Dear Dr. Asli Baysal,

Thank you for your submission entitled “Alveolar Bone Thickness and Lower Incisor Position in Skeletal Class I and Class II Malocclusions Assessed with Cone-Beam Computed Tomography ”.

We would like to congratulate you on the acceptance of your article for publication in the KJO.

Further information regarding the publication procedures will be forwarded to you via email.
We look forward to working with you again in the future.

With warm regards,

Hyoung-Seon Baik, DDS, MS, PhD
Editor in Chief
Korean Journal of Orthodontics

Alveolar Bone Thickness and Lower Incisor Position in Skeletal Class I and Class II Malocclusions Assessed with Cone-Beam Computed Tomography

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Running Title: Alveolar bone in Class I and II patients

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Alveolar Bone Thickness and Lower Incisor Position in Skeletal Class I and Class II Malocclusions Assessed with Cone-Beam Computed Tomography

ABSTRACT

Objective: To evaluate the possible differences in lower incisor position and bony support between Class II average- and high-angle patients and compared to subjects with Class I malocclusions.

Materials and Methods: Cone-beam computed-tomography (CBCT) records of 79 patients were divided into two groups according to sagittal jaw relationships (Class I Class II). Then, groups were divided into average- and high- angle subgroups. Six-angular, six-linear were performed. Independent samples *t*-test, Kruskal-Wallis and Dunn post-hoc tests were performed for statistical comparisons. Statistical significance was set at $p<.05$.

Results: Labial alveolar bone thickness was higher (1.4±0.47 mm) in Class I group compared to Class II (1.09±0.39 mm) group. (p=0.003). Greater differences were recorded for subgroup comparisons: lower incisor protrusion-proclination and lingual alveolar bone angle was greatest in Class II average-angle patients. Spongious bone was thicker in Class II average-angle subgroup compared to high-angle subgroups. Root apex was closer to labial cortex in high-angle subgroups compared to Class II average-angle subgroup (p=0.004).

Conclusion: Lower anterior bony support and lower incisor position showed distinct differences between average and high-angle Class II patients. These differences were not recorded to the same extent in Class I average and high-angle subjects.

INTRODUCTION

Correction of Class II malocclusion includes growth modification, dental camouflage and orthognatic surgery procedures. Dental camouflage with upper first premolar extraction treatment involves the risk of over-retraction of maxillary incisors and may result with an obtuse nasolabial angle and compromised soft tissue profile, if the lower incisors are not attempted to protrude.[1] Treatment may also include excessive proclination of mandibular incisors as Class II elastics are overused to attempt to decrease the overjet, causing both an unstable situation and stressing the labial periodontal support.[1] According to Proffit and Fields,[2] even in most favorable circumstances no more than half of the changes needed to correct a Class II malocclusion in an adolescent would be gained by differential jaw growth. Thus, it may be assumed that both growth modification and dental camouflage treatments necessitates forward movement of the lower dental arch. The movement and position of the mandibular incisors may play an important role in diagnostic and orthodontic treatment of Class II malocclusions and the boundaries of the lower incisor movement may be important for the treatment plans of Class II patients.

The protrusion limits of lower incisors should be established before treatment, especially in patients with severe skeletal discrepancies.[3] These movement limits means biological factors, such as characteristics of the periodontal tissues[3] or anatomy of the symphysis.[4]

The dimensions of the anterior alveolus appear to set limits to orthodontic treatment and challenging these boundaries may accelerate iatrogenic sequel.[5] Thus, the treatment plan should be greatly influenced by the morphology of the symphysis and the position of mandibular incisors. Mulie and Ten Hoeve[6] reported that a contact to the cortical plate of the symphysis inhibits orthodontic tooth movement and greater forces result in dehiscences or fenestrations.

Several studies were performed on the relation between alveolar morphology and facial types.[7-9] Based on the results of these studies; differences were recorded for alveolar bone thickness or morphology relative to facial type. Handelman[5] reported that the labial and lingual alveolar widths were thin in high-angle subjects as well as Class III average individuals. Tsunori,[8] reported correlations between facial type, mandibular cortical bone thickness and the buccolingual inclinations of the first and second molars. Gracco et al.,[7] stated that the vestibular portion of the cancellous bone of the symphysis is greater in short face subjects compared to long face subjects. According to Swasty et al.,[10] mandibular height and width differs more than cortical bone thickness among the 3 types of subjects with different vertical facial dimensions.

