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Research Article

Evaluation of Maxillary and Mandibular Labial Alveolar Bone of Incisors in Different Vertical Facial Patterns Using Cone Beam Computed Tomography

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Abstract

Objectives: The aim of the study was to investigate the thickness of maxillary and mandibular labial alveolar bone overlying incisors and the incisal inclination in different vertical facial patterns using cone-beam computed tomography.

Subjects and methods: Eighty-one CBCT scans were carried to evaluate thickness of the labial alveolar bone overlying maxillary and mandibular incisors and the incisal inclination for the following groups: Group I: normal vertical facial pattern. Group II: low vertical facial pattern. Group III: high vertical facial pattern.

Results: Low angled group showed a higher Labial Alveolar Bone thickness in the maxillary and mandibular arches than Normal and High angled groups. High group showed a higher inclination than Normal and Low groups. The inclination of the lower incisors according to L1/MP there was a statistically a non-significant difference in mean inclination in the three groups.

Conclusion: The thickness of the Labial Alveolar Bone was greater in both the upper and lower jaws for people with a low angle than for those with a normal or high angle. People with a high angle had more inclination than those with a normal or low angle. The inclination of the lower incisors according to L1/MP there was a statistically a non-significant difference in mean inclination in the three groups.

Keywords: Labial Alveolar Bone; CBCT; Facial Pattern; Skeletal Malocclusion

Introduction

Skeletal malocclusion may be treated by surgical treatment option or by orthodontic camouflage treatment option. In surgical treatment option, It's important to do presurgical orthodontic bydecompensate the inclination of incisors to get more favorable post-surgical results [1]. In contrast, the purely orthodontic treatment option, clinicians do more compensation by labio-lingual inclination of incisors [2]. Therefore, compensatory mechanism of sagittal malocclusion and quantitative dento-alveolar evaluation can provide critical information on the orthodontic treatment [3,4].

One of the keystones of orthodontic treatment planning is the position and inclination of themaxillary and mandibular incisors owing to the great impact on facial harmony and esthetics [3,5]. Therefore, antro-posterior positioning of incisors are limited by anatomy of the alveolar bone in maxillary and mandibular symphysis and periodontal status to prevent iatrogenic sequelae such as dehiscense or fenestration or resorption of incisors roots [6,7].

The CBCT imaging technique has qualitative and quantitative evaluation of teeth and bone relationship [8,9]. Therefore, it can provide better visualization of the alveolar bone and better assessment of bone thickness which is accurate and more reliable representations of alveolar bone dimensions [10]. There is a lack of studies regarding the labial maxillary and mandibular labial bone which is important for clinicians in anterior tooth movement in labio-lingual direction in subjects with different vertical facial pat-

tern. This may be due to the focus on the Inter-radicular cortical bone thickness at the vertical height in which mini-implants are commonly inserted for skeletal anchorage. The aim of the study was to investigate the thickness of maxillary and mandibular labial alveolar bone overlying incisors and the incisal inclination in different vertical facial patterns using cone-beam computed tomography.

Subjects and Methods

Study design and settings

The current study was retrospective cross-sectional study. It was conducted on unidentified Cone Beam Computed Tomography scans that were selected from the archive of Oral Radiology department, Faculty of Dentistry, Suez Canal University

Sample size calculation

This power analysis used alveolar bone thickness as the primary outcome. Based upon the results of Raber A., *et al.* (2019) [11], the mean values for the three groups were 3.98, 3.43 and 4.48 mm, respectively. Using alpha (α) level of (5%), β level of 0.8 (Power = 80%) and assuming the standarddeviation within each group = (1); the effect size (f) was (0.358) and the minimum estimated sample size was a total of 81 subjects. Sample size calculation was performed using G*Power version 3.1.9.2.

