Original Article
Journal of Pierre Fauchard Academy (India Section), *Vol 34(2), DOI: 10.18311/jpfa/2020/25031, June 2020, p. 40-45*
ISSN (Print) : 0970-2199
ISSN (Online) : 2405-772X

Alveolar Cortical Bone Density among Different Facial Types: A CBCT Study

G. Varun[1], Sanjeev Datana[2], S. S. Agarwal[3*] and S. K. Bhandari[4]

[1]Resident (Orthodontics), Department of Dental Surgery and OHS, AFMC Wanowrie, Pune – 411040, Maharashtra, India
[2]Associate Professor (Orthodontics), Department of Dental Surgery and OHS, AFMC Wanowrie, Pune – 411040, Maharashtra, India
[3]Assistant Professor (Orthodontics), Department of Dental Surgery and OHS, AFMC Wanowrie, Pune – 411040, Maharashtra, India; docshivagarwal@rediffmail.com
[4]Professor (Oral and Maxillofacial Surgery), Department of Dental Surgery and OHS, AFMC Wanowrie, Pune – 411040 Maharashtra, India

Abstract

Aim: To evaluate and compare the cortical bone density amongst skeletally Class I individuals with different facial forms using Cone Beam Computer Tomography (CBCT). **Materials and Methods:** Cross-sectional study was conducted using pre-treatment CBCT records of 45 patients, 15 each of hyperdivergent, normodivergent and hypodivergent facial pattern categories selected from the institutional archives. Median bone density was assessed in anterior and posterior sites of maxilla and mandible, followed by comparison of data between hypodivergent, normodiveregent and hyperdivergent subjects. The inter-group statistical comparison of continuous variables was done using Kruskal-Wallis H test. Intra-group statistical comparison of continuous variables was done using Mann-Whitney U test. **Results:** Median anterior bone density in maxilla and mandible were relatively similar across the 03 facial patterns (P>0.05). However, buccal cortical bone density was increased in normodivergent and hypodivergent subjects compared to hyperdivergent subjects, which was statistically significant (P<0.05). It was also noticed in this study that the density of left buccal region was higher when compared to right which was statistically significant (P<0.05), across 3 facial patterns. **Conclusion:** This study concludes that hyperdivergent subjects have relatively less dense bones in both maxilla and mandible as compared to other facial patterns. Clinically, it is advised to place wider diameter and increased length TADs in these subjects for better initial and long term stability. However, long term prospective studies with a larger sample size are required to validate the findings of these studies.

Keywords: Cortical bone density, Facial pattern, TAD

1. Introduction

It is evident that different individuals have different facial forms which are in turn influenced by the individual's genetic make-up and the environmental factors. These genetic/environmental factors may influence the orientation of maxillary and mandibular skeletal bases and the position of the dental components[1]. Various authors have defined and classified facial forms and divergence in different populations[2,3]. There is ample evidence in literature to assess the co-relation between cortical bone thickness and facial types[4,5]. But the research is limited on evaluation of bone density and its variations amongst different facial patterns. Various studies have assessed the cortical bone density in maxilla and mandible and its clinical implications especially in relation to anchorage planning with Temporary Anchorage Devices (TADs) without considering the facial patterns[6-8]. To the best of our knowledge, there exist a very few studies which evaluates and compares the cortical bone density amongst individuals of different facial types. Hence, this study was designed to evaluate and compare the cortical bone density amongst skeletally Class I individuals with different facial forms using Cone Beam Computer Tomography (CBCT)

*Author for correspondence

to assist the clinician in anchorage planning in different facial typesespecially using TADs.

2. Materials and Methods

This cross-sectional study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics of a tertiary care government teaching institute. Pre-treatment CBCT records of 45 patients, 15 each of hyperdivergent, normodivergent and hypodivergent facial pattern categories were selected from the institutional archives of the patients who met the inclusion criteria of the study. All CBCT data used in this study were recorded from the same equipment using a standardised technique and exposure parameters [NEWTOM GIANO CB (3D)] detector, with tube voltage of 60-90 KV, tube current 1-10 ma (pulsed mode), focal spot of 0.5mm and image resolution of 3.94 IP/mm.