With the introduction of cone-beam computed-tomography (CBCT), high definition images of the teeth and surrounding bone are now possible to be obtained at a far lower dosage of radiation than that of medical imaging and closer to the range of a standard dental film series.[11] In conventional cephalometric radiographs, all structures overlap each other because of the divergent nature of the X-ray beam.[12] High-resolution CBCT images provide clinicians to visualize the shape and the size of the alveolar bones without the disadvantages of conventional radiographs.[13] These images are free from distortion and superimposition; thus, enables quantitative and qualitative evaluation of the relationship between teeth and bone.[14] Moreover, CBCT and traditional methods were found to be comparable with respect to linear periodontal defect measurements.[15]

To date, no study has been undertaken to compare the incisor positions and alveolar bone thickness in subjects with Class I and Class II malocclusions, with CBCT. Thus, the aim of this retrospective archive study is to evaluate the alveolar bone thickness on the lower anterior segment and indicate some aspects for lower incisor movement range in Class I and Class II malocclusion and average-angle and high-angle growth patterns, using CBCT.

MATERIALS and METHODS

Before this study, a power analysis with G*Power 3.0.10 (Franz Faul, Christian-Albrechts-Universität, Kiel, Germany) was performed to estimate the sample size. It showed that total sample size of 70 subjects would give more than 70% (actual power= 0.7359; critical F= 2.5130; non-centrality parameter λ= 11.200) power to detect significant differences with 0.40 effect size and at α=0.05 significance level.

CBCT records of seventy-nine subjects were used in this study. The Cone Beam Computed Tomography (CBCT) records were obtained from the archives of Oral and Maxillofacial Radiology department of the University of XXX.

In this department records were taken to evaluate implant site, airway, impacted, missing or supernumerary tooth, root fracture, bone cyst, dentigerous cyst, abcess, osteomyelitis, odontoma, mucous retention cyst, temporomandibular joints, craniofacial malformations and syndromes. By October 2011, 1800 sets of images were in the database. Among 1800 CBCT scans, 79 were selected according to the criteria described in Table I.

Class I group was compromised of 41 subjects (18 female and 23 male; mean age: 18.52±5.01 years; range= 11.00-32.50 years) and Class II group composed of 38 subjects (22 female and 16 male; mean age: 16.62±4.91 years; range= 10.90-30.50 years). The groups were divided into high- and average-angle subgroups according to SN-GoMe angle.

Due to the reason that this study was an archive study, no ethical approval was gained.

Tomographs were obtained using CBCT (iCAT, Model 17–19, Imaging Sciences International, Hatfield, Pa, USA) with a single 360-degree rotation and a voxel size of 0.3 mm at the following settings: exposures were made with 5.0 mA, 120 kV, and exposure time of 9.6 seconds, and axial slice thickness was 0.3 mm.

Primary and secondary reconstructions of the data were performed with Mimics software 14.01 trial version. This secondary reconstruction allows creating three-dimensional projections of images with maximum intensity for making linear measurements. For standardization, the right lower central incisor was selected but if any rotation existed on the right central incisor, un-rotated left lower central incisor was evaluated in sagittal cross-sectional slices at buccal and lingual surfaces which were parallel to the midsagital plane. Before DICOM data were gained, midsagittal plane was constructed by NNT viewer software (Newtom QR Verona, Italy) and sagittal slice plane of incisors was established. For sagital and vertical classification, ANB and SN-GoGn were measured by SimPlant Pro 2011 (Materialise NV). Whole measurements were performed by a single author (F.I.U.)

All landmark identifications and measurements were adopted from Yamada et al.[12]

Definition of Landmarks (Figure 1)

The center of rotation (CR) was defined as a midpoint of the embedded portion of the root in alveolar bone.[16,17]

Points A and B were defined as the most antero-superior point and the most postero-superior point of the mandibular alveolar bone, respectively.

Points C, D, E, and F were defined on the trajectory of the hypothetical tipping movement of the mandibular central incisor root around the center of rotation.

Points C and F were defined as the most anterior point and the most posterior point of the mandibular alveolar bone, respectively.

Points D and E were defined as the inner contour of the anterior cortical plate and the inner contour of the posterior cortical plate, respectively.

Definition of the Measurements (Figure 2 and 3)

Mandibular line: the line between the menton and gonion point on 3D image and transfer it to the sagittal slices.

L1-B perpendicular: Distance between the incisal edge of central incisor and B perpendicular in millimeters. This line is a perpendicular from B point to mandibular line.[18]

IMPA: The angle between the line central incisor axis and the mandibular line.