Sample selection

- Inclusion criteria: Unidentified full skulls CBCTs. The age of selected patient's scans was above 15 years old. CBCT of high quality with no artifact obscuring the region of the incisors. No orthodontics appliances seen in the CBCT scans. Full set of permanent dentitions (no missing teeth except for the third molars). Male or female patient's Scans.
- Exclusion criteria: CBCTs of patients have previous orthodontic treatment in the past. CBCTs of patients have systematic bone disease or any syndrome. CBCTs of patients have root resorption or impacted teeth.

Grouping criteria

Out of 145 CBCT scans we took 81 CBCT scans which was divided equally into three groups (27 scans in each group) according to their vertical facial pattern angles was extracted from reformatted lateral cephalometry from cone beam computed tomography:

- **Group I:** The inclusion criteria for this group is to have: SN/Mandibular plane angle is within thenormal range. (32 +/- 4). Y axis to Frankfort plane angle is within the normal range. (61+/-4) Frankfort to Mandibular plane angle is within the normal range. (25 +/-3) Gonial angle is within thenormal range. (124 +/-5) Cranial base angle is within the normal range. (132 +/-5)
- **Group II:** The inclusion criteria for this group is to have SN/Mandibular plane angle is decreased. (< 27). Y axis to Frankfort plane angle is decreased. (< 57). Frankfort to Mandibular plane angle is decreased. (< 19). Gonial angle is decreased. (< 119). Cranial base angle is decreased. (< 127)
- **Group III:** The inclusion criteria for this group is to have SN/Mandibular plane angle is increased. (>37). Y axis to Frankfort plane angle is increased. (>66). Frankfort to Mandibular plane angle is increased. (>29). Gonial angle is increased. (>129). Cranial base angle is increased. (>138).

Radiographic measurements

The CBCT scans were performed to the long axis of each upper and lower incisor from the incisal edge to root apex. Labial bone thickness was measured at the apex and at the midpoint on each maxillary and mandibular incisor by a linear measurement perpendicular to the long axis from the labial bone surface to the most anterior root surface at two points. The axial inclination of maxillaryincisor was measured relative to Frankfort horizontal plane, SN and palatal plane. The axial inclination of mandibular incisor was measured relative to mandibular plane.

Images from CBCT examinations was acquired in a digital DICOM format then imported toDolphin software application (Version 11.5; Dolphin Imaging and Management Systems, Chatsworth, CA) where evaluation of the thickness of the labial alveolar bone overlying maxillary and mandibular incisors and the incisal inclination was carried out for the following groups.

- Left maxillary and mandibular incisors were adjusted on sagittal, coronal and axial slices of CBCT scan to evaluate the labial alveolar bone thickness of those detected incisors for each group (normal, low and high angled groups)
- Points at the most anterior surface of left maxillary and mandibular incisors were detected on sagittal slice to evaluate the labial alveolar thickness at these points. (apical, mid and cervical) points
- The thickness of labial alveolar bone at the apex, midpoint and cervical point of leftmaxillary and mandibular incisors by a linear measurement perpendicular to the long axis from the labial bone surface to the most anterior root surface at three points.

- Right maxillary and mandibular incisors were adjusted on sagittal, coronal and axial slicestoevaluate the labial alveolar bone thickness of those detected incisors for each group (normal,low and high angled groups)
- Points at the most anterior surface of right maxillary and mandibular incisors were detected on sagittal slice to evaluate the labial alveolar thickness at these points. (apical, mid and cervical) points
- Thickness of labial alveolar bone evaluated and measured in mm as a linear measurement at these points of right maxillary and mandibular incisors on each
- The average of the thicknesses of labial alveolar bone between left incisor and right incisorof the maxillary and mandibular arches to get mean labial alveolar bone thickness. (mean +/- SD)
- Angular measurements of incisal inclination of maxillary incisors related to SN plane,Frankfort plane and palatal plane and incisal inclination of mandibular incisors related to mandibular plane which measured by tracing of reformatted lateral cephalometry fromCBCT for each group.
- The axial inclination of maxillary incisor was measured relative to Frankfort horizontal plane, SN and palatal plane and the axial inclination of mandibular incisor was measured relative to mandibular plane.

