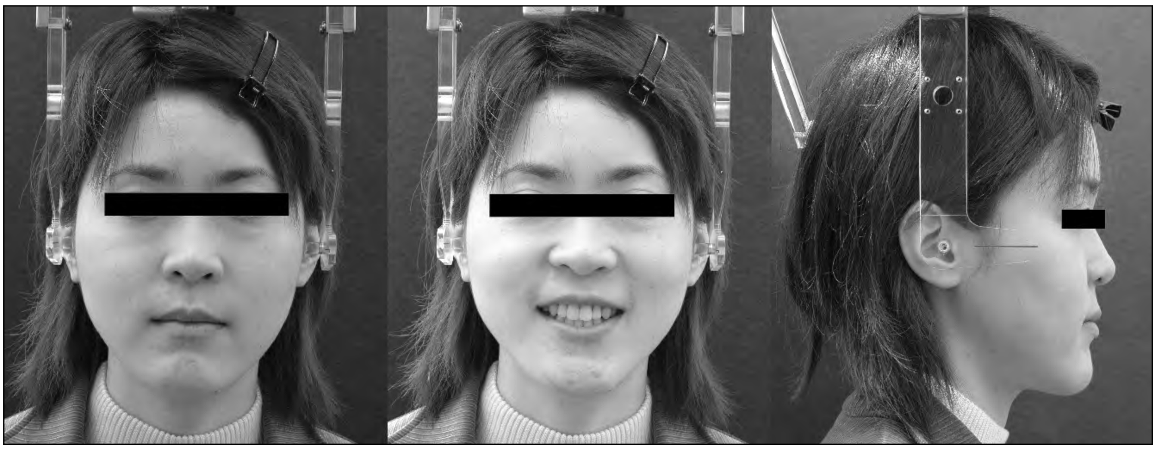
This case report describes an adult patient with skeletal Class III characteristics and thin symphyseal bone, in whom the extraction of a mandibular incisor and a maxillary premolar plus two-jaw surgery were planned after a CT examination.

History

A Japanese female (aged 24 years and 5 months) presented complaining of mandibular protrusion with accompanying poor facial appearance and difficulty in incising. Her maxillary left permanent canine had



(a)



(b)

Figure 1. Facial photographs.
(a) Pretreatment (24 years 5 months), (b) Post-retention (29 years 3 months)

been extracted at the age of 10 years because of severe crowding. The patient was in good general health and had no history of major systemic disease.

Clinical examination

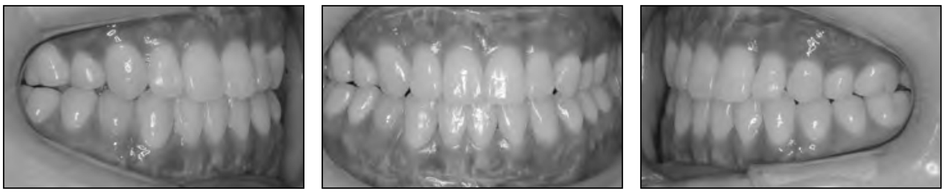
The patient's facial profile was concave and vertically increased. Frontally, a slight facial asymmetry was evident as the chin deviated towards the right side (Figure 1a). Intra-orally, the occlusion showed an Angle Class III molar relationship with an overjet of -4.5 mm and an openbite of 1.2 mm (Figure 2a). There were no inter-arch tooth contacts anterior to the first molars. The midline of the mandibular dentition deviated 5 mm towards the right side with respect to the maxillary arch. The maxillary left permanent canine was absent and complete space closure had occurred. The mandibular dentition exhibited mild crowding, whereas the maxillary dentition was acceptably aligned.

A tooth-size analysis (Table I) revealed a large anterior and overall discrepancy due to the missing left maxillary canine, small maxillary lateral incisors and large mandibular incisors. The maxillary intercanine width was almost normal when the left first premolar was used as a substitute for the missing left maxillary canine, whereas the intercanine width of the mandibular dentition was less than the Japanese normative mean.[7] Triangular-shaped mandibular incisors were noted.

The patient's oral hygiene was satisfactory. There was no clinically discernible sign of clicking or pain in the temporomandibular joints, or limitation or deviation of jaw movement.

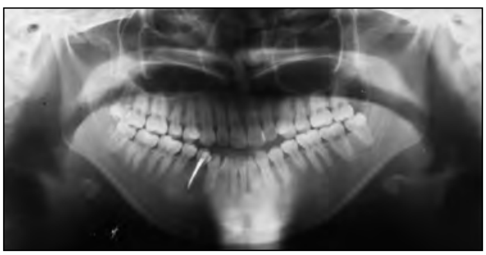
(a)

(b)



(c)

Figure 2. Intra-oral photographs (frontal and lateral views).
(a) Pretreatment (24 years 5 months), (b) Post-active-treatment (27 years 1 month), (c) Post-retention (29 years 3 months)



(a)

(b)

(c)

Figure 3. Panoramic radiographs.
(a) Pretreatment (24 years 5 months), (b) Immediately before debanding (27 years 1 months), (c) Post-retention (29 years 3 months)

Table I. Tooth size analysis.

	Right (mm)	Left (mm)	Normative Mean*	
			Mean	SD
Upper				
Central incisor	8.5	8.4	8.2	0.4
Lateral incisor	6.9	6.8	6.6	0.6
Canine	8.0	-	7.7	0.4
1st premolar	7.4	7.0	7.1	0.4
2nd premolar	6.9	6.4	6.6	0.4
1st molar	10.0	9.5	10.4	0.5
Lower				
Central incisor	5.8	5.5	5.2	0.4
Lateral incisor	6.1	6.1	5.8	0.4
Canine	7.0	7.0	6.6	0.4
1st premolar	6.7	7.1	6.9	0.3
2nd premolar	7.4	7.4	6.8	0.5
1st molar	10.6	11.2	10.7	0.6
	Data (Per cent)	Mean* (Per cent)	SD*	
Over all ratio	102.4	91.4	2.1	
Anterior ratio	97.2	78.1	2.2	

*For Japanese normative mean[7]

Table II. Cephalometric analysis at pretreatment, presurgery, post-active-treatment, and post-retention stages.

Measurement	Pretreatment (24 y 5 mo)	Presurgery (26 y 1 mo)	Post-active-treatment (27 y 1 mo)	Post-retention (29 y 3 mo)	Normative Mean* (Adult, Female)	
					Mean	SD
Angular, degrees						
SNA	78.0	78.0	78.0	78.0	80.8	3.6
SNB	83.5	83.0	76.8	76.8	77.9	4.5
ANB	–5.5	–5.0	1.2	1.2	2.8	2.4
FMA	39.7	40.2	36.7	36.8	30.5	3.6
IMPA	66.0	71.8	74.8	74.5	93.4	6.8
FMIA	74.3	68.0	68.5	68.7	56.0	8.1
U1-FH	112.8	110.3	112.5	113.3	112.3	8.3
Linear, mm						
N-Me	140.5	142.0	135.0	135.0	125.8	5.0
N/PP	54.4	54.4	54.4	54.4	56.0	2.5
Me/PP	85.8	88.0	81.2	81.2	68.6	3.7
Ar-Me	121.5	121.5	119.5	119.5	106.6	5.7
Overjet	–4.5	–7.0	3.8	4.0	3.1	1.1
Overbite	–1.2	–2.1	2.0	1.5	3.3	1.9

*For Japanese normative mean[8]

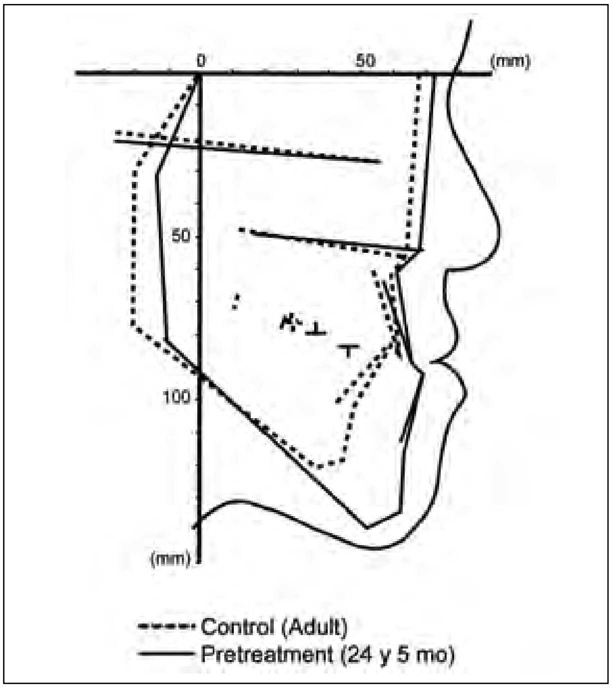


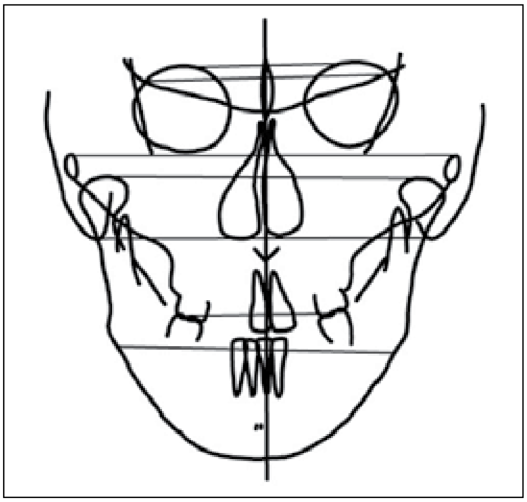
Figure 4. Superimposition of the profilogram at pretreatment with the control (Japanese adult female).[8]

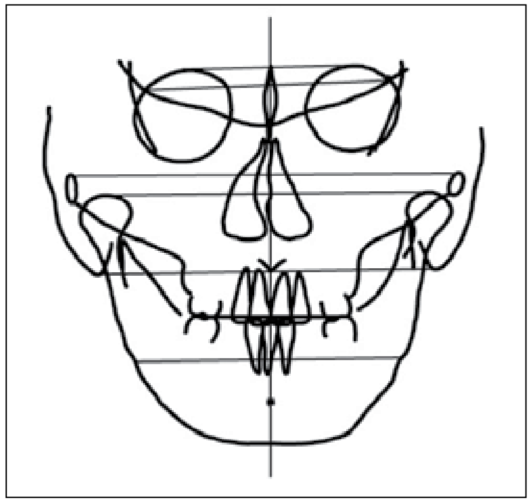
Radiographic examination

There was no pathologic finding on the panoramic radiograph (Figure 3a). Lateral cephalometric analysis (Figure 4 and Table II) revealed that the patient had a Class III skeletal malocclusion due to mandibular excess. The mandibular plane angle was steep. The maxillary incisors were labially inclined and the mandibular incisors were lingually inclined when compared with normative values.[8]

A posteroanterior cephalometric assessment (Figure 5a) showed a 3 mm chin deviation toward the right side from the facial midline but the occlusal plane was not canted.

A multi-detector CT examination revealed that the labiolingual diameters of the mandibular incisor roots at the mid-transverse level corresponded approximately to the maximal width of the surrounding symphyseal bone (Figure 6). Interdental alveolar bone adjacent to the mandibular incisor roots was shown to be extremely thin.





(a) (b)

Figure 5. Tracing of posteroanterior cephalometric radiographs.
(a) Pretreatment (24 years 5 months), (b) Post-retention (29 years 3 months)

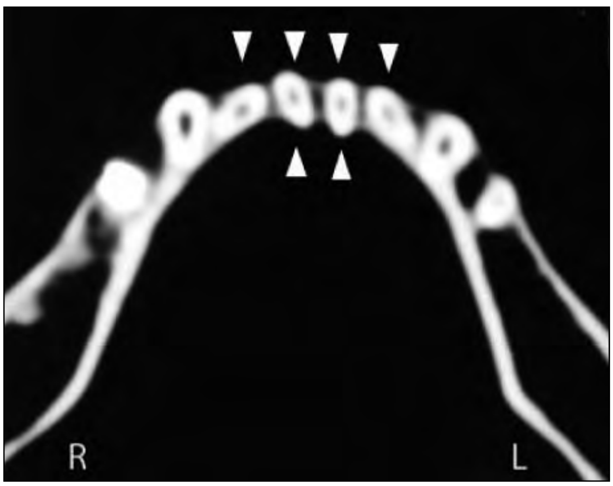


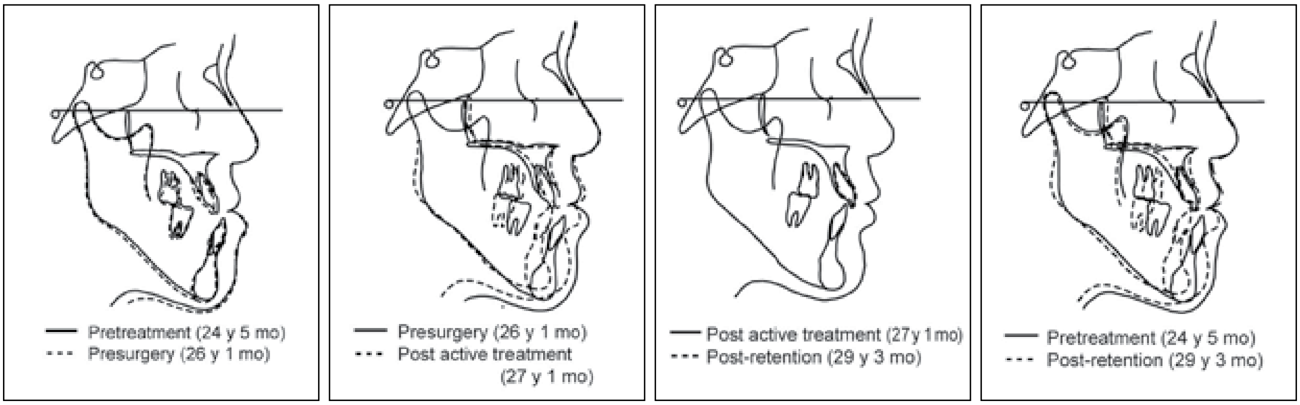
Figure 6. Axial CT image at the mid-transverse level of the lower incisor roots.