Labial alveolar bone angle: The angle between the line A-C and the mandibular line.

Lingual alveolar bone angle: The angle between the line B-F and the mandibular line.

Labial cortical bone thickness (D-C): The length of the arc between the points D and C measured in millimeters..

Lingual cortical bone thickness (F-E): The length of the arc between the points F and E measured in millimeters.

Alveolar spongious bone thickness (E-D): The length of the arc between the points E and D measured in millimeters.

Alveolar spongious and cortical bone thickness (F-C): The length of the arch between the points F and C in millimeters.

L1a-D: The length of the arc between the points L1a and D measured in millimeters.

L1a-E: The length of the arc between the points L1a and E measured in millimeters.

Statistical Evaluation

All statistical analyses were performed with SigmaStat 3.1 (SPSS, Inc, Chicago, IL, USA). The normality test of Shapiro–Wilks and Levene's variance homogeneity test were applied to the data. Data was found normally distributed and there was homogeneity of variance among the groups. Thus, the statistical evaluations of these data were performed using parametric tests. Subgroup comparisons were performed with non-parametric tests, as the data was not normally distributed.

Arithmetic mean and standard deviation values were calculated for all measurements. An independent sample *t*-test was used to compare the mean values between the Class I and Class II groups. Kruskal Wallis test and Dunn post hoc test was used for subgroup comparisons. Statistical significance was tested at alpha level 0.05.

To determine the errors associated with CBCT measurements, 15 tomographs were selected randomly. Their measurements were repeated 4 weeks after the first measurements. A paired samples *t*-test was applied to the first and second measurements, and the differences between the measurements were insignificant. Correlation analysis applied to the same measurements showed the highest *r* value (0.985) for incisor mandibular angle and the lowest *r* value (0.699) for L1a-D measurement.

RESULTS

Descriptive statistics and intergroup comparisons between Class I and Class II groups were given in Table II. No statistically significant difference was found between two groups except for labial alveolar bone thickness (*p*<0.001). In Class I group, labial alveolar bone thickness was higher (1.4±0.47 mm) than Class II (1.09±0.39 mm) group.

Table III shows the statistical comparison between normal and high-angle subgroups of Class I and Class II groups. Greater differences were found between Class I and Class II groups, when the subgroups were evaluated. Lower incisor protrusion (*p*=0.007) and proclination (*p*=0.046) were higher for Class II average-angle group compared to other subgroups. Lingual alveolar bone angle showed similar increase in the same group compared to other subgroups. Labial cortical bone was thicker in Class I subgroups compared to Class II subgroups. The difference between Class I average-angle group and Class II subgroups were statistically significant (p=0.030). Alveolar spongious bone thickness (the arch between E-D), F-C distance and L1a-E measurements were highest for Class II average angle group. The difference was statistically significant between Class II average angle and Class I-II high-angle subgroups (p=0.016, p=0.012 and p=0.004, respectively)

DISCUSSION

Teeth may be decentralized from the alveolar bone envelope with orthodontic treatment, depending on the initial morphology of the alveolar bone and the amount of tooth movement.[19] The decision on how much the lower incisors would be moved or how the bone would be affected with tooth movement is critical in treatment planning. This study is conducted to evaluate the alveolar bony support of lower incisor teeth and carry out an evaluation of the position of these teeth in Class II average-angle and high-angle patients, compared to Class I subjects.

Greater differences were found when the groups were subdivided according to vertical growth pattern. It was obvious that in Class II average-angle subjects, the lower incisors are more protrusive and proclined than other subgroups. On the other hand, labial alveolar bone angle is not different among groups; also the lower incisor position is different. But a positive correlation between the inclination of the incisors and lingual alveolar bone was observed. Yamada et al.,[12] showed positive correlation between the labio-lingual inclination of the incisors and the alveolar bone on labial and lingual sides for subjects with Class III malocclusion.

Schudy[20] has suggested that the inclination of the mandibular plane is a good indicator of mandibular rotation. In the current study, mandibular plane angle was used to divide the groups as average- and high-angle. Björk[21] and Nielsen[22] explained the dentoalveolar development in characteristic vertical facial growth pattern. They showed that the direction of tooth eruption is almost vertical and the mandibular incisors are erupting posteriorly. According to the results of the present study, regardless of the basal jaw relationships (Class I or Class II malocclusions) the position and inclination of lower incisors were similar in Class I malocclusion subgroups and Class II high-angle group. The positions of lower incisors are really different between Class II subgroups; whereas, this is not the case for Class I subgroups.

