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Determination of buccal cortical bone thickness for mini-screws placement in horizontal growth type patients by cone beam computed tomography

Abstract

Background: Determination of cortical bone thickness is important because it is the major determinant of initial stability of a micro implant.

Aim: This study was performed to measure the available buccal cortical bone thickness between first and second bicuspids and first molars and between first and second molars as the suggested site for mini-implant placement in horizontal growth type patients by using cone beam computed tomography (CBCT).

Methods: Three dimensional CBCT images of twelve patients (5males, 7females; age range, 19-25years; average age, 21.7years) were examined. Maxillary and mandibular cortical bone thickness between first and second bicuspids and first molars and between first and second molars was measured at 8mm level from cementoenamel junction (CEJ).

Results: Maxillary buccal cortical bone thickness ranged from 1.2 to 2.4mm and mandibular buccal cortical bone thicknesses was 1.1 to 2.3mm.

Conclusion: According to our results the greatest Buccal Cortical Bone Thickness's values were between second premolar and first molar, whereas the least were found between first and second left molars.

Keywords: mini-screws, cortical bone thickness, horizontal growth type, CBCT

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Introduction

Anchorage control is a critical step in orthodontics and a major aspect of orthodontic biomechanics. Different extra dental anchorage strategies, such as implants, miniplates and zygomaligatures have been introduced.[1] However, limitations of these methods, such as poor compliance, high cost and tooth movement, have prompted orthodontists to resort to miniscrews,[2] which are modified orthopedic screws. Mini screws have been found to successfully withstand orthodontic forces.[3,4] There, advantages include low cost patient comfort, easy insertion and removal, shorter treatment times, immediate loading, fewer complications, complete recovery & restoration of function.[5,6] However, clinicians have experienced mini-screw loosening during treatment and it did not reach the high success rates associated with dental implants.[7–9] Immediate loading can be considered a risk factor for failure since a load is applied during healing and primary stability can be adversely affected. The primary stability of the orthodontic mini-screw might be supported mainly by mechanical retention. Primary stability is determined by the bone properties, surgical technique and implant size and design.[10,11]

Screw mobilization mechanisms are strongly correlated with the structural response of bony tissue to the mini-screw and the stress/strain field developing within the mini-screw and surrounding bone. It was reported that the jaw of placement showed significant differences in terms of the failure rate.[12,13] The bone quality impact on dental implant therapy has been studied. A critical component of treatment planning in dental implant therapy is the amount of available bone. Recent findings suggested that the cortical bone thickness played a greater role in initial implant stability than the implant length and pointed out that adequate cortical engagement is necessary when placing dental implants. Likewise, the primary stability of the immediate loading orthodontic mini-screw was also dominated by the mechanical retention between the cortical bone thickness and mini-screws.[14,15]

A number of studies have attempted to evaluate optimal locations for miniscrews placement by using various methods including panoramic radiographs, computed tomography, digital volume tomography based on the cone-beam technique.[15,16] In recent years CBCT which offers clear 3-dimensional (3D) images with small voxel size, has been widely used in head and neck diagnoses, orthodontics and implant dentistry and for accurate surgical guidance for mini-screws placement.[17,18] With the aid of 3D CBCT images, the purpose of the present investigation was to determine the optimal buccal cortical bone thickness of mini-screws placement in the posterior maxilla and mandible in horizontal growth type's patients.

Materials and methods

Patient selection

The sample consisted of initial 3D images of 12patients (5men, 7women, age range: 19-25years; average age: 21.7years) selected from a larger sample of adults at the Orthodontic Department Faculty of Dentistry Damascus University who were planned to have an orthodontic mini-screws in the maxillary or mandibular buccal segment between first and second bicuspids and first molars and between first and second molars. The subjects were not divided by age because of the small sample size. Patients were examined at the Diagnostics Imaging Center. We obtained their consent to participate in this study before the CBCT images were taken. Images were taken with an iCAT cone beam 3D dental imaging system (Imaging Sciences International, Hatfield, PA, US) at 120kVp 5mA, scanning time 4-5sec and slice thickness 1mm.

Patient selection criteria were as follows:

a. permanent dentition; all teeth present except the third molars
b. Complete eruption of crowns
c. No diseases affecting bone density(bone resorption)
d. No or moderate posterior crowding
e. No large metal restorations (including crowns and fillings that produce scatter and interfere with 3D radiographic evaluation).