Diagnosis and objectives of treatment

The patient was diagnosed with a severe skeletal Class III crowded malocclusion due to mandibular excess with the complication of thin symphyseal bone. A combined surgical-orthodontic approach was indicated to achieve an acceptable occlusal correction and improved facial aesthetics. The thin alveolar bone around the mandibular incisor roots indicated the possibility of root resorption and/or bony dehiscence if the mandibular incisors made contact with adjacent cortical plates during treatment. Therefore, the extraction of the right mandibular lateral incisor was planned in order to create space in the crowded mandibular incisor region. Labial tipping of the mandibular incisors was to be minimised to reduce the possibility of the incisor root apices making bony contact. The incisor extraction also assisted in the correction of the mandibular anterior tooth size excess. The maxillary midline deviation to the left side was attributed to the missing permanent left canine. Therefore, the extraction of the right first premolar was planned to enable the correction of this asymmetry. A diagnostic set-up demonstrated that the treatment objectives were achieveable.

The following summary treatment plan was therefore adopted:

1. The extraction of the maxillary right first premolar, the mandibular right lateral incisor and the third molars.
2. Preoperative tooth alignment with edgewise fixed appliances in both arches (0.022 inch slot).
3. Correction of the maxillary midline deviation.
4. A LeFort I impaction and advancement osteotomy to correct the anterior openbite and to reduce facial height.
5. A bilateral sagittal split osteotomy (BSSO) setback to shorten mandibular length and to correct the mandibular deviation.
6. Post-operative orthodontic detailing of the occlusion.



(a) (b) (c) (d)

Figure 7. Superimposition of cephalometric tracings. Superimposition in the F–H plane at the Porion.
(a) Changes from pretreatment to presurgery
(b) Changes from presurgery to post-active-treatment
(c) Changes from post-active-treatment to post-retention
(d) Changes from presurgery to post-retention

7. A reduction genioplasty to decrease lower facial height.
8. Retention using wrap-around-type retainers.
9. Cosmetic reshaping of the mandibular incisors with composite resin.

Treatment progress

The duration of active treatment was 32 months. Prior to the placement of orthodontic appliances, the third molars, the maxillary right first premolar, and the mandibular right permanent lateral incisor were extracted. The molars were banded and brackets were bonded on all other teeth (0.022 inch edgewise slot). For anchorage purposes, a transpalatal arch was placed between the maxillary first molars. The maxillary and mandibular arches were levelled and aligned with a series of archwires, starting with 0.014 inch nickel-titanium and progressing to 0.019 x 0.025 inch stainless steel wires. The maxillary right canine was retracted with chain elastics for 7 months on a 0.019 x 0.025 inch stainless steel archwire. After the completion of canine distal movement, the maxillary dental midline deviation was corrected and coincided with the facial midline.

Twenty months after initiating preoperative orthodontic treatment, the patient underwent orthognathic surgery. The anterior nasal spine was repositioned 3.0 mm forward and the posterior nasal spine was repositioned 2.0 mm upward following a LeFort I 'down' fracture procedure. Fixation of the maxilla was carried out with titanium plates. After maxillary surgery, the mandible was repositioned 5.0 mm posteriorly on the right side and 4 mm posteriorly on the left side and titanium plates were used to fix the proximal and distal bone segments. Intermaxillary fixation was applied with vertical elastics for 14 days. After 12 months of postoperative orthodontic treatment, the titanium plates were removed and a genioplasty was performed, which repositioned the chin 3.0 mm superiorly. The orthodontic appliances were removed, and maxillary and mandibular wrap-around-type retainers were inserted and worn full time. After twelve months, retainer wear was reduced to night time and the lower anterior teeth were reshaped using composite resin.

Results

The occlusion remained stable with normal overjet and overbite after two years of retention. Pretreatment and post-retention comparisons showed that the facial profile changed from concave to straight (Figure 1b). Orthodontic treatment provided good intercuspation of the teeth, a Class I molar and canine relationship, an overjet of +4.0 mm and an overbite of +1.5 mm. The mandibular anterior crowding was eliminated (Figure 2b).

Comparisons of cephalometric tracings (Figure 7) and measurements (Table II) showed the following

Figure 8. Lateral cephalogram at pre-retention (left) and post-retention (right).

changes. The ANB angle improved from -5.5 degrees to 1.2 degrees; the maxillary incisors were tipped 2.5 degrees palatally; and the mandibular incisors were slightly intruded and tipped 5.0 degrees labially. The mandibular plane angle decreased from 45.0 degrees to 42.0 degrees. The apices of the mandibular incisors were close to the lingual cortical plate but remained within cancellous bone (Figure 8). Significant root resorption was not observed (Figure 3b and 3c). Clinical examination revealed no pathologic tooth mobility of the lower anteriors after two years of retention.

Postero-anterior cephalometric radiography showed skeletal symmetry (Figure 5b). The midline of the maxillary dental arch coincided with the mid-sagittal plane.

Discussion

In the presented case, the three-dimensional morphological traits of the symphyseal bone in the mandibular incisor region were investigated using CT to estimate the possible extent of tooth movement. This was important as it has been shown that if the incisor root apices are moved against the cortical plates of the alveolus or beyond, there is a likelihood of root resorption and/or bony dehiscence.[5,6,9,10]

The CT images indicated that the labial and lingual cortical bone plates were close to the mandibular incisors. In order to minimise the change in mandibular incisor position and to maintain overall root apex position within the alveolar bone, one of the mandibular lateral incisors was extracted to create sufficient space to resolve the crowding. The advantages of mandibular incisor extraction have been reported as an increase in long-term stability[11] and a reduction in treatment time.[12] From pre- and post-treatment cephalograms, the mandibular central incisor root apex was repositioned 2.0 mm lingually, but still maintained position within cancellous bone. No obvious root resorption was seen in the post-retention lateral cephalogram and the panoramic radiograph (Figures 8 and 3c).

A reported disadvantage associated with the extraction of a mandibular incisor is the possible creation of a tooth-size discrepancy between the dental arches (small anterior overall ratio). Additional disadvantages include the difficulty in obtaining an ideal incisor overjet and overbite and the creation of aesthetic and/or functional problems.[13,14] It is therefore important that clinicians select a case with a Bolton discrepancy favouring the mandibular incisors. Alternatively, crown width may be altered by interproximal reduction, or an increase in tooth size, to achieve an acceptable result following the extraction of a single incisor.[13] A diagnostic set-up is recommended to gauge the success of a proposed treatment plan to manage an expected tooth-size discrepancy.[13,15] The present case showed a smaller crown width of the maxillary lateral incisors and a larger crown width of the mandibular incisors. Following a diagnostic set-up, a decision was made to extract a single mandibular incisor.

A secondary clinical concern is the possible formation of 'black triangles'[14] caused by interproximal gingival recession at extraction sites.[16] This unwelcome aesthetic problem is frequently found after orthodontic treatment[16] and is related to divergent root angulation,[16,17] triangular-shaped crown forms,[17] and the long distance of the interproximal contact point to the alveolar crestal bone.[18] In the present case, reshaping the mandibular incisors, achieved by restorative procedures with composite resin or reducing interproximal enamel in the contact areas of the incisors, was considered. Interproximal enamel reduction would have worsened the anterior overall tooth-size ratio and so interproximal composite resin reshaping of the mandibular incisors was performed (Figure 2c).

Conclusions

The present case report demonstrates that a CT examination is useful for the diagnosis and treatment planning of patients with thin symphyseal bone in the mandibular incisor region. It enables an assessment of the three-dimensional morphological characteristics of alveolar bone and an estimation of the possible extent of tooth movement. The extraction of a mandibular incisor is an option for a patient with mild crowding and inadequate bone in the lower anterior region.

Corresponding author

Dr Chihiro Tanikawa
Department of Orthodontics and Dentofacial Orthopedics
Graduate School of Dentistry
Osaka University
1-8 Yamadaoka Suita Osaka 565-0871
Japan

Email: ctanika@gmail.com

References

1. Solow B. The dentoalveolar compensatory mechanism: background and clinical implications. Br J Orthod 1980;7:145-61.
2. Worms FW, Isaacson RJ, Speidel TM. Surgical orthodontic treatment planning: profile analysis and mandibular surgery. Angle Orthod 1976;46:1-25.
3. Rakosi T. Treatment of Class III malocclusions. In: Graber TM, Rakosi T, Petrovic A, eds. Dentofacial Orthopedics with Functional Appliances. St Louis, Mosby Year Book, 1997:395, 398-409.
4. Yamada C, Kitai N, Kakimoto N, Murakami S, Furukawa S, Takada K. Spatial relationships between the mandibular central incisor and associated alveolar bone in adults with mandibular prognathism. Angle Orthod 2007;77:766-72.
5. Handelman CS. The anterior alveolus: its importance in limiting orthodontic treatment and its influence on the occurrence of iatrogenic sequelae. Angle Orthod 1996;66:95-109.
6. Wehrbein H, Bauer W, Diedrich P. Mandibular incisors, alveolar bone and symphysis after orthodontic treatment: a retrospective study. Am J Orthod Dentofacial Orthop 1996;110:239-46.
7. Otsubo J. A study on the tooth material in Japanese adults of normal occlusion, its relationship to coronal and basal arches. Jpn Orthod Soc 1957;16:36-46.
8. Wada K. A study on the individual growth of maxillo-facial skeleton by means of lateral cephalometric roentgenograms. J Osaka Univ Dent Sch 1977;22:239-69.
9. Mulie RM, Hoeve AT. The limitations of tooth movement within the symphysis, studied with laminagraphy and standardized occlusal films. J Clin Orthod 1976;10:882-93,886-9.
10. Thilander B, Nyman S, Karring T, Magnusson I. Bone regeneration in alveolar bone dehiscences related to orthodontic tooth movements. Eur J Orthod 1983;5:105-14.
11. Riedel R, Little RM, Bui TD. Mandibular incisor extraction: post-retention evaluation of stability and relapse. Angle Orthod 1992;62:103-16.
12. Riedel RA, Brandt S. Retention and relapse. J Clin Orthod 1976;10:454-72.
13. Kokich VG, Shapiro PA. Lower incisor extraction in orthodontic treatment. Four clinical reports. Angle Orthod 1984;54:139-53.
14. Leitao PM. Lower incisor extraction in Class I and Class II malocclusion: case reports. Prog Orthod 2004;5:186-99.
15. Fields HW. Orthodontic-restorative treatment for relative mandibular anterior excess tooth-size problems. Am J Orthod 1981;79:176-83.
16. Burke S, Burch JG, Tetz JA. Incidence and size of pretreatment overlap and post-treatment gingival embrasure space between maxillary central incisors. Am J Orthod Dentofacial Orthop 1994;105:506-11.
17. Kurth JR, Kokich VG. Open gingival embrasures after orthodontic treatment in adults: prevalence and etiology. Am J Orthod Dentofacial Orthop 2001;120:116-23.
18. Tarnow DP, Magmer AW, Fletcher P. The effect of the distance from the contact point to the crest of bone on the presence or absence of the interproximal dental papilla. J Periodontol 1992;63:995-6.