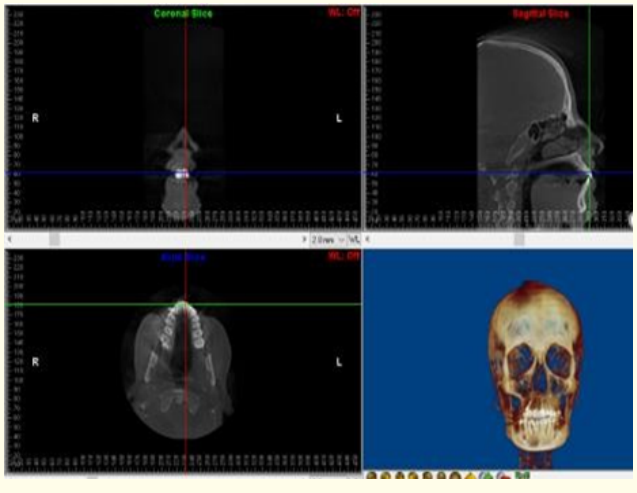

Figure 1: Left upper and lower central incisors detected on coronal, sagittal and axial slices.

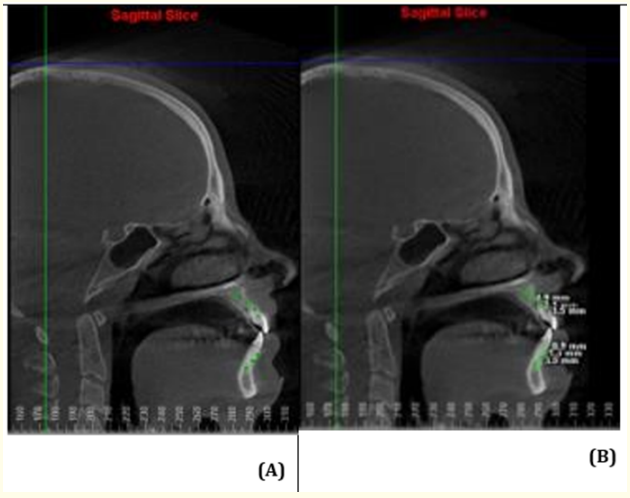

Figure 2: (A) Points at left upper and lower incisors, (B) Linear measurements of left upper and lower incisors.

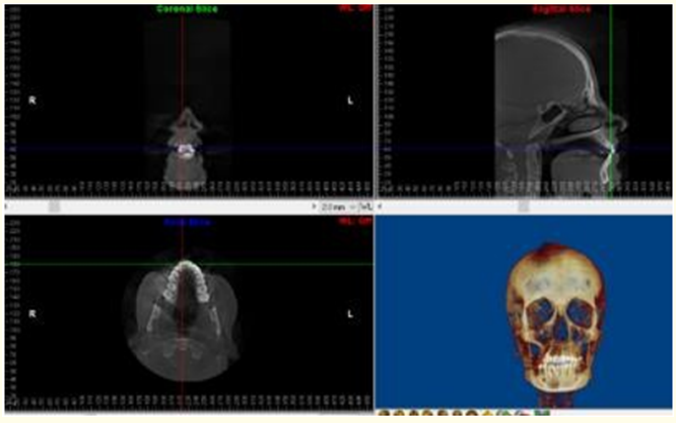

Figure 3: Right upper and lower central incisors detected on coronal, sagittal and axial slices.

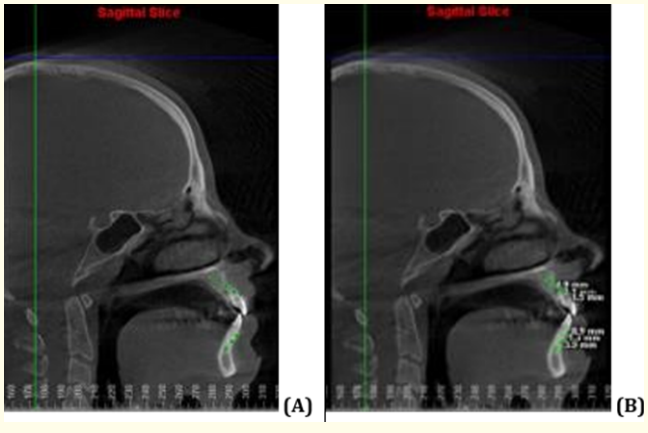

Figure 4: (A) Points at right upper and lower incisors, (B) Linear measurements of right upper and lower incisors.