Methods

The 3D volumetric images were generated by the iCAT software. To minimize measurement errors produced from non-standardized head postures, all images were oriented using a standardized protocol in which the palatal plane was aligned parallel to the horizontal axis supplied by the software, and the nasal septum was aligned parallel to the vertical axis. The slicing angle would be adjusted accordingly. All measurements were made at preset magnification (4times), picture brightness and contrast.

Measurements

A lateral cephalometric photo was obtained from the CBCT image to determine the horizontal growth type of the patient, then for each inter radicular space; the buccal cortical bone was measured between first and second bicuspids and first molars and between first and second molars at 8mm level from cementoenamel junction (CEJ) (Figure 1). A total of 144 measurements were recorded in each of the mandibular and in maxilla.

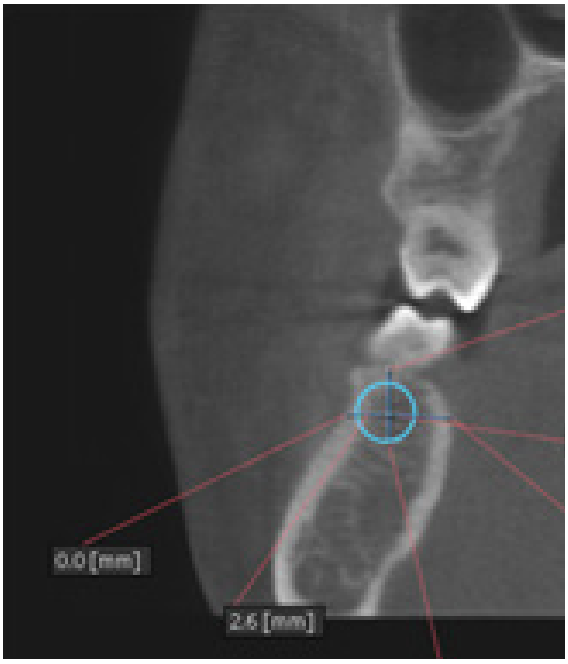

Figure 1 Measurements of buccal cortical bone at level 8mm from CEJ.

Statistical analysis

Descriptive analysis was used to obtain the mean and standard deviation (SD) of all the studied measurements. One-Way ANOVA test was applied to know if there were significant differences in Buccal Cortical Bone Thickness values between Studied Zones. (P-value<0.05) was considered significant and highly significant at (p-value<0.01).

Results

In the maxilla, average buccal cortical bone thickness at 8mm level ranged from 1.2 to 2.4mm (SD, 0.1-0.24) by the ANOVA test Significant at (p-value<0.01). In the mandible, average buccal cortical bone thickness at 8mm level ranged from 1.1 to 2.3mm (SD, 0.14-0.24) by the ANOVA test Significant at (p-value<0.01) (Table 1). All calculated P-values were much lower than 0.05, so we can conclude at 95% of confidence level that there is significant differences between at least two subgroups of the Studied Zone variable whatever the Studied location was, so we apply Bonferroni Pair wise to Compare between Studied Zone subgroups according to Studied Location variable (Table 2). P-values of pair wise comparison between first and second bicuspids and first and second molars subgroups were much greater than 0.05 in both Right Maxillary and Right Mandibular locations. So we can conclude at 95% of confidence level that there were no significant differences in Buccal Cortical Bone Thickness between first and second bicuspids and first and second molarssugroups in both right maxillary and right mandibular locations.

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All other P-values were lower than 0.05, So we can conclude at 95% of confidence level that there were significant differences in Buccal Cortical Bone Thickness values between the according Studied Zone subgroups. According algebraic signs indicate that Buccal Cortical Bone Thickness's values in second premolar and first molar subgroup were higher than those of the tow other Zone subgroups (first and second bicuspids, first and second molars) whatever the studied location was. Buccal Cortical Bone Thickness's values in first and second bicuspids subgroup were higher than those of first and second molars subgroup in both Left Maxillary and Left Mandibular locations. Then, we applied One-Way ANOVA test to know if there were significant differences in Buccal Cortical Bone Thickness between Studied Location subgroups (Right Maxillary, Left Maxillary, Right Mandibular, and Left Mandibular) according to Studied Zone variable. And it shows that all P-values were greater than 0.05 whatever the Studied Zone was, so we can conclude at 95% of confidence level that there were no significant differences in Buccal Cortical Bone Thickness between Studied Location subgroups (Right Maxillary, Left Maxillary, Right Mandibular and Left Mandibular) whatever the studied zone was (Table 3 & 4).