Uprighting of severely impacted mandibular second molars: a case report

Tadashi Fujita, Maya Shirakura, Hidetaka Hayashi, Yuji Tsuka, Eri Fujii and Kazuo Tanne
Department of Orthodontics and Craniofacial Developmental Biology, Applied Life Sciences, Hiroshima University Institute of Biomedical and Health Sciences, Hiroshima, Japan

Introduction: The incidence of mandibular first and second molar impaction is increasing but still recorded as rare. Treatment methods involving uprighting, extraction, or autologous tooth transplantation have been described.
Aim: The present study describes the uprighting of 3 impacted mandibular second molars presenting with eruptive disorders.
Methods: The application of limited and appropriate orthodontic therapy completed treatment in 11 months, 5 months, and 2 years and 3 months, respectively. Although no absolute anchorage in the form of miniscrews was required, no significant anchorage demands were considered necessary. Although the third molar tooth germs were identified and preserved in each case, no adverse influence on the uprighting of the second molars was encountered.
Results: The favourable molar repositioning results were likely due to the youth of the 3 patients as the third molars were in early development and bone remodelling was marked. Furthermore, no problems related to anchorage or alveolar bone loss were identified after treatment.
Conclusion: The results indicated the benefits of limited orthodontic treatment and early intervention for the uprighting of impacted mandibular second molars.
(Aust Orthod J 2012; 28: 258–264)

Received for publication: April 2012
Accepted: October 2012

Tadashi Fujita: seven@hiroshima-u.ac.up; Maya Shirakura: maya714tama@hiroshima-u.ac.jp;
Hidetaka Hayashi: hayashihide@hiroshima-u.ac.jp; Yuji Tsuka: d102580@hiroshima-u.ac.jp; Eri Fujii: fujii-eri@hiroshima-u.ac.jp;
Kazuo Tanne: tanne@hiroshima-u.ac.jp

Introduction

The impaction of permanent teeth chiefly involves the maxillo-mandibular third molars, maxillary canines and central incisors, and mandibular second premolars.[1] It has been identified that the impaction and abnormal eruption of the mandibular first and second molars is rare, with a reported incidence less than 2.5% of all impacted tooth cases.[2,3] Congenital diseases and syndromes[4,5] have been noted as contributing factors in the general aetiology of molar impaction. As local factors, insufficient eruptive space, abnormalities in eruptive pathway, and the influence of adjacent teeth have been cited.[3]

Treatment options for impacted teeth have commonly involved surgical exposure and traction, while impacted tooth extraction and autologous tooth transplantation have been performed less often. However, reports have indicated that traction possibly inhibits tooth root formation, and the effects on alveolar bone and periodontal tissue are poor when the traction period is inappropriate.[6,7] Furthermore, root resorption of adjacent teeth may occur, which necessitates long-term monitoring.[8]

Although various techniques may be used to manage impacted teeth, there are no definitive guidelines. The present study describes three cases of eruptive disorders resulting in marked mesial inclination

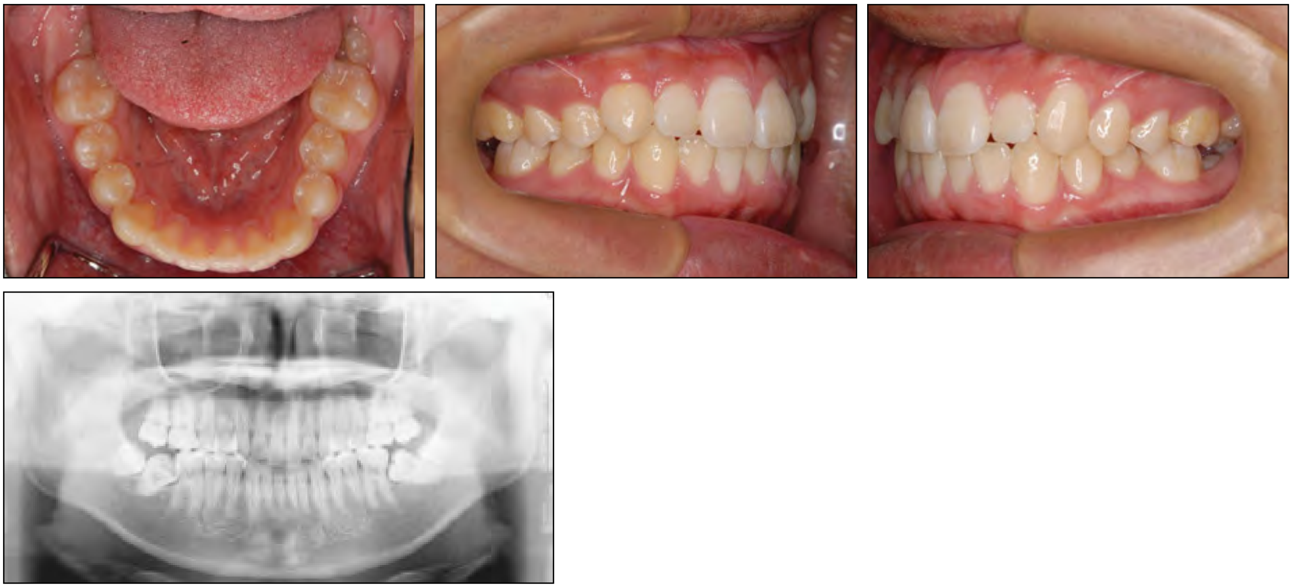


Figure 1. Intra-oral and panoramic x-ray images at the time of treatment initiation in Case 1.

(a) (b) (c)

Figure 2. Intra-oral images during treatment in Case 1.
(a) At the time of the insertion of appliances; (b) Four months after initiating treatment and (c) Seven months after initiating treatment.

leading to impaction of mandibular second molars. Uprighting orthodontic treatment was directed at the impacted molars in an attempt to establish treatment protocols.

Case 1

An 18-year and 9-month-old male presented with the bilateral impaction and mesial inclination of the mandibular second molars. Figure 1 shows the intra-oral and panoramic radiographs at the start of treatment. The presence of the developing third molars was identified and confirmed.The occlusion was generally sound and the impacted second molars were considered the chief complaint. The treatment plan involved the placement of a stabilising lower lingual arch, followed by uprighting of the mandibular second molars using sectional mechanics after surgical exposure.

Figure 2a shows intra-oral images at the time of insertion of the appliances. After exposure, brackets (One Piece, Rocky Mountain Morita, Tokyo, Japan) and a 0.014 inch nickel-titanium (Ni-Ti) wire (Bio-Flex, Rocky Mountain Morita, Tokyo, Japan) were attached to initiate molar movement. Four months after commencement, the second molars were still markedly mesio-lingually inclined (Figure 2b) and, after an additional 3 months of molar uprighting, a 0.016 inch cobalt-chromium (Co-Cr) wire (Elgiloy, Rocky Mountain Morita, Tokyo, Japan) (Figure 2c) was inserted. Active treatment was completed in 11 months and bilaterally, the molars uprighted and an

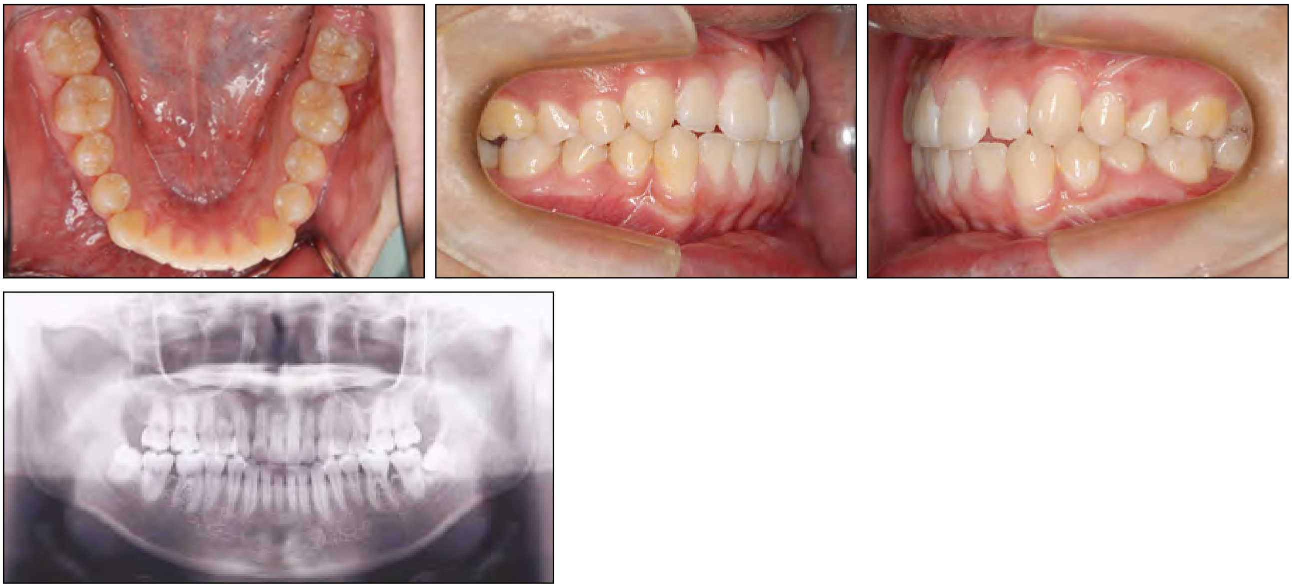


Figure 3. Intra-oral and panoramic x-ray images at the time of treatment completion in Case 1.

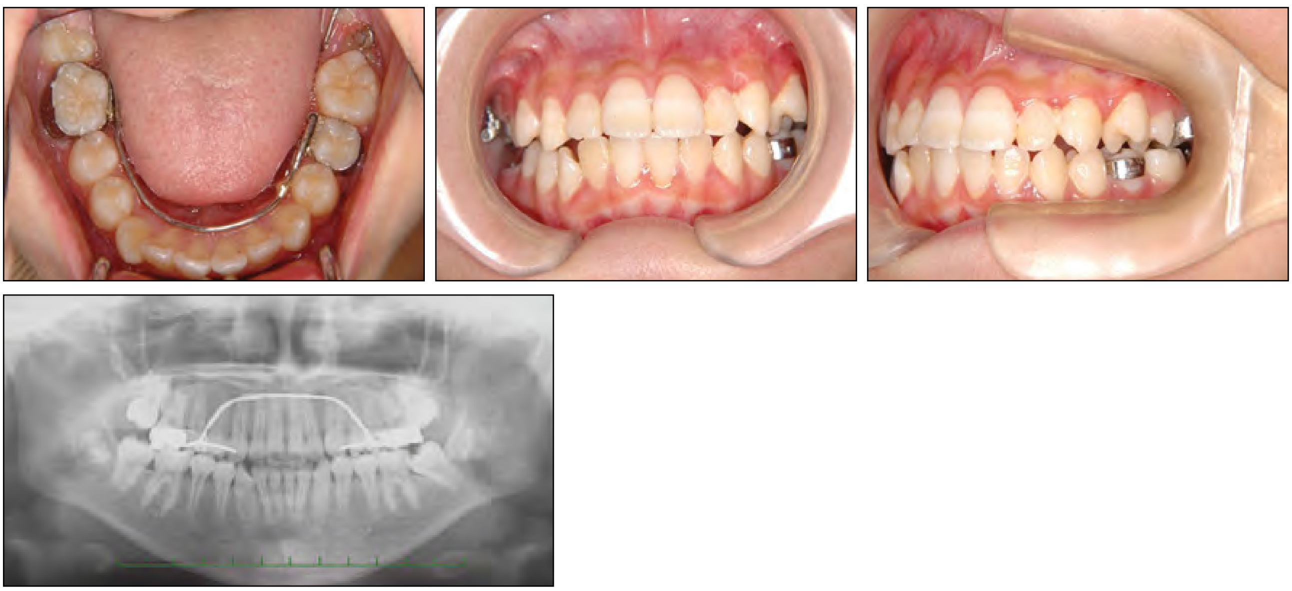


Figure 4. Intra-oral and panoramic x-ray images at the time of treatment initiation in Case 2.

acceptable occlusal relationship was achieved (Figure 3). No alveolar bone problems were encountered and although considerable uprighting of the second molars was achieved, no marked change in the anchorage teeth was noted.

Case 2

The presenting patient was a 12-year and 3-month-old female. Although expansion of the maxillary dental arch was indicated, mesial inclination and impaction of the mandibular left second molar was detected radiographically. Figure 4 shows the intra-oral and panoramic radiographic images at the start of treatment. Although the level of molar impaction was less severe, the mesial inclination of the left mandibular second molar was still significant. Furthermore, the developing tooth germs of the third molars were noted. The treatment plan was to place a lingual arch for anchorage and to initiate molar uprighting using an elastomeric power chain from the tooth to hooks attached to the arch.

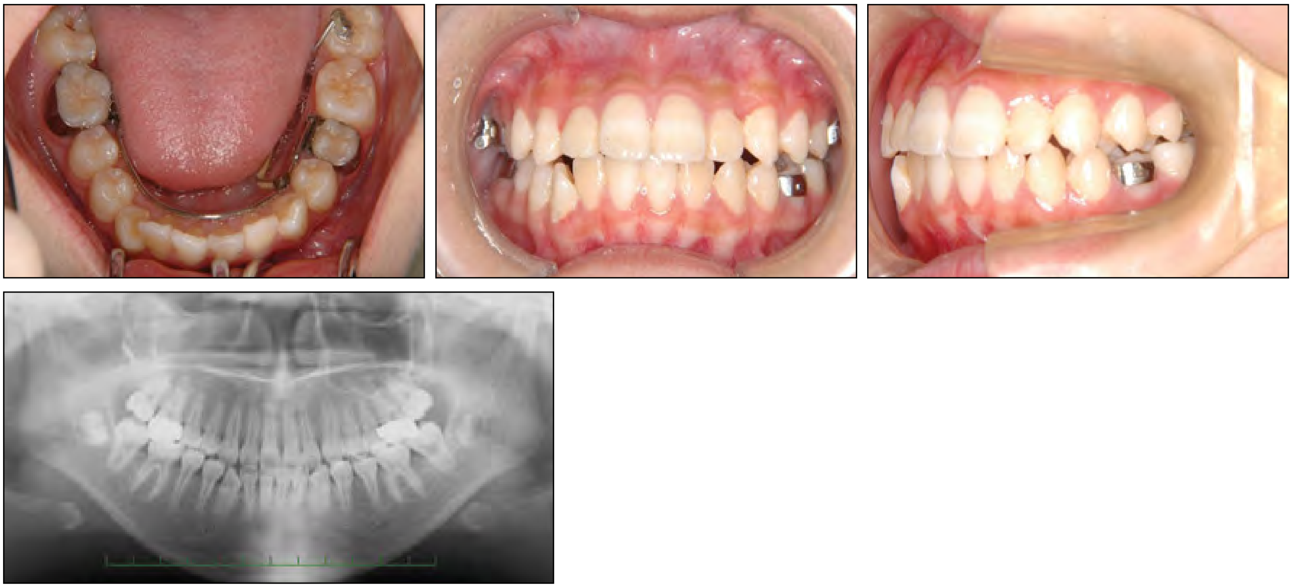


Figure 5. Intra-oral and panoramic x-ray images at the time of treatment completion in Case 2.