Labial cortical bone thickness was greater in Class I subjects compared to Class II subjects. Thickness of the buccal alveolar cortical bone may increase the resistance of the bone to resorption. This may be especially important for treatment planning of Class II malocclusions, which necessitates incisor protrusion, as the alveolar bone is thin and liable to sustain iatrogenic damage.

E-D and F-C distance measurements are related to the cancellous bone thickness of the symphysis. These measurements were greater for Class II average-angle group. In high-angle subgroups, these values were smaller. As the incisors should be positioned within the cancellous bone, it may be said that lower incisors movement range in Class II malocclusion subjects is limited in high-angle cases compared to average-angle subjects.

The distance between the lower incisor root apex and the inner contour of the labial alveolar cortical bone (L1a-D) showed great variability between groups. In high-angle subgroups, the distance was relatively small. Similarly, Handelman[5] and Gracco et al.,[7] reported that the distance between the apex and internal surface of the vestibular cortex is greater in short face than in long face subjects. On the other hand, the difference of between groups regarding this measurement (L1a-E) was statistically not significant for the lingual side. But for all subgroups, apex to vestibular cortex distance was greater than apex to lingual cortex distance. This finding was in accordance with the findings of Gracco et al.[7] One might think that proclination of lower incisors with tipping may cause damage as the apex of the tooth is too close to the lingual cortex.[7]

Probing, periapical or bitewing radiographs and cephalometric radiographs are used for the assessment of bony support.[23] But, there are limitations of radiographic method, such as superimposition of the anatomic structures and difficulty to reproduce the angles over time.[24] Moreover, underestimation of the amount of the real bone loss was reported for X-ray assessment.[13] Cephalometric radiography is a limited tool for the assessment of inclination and thickness of the alveolar bone especially in the lower anterior alveolar region, because images of all structures overlap in 3D space thereby create an important enlargement error arise from the divergence of the x-ray beam.[7] The main advantage of CBCT is the ability to evaluate the real anatomy in three-dimensional, true-to-scale without superimpositions of the neighboring structures and distortions. On the other hand, secondary computerized reconstructions also provide qualitative and quantitative evaluation of bone surfaces, quantitative evaluation of the relationship between teeth and bone,[25] and the selection of the desired sections.[23]

Clinicians should be aware of the differences between different vertical facial growth directions in their treatment planning. The vertical growth pattern may play a more important role in the treatment of Class II malocclusions. . Movement range of lower incisors in high-angle Class II patients should be limited, compared to average-angle Class II group.

Conclusion

Within the limitations of this study, following conclusions may be drawn;

- The only statistically significant difference between Class I and Class II groups was the buccal alveolar bone thickness, which was thinner in Class II sample.
- Greater differences were found when the groups were divided into average- and high-angle subgroups.
- Lower incisors were more protrusive and proclined in Class II average-angle subgroup compared to other subgroups.

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FIGURE LEGENDS

Figure 1: Points identified on the symphysis and mandibular incisor

Figure 2: Angular measurements.

Figure 3: Length of arch measurements

Table I. Criteria for sample selection.

Inclusion criteria	Exclusion criteria
*Class I malocclusion (0º<ANB<4º) with bilateral Class I molar and canine relationship	*Class III skeletal or dental relationship
*Class II malocclusion (ANB>4º) with bilateral Class II molar and canine relationship	* Lesion or root canal tretament of lower incisors
*Normal or high angle vertical growth pattern (SN-GoGn ≥26 degrees)	*Partial and low-resolution images
*No congenitally missing or extracted teeth	*Congenitally missing or extracted teeth
*Permanent dentition	*Deciduous dentition
*Lack of orthodontic treatment	*Young people in or that had been under orthodontic treatment
*Mild to moderate crowding	*Severe crowding
*No head or neck injury	*Head or neck injury
Patienst without severe skeletal asymmetry	Patienst who has severe asymmetry

Table II: Means and standard deviations of the values compared between Class I and Class II patients.

