Radiographic Evaluation of Alveolar Bone Dimensions in the Inter-Radicular Area between Maxillary Central Incisors as "Safe Zone" for the Placement of Miniscrew Implants in Different Growth Patterns- A Digital Volume Tomographical Study

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ABSTRACT

BACKGROUND

Obtaining absolute anchorage with miniscrew has gained momentum in clinical orthodontics as rigid anchorage modality. Determining an ideal anatomical location for mini-implant placement is very important for its successful use. We wanted to evaluate the alveolar bone thickness in hyperdivergent and hypodivergent growth patterns compared to normal growth pattern individuals at different heights in between maxillary central incisors as a safe zone for placement of miniscrew implants.

METHODS

3-dimensional Digital Volumetric Tomography of 45 individuals was done who were in 3 groups- hypodivergent, hyperdivergent and normal growth patterns. The images were generated, analysed by Kodak 3D viewer, 2.2 version software and oriented in three planes – transverse, horizontal and vertical at 3 mm, 5 mm and 7 mm heights respectively.

RESULTS

Horizontal bone thickness has tendency to increase from CEJ to apex. It was also increased in hypodivergents and individuals with normal growth pattern. Transverse bone thickness for mini-implant placement was found more at 7 mm height in hypodivergent, at 5 mm and 7 mm in hyperdivergent. Vertical bone was found to be highest in hyperdivergent individuals.

CONCLUSIONS

There is difference in cortical bone thickness in different growth pattern individuals. Hence growth pattern must be taken into account while placing the mini screw implants.

KEY WORDS

Miniscrew Implants, Maxillary Central Incisors, 3-Dimensional Digital Volumetric Tomography

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BACKGROUND

A skeletal anchorage system (SAS) is derived from typical dental implants & uses titanium anchor plates and screws as absolute anchorage units. Implants are used as skeletal anchorage and the retention and stability is derived from mechanical locking between the cortical bone and the mini-implant. The thickness & the calcification of cortical bone is vital for the providing stability to the implant.[1] Therefore, sites with thick and dense cortical bone are the most favourable sites to place miniscrew implants.

Miniscrew implants can be used both in anterior and posterior regions. Implants in anterior region are used for the control of anchorage in horizontal plane which maintains over jet and protraction of posterior teeth and vertical plane which is used to correct overbite, extrusion/intrusion of anterior teeth, correction of cant of occlusion and asymmetry.[2] Intrusion of teeth is considered to be most difficult and hence, the treatment of deep bite is one of the priorities of the orthodontist as deep bite can have negative effects on the teeth and their supporting periodontal tissues. The choice of treatment depends on several factors, such as incisor display at rest, smile, interocclusal space, and vertical dimension. Proffit, Fields and Houston et al reported that, extrusion of incisors will create a gummy smile & concluded that it would be better to intrude incisors to obtain proper gingival exposure for good aesthetic result.[3,4]

Intrusion arch wire systems such as a utility arch or an intrusion base arch are frequently used for incisor intrusion which generated a force that tends to extrude the molars in non-growing patients, especially for vertical growth pattern in which molar extrusion should be avoided. Mini screw implant anchorage demonstrates that incisor intrusion does not have any effect on vertical molar positioning and is also not influenced by patient's co-operation.[5] For placing a miniscrew, cortical bone thickness is of utmost importance. It is documented in literature that the cortical bone thickness varies in different growth pattern & therefore the same principle of anchorage & stability of miniscrew cannot be applied to all.

Two characteristics which are important when describing the osseous morphology of the maxilla and mandible are cortical bone density and thickness. Density is a description of the quality of cortical bone and its ability to withstand forces. Thickness is a measure of the quantity of cortical bone. The maxilla is composed of relatively thin cortices connected with fine trabeculae, whereas the mandible is composed of thick cortical bone connected with coarse trabeculae. Cortical bony morphology is influenced by force applications and also influenced by the stresses and strains produced by functional loads of associated muscles and mastication. Also facial divergence is related to muscular function and there is a relationship between cortical bone thickness and facial divergence. However the subjects with high mandibular plane angle and large gonial angle have thin cortical bone and therefore have increased incidence of mini-implant failure.