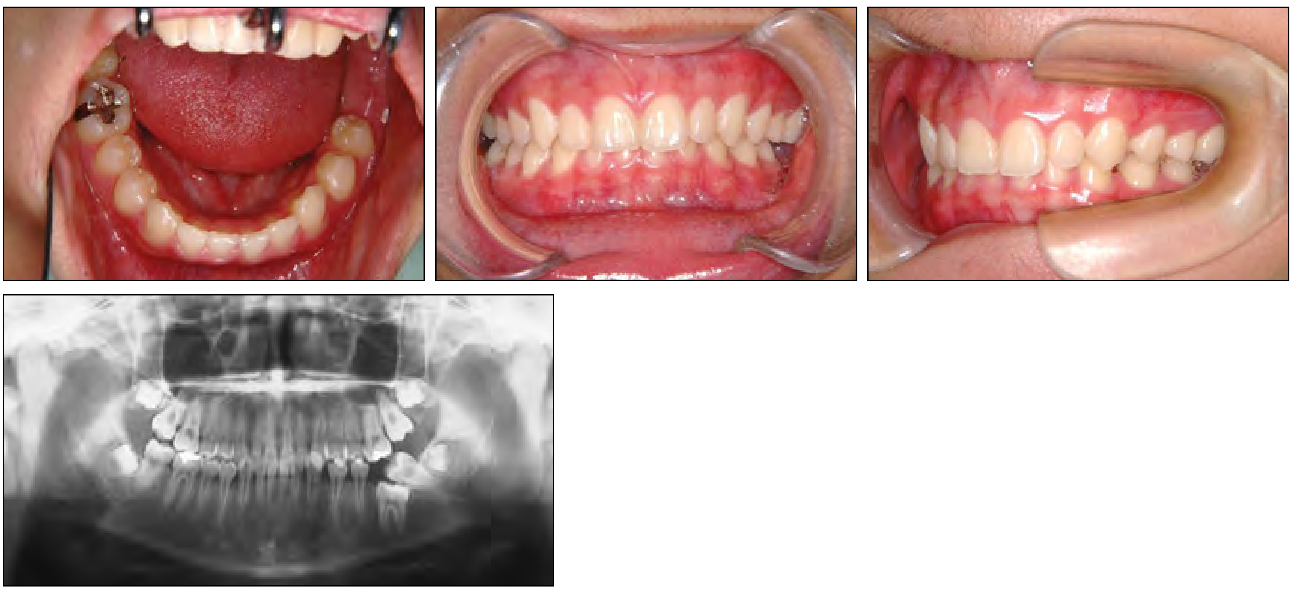


Figure 6. Intra-oral and panoramic x-ray images at the time of treatment initiation in Case 3.

Treatment was completed in 5 months. The mandibular left second molar uprighted and no alveolar bone problems around the corrected molar were evident (Figure 5). Furthermore and consistent with Case 1, the uprighting of the second molar caused no marked change in position of the anchor teeth.

Case 3

The presenting patient was a 14-year and 11-month-old male. Figure 6 shows the intra-oral and panoramic x-ray images at the time of the initial examination. The mesial inclination of the mandibular left second molar and impaction of the first molar under the second molar were identified. Furthermore, a complicating factor was the overeruption of the left maxillary first molar due to the mandibular molar displacements. The presence of the tooth germ of the third molar was also confirmed. The treatment plan was to expose and upright the second molar using a sectional arch which would be followed by surgical exposure and traction of the first molar.

(a) (b) (c)

Figure 7. Intra-oral images during treatment in Case 3.
(a) At the time of the insertion of appliances; (b) Seven months after initiating treatment and (c) Ten months after the initiation of traction of the mandibular first molar.

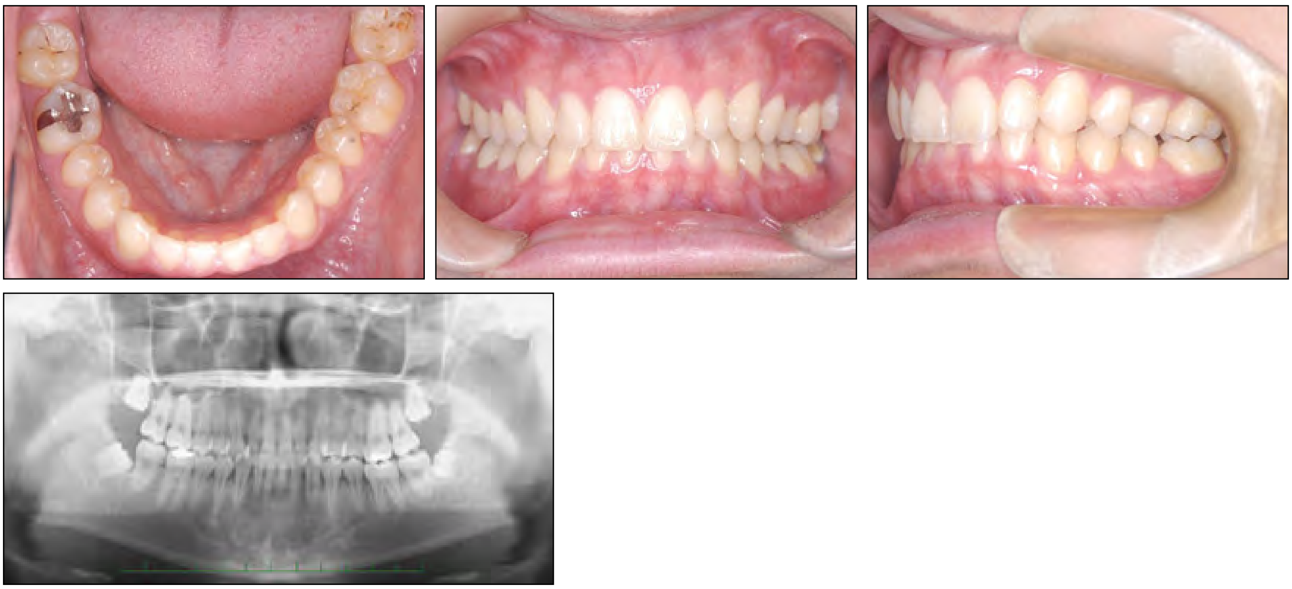


Figure 8. Intra-oral and panoramic x-ray images at the time of treatment completion in Case 3.

Figure 7a shows the intra-oral images at the time of appliance insertion. A sectional arch (0.016 x 0.022 inch Co-Cr, Elgiloy, Rocky Mountain Morita, Japan) was attached to the canine and premolars for anchorage. Subsequently, the mandibular second molar was exposed, brackets (0.018 inch slot, One Piece, Rocky Mountain Morita, Japan) and a 0.014 inch Ni-Ti wire (Bio-Flex, Rocky Mountain Morita, Japan) were placed and molar uprighting commenced using an open coil spring. After seven months of treatment and after confirmation of uprighting improvement in the second molar, exposure and traction to the first molar was initiated (Figure 7c). Wire and power chain elevation of the first molar continued, using a 0.012 inch Ni-Ti wire (Bio-Flex, Rocky Mountain Morita, Japan) (Figure 7) and after two years and 3 months, active treatment was completed. Figure 8 shows the final intra-oral and panoramic radiographic images. The mandibular left first and second molars were uprighted, and a favourable occlusion was achieved. No problems related to the alveolar bone level around the molars were identified and no reciprocal movement of the anchor teeth occurred.

Discussion

The advantages of uprighting and correcting impacted molars is desirable for functional and hygienic reasons. As indicated in the presented cases, teeth without opposing contacts are likely to extrude, particularly in young patients.[9] Therefore, functional improvement is anticipated following the recovery of impacted teeth to full occlusion. Furthermore, since it is difficult to clean partially erupted teeth, periodontal inflammation and dental caries are possible sequelae.[10] Therefore, the uprighting and repositioning of impacted teeth is beneficial from an oral hygiene perspective.

There have been several reports which have focussed on the aetiology of impaction or eruptive disorders of the mandibular second molars. Crowding is considered to be a major factor.[11] However, crowding of the mandibular dentitions of the three presented cases was not severe, which indicates that the crowding/impaction relationship is not strong. It was also considered that previous orthodontic treatment can be the cause of second molar impaction. In this regard, inappropriate cementation of first molar bands, and the restriction of mesial movement of the first molar through the use of a lip bumper, lingual arch, or headgear have been suggested as associated factors.[12] However, Cases 1 and 3 received no previous orthodontic treatment, and although orthodontic treatment had already been initiated, treatment restricting the mesial movement of the mandibular first molar was not conducted in Case 2.

Sawicka et al.[12] reported that the most suitable period for treating impacted second molars was between the ages of 11 and 14 years because root development was incomplete. Although the age at the start of treatment in the presented cases was 12 years and 3 months, 14 years and 11 months, and 18 years and 9 months, respectively, tooth movement occurred uneventfully in all patients in whom the tooth roots of the second molar had completely formed. It was considered that the incomplete development of the third molar facilitated its distallisation, along with distal uprighting of the second molar.

Previous studies have recommended the extraction of third molars to assist second molar uprighting.[13,14] The third molars were present in all presented cases and extraction was considered only if movement of the second molar stalled or an adverse event occurred. However, movement of the second molars went smoothly without resorting to third molar extraction. Although the uprighting of the second molar is arguably easier following the extraction of the third molar, it has been reported that a bone defect is often created distal to the second molar.[15] Therefore, to preserve periodontal health, it is advantageous if the third molar is retained, provided that second molar movement is not inhibited and the eruption of the third molar is expected.

Either sectional or lingual arches or both were used in the management of the three presented cases. Published reports on molar uprighting methods have described the use of brass wires if the mesial inclination is slight,[16] and the use of miniscrews if absolute anchorage is required.[17,18] Further reports regarding sectional arches have detailed the use of various wire forms and materials.[19,20] While the establishment of anchorage is important to effectively achieve desired tooth movement, no absolute anchorage was considered necessary to complete active treatment in the three cases. It was determined that second molar uprighting could be performed without adverse effects and treatment completed using limited orthodontic appliances. Preservation of the third molar and the neighbouring alveolar bone was deemed a reflection of the youth of the patients and their high metabolic bone activity. In addition, it was considered that alveolar bone preservation was also attributed to the gentle and slow tooth movement performed.

Conclusion

The present outcomes reveal the benefits of limited orthodontic treatment for uprighting a mesially impacted mandibular second molar and protocol suggests that early treatment is desirable.

Corresponding author

Dr Tadashi Fujita
Department of Orthodontics and Craniofacial Developmental Biology
Applied Life Sciences
Hiroshima University Institute of Biomedical and Health Sciences
1-2-3 Kasumi, Minami-ku
Hiroshima 7348553
Japan

Email: seven@hiroshima-u.ac.jp

References

1. Aitasalo K, Lehtinen R, Oksala E. An orthopantomographic study of prevalence of impacted teeth. Int J Oral Surg 1972;1:117-20.
2. Farman AG, Eloff J, Nortjé CJ, Joubert JJ. Clinical absence of the first and second permanent molars. Br J Orthod 1978;5:93-7.
3. Bondemark L, Tsiopa J. Prevalence of ectopic eruption, impaction, retention and agenesis of the permanent second molar. Angle Orthod 2007;77:773-8.
4. Farronato G, Maspero C, Farronato D, Gioventù S. Orthodontic treatment in a patient with cleidocranial dysostosis. Angle Orthod

2009;79:178-85.
5. Gorlin RJ, Pindborg JJ, Cohen MM. Syndromes of head and neck. 2nd ed. New York, NY: McGraw-Hill; 1976:180-4.
6. Vanarsdall RL, Corn H. Soft-tissue management of labially positioned unerupted teeth. Am J Orthod 1977;72:53-64.
7. Artun J, Osterberg SK, Joondeph DR. Long-term periodontal status of labially erupted canines following orthodontic treatment. J Clin Periodontol 1986;13:856-61.
8. Ericson S, Kurol PJ. Resorption of incisors after ectopic eruption of maxillary canines: a CT study. Angle Orthod 2000;70:415-23.
9. Fujita T, Montet X, Tanne K, Kiliaridis S. Supraposition of unopposed molars in young and adult rats. Arch Oral Biol 2009;54:40-4.
10. Shellhart WC, Oesterle LJ. Uprighting molars without extrusion. J Am Dent Assoc 1999;130:381-5.
11. Magnusson C, Kjellberg H. Impaction and retention of second molars: diagnosis, treatment and outcome. A retrospective follow-up study. Angle Orthod 2009;79:422-7.
12. Sawicka M, Racka-Pilszak B, Rosnowska-Mazurkiewicz A. Uprighting partially impacted permanent second molars. Angle Orthod 2007;77:148-54.
13. Shipper G, Thomadakis G. Bone regeneration after surgical repositioning of impacted mandibular second molars: a case report. Dent Traumatol 2003;19:109-14.
14. Ferrazzini G. Uprighting of a deeply impacted mandibular second molar. Am J Orthod Dentofacial Orthop 1989;96:168-71.
15. Kugelberg CF, Ahlström U, Ericson S, Hugoson A, Thilander H. The influence of anatomical, pathophysiological and other factors on periodontal healing after impacted lower third molar surgery. A multiple regression analysis. J Clin Periodontol 1991;18:37-43.
16. Moro N, Murakami T, Tanaka T, Ohto C. Uprighting of impacted lower third molars using brass ligature wire. Aust Orthod J 2002;18:35-8.
17. Giancotti A, Arcuri C, Barlattani A. Treatment of ectopic mandibular second molar with titanium miniscrews. Am J Orthod Dentofacial Orthop 2004;126:113-17.
18. Sohn BW, Choi JH, Jung SN, Lim KS. Uprighting mesially impacted second molars with miniscrew anchorage. J Clin Orthod 2007;41:94-7.
19. Melsen B, Fiorelli G, Bergamini A. Uprighting of lower molars. J Clin Orthod 1996;30:640-5.
20. Going RE Jr, Reyes-Lois DB. Surgical exposure and bracketing technique for uprighting impacted mandibular second molars. J Oral Maxillofac Surg 1999;57:209-12.