Measurement	Class I (n=41)		Class II (n=38)		*P*
	Mean	SD	Mean	SD	
Age (years)	18,52	5,01	16,61	4,91	NS
ANB (degrees)	2,93	0,93	6,59	1,76	<0.001
SN-GoMe (degrees)	34,72	5,31	35,96	5,89	NS
L1-B perp (mm)	-0,85	2,56	-0,33	2,74	NS
IMPA (degrees)	94,78	8,20	98,07	7,71	NS
Labial alveolar bone angle (degrees)	86,69	11,09	87,01	10,76	NS
Lingual alveolar bone angle (degrees)	94,32	8,17	96,31	10,09	NS
D-C (mm)	1,40	0,47	1,09	0,39	0,003
E-F (mm)	1,92	0,55	1,98	0,48	NS
E-D (mm)	4,23	1,28	4,83	1,59	NS
F-C (mm)	7,56	1,51	7,91	1,83	NS
L1a-D (mm)	2,76	1,10	3,00	1,45	NS
L1a-E (mm)	1,46	0,91	1,82	0,80	NS
L1a-D/D-E	0,64	0,20	0,60	0,20	NS
L1a-E/D-E	0,35	0,20	0,39	0,20	NS

Table III: Descriptive statistics of the values compared between Class I and Class II subgroups and the result of multiple comparison test

Measurements	Class I Average-angle (A) n=25		Class I High-angle (B) n=16		Class II Average-angle (C) n=19		Class II High-angle (D) n=19		*Kruskal Wallis (p-value*	Multiple Comparison
	mean	SD	mean	SD	mean	SD	mean	SD		
Age (years)	19.72	5.13	16.65	4.31	16.30	4.35	16.93	5.52	NS	
ANB (°)	2.87	0.95	3.01	0.92	6.07	1.55	7.11	1.84	<0.001	
SN-GoMe (°)	31.13	3.31	40.32	1.62	30.96	3.64	40.95	2.36	<0.001	
L1-B perp (n	-0.47	2.36	-1.45	2.81	0.98	1.94	-1.65	2.84	0.007	C-A, C-B, C-D
IMPA (°)	94.81	7.46	94.73	9.49	101.03	6.83	95.11	7.56	0.046	C-A, C-B, C-D
Labial alveolar	86.73	11.78	86.63	10.31	89.55	7,06	84.47	13.22	NS	
Lingual alveolar	94.74	7.58	93.66	9.25	101.10	7.06	91.53	10.36	0.004	C-A, C-B, C-D
D-C (mm)	1.41	0.45	1.39	0.51	1.10	0.31	1.09	0.46	0.03	A-C, A-D
E-F (mm)	1.96	0.56	1.86	0.53	2.17	0.44	1.79	0.45	NS	
E-D (mm)	4.51	1.28	3.78	1.19	5.41	1.72	4.25	1.23	0.016	C-B, C-D
F-C (mm)	7.89	1.47	7.04	1.48	8.69	1.82	7.14	1.53	0.012	C-B, C-D
L1a-D (mm)	3.07	1.02	2.28	1.09	3.66	1.31	2.35	1.31	0.004	C-B, C-D
L1a-E (mm)	1.44	0.99	1.50	0.80	1.75	0.86	1.89	0.74	NS	