Table 1 One-way ANOVA test results

Studied variable = buccal cortical bone thickness (in mm)									
Studied location	**Studied zone**	**N**	**Mean**	**Std. dev.**	**Std errs.**	**Min**	**Max**	**F**	**P value**
	PM1-PM2	12	1.48	0.11	0.03	1.3	1.7		
Right-maxillary	PM2-M1	12	1.90	0.19	0.06	1.6	2.4	35.879	0.000**
	M1-M2	12	1.40	0.16	0.05	1.2	1.7		
	PM1-PM2	12	1.54	0.18	0.05	1.2	1.9		
Left-maxillary	PM2-M1	12	1.88	0.24	0.07	1.4	2.1	25.033	0.000**
	M1-M2	12	1.32	0.15	0.04	1.2	1.7		
	PM1-PM2	12	1.51	0.14	0.04	1.3	1.7		
Right-mandibular	PM2-M1	12	2.03	0.17	0.05	1.7	2.3	48.048	0.000**
	M1-M2	12	1.42	0.19	0.05	1.2	1.7		
	PM1-PM2	12	1.59	0.22	0.06	1.3	2		
Left-mandibular	PM2-M1	12	2.04	0.15	0.04	1.8	2.3	36.439	0.000**
	M1-M2	12	1.34	0.23	0.07	1.1	1.9		

*: Significant at (p-value<0.05), **: Significant at (p-value<0.01)

Table 2 Bonferroni pair wise comparisons results

Studied variable = buccal cortical bone thickness (in mm)					
Studied location	**Zone (I)**	**Zone (J)**	**Mean difference (I-J)**	**Std. error**	**P value**
Right-maxillary	PM1-PM2	PM2-M1	-0.43	0.06	0.000**
		M1-M2	0.08	0.06	0.742
	PM2-M1	M1-M2	0.50	0.06	0.000**
Left-maxillary	PM1-PM2	PM2-M1	-0.33	0.08	0.001**
		M1-M2	0.23	0.08	0.023*
	PM2-M1	M1-M2	0.56	0.08	0.000**
Right-mandibular	PM1-PM2	PM2-M1	-0.53	0.07	0.000**
		M1-M2	0.09	0.07	0.558
	PM2-M1	M1-M2	0.62	0.07	0.000**
Left-mandibular	PM1-PM2	PM2-M1	-0.45	0.08	0.000**
		M1-M2	0.25	0.08	0.015*
	PM2-M1	M1-M2	0.70	0.08	0.000**

*: Significant (p-value<0.05), **: Significant at (p-value<0.01)

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Table 3 One-way ANOVA test results

Studied variable = buccal cortical bone thickness (in mm)									
Studied zone	**Studied location**	**N**	**Mean**	**Std. dev.**	**Std. errs.**	**Min**	**Max**	**F**	**P value**
PM1-PM2	Right-maxillary	12	1.48	0.11	0.03	1.3	1.7	1.046	0.382
	Left-maxillary	12	1.54	0.18	0.05	1.2	1.9		
	Right-mandibular	12	1.51	0.14	0.04	1.3	1.7		
	Left-mandibular	12	1.59	0.22	0.06	1.3	2		
PM2-M1	Right-maxillary	12	1.90	0.19	0.06	1.6	2.4	2.516	0.071
	Left-maxillary	12	1.88	0.24	0.07	1.4	2.1		
	Right-mandibular	12	2.03	0.17	0.05	1.7	2.3		
	Left-mandibular	12	2.04	0.15	0.04	1.8	2.3		
M1-M2	Right-maxillary	12	1.40	0.16	0.05	1.2	1.7	0.798	0.502
	Left-maxillary	12	1.32	0.15	0.04	1.2	1.7		
	Right-mandibular	12	1.42	0.19	0.05	1.2	1.7		
	Left-mandibular	12	1.34	0.23	0.07	1.1	1.9		

*: Significant at (p-value<0.05), **: Significant at (p-value<0.01)

Table 4 Standard deviation for the cephalometric variables with patient growth type