Letters

Letters and brief communications are welcomed and need not relate to publications in the *Australian Orthodontic Journal*. The Journal will print experimental, clinical and philosophical observations, reports of work in progress, educational notes and travel reports relevant to orthodontics. Right will be reserved to edit all Letters to meet Journal requirements of space and format. All financial interests relevant to the content of a Letter must be disclosed. The views expressed in Letters represent the personal opinions of individual writers and not those of the Australian Society of Orthodontists Inc., the Editor, or BPA Print Group Pty Ltd.

The new Fandangle

Sir,

I commend you on your timely Editorial in the *Australian Orthodontic Journal* (Volume 28 No.1 May 2012) calling for a reappraisal of what exactly is the purpose of professional development, and who is qualified to deliver CPD points? Implicit in your comments is that CPD points are presently being abused when folded into a commercial agenda. Worse than that, CPD is effectively used by Fandangle promoters as a shield of intellectual and professional respectability. Ultimate losers will be the practitioners themselves when the cases are subject to long-term audit, and of course the patients.

As a Society, the ASO has come a long way in recognising that the Art and Science of our profession have embraced 'evidence-based dentistry'. However, the Society also has to take some blame for our reluctance to practise what we preach. As a practising scientist, I have been agitating for some time that a question-time be allocated at the end of every lecture at our State and National Scientific meetings, otherwise the lecturn is really a pulpit in disguise. Politeness aside, a lecture is only as good as the discussion that it provokes and every lecturer at our meetings should look forward to probing questions. Over time, this type of discourse will energise Society members to become good practitioners of 'evidence-based orthodontics' and our Art will benefit from the Science. Mr Fandangle can only flourish in a culture where the practitioners prefer to practise more Art and less Science, and therefore easily dazzled by dodgy data and bad statistics. Our Universities do a great job of training graduates in the scientific method, and by embracing the same values, the Society will only enhance the quality of our new practitioners.

Thank you Professor Dreyer, for instigating this timely debate.

Professor Seong-Seng Tan

Division Head, Brain Development & Regeneration
Kenneth Myer Building
Genetics Lane
University of Melbourne
Victoria 3010
Australia
Email: stan@florey.edu.au
Web: www.florey.edu.au; www.thetanlab.org

Sir,

Thank you for your editorial which was published in Volume 28, No.1 of the *Australian Orthodontic Journal* (May 2012).

Certainly I have been concerned about CPD points for a period of time as a lot of CPD points are linked to particular products by particular manufacturers. Because of this, I am really concerned that our education will be jaundiced by the financial considerations of the dental supply companies.

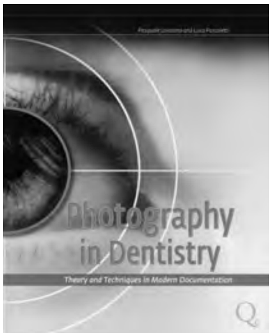
Another issue which was perhaps not mentioned was that some of our graduated orthodontists have come through our education system where reproduction of knowledge, rather than lateral thinking has been very important. Critical thinking has not been encouraged as much as I would like to see in our high schools, and even in some of our university courses, and because of this, even some orthodontic graduates may be overly influenced by the providers of the new fandangle.

Thank you again for your editorial in the journal.

Robert Fox

Senior Clinical Associate in Orthodontics
University of Sydney
PO Box 6248
Baulkham Hills, BC 2153
Australia

Book
reviews



Photography in Dentistry: Theory and Techniques in Modern Documentation

Authors: Pasquale Loiacono and Luca Pascoletti
Publisher: Quintessence 2012 (www.quintpub.com)
ISSN: 978 88 7492 169 0
Price: US$160.00

They say that a picture is worth a thousand words and, whether they are used for patient communication, consultation with a laboratory or colleague, diagnosis, clinical or legal records, or scientific presentation or publication, clinical photographs can be a powerful means of communication in all fields of dentistry.

Most orthodontists routinely take pre- and post treatment intra- and extra-oral photographs which are sent to the patient and the referring dentist. As such, excellent quality photographs can be an effective way to convey and reinforce a general standard of treatment excellence to the patient and to the referring dentist.

Dental photography is lacking a set of standards that would allow the continuity and reproducibility essential to clinical and scientific documentation. To address this need, this book presents guidelines for photographic documentation that will enable practitioners to produce images that faithfully convey clinical data.

Interestingly, the series of orthodontic views recommended in this book differ from those recommended by the American Board of Orthodontics; this book states that the patient should be smiling with lips relaxed in all extra-oral views, whereas the AOB states that the patient should be smiling in the three-quarter profile view only. The book does not go into any detail about the printing of images in-house.

This hard-back book of 336 pages contains 847 illustrations. Needless to say, the quality of the images is excellent. The book is divided into two parts with various chapters:

Part One: Theory

1. General Principles of Photography
2. The Optical System
3. The Concept of Exposure
4. Principles of Digital Photography
5. The Role of Photography in Clinical Practice
6. Camera Settings for Dentistry
7. The Orthography of Images
8. Flash Units
9. Photographing Radiographs

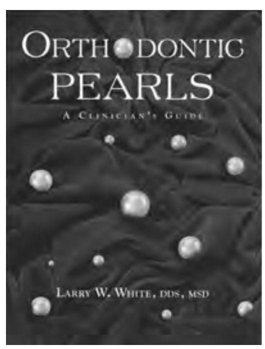
Part Two: Techniques

10. Equipment and Accessories
11. Extra-oral Series
12. Intra-oral Series
13. Photographic Documentation

Precise instructions, including the positions of the patient, assistant, and practitioner, camera settings and flash positions, aiming and focal points, and the types and positions of required accessories are detailed in text and images. Numerous fine examples of the desired final image are provided.

This comprehensive text should provide clinicians with all the information they need to feel confident in creating effective and compelling dental images.

David Fuller



Orthodontic Pearls – A Clinician's Guide

Author: Dr Larry W. White
Publisher: Larry White (larrywwhite@hotmail.com) and www.orthoarch.com
Price: $US89.00

This is certainly one of those books with a very appropriate title as it is a 'pearl' of a book for every practicing orthodontist or for any practitioner practicing orthodontics, irrespective of that clinician's level of expertise or experience. As Dr White says in his forward: 'The entire book rests on the premise that all of us are a lot smarter than any single one of us'.

While none of the clinical tips are scientifically substantiated, it was never the author's intention to scientifically substantiate the clinical suggestions proffered but merely to provide them to the reader and to allow the reader the opportunity to incorporate these tips into clinical practice.

The tips cover a broad range of orthodontic practice including, as Dr White states: 'patient management, diagnosis and treatment planning, compliance issues, personnel solutions and office management, in addition to orthodontic therapies'.

The book does not have any chapters or a firm structural organisation. While this was the intent of the author, the reviewer found it was rather disconcerting and would have preferred all tips involving one particular subject to be handled together. This would have made it easier for the reader to access, to assess and to compare one tip from the other with regard to a particular situation. It would also have been easier for the reader if tips on similar clinical events could have been cross-referenced. Once again, this would have facilitated the decision-making process as to which clinical tip is most appropriate for the clinician.

At the beginning of the book, there is a Table of Contents which permits the reader to peruse the topics available within the forthcoming pages. However, this Table of Contents itself is five pages in length and provides the reader with little help in comparing all tips about a particular situation. At numerous times, the reviewer commented to himself: 'Why didn't I think of that myself?' Many of the tips are so simple and yet so usable in everyday practice.

This book is one which can be read and re-read several times over. Each time the clinician will learn something that will help in their clinical life. Certainly, some of the challenges with which we are faced every week will be made less challenging by engaging some of the tips learnt in *Orthodontic Pearls*.

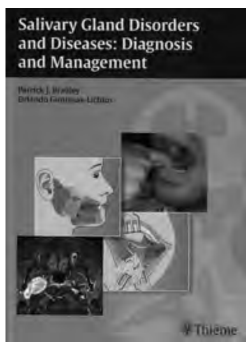
Some readers may pay more attention to one aspect of the book rather than another. For example, clinical situations may be more important to one reader than management or compliance issues. This book of tips covers many of these orthodontic issues and will find favour with the vast majority of readers, irrespective of which aspect of the book the reader is investigating.

The book is only 200 pages short. Most of those pages are filled with photographs. One can quite comfortably peruse the entire book in a weekend or in just a few days. Furthermore, it is one of those books that you can pick up for only a few minutes at a time, whenever and wherever you happen to be and still get some benefit from it.

One can be critical of the quality of many of the photographs. However, Dr White collected these from the contributing tipsters, many of whom the reviewer imagines did not envisage that the clinical tip eventually would be incorporated into print form for public consumption.

The reviewer feels extremely comfortable in recommending this book to every orthodontic clinician, irrespective of whether that clinician is an employer, employee, experienced or inexperienced clinician or a post-graduate student of orthodontics.

Hilton Katz



Salivary Gland Disorders and Diseases: Diagnosis and Management

Editors: Patrick J. Bradley and Orlando Guntinas-Lichius
Publisher: Thieme 2011
(www.thieme.com)
ISBN: 9783131464910
Price: $US169.99

This book is a comprehensive dissertation on salivary glands and includes basic embryology, anatomy, physiology, pathology as well as surgical and medical management.

The book is divided into a number of colour-coded sections so that the reader can quickly find a particular section when referencing information.

The first section is on salivary glands, anatomy and evaluation and includes contemporary aspects of investigation including sialendoscopy; the second smaller section covers paediatric disorders, the third physiological disorders, the fourth benign salivary gland neoplasms and so forth.

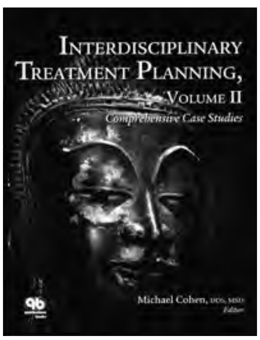
The text is pitched at an advanced level and would appeal to practitioners as a reference text, it would particularly appeal to those surgeons who are involved in management of salivary gland disease as well as those whose specialties have patients with salivary abnormalities, the sections on Sjogren's are particularly helpful in this book.

The book is extremely well set out; it is illustrated with clinical slides, photographs of the instrumentation used, photographs of common investigations including CT and MRI and histology. Where applicable, these photographs are supplemented by easy-to-read, clear and concise drawings. There are many flow charts to illustrate steps in management of the various salivary gland pathologies.

At the end of chapters and sections key points are placed in a separate text box and 'hints' are placed throughout the text in coloured boxes.

In summary, this is a well-written and superbly illustrated reference text on salivary gland disorders and would be a worthwhile addition to medical and dental libraries.

Paul Sambrook



Interdisciplinary Treatment Planning, Volume II. Comprehensive Case Studies

Author/Editor: Michael Cohen, Editor
Publisher: Quintessence 2012 (www.quintpub.com)
ISBN: 9780867155013
Price: $US378.00

Co-reviewed by Drs Alex Selby (Restorative Dentist) and Morris Rapaport (Orthodontist). Dr Selby commences:

This is physically a large book and is the second volume, following an earlier book conceived, developed and edited by Dr Michael Cohen.

Dr Cohen is in private practice in Seattle, USA, and is a visiting Assistant Professor in the Department of Periodontics at the University of Washington School of Dentistry. He conceived the Seattle Study Club, which now has over 6,500 members in branches throughout the United States and around the world. A central focus of the study club is comprehensive treatment planning, encouraging interaction between dentists from different disciplines.

The previous book, in keeping with the philosophy of the Seattle Study Club, introduced the essential principles of systematic treatment planning, and included many case studies. This second volume is a further compilation of treated patient cases; each one a collaboration of treatment by skilful clinicians from different disciplines of dentistry.

The aim of the book, and its predecessor, is to highlight the importance and demonstrate the manner in which careful treatment planning of each patient's requirements can lead to greater 'predictability and excellence' with treatment outcomes. As with all publications from the Quintessence publishing company, this book is beautifully illustrated with superb intra-oral and clinical photographs, and is comparable with any 'coffee table' book one may find in an elegant home.