NS: not significant

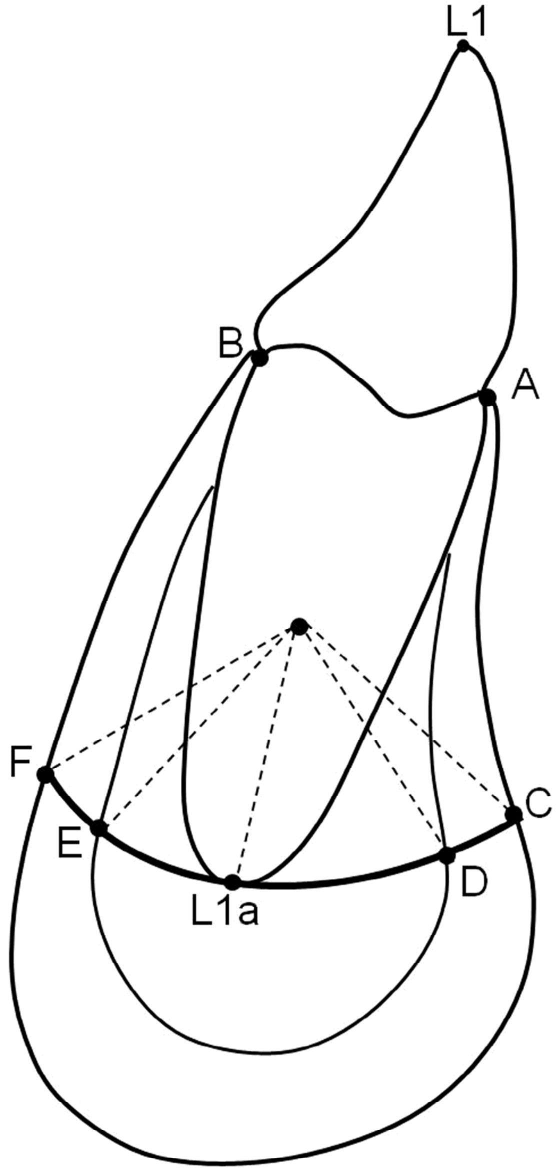

Figure 1: Points identified on the symphysis and mandibular incisor

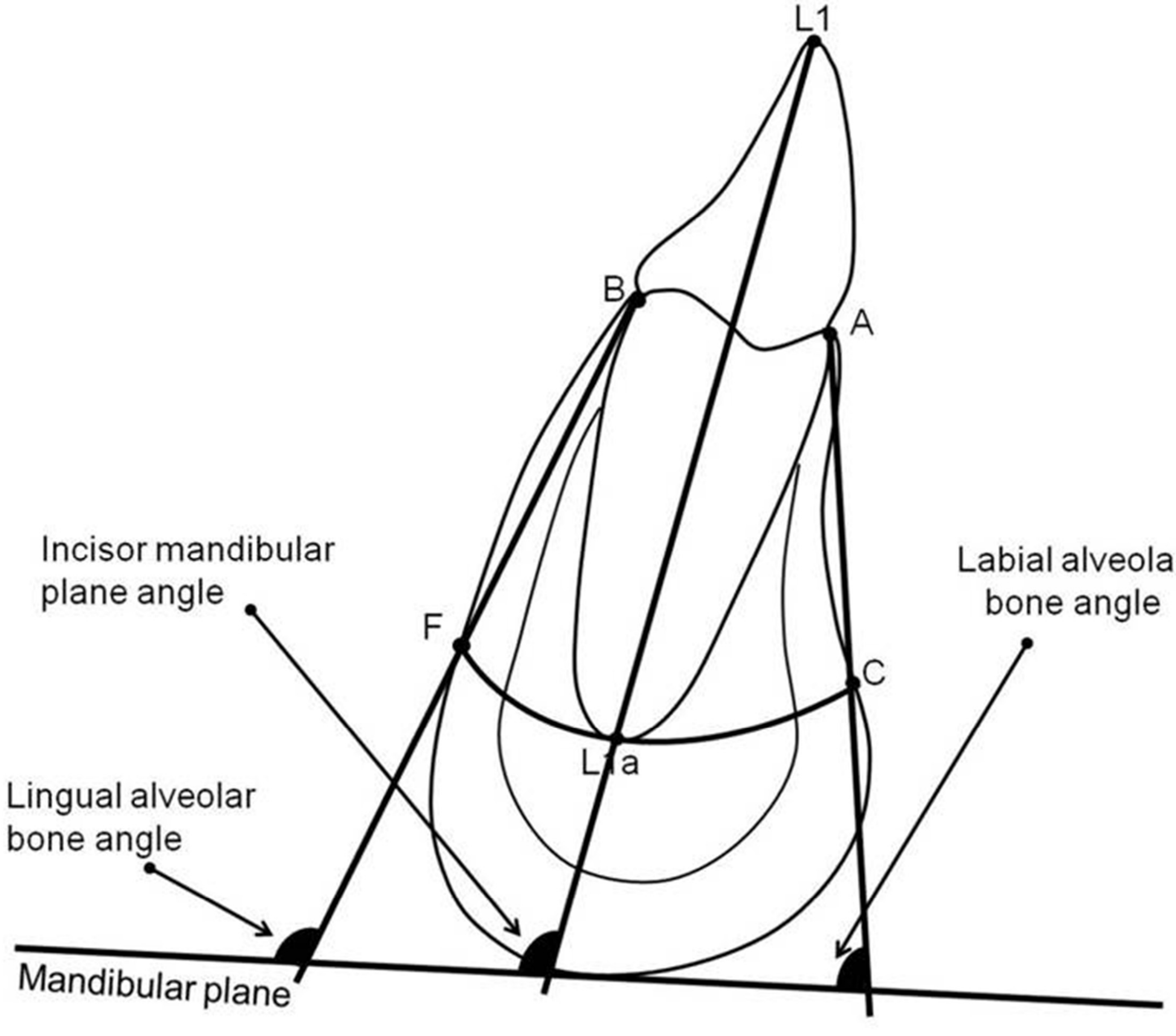

Figure 2: Angular measurements.

Figure 3: Length of arch measurements