Inclusion criteria included records of healthy adults in Cervical Vertebrae Maturation Index (CVMI) stage VI, skeletally and dental Class I patients with complete set of medical and dental records available and those with absence of any systemic conditions/disease affecting bone metabolism. Exclusion criteria included patients with any missing or unerupted teeth in the quadrant measured, presence of periapical or periodontal pathologies, periodontal bone loss, history of previous jaw surgery/ trauma, malignancy, malformed teeth/ anodontia/ oligodontia or any other systemic disease/condition affecting bone metabolism.

Images of each CBCT scan were exported to DICOM 3.0 format and assessed using NEWTOM.NNT analysis software. The angular measurements were done on lateral cephalometric images obtained from CBCT scans to group the patients into 03 groups based on their vertical facial patterns as:

Group A: Hyperdivergent facial type (FMA>25 degrees)

Group B: Normodivergent facial type (FMA = 22-25 degrees)

Group C: Hypodivergent facial type (FMA < 22 degrees)

The CBCT images were standardised by rotating the sagittal slice, so that the FH plane was oriented parallel to the true horizontal. Site selection was done based on the most common sites preferred for placing TAD in maxilla and mandible[9].

In the mandibular arch, sagittal slice was used to locate the inter-radicular sites i.e. 5-6 mm vertically below the alveolar crest between 1st molar and 2nd premolar and 5-7 mm vertically below the alveolar crest between canine and 1st premolar [Figure 1 - A, B]. The buccal cortical bone thickness was evaluated in axial slice [Figure 1 - C]. In the maxillary arch, sagittal slice was used to locate the inter-radicular sites 6-8 mm vertically above the alveolar crest between 1st molar and 2nd premolar [Figure 2 - A]. The buccal cortical bone thickness was evaluated in axial slice [Figure 2 - B]. However maxillary anterior site was located on the coronal slice 2-3 mm apically in between the roots of maxillary anterior [Figure 2 - C] and bone density was measured in sagittal slice [Figure 2 - D]. The bone density was measured in Hounsfield Unit (HU) and the data obtained was compiled in MS Excel sheet and subjected to statistical analysis.

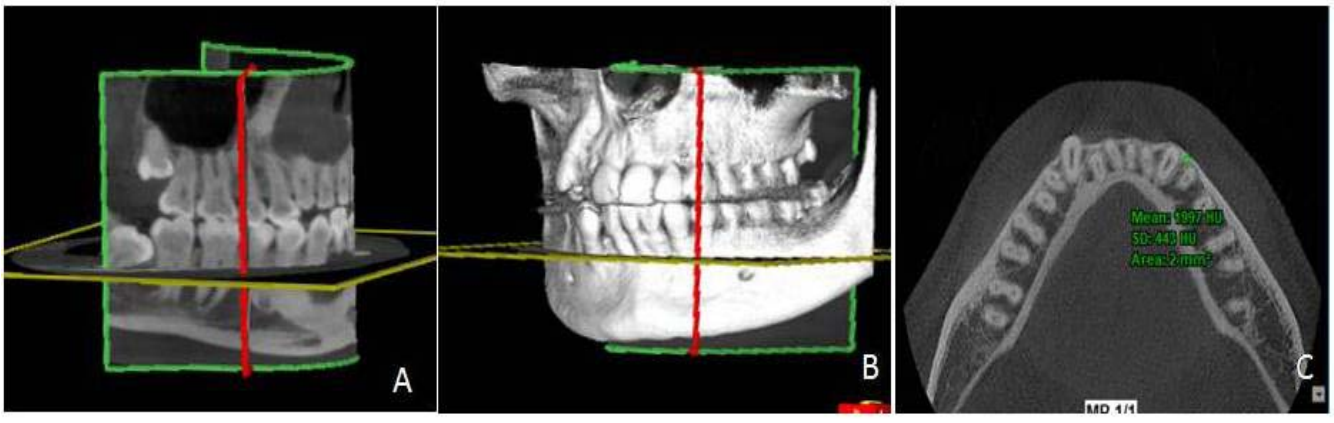


Figure 1. **A** - Inter-radicular site between 1st molar and 2nd premolar in the mandible. **B** - Inter-radicular site between canine and premolar in the mandible. **C** - Evaluation of buccal cortical thickness in axial slice.