Dr Cohen has enlisted thirty world acclaimed and highly regarded 'master clinicians' to author the different chapters. Each case presentation is carried out in a systematic manner following a prescribed format. Information is provided regarding the patient's background, the results of examinations and diagnostic findings. This is followed by a 'Summary of Concerns' and 'Treatment Planning Considerations'.

At this point in each chapter, as a learning experience, the reader is offered an opportunity to consider the treatment goals and develop his or her own treatment plan, before turning the page and reading the authors' proposed treatment plan and the actual clinical treatment carried out. This is accompanied by step-by-step photographs. Each chapter is concluded with a commentary including a discussion of the case, difficulties encountered, how the clinicians might carry out treatment differently if given the opportunity to begin again, and any additional thoughts or comments.

Although the book is largely centred on the restorative clinician's perspective, the chapters embrace a wide range of disciplines and a variety of treatment modalities. Implant treatment, orthodontic treatment and periodontal surgery are frequently showcased. Most cases are partially edentulous patients, or fully dentate but with cosmetic complaints. There is one patient for whom a central incisor is replaced by autotransplantation of an unerupted premolar, and another for whom interdisciplinary care involves orthognathic surgery. Many challenging cases are presented and I found it interesting to discover how the problems were addressed, with admirable outcomes in every instance.

Throughout the book the clinicians explain the philosophy and treatment concepts upon which their treatment is based. As a minor criticism I found much of the written text to be verbose with somewhat lengthy discussions and explanations. On the other hand, I admired the precision with which each case was analysed and the many details provided with respect to the provision of treatment. The clinical photographs are impressive and help to ensure the reader understands what is being presented.

The book has been written employing the United States' tooth numbering system in which teeth are numbered sequentially from 1 to 32. However Australian readers are familiar with FDI tooth identification system and may find, as this reviewer found, the numbering system utilised in the text was disorientating.

Overall, the book offers a great deal of information, together with beautiful dental photography. It provides an opportunity to improve one's treatment planning abilities and to learn from the experiences of master clinicians. It is a commendable achievement by the editor and will serve as a worthwhile resource for the profession.

Dr Rapaport continues:

A useful teaching methodology in the training of postgraduate orthodontic students is to have them look at patient records as a group, sometimes with other specialists present, and discuss aspects of the diagnosis before arriving at various treatment alternatives. The students then consider the likely prognosis of the alternatives. With repetition from applying this method to many different cases, students cover a broad range of orthodontic problems and learn the rationale for the various orthodontic approaches. Many of the variables are interrelated, making the cases interesting puzzles to solve. By studying the magnificently presented cases in this second volume of interdisciplinary reports the reader can achieve a similar benefit by making a diagnosis, suggesting a treatment plan to themself and then comparing what he or she would have done with what actually was done. Seeing the outcome achieved gives the clinician much to ponder and there is the potential for even experienced orthodontists to thereby reach a higher level of proficiency.

You might consider it unlikely to have to deal with a patient suffering amelogenesis imperfect – one such case is presented – but a young man with a Class I deep bite, retroclined maxillary incisors and spacing is commonly seen and would you have thought to treat him by adding a third bicuspid tooth implant in each quadrant? That is what was done in one of the cases documented. The same patient also had aesthetic crown lengthening surgery. Should that surgery have been done before or after the placement of the implants? The answer is before, so that the surgeon can determine the correct position for implant platform placement. The point illustrated by this example is that this book demonstrates many lateral thinking approaches and also elucidates the finesse required to achieve the superior results shown.

Another case, already briefly mentioned above, and once again showing a lateral thinking approach to treatment, is that of a ten year-old boy who presented following a pool accident six months earlier with a maxillary central that had become ankylosed. This was extracted and replaced immediately by his autotransplanted, unerupted, lower left second bicuspid so as to allow continued alveolar ridge development and restore aesthetics and function. Healing was monitored over the next three months and the premolar began to erupt through the follicle in the area of the central incisor and radiographically showed continued root formation. What instructions regarding positioning of the transplanted tooth needed to be given to the surgeon to maximise the aesthetics of the subsequently placed composite laminate veneer? Firstly, the transplanted tooth needed to be turned 90 degrees so as to more closely match the mesiodistal dimensions of a central incisor, but two thirds of the remaining space was to be left at the distal and one third at the mesial. Heightwise, the cemento-enamel junction of the transplanted tooth needed to match that of the adjacent central incisor and labiopalatally, the transplanted tooth was to be positioned slightly palatally on the ridge, leaving space for the facial veneer. Once a periodontal ligament was confirmed, orthodontic tooth movement could commence and the donor site was closed by unilateral protraction of the posterior teeth, utilising temporary anchor mechanics.This case and others in the book are not routine and therefore, make interesting reading. The many out of the ordinary aspects that must be considered to finesse the high quality result achieved, are spelt out too.

Not all of the interdisciplinary cases presented involve orthodontics but many others are shown to have a better outcome because of prior orthodontic therapy. Treatment options are chosen through educated reasoning rather than simple, visceral, emotional responses. This led, in one instance, to a case where 5 mm of vertical bone and tissue height was created by controlled orthodontic extrusion of the maxillary incisors and several other cases, which ultimately required multiple implants, also benefited from orthodontics beforehand.

I too found the US tooth numbering system used throughout the book annoying. You take for granted that in most of the dental publications you are likely to read in Australia, if you see tooth 1.1, you automatically know it is the upper right central incisor and you know this without thinking. So in a book where US tooth designations are used, there may not be the automatic recognition but this is a quibble and does little to detract from the inspiring cases presented.

Alex Selby and Morris Rapaport

Recent
literature

These reviews have been prepared by the orthodontic postgraduate students from the University of Queensland, Brisbane, Australia

Measurements of the torque moment in various archwire-bracket-ligation combinations

Hirai M, Nakajima A, Kawai N, Tanaka E, Igarashi Y, Sakaguchi M, Sameshima GT and Shimizu N

European Journal of Orthodontics 2012; 34: 374-80

The expression of torque moment is an important determinant governing treatment outcome in clinical orthodontics.

The aim of this study was to measure the torque moment delivered by various archwire, bracket, and ligation combinations at a targeted tooth.

Stainless steel (SS) upper anterior standard edgewise twin brackets with 0.018 x 0.022 and 0.022 x 0.025 inch slots were used. Archwires included various sizes of nickel-titanium (Ni-Ti) and SS wires. The wires were attached either with elastics or wire ligatures. A measuring apparatus, consisting of a torque transducer connected to a torque gauge, recorded the torque moment delivered by various archwire-bracket-ligation combinations. Statistical analysis was performed using analysis of variance (multiple comparison tests and Tukey's post hoc test).

Torque moment increased with the application of larger degrees of torque and wire sizes. Comparison between the SS and Ni-Ti wires showed that the torque moments of SS wires were generally larger than those of Ni-Ti wires. At low degrees of torque, there was no significant difference in torque moment between the SS and Ni-Ti. When the wire torque was increased to 15-20 degrees in the 0.018 inch slot brackets and 25 degrees in the 0.022 inch slot brackets, the torque moment of SS wires was approximately 1.5 times larger than that of Ni-Ti wire.

When elastic and wire ligation were compared, most of the torque moments with wire ligation were significantly larger than with elastic ligation. The moment with wire ligation was approximately 1.1-1.5 times larger than with elastic ligation; however, when full slot archwires of 0.018 x 0.025 inch and 0.0215 x 0.028 inch were respectively engaged in the 0.018 and 0.022 inch slot brackets, there was no difference in moment between elastic and wire ligations. A limitation of this study was the dry conditions under which the torque moments were measured.

Although discrepancies may arise between in vitro and in vivo studies, the results from this study provide an insight to the amount of third-order bend with various wire-bracket-ligation combinations required for generating maximum torque moments.

Chien Wei Tan

The effect of Teflon coating on the resistance to sliding of orthodontic archwires

Farronato G, Maijer R, Caria M, Esposito L, Alberzoni D and Cacciatore G

European Journal of Orthodontics 2012; 34: 410-417

The use of Teflon-coated archwires offers an aesthetic alternative to conventional silver coloured archwires. As Teflon has a low coefficient of friction, archwires with a Teflon coating may show a reduction in resistance to sliding. The purpose of this in vitro study was to assess the effect of a Teflon coating on the resistance to sliding of orthodontic archwires. The study tested twelve different archwires, including nickel titanium and stainless steel, in sizes of 0.014 (round), 0.018 (round), and 0.018 x 0.025 inch (rectangular), which were either uncoated or coated with Teflon. Each archwire was tested with three self-ligating bracket systems, SmartClip™, Quick® and Opal®. Eight stainless steel plates were constructed for each type of bracket to imitate several clinical scenarios, incorporating varying displacements, in-out and torque. Resistance to sliding was measured 10 times by moving the archwire through the test brackets at the rate of 10 mm per minute using a frictional testing apparatus. Friction was found to be less for archwires of smaller diameter, for Ni-Ti archwires, for Quick® brackets, and for Teflon-coated archwires. The results suggest that coating archwires with Teflon may reduce their resistance to sliding. Follow up in vivo studies are indicated to confirm this finding.

Paulina Lee

Frequency of errors and pathology in panoramic images of young orthodontic patients

Granlund CM, Lith A, Molander B, Gröndahl K, Hansen K and Ekestubbe A

European Journal of Orthodontics 2012; 34: 452-7

This Swedish study aimed to evaluate the frequency of errors and abnormal conditions in panoramic radiographs taken for young orthodontic patients, as well as to compare the conditions found with those listed in their respective orthodontic records.

One thousand, two hundred and eighty-seven (1287) panoramic radiographs belonging to children and adolescents referred to The Clinic of Orthodontics in Goteborg were analysed. The radiographs were taken by specially trained orthodontic assistants and analysed by 4 observers, 3 oral radiologists and 1 postgraduate student in oral and maxillofacial radiology.

Ninety-six per cent of the panoramic radiographs were found to have errors, the most common being that the tongue had not been placed into the hard palate. Another common error involved head rotation. Forty-three per cent of the radiographs demonstrated pathology and 63 of the records showed pathology which, in the radiologist's opinion, might have had a bearing on orthodontic treatment although, of these, only 12 were noted in the patient's orthodontic records.

The panoramic radiograph is a common tool utilised in orthodontics but it is susceptible to a variety of errors which can adversely affect its diagnostic value. Additionally, it is a radiographic view which extends beyond the teeth and jaws and therefore all areas shown in the image need to be considered to make full use of the information provided.

The authors of the study concede that the quality of the panoramic radiograph will be affected by operator experience and that interpretation of the radiograph will also be affected by the experience and skill of the interpreter, as well as by the viewing conditions. Furthermore, the discrepancy between the orthodontic records and the observations made by the oral radiologists might be due to differences in opinion regarding pathological findings of consequence for orthodontic treatment.

In conclusion, it would seem wise to ensure that those taking panoramic radiographs are appropriately trained to avoid replicating the common errors indicated by this study. Also, professionals responsible for the interpretation of radiographs should remain vigilant to the potential for finding symptom free pathological changes or other anomalies.

Emily-Ruth Close

A prospective clinical evaluation of mandibular lingual retainer survival

Taner T and Aksu M

European Journal of Orthodontics 2012; 34: 470-4

Lower lingual fixed retainers are widely used by orthodontists. Their failure can be a source of frustration for patient and clinician alike. This prospective investigation aimed to compare the success of directly and indirectly bonded lingual fixed retainers, evaluating survival time and type of failure.

There were 66 lower lingual fixed retainers fitted (32 attached using a direct bonding method and 34 fitted using the authors' recommended indirect method). The patients were observed monthly for six months.

Over this period 25 of the retainers failed (failure rate 37.9%), with 7 patients having repeated failures. The first month had the highest failure rate, which was one third of the total failures. There was no statistically significant difference in the success rate between the two bonding methods; however, 46.9% of the directly bonded retainers failed and 29.4% of the indirectly bonded failed.

Interestingly, there was a higher failure rate observed in the right quadrant and a tendency for more breakages to involve the lower incisors. Patients rarely noticed a failure which was considered to be related to having all of the teeth bonded. The authors recommended routine early follow-up appointments in retention for patients with a bonded retainer and suggested bonding the retainer one month prior to debond. Predictably, adequate and even adhesive application, good adaptation of the wire and moisture control were all seen to be vital for the success of lower lingual fixed retainers.

Jonathan Rooke

Enamel colour changes after debonding using various bonding systems

Zaher AR, Abdalla EM, Abdel Motie MA, Rehman NA, Kassem, H and Athansiou AE

Journal of Orthodontics 2012; 39: 82-8

Alterations in enamel colour may be associated with the removal of fixed appliances after orthodontic treatment. This study aimed to explore possible differences in the colour change of enamel after debonding brackets attached with different bonding systems and also, to investigate any correlation between enamel colour changes and the depth of resin tag penetration into enamel.

Fifty premolar teeth were collected from 12-16-year-old patients requiring extractions for orthodontic treatment. All teeth had been exposed to fluoride in drinking water at 6 ppm and were free of any visible cracks, caries, decalcification or discolouration on the bonding surface.