Statistical analysis

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0. (Armonk, NY: IBM Corp). The Shapiro-Wilk test was used to verify the normality of distribution Quantitative data were described using range (minimum and maximum), mean, standard deviation, median and Confidence interval of mean. Significance of the obtained results was judged at the 5% level. The used tests were One-way ANOVA test for normally distributed quantitative variables, to compare between more than two groups, and Post Hoc test (Tukey) for pairwise comparisons. Pearson coefficient to correlate between two normally distributed quantitative variables.

Results

Demographic data (Groups according to gender)

Table (1) Comparison between the three studied groups according to gender. Group I (normal angle) had 9 males and 18 females, Group II (low angle) had 17 males and 10 females, while group III (High angle) had 10 males and 17 females. There was statistically non-significant difference between gender distributions in the THREE groups (P = 0.058).

	Normal (n = a27)	Low (n = 27)	High (n = 27)	$\chi 2$	P
Gender				5.700	0.058
Male	9 (33.3%)	17 (63.0%)	10 (37.0%)		
Female	18 (66.7%)	10 (37.0%)	17 (63.0%)		

Table 1: Comparison between the three studied groups according to gender.

$\chi 2$: **Chi square test**

p: p value for comparing between the three studied groups.

Intra-class correlation coefficient data

Table (2) summarizes the Intra class Correlation coefficient between the two readings. Intraclass Correlation Coefficient (ICC) values less than 0.5 are indicative of poor similarity, values between 0.5 and 0.75 indicate moderate similarity, values between 0.75 and 0.9 indicate good similarity, andvalues greater than 0.90 indicate excellent similarity. A high ICC was greater than 0.90 indicates high similarity and agreement between the two readings.

	Group	ICC coefficient	95% C. I	p	Level of agreement
Apical Upper	Normal	0.951	0.895-0.977	<0.001*	Excellent
	Low	0.993	0.983-0.997	<0.001*	Excellent
	High	0.992	0.983-0.997	<0.001*	Excellent
Apical Lower	Normal	0.930	0.852 0.968	<0.001*	Excellent
	Low	0.994	0.986-0.997	<0.001*	Excellent
	High	0.997	0.993-0.999	<0.001*	Excellent
Middle Upper	Normal	0.750	0.526-0.877	<0.001*	Good
	Low	0.985	0.964-0.993	<0.001*	Excellent
	High	0.973	0.940-0.988	<0.001*	Excellent
Middle Lower	NormalLow	0.826 0.983	0.656 0.917 0.959-0.992	<0.001* <0.001*	Good Excellent
	High	0.990	0.977-0.995	<0.001*	Excellent
Cervical Upper	NormalLow	0.950 0.957	0.878 0.978 0.903-0.981	<0.001* <0.001*	Excellent
	High	0.969	0.932-0.986	<0.001*	Excellent
Cervical Lower	NormalLow	0.994 0.968	0.987- 0.997 0.927-0.986	<0.001* <0.001*	Excellent
	High	0.918	0.827-0.962	<0.001*	Excellent
U1/SN	NormalLow	0.971 0.832	0.937- 0.987 0.665-0.920	<0.001* <0.001*	Excellent Good
	High	0.878	0.746-0.943	<0.001*	Good

U1/FH	Normal	0.928	0.846-0.967	<0.001*	Excellent
	Low	0.897	0.785-0.952	<0.001*	Good
	High	0.879	0.749-0.944	<0.001*	Good
U1/PL	NormalLow	0.951 0.907	0.895- 0.978 0.808-0.956	<0.001* <0.001*	Excellent
	High	0.931	0.851-0.968	<0.001*	Excellent
L1/MP	Normal	0.960	0.939- 0.981	<0.001*	Excellent
	Low	0.969	0.936- 0.983	<0.001*	Excellent
	High	0.986	0.989- 0.996	<0.001*	Excellent

Table 2: ICC coefficient for different parameters in each group (n = 27).