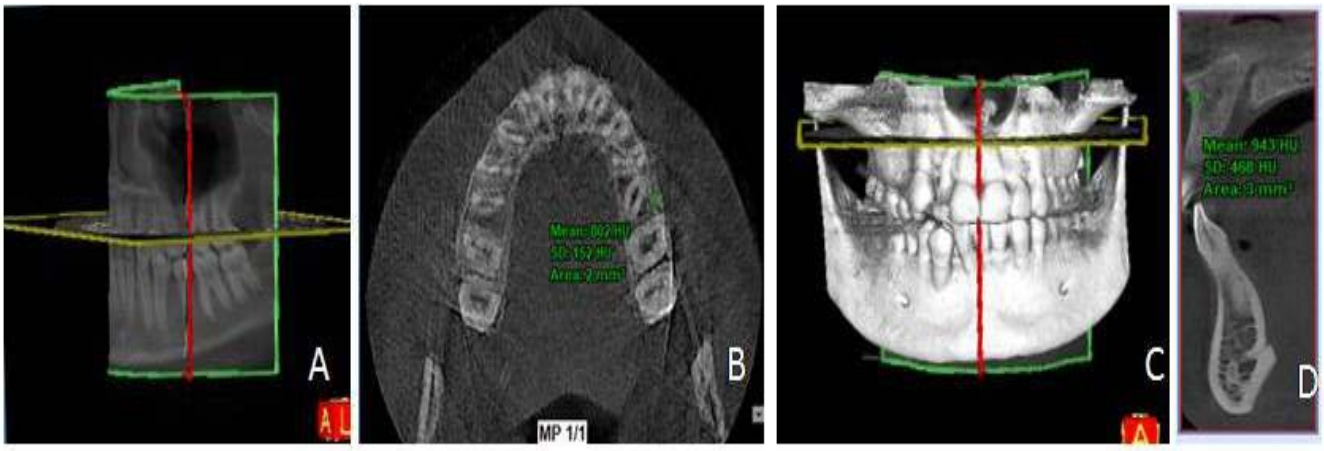


Figure 2. **A** - Inter-radicular site between 1st molar and 2nd premolar in the maxilla. **B** - Evaluation of buccal cortical thickness in axial slice. **C** - Inter-radicular site above the root apices of central incisors. D - Evaluation of cortical thickness in maxillary anterior in sagittal slice.

3. Statistical Analysis

The entire data was statistically analysed using Statistical Package for Social Sciences (SPSS version 21.0, IBM Corporation, USA) for MS Windows. The data on continuous variables was presented as Median across the three study groups. The inter-group statistical comparison of continuous variables was done using Kruskal-Wallis H test (Non-parametric ANOVA). The intra-group statistical comparison of continuous variables was done using Mann-Whitney U test. All the results are shown in tabular as well as graphical format to visualize the statistically significant difference more clearly. The p-values less than 0.05 were considered to be statistically significant. All the hypotheses were formulated using two tailed alternatives against each null hypothesis (hypothesis of no difference).

4. Results

On comparing the median bone density in maxilla, anterior bone density was relatively similar across the 03 facial patterns (P>0.05). Buccal cortical bone density was almost similar between normodivergent and hypodivergent subjects (P>0.05). However, bone densities were increased in normodivergent and hypodivergent subjects compared to hyperdivergent subjects, which was statistically significant (P<0.05) [Table 1].