The teeth were randomly numbered from 1 to 50 and a spectrophotometer was used to measure the initial colour of enamel. The teeth were then randomised into 5 groups of 10; Group 1 (control) and Groups 2-5 (experimental groups) that had brackets bonded using different bonding systems. All groups were stored for 48 hours (in distilled water at 37°), then debonded and polished until normal lustre was restored. Final colour measurements were taken for each tooth with the same procedure using the spectrophotmeter. The final part of the study involved sectioning the teeth in Groups 2-5 and measuring the depth of resin tag penetration in enamel using scanning electron microscopy (SEM).

There was a statistically significant colour change in all experimental groups compared with the unbonded control group; however there were no differences between the different bonding systems.

The amount of enamel colour change for each experimental group was compared with the 'critical value for clinical detection' and all bonding systems showed values greater than the critical value.

The SEM images indicated great variation in resin tag length; however, there was a statistically significant difference between the different bonding systems (Group 3 was longer than 2, 4 and 5 and Group 2 was longer than 4 and 5). Although this was not correlated with the change in enamel colour for each group when Groups 2, 3, 4 and 5 were pooled, there was a significant positive correlation of moderate strength.

It would appear that unintentional changes in the colour of enamel do occur post debonding (regardless of the bonding system) and that these changes are clinically detectable. There is moderate evidence to suggest that shorter resin tag lengths produce significantly less change in enamel colour. The self-etch primers (Groups 4 and 5) had the shortest resin tag lengths, which may suggest that these bonding systems produce fewer changes in enamel colour after debonding.

Lisa Sakzewski

The effects of facemask and reverse chin cup on maxillary deficient patients

Showkatbakhsh R, Jamilian A, Ghassemi M, Ghassemi A, Taban T and Imani Z

Journal of Orthodontics 2012; 39: 95-101

A skeletal Class III malocclusion can be due to excessive mandibular protrusion, maxillary retrusion or a combination of both. A variety of treatment options exist for orthopaedic Class III correction and these include the possible use of a face mask, a Frankel appliance, reverse headgear, chin-cup, mini-implants and a reverse chip cup.

The aim of this randomised clinical trial was to assess the treatment effects of a reverse chin cup and facemask on Class III growing patients.

Forty-two patients were selected and allocated randomly into two groups. Group 1 consisted of 21 patients (Mean age of 8.9, SD: 1.4 years) who each received a Multi-Adjustable facemask (Ortho Technology Inc., Tampa FL, USA) and a fully adjustable removable appliance in the upper arch. Treatment extended over 18 months (SD: 2 months).

Group 2 received a reverse chin cup. This group comprised 21 patients with a mean age of 9.2 (SD: 1.1) years. The upper removable appliance consisted of clasps on the permanent first molars, primary canines and the permanent central incisors. An acrylic chin cup was fabricated for each patient. Stainless steel hooks were attached to the chin cup and elastics extended to the palatal canine area of the removable appliance to deliver approximately 500 g of force on each side. A high pull head cap was used to secure the reverse chin cup. Patients wore the appliance full-time and treatment lasted 19 months (SD: 4 months).

Lateral cephalograms, panoramic radiographs, study casts and photos were taken before and after treatment. SNA, SNB, ANB, Upper incisor to SN, ANS-PNS, to SN, Go-Gn, Jarabak ratio, upper incisor to ANS-PNS, Go-Gn to Sn and IMPA were measured.

Analysis of the results showed that there were no statistically significant differences between the cephalometric measurements between the groups. SNA and ANB increased for both groups while there was no significant change in SNB.

The results indicate that both appliances may have an effect that accounts for forward movement of the maxilla and the maxillary dentition while lingual movement of the lower incisors occurs. The reverse chin cup appliance is smaller in size than the facemask and this may improve compliance. The findings of this study are similar to others in that the effects on the dentition include proclination of the upper incisors and retroclination of the lower incisors.

In the growing child, the facemask and reverse chin cup are able to produce forward movement of the maxilla. Both appliances were associated with lower incisor labial tipping and upper incisor lingual tipping.

Jasyn Randall

Mini-screw implant or transpalatal arch-mediated anchorage reinforcement during canine retraction: a randomized clinical trial

Sharma M, Sharma V and Khanna B

Journal of Orthodontics 2012; 39: 102-10

The use of miniscrew implants to enhance orthodontic anchorage has become increasingly popular in recent years. The objective of this randomised clinical trial was to compare the effectiveness of a transpalatal arch or miniscrew implants in conserving orthodontic anchorage during maxillary canine retraction with fixed preadjusted edgewise appliances. Patients with bimaxillary protrusions requiring extraction of both upper first premolars were selected. Following extractions, the patients were randomly allocated to receive either bilateral miniscrew implants or a transpalatal arch. All miniscrew implants were inserted between the maxillary second premolar and maxillary first molar and ligature-tied to the adjacent bracket of the second premolar. Following levelling and alignment, the maxillary canines were retracted using nitinol closed coil spring engaged from the canine hook to the miniscrew head and molar tube hook, respectively. Upon completion of canine retraction, the miniscrew implants or transpalatal arch were removed and the extent of mesial movement of the upper first molars measured and compared using pre- and post-treatment lateral cephalometric radiographs. It was shown that the miniscrew implants provided absolute anchorage during maxillary canine retraction, whereas the transpalatal arch permitted approximately 2.5 mm of mesial movement of the first molars. The authors suggest further studies be carried out to investigate tooth movement in the mandibular, as well as the maxillary arch.

Jason Yap

Comparison of deactivation forces between thermally activated nickel-titanium archwires

Figueirêdo MM, Cançado RH, Freitas KM and Valarelli FP

Journal of Orthodontics 2012; 39: 111-16

Thermally activated nickel-titanium wires are widely used for the initial alignment of teeth. An important characteristic of the material is its ability to deliver a light continuous force upon deactivation. However, studies have found variability in the properties of these wires. Therefore, the aim of this study was to compare the load-deflection curves between a group of commercially available, thermally activated, Ni-Ti wires. Six 0.019 x 0.025 inch thermally activated Ni-Ti wires from different manufacturers were investigated. A three-point bending test was conducted. Forces generated at deactivation for a deflection of 3, 2, 1, and 0.5 mm were used for statistical comparison. The results revealed that there was a statistically significant effect of wire alloy on deactivation force (p = 0.0006). None of the archwires exhibited permanent deformation after the bending test. The load-deflection curves obtained in the study were considered to be typical of superelastic wires. The authors concluded that there were significant differences in the deactivation forces among the six types of thermally activated Ni-Ti wires. NiTinol Termo-Ativado (Aditek, Cravinhos, São Paulo, Brazil) and NeoSentalloy F200 (GAC, Bohemia, NY, USA) produced the least amount of force in all four deactivation categories.

Devan Naidu

The effect of chewing gum on the impact, pain and breakages associated with fixed orthodontic appliances: a randomized clinical trial

Benson PE, Razi RM, Al-Bloushi RJ

Orthodontics and Craniofacial Research 2012; 15:178-87

Chewing gum could potentially be a method of controlling pain from orthodontic appliances but there are concerns that it could possibly lead to weakening of the appliance bond. This study aimed to determine whether chewing gum reduced pain from fixed orthodontic appliances and whether there was an associated risk of appliance breakage. Patients who were to commence fixed orthodontic appliance therapy were selected and randomly allocated to one of two groups. The intervention group was instructed to chew gum 'as required' and to begin its use at the bonding/separator visit and continue until after the working arch wire was placed. The control group was asked not to chew gum throughout the study. Appliance breakages were recorded at the end of treatment. Patients were given a diary to complete at 24 hours and again 1 week after placement or adjustment of their appliance. The diary included an Impact of Fixed Appliances (IFA) questionnaire and a contained a visual analogue scale (VAS) to assess the impact and intensity of pain from the appliance. Participants also recorded their use of oral analgesics. It was shown that chewing gum significantly decreased the impact and pain from fixed appliances without increasing the incidence of appliance breakage. Chewing gum use by orthodontic patients shows promise as it also has the added benefit of reducing the incidence of demineralisation and caries.

Sarah RYJ Ting

ASO Perth Congress 2012:
Poster presentations

Research papers were presented at the Australian Society of Orthodontists' 23rd Congress, held in Perth, Australia, from 10–14th February 2012.

The abstracts are published in full on the journal website: www.aso.org.au/aoj
Click on Past Issues, then on Meeting Abstracts.

Dental caries experience in schoolchildren in two North Queensland communities and its potential effects on the development of malocclusions

Abdalla Y, Sandham A, Boase R, Luhrs, J, Ye Q

Treatment of Class III malocclusions using Temporary Anchorage Devices (TADs) and intermaxillary Class III elastics in the growing patient

Al-Mozany S, Tarraf N, Dalci O, Gonzales C and Darendeliler M

Effect of Slurp-1 on pre-osteoblast gene expression and apoptosis

Alshahrani A, Phan T, Goonewardene MS and Ang E

The influence on osteogenic expression by human osteoblasts (Hfob 1.19) when treated with Bone Morphogenetic Protein-4 and Nerve Growth Factor

Bond G, Phan T, Goonewardene MS and Ang E

An investigation into the relationship between periodontal ligament associated Protein 1 and maintenance of the periodontal ligament

Chen C, Sampson W, Dreyer C and Dharmapatni K

Smoking patterns in adolescent orthodontic patients and school children: a 12-year follow-up

Collet T, Lilja C and Schulz N

The extent of root resorption and tooth movement following the application of ascending and descending magnetic forces: a microcomputer-tomography study

Huang T, Karadeniz E, Gonzales C, Walsh W, Petocz P, Dalci O, Turk T and Darendeliler A

A proteomic search for biomarkers of orthodontic tooth loss

Dever P, Schneider P, Mandon D, Mangum J and Hubbard M

The effect of denervation and ß2 agonist administration on bone radiodensity

Fitzpatrick B

Evaluation of facial aesthetics self-ratings, satisfaction with treatment and self-reported desire for further treatment of adult patients treated for orofacial clefting

Foo P, Sampson W, Dreyer C, Roberts R, Jamieson L and David D

Facial aesthetics and desire for further treatment of adult patients treated for orofacial clefting: a comparison of expert and lay people panel ratings with self-reported ratings

Foo P, Sampson W, Dreyer C, Roberts R, Jamieson L and David D

The development of the curve of Spee in Australian twins

Gagliardi A, Sampson WJ, Townsend GC and Hughes T

Ratio of soft tissue changes of lower lip and chin to hard tissues of lower incisive and chin after mandibular surgery and genioplasty among skeletal Class III patients

Gan S, Soemantri E and Astuti A

The value of digital model diagnostic set-up in treatment planning complex interdisciplinary treatment

Goonewardene RW, Goonewardene MS, Razza MJ and Murray K

Vitamin D3: a potential adjunct to orthodontic tooth movement

Griffin R, Sandham A and Ye Q

Space regainer in orthodontic treatment

Halim H

Corticotomy enhanced orthodontics

Jong M, Sampson W, Parkinson I, Dreyer C, Fazzalari N and Bartold M

Craniofacial and airway morphology in children with Obstructive Sleep Apnoea (OSA) and identification of cases at-risk for non-curative adenotonsillectomy (T&A): a research plan

Katyal V, Pamula Y, Kennedy D, Martin J and Sampson WJ

Development of a method for the quantitative analysis of residual enamel on debonded orthodontic brackets

Lo T, Cochrane NJ and Reynolds E

Orthodontic camouflage treatment effect on maxillary anterior teeth tip and torque values

Mah M, Chan Y and Foong K

Load-deflection behaviour of tubular braided nickel titanium wire

Makhmalbaf P, Mandon DJ and Palamara JEA

The relationship between menarcheal age and skeletal maturation stage of Deutero-Malayid Indonesian subject

Mardiati E, Soemantri ESS, Harun ER, Thahar B and Sutrisna B

Assessment of the periodontal health status in patients undergoing orthodontic treatment with fixed or removable appliances. A microbiological and preliminary clinical study

Migliori F, Abbate G, Levrini L and Caprioglio A

Interleukin 1-ß levels in peri-miniscrew implant crevicular fluid: a contrivance for predicting success or failure of miniscrew implant

Monga N, Kharbanda O, Duggal R and Moganty T

Comparing DAI and IOTN in determining the orthodontic treatment needs of 11 to 14 year-old schoolchildren in Qazvin city

Naseh R, Padisar P and Babakhani A

Dental and chronological age correlation of 6-15 year-old orthodontic patients in Qazvin

Naseh R, Padisar P and Rahmani J

Orthodontic treatment need and oral health quality of life in Qazvin 11 to 14 year-old schoolchildren

Naseh R, Padisar P, Tayebi A and Shojaeenejad HA

The relationships between craniofacial morphology and dimensions of the pharyngeal airway in adults: a CBVT study

Kiertiburanakul J, Naser-ud-Din S, Layton D, Gibbs T and Monsour P

The associations between palatally displaced canines and maxillary lateral incisors

Liuk IW, Olive R, Griffin M and Monsour P

The changes in interdental papillae heights following alignment of anterior teeth in adults

Patel A, Murray K, Phan T and Goonewardene M

Electromyographic activity in massseter and temporalis muscle during maxillary protraction therapy

Rajiv B, Duggal R, Kharbanda O, Yadav R

Gender differences in mandibular arch width in normal occlusion and mandibular prognathism in the Japanese population

Suzuki A, Arai K, Hisa I, Oda S, Will LA and Miner M

Invisalign treatment of the growing Class II patient

Weir T

The nature of overbite correction using Invisalign appliances

Weir T

Evaluation of treatment outcome of maxillary osteotomies in cleft lip/palate patients treated with conventional orthognathic surgery and distraction osteogenesis

Wong F and Heggie A

Identifying the confounding factors of the Flexcell system: standardising mechanobiology

Yang D, Boyd N, Goonewardene M, Ang E and Phan T

Mechanical force induced differentiation of preosteoblasts with finite element parameter of distraction osteogenesis and orthodontic forces

Yang D, Boyd N, Goonewardene M and Phan T

Periodontitis and orthodontic treatment: a pilot study

Ye Q, Zhao Z, Ren Y, Zou S and Sandham A

Trends in orthodontic management strategies for patients with congenitally missing lateral incisors and premolars

Yeap CK, Goonewardene M, Razza MJ and Murray K

In appreciation

Reviewers for the *Australian Orthodontic Journal*

Over the past year the following individuals have generously offered their time, knowledge and expertise reviewing articles for the Journal. We sincerely thank them and acknowledge their considerable contributions which have improved the quality of the Journal.