Initial stability is obtained by placing miniscrew implant in alveolar bone with sufficient quantity (Bone thickness) and quality (Bone mineral density). To evaluate optimal locations for miniscrew implant placement various methods have been used including panoramic radiographs, computed tomography, digital volume tomography based on the cone-beam technique, and human cadaver skulls.[6]

Out of these methods, 3D volumetric tomographic images (3DVT) was selected. As it provided accurate measurements of small bone to determine the best area for the placement of miniscrew implants. This offers significant protection against the 2 major problems of miniscrew implant placement i.e. safety and stability with decreased patient radiation exposure that is 2.7 times less than that of panoramic radiograph. 3DVT provides volume data that is used to obtain cross-sectional slices of the jaws and it can also assess the volume of the alveolar bone (Widths and height), thickness of cortical bone prior to miniscrew implant placement.

So, the objective of this study was to evaluate the alveolar bone thickness in hyperdivergent and hypodivergent facial patterns as compared to normal growth pattern individuals at different heights in maxillary anterior region as a safe zone for placement for mini-screws implants using 3D Volumetric Tomography.[7]

METHODS

This study was an observational study, was carried out at Department of Orthodontics and Dentofacial Orthopaedics, Sharad Pawar Dental College, Sawangi, Wardha. Following criteria was kept for selecting the cases for evaluation.

Inclusion Criteria

Individuals without any systemic illness and with no history of orthodontic treatment.

Exclusion Criteria

Individuals with missing central incisors, with incomplete eruption of crowns, with severe periodontitis (Determined from radiographic signs of alveolar bone resorption), large metal restoration (Including crowns and fillings that produces scatter and interfere with CT evaluation), moderate interdental spacing, blurry or unclear images and with severe anterior crowding.

Sample Size

Sample size calculations-

$$N = \frac{16\sigma^2 + 1}{2}$$

σ is difference in mean from previous studies-

Σ = 2.6 -1.2 = 1.40

= is difference in means

$$n = \frac{16 \times 1.4 \times 2 + 1}{0.06}$$

$$= 44.8 + 1$$

Total sample size for three groups = 45.8

So, the sample size selected 45 for three groups.

Cephalograms were taken with the teeth in maximum intercuspation in a standardized manner. Total 45 individuals within the age group of 18 to 26 years were selected for this study and divided into 3 groups of 15 individuals. These groups are-

Group I- 15 individuals having normal divergent growth pattern,
Group II- 15 individual having hyperdivergent growth pattern,
Group III- 15 individual having hypodivergent growth pattern based on values of FMPA angle.

Each group was evaluated at 3 mm, 5 mm and 7 mm in three planes of space between upper central incisors Written consent was taken from the patients for participating in the study. 3-Dimensional Digital Volumetric Tomographic was obtained for each patient by following procedure.All patients were standing in an erect position, with support of hand grip rods. Face was stabilized with 3D chin rest in the standard planes, which consists of midpoint of both central incisors coinciding with the centre mark on the 3D chin rest, later head was adjusted to the x-ray beam and stabilized with the temple support rods. The laser beam was then used to position the patient in a correct manner. In case of incorrect positioning, red light gets displayed on the control panel& whole procedure was repeated & position was corrected. 3Digital Volumetric Tomography scan was conducted on KODAK 9000C 3D and KODAK 9000C.