Table 1. Inter-group distribution of median bone density in maxilla

	Group A [Hyperdivergent] (n=15)		Group B [Hypodivergent] (n=15)		Group C [Average] (n=15)		P-value (Inter-Group)		
Maxilla	**Median**	**Min-Max**	**Median**	**Min-Max**	**Median**	**Min-Max**	**Group A vs Group B**	**Group A vs Group C**	**Group B vs Group C**
Anterior side (HU)	791.8	103.4 – 1299.0	721.7	268.8 – 1235.0	846.6	460.9 – 1308.1	0.866^{NS}	0.769^{NS}	0.561^{NS}
Left side (HU)	627.5	280.5 – 2136.5	845.6	425.4 – 1036.6	873.6	672.4 – 1368.8	0.030*	0.004**	0.377^{NS}
Right side (HU)	577.3	311.3 – 909.6	735.8	290.9 – 1080.0	714.7	507.0 – 1170.5	0.059^{NS}	0.048*	0.985^{NS}

P-values by Kruskal-Wallis H test (Non-parametric ANOVA). P-value<0.05 is considered to be statistically significant.
*P-value<0.05, **P-value<0.01, NS-Statistically non-significant.

On comparing the cortical bone density in mandible, median bone density did not differ significantly across the 03 facial patterns in anterior region (P>0.05). Buccal cortical bone density was similar between normodivergent and hypodivergent subjects (P>0.05). However, bone densities was increased in normodivergent and hypodivergent subjects compared to hyperdivergent subjects, which was statistically significant (P<0.05) [Table 2].

On comparing the relative bone densities, there was no statistically significant difference between different sites of maxilla and mandible (P>0.05). There was increase in bone densities on evaluating the different sites of maxilla and mandible in hypodivergent and normodivergent subjects, which was statistically significant (P<0.05). However, it was also noticed that the density of left buccal region was higher when compared with its counterpart on right which was statistically significant in all 3 facial planes (P<0.05) [Table 3].

5. Discussion

Placement of TADs in maxilla and mandible requires an assessment of cortical bone in the region of TAD placement. Various authors have proposed preferred sites for placement of TADs based on cortical bone thickness[9,10]

Table 2. Inter-group distribution of median bone density in mandible

	Group A [Hyperdivergent] (n=15)		Group B [Hypodivergent] (n=15)		Group C [Average] (n=15)		P-value (Inter-Group)		
Mandible	**Median**	**Min-Max**	**Median**	**Min-Max**	**Median**	**Min-Max**	**Group A v Group B**	**Group A v Group C**	**Group B v Group C**
Anterior (HU)	1014.2	344.0 – 1483.0	1080.9	766.9 – 1503.5	1042.0	566.0 – 1607.9	0.512^{NS}	0.285^{NS}	0.488^{NS}
Left side (HU)	665.9	468.0 – 1248.3	1028.6	609.5 – 1679.3	1137.8	616.3 – 1940.9	0.001***	0.001***	0.896^{NS}
Right side (HU)	573.5	343.9 – 1165.2	1054.8	611.6 – 1245.2	1043.9	837.3 – 1275.9	0.001***	0.001***	0.750^{NS}

P-values by Kruskal-Wallis H test (Non-parametric ANOVA). P-value<0.05 is considered to be statistically significant.
***P-value<0.001, NS-Statistically non-significant.

Table 3. Intra-group distribution of median bone density

Group		Maxilla (n=45)		Mandible (n=45)		P-value
		Median	**Min-Max**	**Median**	**Min-Max**	**Maxilla v Mandible**
Group A [Hyperdivergent]	Anterior (HU)	791.8	103.4 – 1299.0	1014.2	344.0 – 1483.0	0.150^{NS}
	Left side (HU)	627.5	280.5 – 2136.5	665.9	468.0 – 1248.3	0.194^{NS}
	Right side (HU)	577.3	311.3 – 909.6	573.5	343.9 – 1165.2	0.839^{NS}
Group B [Hypodivergent]	Anterior side (HU)	721.7	268.8 – 1235.0	1080.9	766.9 – 1503.5	0.001***
	Left side(HU)	845.6	425.4 – 1036.6	1028.6	609.5 – 1679.3	0.001***
	Right side (HU)	735.8	290.9 – 1080.0	1054.8	611.6 – 1245.2	0.001***
Group C [Average]	Anterior side (HU)	846.6	460.9 – 1308.1	1042.0	566.0 – 1607.9	0.004**
	Left side (HU)	873.6	672.4 – 1368.8	1137.8	616.3 – 1940.9	0.035*
	Right side (HU)	714.7	507.0 – 1170.5	1043.9	837.3 – 1275.9	0.001***