Michael Anderson, Ashgrove, Q
Chrys Antonio, Dubbo, NSW
John Armitage, Melbourne Vic
David Armstrong, Coffs Harbour, NSW
Jonathan Ashworth, Adelaide, SA
Stephen Atkin, Upper Mount Gravatt, Q
Steve Bajada, Rose Park, SA
Bruce Baker, Wantirna South, Vic
Laura Barbagallo, Brisbane, Q
Andrew Barbera, North Adelaide, SA
Andrew Barry, Wollongong, NSW
Melinda Barva, Modbury North, SA
Luc Bensch, Edegem, Belgium
Joseph Bleakley, Biggera Waters, Q
Jim Bokas, Burwood, Vic
Anita Bonic, Pennant Hills, NSW
Paul Buchholz, Geelong, Vic
Guy Burnett, Adelaide, SA
Fatma Caglayan, Erzurum, Turkey
John Cameron, Norwood, SA
Andrew Chang, Blacktown, NSW
Tony Collet, Ferntree Gully, Vic
John Coolican, Chatswood, NSW
Angela Coombe, Toukley, NSW
Rhonda Coyne, Cairns, Q
Edward Crawford, Melbourne, Vic
Stuart Dashper, Melbourne, Vic
Grant Duncan, Norwood, SA
Padhraig Fleming, London, United Kingdom
Carlos Flores-Mir, Edmonton, Canada
Justin Fong, Gordon, NSW
Terry Freer, Brisbane, Q
John Fricker, ACT
Yan Gu, Beijing, P.R. China
Fiona Hall, Mount Lawley, WA
Patrick Hannan, Warana, Q
Paul Hanrahan, Townsville, Q
Peter Hardman, Nooseville, Q
Julia Harfin, Buenos Aires, Argentina
Chris Ho, Brisbane, Q
John Hodgson, Auckland, New Zealand
Howard Holmes, Cannington, WA
Kip Homewood, Berwick, Vic
Daniel C. Shing Huang, Taipei, Taiwan
Chung Ju Hwang, Seoul, Korea
Michael Hyde, Canberra, ACT
Paul Ichim, Nedlands, WA
Hideki Ioi, Fukuoka, Japan
John Jenner, Adelaide, SA
Sanj Kandasamy, Midland, WA
Tom Kardos, Dunedin, New Zealand
Gopal Kataria, Balwyn, Vic
Hilton Katz, Doncaster, Vic
Heather Keall, Auckland, New Zealand
Peter Keay, Sunnybank, Q
Brett Kerr, Ashgrove, Q
Russell Kift, Maitland, NSW
Stavros Kiliaridis, Geneva, Switzerland
Katherine Kula, Indianapolis, United States of America
Mark Kum, Christchurch, New Zealand
Eden Lau, Lower Mitcham, SA
Igor Lavrin, Melbourne, Vic
Gavin Lenz, Brisbane, Q
Pei-Ti Lin, Parkville, Vic
José Llamas, Seville, Spain
Eva Low, Liverpool, NSW
David Madsen, Manuka, ACT
Mariana Marquezan, Rio de Janeiro, R.J. Brazil
Robert Mayne, Shepparton, Vic
Brendan McCane, Dunedin, New Zealand

Helen McLean, Eastwood, SA
Murray Meikle, Singapore
Claudia Melo, Curitiba, Brazil
Christopher Miles, Clifton Hill, Vic
Peter Miles, Caloundra, Q
James Moses, Adelaide, SA
Didem Nalbantgil, Istanbul, Turkey
Colin Nelson, Chermside, Q
Daniel Ngan, Sydney, NSW
Kevin O'Brien, Manchester, United Kingdom
Richard Olive, Brisbane, Q
Desmond Ong, Brisbane, Q
Stephen Papas, Nundah, Q
Ashish Patel, Mandurah, WA
Edward Peel, Sydney, NSW
Timo Peltomaki, Tampere, Finland
Angela Pierce, Adelaide, SA
Andrew Quick, Dunedin, New Zealand
Mike Razza, Booragoon, WA
Christoph Reichert, Bonn, Germany
David Rogers, Perth, WA
Adam Rose, Wantirna, Vic
Parisa Salehi, Shiraz, Iran
Wayne Sampson, Adelaide, SA
Jonathan Sandy, Bristol, United Kingdom
Paul Schneider, Hawthorn, Vic
Tracey Shell, Moonee Ponds, Vic
Steven Singer, Kingsley, WA
Jonathan Skilton, Melbourne, Vic
Kieran Soma, Carlton, Vic
Janice Sommerville, Auckland, New Zealand
Liselotte Sonnesen, Copenhagen, Denmark
Anthony Stankevicius, Launceston, Tas
Steve Stramotas, Chatswood, NSW
Theresia Sudjalim, Berwick, Vic
Murray Thompson, Dunedin, New Zealand
Marcus Tod, Upper Mount Gravatt, Q
Caroll-Ann Trotman, Maryland, United States of America
Orhan Tuncay, Philadelphia, United States of America
Christine Underhill, Edgecliff, NSW
Daniel Vickers, Pennant Hills, NSW
Vicky Vlaskalic, Hawthorn East, Vic
William Weekes, Gosford, NSW
Anthony Weir, Greenslopes, Q
Hans Wellens, Brugge, Belgium
Geoffrey Wexler, Toorak, Vic
Gregory White, Hawthorn, Vic
Matthew Williams, Wellington, New Zealand
Ricky Wong, Hong Kong
Michael Woods, Malvern, Vic
Jason Yee, Sydney, NSW

We also sincerely thank our book reviewers, who have generously donated their time and energy during the year.

Ross Adams
Sax Dearing
David Fuller
Carmen Gonzales
Hilton Katz
Igor Lavrin
Barry Lewin
Peter Miles
Morris Rapaport
Paul Sambrook
Alex Selby

New
products

topsCheck-In for iPad

The topsCheck-In for iPadTM application allows patients to use an iPad as a touch-screen check-in kiosk (instead of a computer monitor and keyboard). The manufacturer states that, upon arrival at the practitioner's office, a patient can select his or her name on the touch screen. After check-in, all workstations automatically update and reflect appointment changes. Practitioners can select a one-column or two-column format and customise the messages and information shown to patients such as, 'You are five minutes early for your appointment. Please take a seat in our reception area.' The topsCheck-In for iPadTM application requires the most current version of topsOrtho, a Wi-Fi network, and any iPad that is running iOS 5.

For more information, contact tops Software at
iPad@topsOrtho.com or visit
topsOrtho.com/index.php/ipad

topsCephMate 3.0

topsCephMate is a digital cephalometric tracing and treatment-simulation program that integrates with topsOrtho. The manufacturer states that the program also integrates with other management and imaging systems that store tracings, photos, and x-ray images in PDF or JPEG format. Key features of version 3.0 are the ability to drag and drop to create customised cephalometric analyses, and the ability to create an infinite number of customised analyses that can be shared with colleagues (provided they also have topsCephMate 3.0).

The manufacturer also states that practitioners can perform cephalometric superimpositions from any time point in the patient's treatment, any plan, initial tracing, or combinations of two, three or more tracings; surgical predictions can be performed with a unique interface and soft-tissue simulations, and may be used without a network connection (ie. on a laptop or at home). Files will be synched upon reconnection to the topsOrtho database.

For more information, contact tops Software at
sales@topsOrtho.com or visit us at
topsOrtho.com/index.php/products/tops-cephmate

©2012 TP Orthodontics, Inc.

Originator clear aligner system from TP Orthodontics

Originator is a simple aesthetic system used to correct minor to moderate anterior crowding or spacing. The manufacturer claims that similar to traditional braces, Originator places force on anterior teeth, allowing movement into desired positions. The movement is achieved incrementally through a series of clear aligner trays, each tray generating up to 0.5 mm of movement. The Originator basic system includes up to five trays per arch; most minor to moderate corrections can be achieved in three trays. The manufacturer states that the Originator basic system is not intended for correction of Class II, Class III, severe crowding or open or closed bites. No minimum case requirements are required. Continuing education is not provided.

For more information contact TP Orthodontics
Tel (Aust): 1 800 643 055
Email: tpaus@tportho.com
Website: www.tportho.com

©2012 TP Orthodontics, Inc.

Click-It aesthetic self-ligating bracket system from TP Orthodontics

Click-It is a self-ligating bracket system with a four-walled archwire slot that adjusts to varying wire shapes, sizes and treatment objectives. Manufactured using an injection moulded process, key features include fully concealed metal parts, hidden tie-wings and a polymer mesh base. According to the manufacturer, brackets are designed to adjust to the colour of the teeth, using a personalised colour-matching technology. Click-It features a spring-loaded jaw mechanism designed for smooth efficient operation and patient comfort.

For further information contact TP Orthodontics
Tel (Aust): 1800 643 055
Email: tpaus@tportho.com
Website: www.tportho.com

Investec Notice Account

The Investec Notice Account is a new type of savings account. The service provider claims that the account pays a competitive rate of interest, currently at 4.75% p.a. Key features include a premium savings rate usually reserved for fixed term deposits and the added flexibility of being able to access funds after 32 days notice has been given. Account holders can choose to make partial or full withdrawals from a Notice Account, provided the requisite notice period has elapsed. For dental clients opening a new savings account with Investec, an extra 1% bonus rate above the current rate is being offered on the first 90 days after the account has been opened. It is available for balances up to $250,000 with interest paid monthly. Terms and conditions apply.

For further information visit www.investec.com.au/notice

SmartForce innovations from Invisalign

SmartForce innovations are aligner features and attachments engineered to help deliver the force systems required for more predictable tooth movements and better clinical outcomes.

For further information about SmartForce innovations visit www.aligntechinstitute.com/G4

New products are presented as a service to our readers, and in no way imply endorsement by the *Australian Orthodontic Journal*.

Orthodontic
calendar

2012

November 29 – December 2

8th Asian Pacific Orthodontic Society's Conference and 47th Indian Orthodontic Conference, Ashok Hotel, New Delhi, India.
Web: www.8thapoc-47thioc.in

2013

May 3–7

American Association of Orthodontists' 113th Annual Session, Philadelphia, USA.

June 26–30

European Orthodontic Society's 89th Annual Congress, Reykjavik, Iceland.
Web: www.eos2013.com

September 18–21

New Zealand Association of Orthodontists' Conference in association with the Australian Begg Orthodontic Society's 48th Meeting, Rotorua, New Zealand.
Web: orthodontists.org.nz
Email: terri@conference.co.nz

September 19–21

Canadian Association of Orthodontists' Annual Session, Fairmont Banff Springs Hotel, Banff, Alberta, Canada.
Web: cao-aco.org@EVENTS/future.aso

2014

March 29 – April 2

Australian Society of Orthodontists' 24th Australian Orthodontic Congress, Adelaide Convention Centre, Adelaide, South Australia, Australia.
Web: www.aso2014adelaide.com.au
Email: aso2014@fcconventions.com.au

April 25–29

American Association of Orthodontists' 114th Annual Session, New Orleans, Lousiana, USA.

June 18–21

European Orthodontic Society's 90th Annual Congress, Warsaw, Poland.
Web: www.eos2014.com

July 5–8

9th Asia Pacific Orthodontic Congress, Kuching, Sarawak, Malaysia.
Web: apoc2014.com

September 4–6

Canadian Association of Orthodontists' Annual Congress, Montreal, Quebec, Canada.
Web: cao-aco.org/EVENTS/future.asp

November 22–24

48th Indian Orthodontic Conference, Ahmedabad, India.
Web: www.48ioc.com

2015

May 15–19

American Association of Orthodontists' 115th Annual Congress, San Francisco, USA.

June 13–18

European Orthodontic Society's 91st Annual Congress, Venice, Italy.
Web: www.eos2015.com

September 27–30

8th International Orthodontic Congress and 5th Meeting of the World Federation of Orthodontists, ExCel London, London, United Kingdom.
Web: www.wfo2015london.org

For a list of meetings and links to website of national and international orthodontic societies, visit the World Federation of Orthodontics, www.wfo.org.

Index to Volume 28

The Australian Orthodontic Journal

Author index

Subject index