3Digital Volumetric Tomography images were generated by the Kodak 3D viewer, 2.2 version software for each patient. By using this software, curved slicing images with sections of 76 µm thickness were chosen for measurements. The images were oriented in three planes of space so that the transverse bone thickness, horizontal bone thickness and vertical bone height in the proximity of maxillary central incisors could be measured from the cemento-enamel junction. First measurement (i.e. transverse bone thickness/mesiodistal bone thickness/interradicular space) was done between the right and left central incisors at different inter-dental area from cemento-enamel junction. Second measurement (i.e. horizontal bone thickness/antero-posterior width/buccal cortical bone thickness) was made between the interdental space between both the central incisors at 3 different levels i.e. at 3 mm, 5 mm and 7 mm. Each measurement was taken from the buccal alveolar plate. Third measurement (i.e. vertical bone height) was done between the cemento-enamel junction and the nasal floor. All measurements were done with the help of measurement tools in the KODAK 3D viewer software.

Statistical Analysis

The cemento-enamel junction was used instead of the alveolar crest as the reference point for measurements because the alveolar crest cannot serve as a constant and reliable reference point as periodontitis could affect this point. The statistical tests used for the analysis of the result were One-way ANOVA (F-Test) and Tukey Multiple Comparison Test.

RESULTS

The transverse bone thickness in three different groups was compared at 3 mm, 5 mm and 7 mm between upper central incisors. Statistical analysis with Multiple comparison Turkey test shows significant value when Group I is compared to Group II & Group II compared to Group III with p-value of 0.000 at 5 mm. At 7 mm significant value where observed between Group II and Group III with p-value of 0.015 (Table no-1).

The horizontal bone thickness in three different groups was compared at 3 mm, 5 mm and 7 mm between upper central incisors. Significant value was observed when Group I is compared to Group II with p-value of 0.004 and Group II with Group III with p-value of 0.007 at 3 mm distance. At 5 mm distance significant value between Group I and Group II with p-value of 0.006 was observed. Significant difference when Group I is compared to Group II with p value of 0.000 & Group II with Group III with p-value of 0.001 at 7 mm distance was observed (Table 2).

When the vertical bone thickness in three different groups was evaluated significant difference was observed between Group I and Group II with p-value of 0.010 & also between Group II and Group III with p-value of 0.000 (Table 3).

Distance	n	Growth Pattern	Mean	S.D.	One-Way ANOVA	Multiple Comparisons: Tukey Test		
						Group I:II	Group I:III	Group II:III
3 mm	15	Group I	3.22	1.02	F- test 2.480 p- value 0.096 NS, p>0.05	0.442 NS, p>0.05	0.585 NS, p>0.05	0.079 NS, p>0.05
	15	Group II	2.84	0.49				
	15	Group III	3.53	0.92				
5 mm	15	Group I	3.72	1.29	F- test 47.75 p- value 0.000 S, p<0.05	0.245 NS, p>0.05	0.001 S, p<0.05	0.000 S, p<0.05
	15	Group II	3.22	0.62				
	15	Group III	0.90	0.22				
7 mm	15	Group I	4.55	1.41	F- test 4.35 p- value 0.019 S, p<0.05	0.210 NS, p>0.05	0.450, NS, p>0.05	0.015 S, p<0.05
	15	Group II	3.73	0.94				
	15	Group III	5.13	1.48				

Table 1. Comparison of Transverse Bone Thickness between Average (Group I), Hyperdivergent (Group II) and Hypodivergent (Group III) Growth Patterns in Patients at 3 mm, 5 mm and 7 mm

Distance	n	Growth Pattern	Mean	S.D.	One-Way ANOVA	Multiple Comparisons: Tukey Test		
						Group I:II	Group I:III	Group II:III
3 mm	15	Group I	3.22	1.02	F- test 7.27 p- value 0.002 S, p<0.05	0.004 S, p<0.05	0.984 NS, p>0.05	0.007 S, p<0.05
	15	Group II	2.84	0.49				
	15	Group III	3.53	0.92				
5 mm	15	Group I	0.97	0.20	F- test 5.715 p- value 0.006 S, p<0.05	0.006 S, p<0.05	0.637 NS, p>0.05	0.058 NS, p>0.05
	15	Group II	0.73	0.16				
	15	Group III	0.90	0.22				
7 mm	15	Group I	1.16	0.21	F- test 10.84 p- value 0.000 S, p<0.05	0.000 S, p<0.05	0.970 NS, p>0.05	0.001 S, p<0.05
	15	Group II	0.81	0.20				
	15	Group III	1.14	0.27				