CI: Confidence Interval; LL: Lower Limit; UL: Upper Limit

*: Statistically significant at p ≤ 0.05

Measurements in sagittal plane

Linar measurements

Labial alveolar bone thickness

- **At apical point**: Comparison between the three studied groups according to apical point in each arch. In the upper: Labial Alveolar Bone thickness in normal group was 3.23 ± 0.65, Low was 3.62 ± 0.64, and in high was 2.73 ± 0.56. In the Lower: Labial Alveolar Bone thickness in normal group was 3.74 ± 0.58, Low was 4.13 ± 0.74, and in high was 2.96 ± 0.84. At Upper: there was a statistically A significant difference in mean Labial Alveolar Bone thickness in the three groups (p < 0.001*). Low group showed a higher Labial Alveolar Bone thickness than Normal and High groups.
- **At middle point**: Comparison between the three studied groups according to Middle point ineach arch. In the upper: Labial Alveolar Bone thickness in normal group was 1.16 ± 0.28, Low was 1.61 ± 0.44, and in high was 1.01 ± 0.29. In the Lower: Labial Alveolar Bone thickness in normal group was 1.19 ± 0.34, Low was 1.43 ± 0.42, and in high was 1.08 ± 0.47. At Upper: there was a statistically A significant difference in mean Labial Alveolar Bone thickness in the three groups (p < 0.001*). Low group showed a higher Labial Alveolar Bone thickness than Normal and High groups.
- **At cervical region**: Comparison between the three studied groups according to cervical pointin each arch. In the upper: Labial Alveolar Bone thickness in normal group was 0.83 ± 0.24, Low was 1.03 ± 0.21, and in high was 0.71 ± 0.27. In the Lower: Labial Alveolar Bone thickness in normal group was 0.76 ± 0.22, Low was 0.99 ± 0.24, and in high was 0.91 ± 1.24. At Upper: there was a statistically A significant difference in mean Labial Alveolar Bone thickness in the three groups (p < 0.001*). Low group showed a higher Labial Alveolar Bone thickness than Normal and High groups.

Angular measurements

Comparison between the three studied groups according to inclination of upper incisors U1/SN,U1/FH and U1/PL in each site. In U1/SN: inclination in normal group was 104.5 ± 3.50, Low was 102.6 ± 4.56, and in high was 108.1 ± 6.31. In U1/FH: inclination in normal group was 113.7 ± 3.01, Low was 110.1 ± 4.98, and in high was 118.7 ± 6.47. In U1/SN: inclination in normal group was 112.2 ± 2.26, Low was 108.0 ± 4.48, and in high was 116.5 ± 8.72. At U1/SN, U1/FH, and U1/PL: there was a statistically A significant difference in mean inclination in the three groups (p < 0.001*). High group showed a higher inclination than Normal and Low groups.

Comparison between the three studied groups according to inclination of lower incisors L1/MP in each site. In L1/MP: inclination in normal group was 96.37 ± 3.41, Low was 95.73 ± 2.95, and in high was 94.55± 3.37. there was a statistically a nonsignificant difference in mean inclination in the three groups (p = 0.122).

Discussion

Labial alveolar bone thickness of maxilla and mandible

The current study showed there was a statistically significant difference in mean thickness of labial alveolar bone overlying the maxillary and mandibular incisors in the three groups (p 0.001*). Low- angled facial pattern groups showed a higher labial alveolar bone thickness at the three points (apical point, middle point, and cervical point) than normal and high-angled pattern groups, which was consistent with [12,13].

The present study showed that the low angle group which have short face type showed higher bone thickness in anterior region of maxilla and mandible than the high angle group which have long face type. This was similar to several studies including [14,15].

