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Bone density and miniscrew stability in orthodontic patients

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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.

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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.

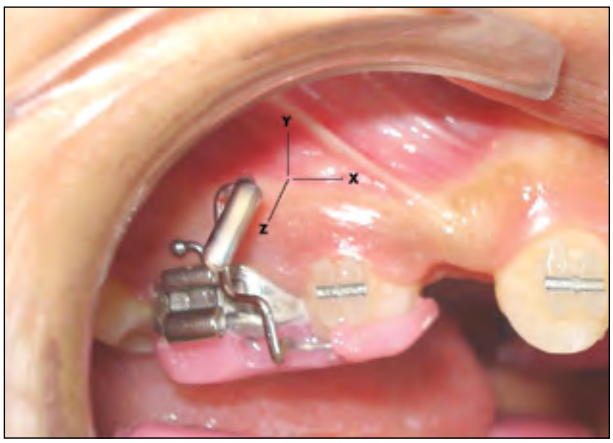

Figure 1. Implant guide in patient's mouth. The metal tube helped in orienting the miniscrew in X-, Y- and Z-axis. The miniscrew parallel to the metal tube will maintain the desired angulation with tooth surface.

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 dentaoalveolar 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).

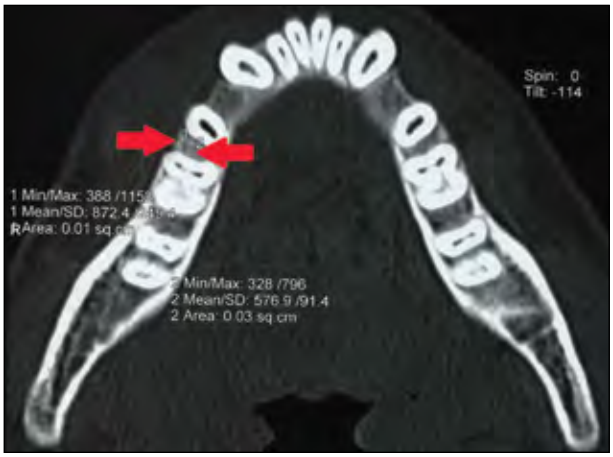

Figure 3. (b) Mandibular axial section with site markings for bone density determination (arrows).

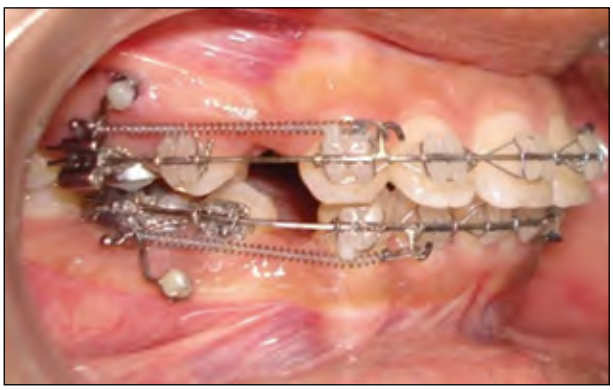

Figure 4. Miniscrews used as indirect anchorage saver for en masse retraction of anteriors. (Kharbanda OP, ed. Orthodontics: Diagnosis and Management of Malocclusion and Dentofacial Deformities. 2nd ed. India:Elsevier;2013. Chapter 47, Temporary anchorage devices. p.591 (Figure 47.13B). Cited with permission).

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.

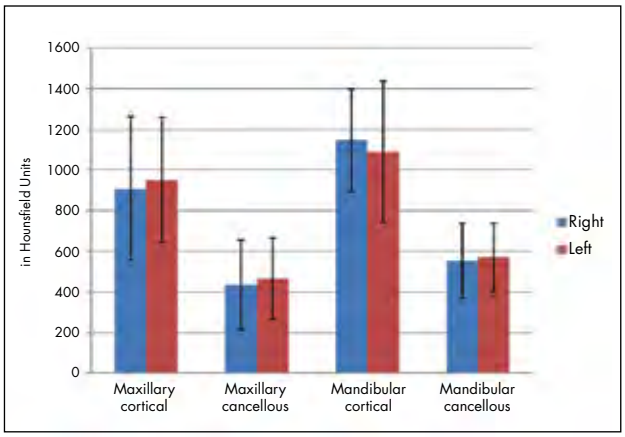

Figure 5. (a) Bone density values on left and right sides of maxilla and mandible.

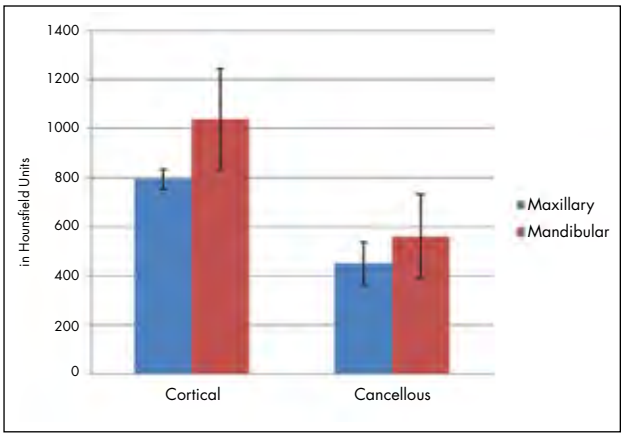

Figure 5. (b) Bone density values for cortical and cancellous region of maxilla and mandible.

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.

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