Table 2. Comparison of Horizontal Bone Thickness between Average (Group I), Hyperdivergent (Group II) and Hypodivergent (Group III) Growth Patterns in Patients at 3 mm, 5 mm and 7 mm

Growth Pattern	n	Mean	Std. Deviation	One-Way ANOVA	Multiple Comparisons: Tukey Test		
					Group I:II	Group I:III	Group II:III
Group I	15	16.58	2.01	F- test 11.32 P- value 0.000 S, p<0.05	0.010 S, p<0.05	0.253 NS, p>0.05	0.000 S, p<0.05
Group II	15	18.97	1.69				
Group III	15	15.32	2.58				

Table 3. Comparison of Vertical Height between Average (Group I), Hyperdivergent (Group II) and Hypodivergent (Group III) Growth Pattern in Patients

DISCUSSION

It is important to correlate the interradicular space measurements with the mini-implant's diameter and the bony clearance is needed for both periodontal health and miniscrew stability. Currently, most miniscrews have diameters ranging from 1.2 to 2 mm. Conical mini screws have an initial diameter of 1.5 mm with the diameter decreasing at the tip to 1.2–1.1 mm. The differences between the initial diameter and the tip are approximately 0.3–0.4 mm. Considering the width of periodontal ligament to be approximately 0.25 mm. In this study, available interradicular space for miniscrew placement between maxillary central incisors greater than 3 mm was found at 7 mm height in hypodivergent (Group III), at 5- and 7-mm height in hyperdivergent (Group II) and at 3, 5- and 7-mm height in normal growth pattern (Group I). Poggio et al (2006) recommended that miniscrew placement in an oblique direction to the dental axis (30˚–40˚) to allow for miniscrew placement on the attached gingiva.[8] Moreover, more space can be obtained with angulated placement of miniscrews in an apical direction because of divergent tooth root morphology. Assessment of interradicular distance is important because it relates to both safety and stability of mini-implants. Kuroda et al and Asscherickx K et al showed that root proximity is a major factor for screw failure.[9] Their results demonstrated a significant correlation between late stability and clearance of the mini-implant. Not only does it confirm the advantage of relatively small Mini-implant diameters, but also it suggests that sufficient interradicular space is crucial for both safety and late stability. Schnelle et al. considered 3 to 4 mm of interradicular distance as the minimum amount of space required for a mini-implant placement.[10] Poggio et al also emphasized combining interradicular space measurements with the mini-implant's diameter and bone clearance to protect periodontal health and ensure implant stability.[8] They assumed a minimum clearance of 1 mm of bone around the mini-implant to be safe. Therefore, they recommended interradicular spaces greater than 3.1 mm as safe zones for mini-implants with diameters of 1.2 to 1.3 mm. With the age, sex and presence or absence of third molar may alter the interradicular space.

In present study, interradicular space ranged from 3.5 to 5.13 mm in the maxilla in hypodivergent individuals, 2.84 to 3.73 mm in hyperdivergent and 3.22 to 4.5 mm in normal growth pattern. In some cases of crowding, there would be less than 1 mm of clearance around the mini-implant, even with a 1.2-mm diameter of mini-implant. To obtain some clearance, the mini-implant might need to be placed further apically in a tight interradicular space.

Therefore, in general, it is recommended to place mini-implants 5 mm or more apically from the CEJ in maxillary anterior region.

In our study the results showed the cortices of hypodivergent subjects were thicker than hyperdivergent subjects. The differences of cortical bone thickness may be explained by masticatory function. Motoyoshi et al. suggested that miniscrew implant success depends on placing the mini-screw in at least 1 mm of cortical bone.[11] In our study, the horizontal bone thickness for miniscrew implant placement in the maxilla greater than 1 mm was found at 5 mm & 7 mm height in average and hypodivergent growth pattern individuals respectively.