	Normal(n = 27)	Low (n = 27)	High (n = 27)	F	P	Post Hoc Test		
						p1	p2	p3
ApicalUpper	3.23 ±0.65	3.62 ± 0.64	2.73 ±0.56	14.284*	< 0.001*	0.060	0.010*	< 0.001*
Lower	3.74 ± 0.58	4.13 ± 0.74	2.96 ±0.84	18.195*	< 0.001*	0.134	< 0.001*	< 0.001*
MiddleUpper	1.16 ±0.28	1.61 ± 0.44	1.01 ±0.29	21.788*	< 0.001*	< 0.001*	0.236	< 0.001*
Lower	1.19 ± 0.34	1.43 ± 0.42	1.08 ±0.47	5.002*	0.009*	0.087	0.620	0.008*
Cervical Upper	0.83 ±0.24	1.03 ± 0.21	0.71 ±0.27	12.848*	< 0.001*	0.008*	0.134	< 0.001*
Lower	0.76 ± 0.22	0.99 ± 0.24	0.91 ±1.24	0.657	0.521	–	–	–

Table 3: Comparison between the three studied groups according to apical, Middle andCervical points in each arch.

Data was expressed using Mean ± SD. SD: Standard deviation

F: F for One way ANOVA test, Pairwise comparison bet. each 2 groups was done using Post HocTest (Tukey)

p: p value for comparing between the three studied groups p1: p value for comparing between Normal and Low p2: p value for comparing between Normal and High p3: p value for comparingbetween Low and High

	Normal(n = 27)	Low (n = 27)	High (n = 27)	F	p	Post Hoc Test		
						p1	p2	p3
U1/SN	104.5 ±3.50	102.6 ±4.56	108.1 ± 6.31	8.664*	< 0.001*	0.333	0.024*	< 0.001*
U1/FH	113.7 ±3.01	110.1 ±4.98	118.7 ± 6.47	19.721*	< 0.001*	0.030*	0.001*	< 0.001*
U1/PL	112.2 ±2.26	108.0 ±4.48	116.5 ± 8.72	14.424*	< 0.001*	0.027*	0.021*	< 0.001*
L1/MP Mean ± SD.	96.37 ± 3.41	95.73 ± 2.95	94.55 ± 3.37	2.165	0.122	0.755	0.107	0.381

Table 4: Comparison of upper incisors inclination between the three studied groupsaccording to U1/SN, U1/FH and U1/PL, and L1/MP.

Data was expressed using Mean ± SD. SD: Standard deviation.

F: F for One way ANOVA test, pairwise comparison bet. each 2 groups was done using Post HocTest (Tukey)

p: p value for comparing between the three studied groups.

p1: p value for comparing between Normal and Low p2: p valuefor comparing between Normal and High p3: p value for comparing between Low and High

*: Statistically significant at p ≤ 0.05.

Also, previous research such as [16,17], shown that the short-face type group had larger bone thickness in the anterior region of the maxilla and mandible than the long-face type group. On the other hand [18] the thickness of the buccal and lingual bone is very similar and does not differ between the facial patterns.

Mandibular labial alveolar bone thickness

Our study showed that in the mandibular Labial Alveolar Bone thickness in normal group was 3.74 ± 0.58, Low was 4.13 ± 0.74, and in high was 2.96 ± 0.84. there was a statistically A significant difference in mean Labial Alveolar Bone thickness in the three groups ($p < 0.001^*$). Low angled group and normal group showed a higher Labial Alveolar Bone thickness at the three points (apical point, middle point, and cervical point) than High angled group. This was similar to [19] found in skeletal Class III adults with different vertical patterns. Also, [13] discovered that the high-angle group had considerably thinner alveolus in the lower arch than the low-angle

group at almost all sites. Furthermore, the high-angle group exhibited the shortest mean distance between the toothapex and the labial cortical alveolar bone at (apical point) in the incisal area. This was comparableto what [17] reported. Moreover [14] and [20] discovered a link between face type and mandibular cortical bone thickness. On the other hand, when comparing patients with varied face growth patterns, research have found inconsistent results for alveolar features [21]. showed 80 CBCT scansand discovered no statistically significant differences in the total and cancellous areas of themandibular symphysis across facial types when alveolar bone was considered.