Studied variable	**Gender**	**N**	**Minimum**	**Maximum**	**Mean**	**Std. deviation**
SNA	Male	5	78.1	85.5	81.18	2.88
	Female	7	75.6	86.3	82.47	3.59
	All subjects	12	75.6	86.3	81.93	3.24
SNB	Male	5	73.4	84.2	77.44	4.48
	Female	7	73.2	84.4	79.10	4.26
	All subjects	12	73.2	84.4	78.41	4.23
ANB	Male	5	-1.8	8.7	3.74	4.84
	Female	7	-3.9	9.9	3.37	4.45
	All subjects	12	-3.9	9.9	3.53	4.40
NSAr	Male	5	115	127.9	123.82	5.09
	Female	7	106.6	127.9	117.80	9.02
	All subjects	12	106.6	127.9	120.31	7.96
SArGo	Male	5	135.5	154.1	146.68	7.67
	Female	7	140.3	149.2	144.19	3.48
	All subjects	12	135.5	154.1	145.23	5.45
ArGoMe	Male	5	113.5	129.3	122.12	5.81
	Female	7	122.4	135	126.01	4.95
	All subjects	12	113.5	135	124.39	5.45
Bjork's Sum	Male	5	390.4	393.7	392.62	1.29
	Female	7	378.4	393.5	388.00	5.56
	All subjects	12	378.4	393.7	389.93	4.81
S_Go	Male	5	68.1	95.06	82.21	11.69
	Female	7	68.4	82.8	74.71	5.34
	All subjects	12	68.1	95.1	77.84	8.96
N_Me	Male	5	104.2	138.3	117.37	13.64
	Female	7	101.7	124	113.24	7.22
	All subjects	12	101.7	138.3	114.96	10.03
Jarabac	Male	5	65.4	75.7	69.92	3.79
	Female	7	59.2	72.3	66.07	4.26
	All subjects	12	59.2	75.7	67.67	4.36

Discussion

In our study we used CBCT as a guideline when CT imaging is not possible and also since the effective dose of radiation for CBCT scans is much lower than for traditional computed tomography scans. Many factors could affect the success rates and effectiveness of mini-screws. Some of these factors are implant related (type, diameter, and length of the implant), patient related (sex, age, physical status), surgical related (direction of mini-implant placement and placement torque), location related (peri-implant bone quantity, cortical bone thickness, keratinized versus oral mucosa) the exact role of these factors, however, is not fully understood.[19] It might seem logical that a longer implant can provide greater stability because of a greater surface area contacting the bone. However, Wilmes et al.,[20] Miyamoto et al.,[14] recommended that implant stability at the time of surgery might largely depend on cortical bone thickness rather than implant length.

That is why this study was attempted to evaluate the most major factor that should be considered before mini-screws placement which is the cortical bone thickness which affects mini-screws stability. Stability is obtained by placing mini-screws in alveolar bone with sufficient quantity (cortical bone thickness). In our study we choose to measure from the CEJ and not the alveolar bone crest. If buccal cortical bone thickness measurements are started from the alveolar crest, measurements would vary with levels of alveolar bone resorption. Joo et al.,[21] used inter-lamina dura distances to measure at 4 and 8mm from the CEJ, whereas in this study we used inter-root surface distances. We chose the root surface as it is more obvious in the CBCT image than the lamina dura. We confined the measurement 8mm level of the CEJ because 10mm or more might be beyond the root. Carano et al.,[2] reported the danger of sinus perforation when an orthodontic mini-screw was extended more than 11mm from the bone crest.

Kim et al.,[22] also mentioned in their cadaver study that soft-tissue and cortical bone thickness in the buccal segment were greatest in inter dental area between the maxillary second premolar and the first molar which agree with our present study where we found the greatest cortical bone between second premolar and first molar. In our study, mean maxillary buccal cortical bone thickness ranged from 1.2 to 2.4mm and mandibular buccal cortical bone thicknesses was 1.1 to 2.3mm. According to Dalstraet al.,[23] a micro implant should have enough initial stability if peri-implant bone tissue has more than 1mm of cortical bone thickness. Motoyoshi et al.,[24] stated that the mini-screws site should have a cortical bone thickness of at least 1.0mm. Which we got more than this number in our present study in all locations except between the left mandibular first and second molars; the lowest mean cortical bone thickness was 1.1mm between the left mandibular first and second molars. Therefore, if all other factors of initial stability are satisfied, the range of mean cortical bone thickness in our study should provide sufficient initial stability.

Conclusion

Determination of cortical bone thickness is important because it is the major determinant of initial stability of a micro implant. According to our results the maxillary buccal cortical bone thickness ranged from 1.2 to 2.4mm and mandibular buccal cortical bone thicknesses was 1.1 to 2.3mm. Cortical bone thickness was greater in the maxilla more than the mandible. In future research we should also evaluate, cortical bone thickness at the anterior region.

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Conflicts of interest

The author declares that there are no conflicts of interest.

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