Park, Borges and Mucha[12] concluded that the posterior dentoalveolar area has thicker cortical bone than the anterior dentoalveolar area. These results demonstrate that the alveolar bone at the anterior teeth area is unsuitable as a location for mini-implants. In case of the implantation of mini-implants in the anterior teeth area, the basal bone might be a good site.

Cortical bone thickness was site dependent and it increased as the distance from the alveolar ridge increased. In present study, it was found that the cortical bone thickness has a tendency to increase from CEJ to apex. Horizontal bone thickness ranged from 0.86 to 1.14 mm in the maxilla in Group III individuals, 0.60 to 0.81 mm in Group II and 0.87 to 1.16 mm in Group I. In maxilla, buccal cortical bone thickness tended to increase from the CEJ to the apex.

Anchorage failure is often a result of low bone density due to inadequate cortical thickness. Bone density is classified into 4 groups (D1 (>1250 HU), D2 (850-1250 HU, thickness 2 mm), D3 (350–850 HU, thin 1 mm) and D4 (150–350 HU) based on Hounsfield units (HU)- an x-ray attenuation unit used in computed tomography scan interpretation to characterize the density of a substance. Sevimay et al. reported that osseointegrated dental implants placed in D1 and D2 bone showed lower stresses at the implant-bone interface. D1-D3 bone is optimal for self-drilling miniscrews. Placement of miniscrews in D1 and D2 bone might provide greater stationary anchorage under orthodontic loading. Placement of miniscrews in D4 bone is not recommended due to the reported high failure rate.[13]

The ideal position for inserting mini-implants to intrude upper incisors will depend on how much tipping they have. When incisors are upright or tipped backwards, as is the case with Angle's Class II, Division 2, one single mini-implant is recommended to be placed on the median line, as high as possible and close to the Anterior Nasal Spinein this position. The line of force will be anterior to centre of resistance of anterior teeth, thereby generating an intrusion effect combined with the buccal tipping of these units. However when incisors have reasonable axial inclination, the line of force should be made to run through as closely as possible to centre of resistance. Itis recommended to use two mini-implant, one on each side, positioned between lateral incisors and cuspids.[14]

In hyperdivergent individuals, vertical bone height was highest as compared to hypodivergent individuals and individuals with normal growth pattern. The vertical bone height in hyperdivergent individuals between alveolar crest and nasal floor in between the maxillary central incisors ranged from 16.2 mm to 21.7 mm. In average growth individuals, the vertical bone height between alveolar crest and nasal floor in between the maxillary central incisors ranged from 13.2 mm to 19.9 mm. In hypodivergent individuals, the vertical bone height between alveolar crest and nasal floor in between the maxillary central incisors ranged from 10.8 mm to 19.1 mm.

CONCLUSIONS

Horizontal bone thickness between maxillary central incisors was more in hypodivergent and normal growth pattern individuals as compared to individuals with hyperdivergent growth pattern and was site dependent. The horizontal bone thickness for miniscrew implant placement in the maxilla greater than 1 mm was found at 5 mm & 7 mm height in average and hypodivergent growth pattern individuals respectively. Transverse bone thickness for miniscrew placement between maxillary central incisors greater than 3 mm was found at 7 mm height in hypodivergent, at 5- and 7-mm height in hyperdivergent and at 3-, 5- and 7-mm height in individuals with normal growth pattern. Therefore, in general, it is recommended to place mini-implants 5 mm or more apically from the CEJ in maxillary anterior region. Vertical bone height was formed highest, in general in hyperdivergent individuals, as compared to hypodivergent and individuals with normal growth pattern. 3D imaging is necessary to locate the interradicular space and cortical bone thickness in different areas before determining mini-implant placement.

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