Our study showed that in the maxillary Labial Alveolar Bone thickness in normal group was 3.23 ± 0.65, Low was 3.62 ± 0.64, and in high was 2.73 ± 0.56. there was a statistically A significant difference in mean Labial Alveolar Bone thickness in the three groups ($p < 0.001^*$). Low group showed a higher Labial Alveolar Bone thickness at the three points (apical point, middle point, and cervical point) than Normal and High groups. This was in agreement with [3,13,15,16]. At the upper incisors area, facial type is statistically significantly connected with both alveolar bonethickness and the distance between the root apex and the lingual cortex. This was in contrast to [23]. discovered that alveolar bone at the apex was substantially thinner in skeletal Class III malocclusion participants than in normal occlusion subjects. The mean value of alveolar bone thickness at the tooth apex on the maxillary labial side indicated no statistically significant variations between groups.

Antro-posterior movements limitations

Our study that showed labial alveolar bone thickness in low angle facial pattern thicker than high angle facial pattern which Therefore, it was suggested that the scope of antero-posterior movements of the incisors would be increase in low angle patients which had a great range of antro-posterior movement and less liability to dehiscences and fenestration. This was supported by [24]. Moreover, according to [25], using higher resolution CBCT voxels can increase measurement accuracy. The patients with a high angled facial pattern had slightly narrower cortical bone than those with a low angled facial pattern, indicating that subjects with this facial type have less dense buccal cortical bone in the maxillary and mandibular alveolar processes. As a result, it is recommended that antero-posterior movements be limited in hyperdivergent patients to avoid fenestration and dehiscence.

Inclination of maxillary and mandibular incisors

The orthodontic treatment aimed at improving the slope of the maxillary incisors resulted in a better relationship with the face and growth axis. This correlation demonstrates the relationship betweenan optimal position of the maxillary incisors compared to the individual's matching vertical pattern. our study showed the measurements at U1/SN, U1/FH, and U1/PL: there was a statistically Asignificant difference in mean inclination in the three groups ($p < 0.001^*$). High groups showed ahigher inclination than Normal and Low groups. This was in agreement with [5]. On the other hand [26], maxillary incisor inclination did not connect with face and growth axis in an adult populationprior to orthodontic treatment. However, there were larger associations in the post-treatment evaluation and demonstrated that after orthodontic treatment, all maxillary incisor measurements,including I/PP, I/SN, I/H, I/NBa, and I/NA, had substantial positive correlations, indicating achange into a more harmonic inclination relative to the growth pattern, and thus to face type.

The present study showed that measurements according to L1/MP: inclination in normal group was 96.37 ± 3.41, Low was 95.73 ± 2.95, and in high was 94.55 ± 3.37. there was a statistically a non-significant difference in mean inclination in the three groups ($p = 0.122$). This was similar to [27]. Moreover, [28] showed that the axial inclinations of the upper and lower central incisors of the study had no significant differences ($p > 0.05$).

Conclusion

The thickness of the Labial Alveolar Bone was greater in both the upper and lower jaws for people with a low angle than for those with a normal or high angle. People with a high anglehad more inclination than those with a normal or low angle. The inclination of the lower incisors according to L1/MP there was a statistically a non-significant difference in mean inclination in the three groups.

So our study helps to provide the orthodontists via important knowledge about labial alveolar bone thickness in different facial types to plan proper treatment strategies to preventiatrogenic sequelae such as dehiscence or fenestration.

Also help the periodontists to predict the cause of periodontal defect related to different labial alveolar bone thickness in different vertical facial types. Also help the implantologists to predict and evaluate the success or failure rate of the immediate implant according to the remaining labial alveolar bone thickness after extraction in different facial types

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