P-value by Mann-Whitney U test. P-value<0.05 is considered to be statistically significant. P-value<0.05 is considered to be statistically significant. *P-value<0.05, **P-value<0.01, ***P-value<0.001, NS-Statistically non-significant.

as well as cortical bone density[7,8]. In our study, we have selected 02 sites each in maxilla and mandible based on the study of Fayeda *et al.*[9], a CBCT based study to assess the optimal site for placing TAD.

Stability of TADs depends on the quality and quantity of bone in the region of interest. Various studies have been reported which relates cortical bone thickness[10] and bone density[6,11] and the dimension of TAD (diameter and length)[12,13] to the success of TADs placed in the specific areas of maxilla and mandible. To the best of our knowledge, a limited literature is available which evaluates and compares cortical bone density in various facial patterns. Mashita *et al.*,[5] evaluated the bone density of mandible in different facial patterns and concluded that buccal cortical bone is denser in hypodivergent than hyperdivergent subjects and attributed it to the increased masticatory load in hypodivergent subjects. Ozdemir *et al*., evaluated the alveolar cortical bone density from distal of canine to 2nd molars in adult patients with different vertical facial types and observed that hyperdivergent patients tend to have less dense buccal cortical bone in both the maxillary and mandibular alveolar processes when compared to normodivergent and hypodivergent subjects[14]. In present study, we have included both anterior sites as well as posterior sites to further facilitate our understanding of relative bone density of both maxilla and mandible and its implication on anchorage planning in different facial patterns.

It is also well understood that the masticatory muscle load is different in different in facial patterns[15,16] which contributes to the development of dentofacial structures. Various studies have associated the influence of masticatory muscles on cortical bone thickness and density[17,18]. The difference in relative bone density between different facial patterns observed in our study may also be attributed to this differential influence of masticatory muscles in individuals of different facial patterns.

CBCT which is a contemporary imaging technique, aids in high resolution 3D assessment of dentoalveolar parameters without distortion or any structural superimpositions with relatively low level of radiation exposure to the patients as compared to traditional Computed Tomography (CT) images[7]. Nomura *et al*., observed a positive correlation between implant stability and bone mineral density evaluation on CBCT[19]. Hence, CBCT was used as a diagnostic tool to evaluate variations in cortical bone density amongst various facial patterns in this study.

Orenstein *et al.,* evaluated the bone density at different areas of maxilla and mandible, without taking into account of the different facial patterns and concluded that the anterior region has higher cortical bone density when compared with buccal cortical regions[20]. This is in concurrence with the findings of our study where in anterior region of maxilla has higher cortical bone density compared to rest of the areas across the different facial patterns, which is generally classified as D2 bone.

On evaluating the buccal cortical bone, Ozdemir *et al.,* concluded that there is a significant variation in median cortical bone density of maxillary and mandibular posterior regions which was increased in hypodivergent and normodivergent subjects compared with hyperdivergent subjects[14]. This concurs with the findings of our study.

Evaluating the relative bone densities of maxilla and mandible, present study concluded that the density is greatest in mandibular anterior, followed by maxillary anterior, mandibular posterior and maxillary posteriors in hypodivergent subjects when compared to hyperdivergent subjects, which is in concurrence with the studies of Orenstein *et al.,*[20]. Pesent study also compared the relative bone density on left and right sides of maxilla and mandible and it was observed that left side is more denser than the right side in both maxilla and mandible. This finding is required to be substantiated with further studies.

6. Conclusion

From the results of this study, it can be concluded that hyperdivergent subjects have relatively less dense bones in both maxilla and mandible as compared to other facial patterns. Clinically, it is advised to place wider diameter and increased length TADs in these subjects for better initial and long term stability. However, long term prospective studies with a larger sample size are required to validate the findings of these studies.

7. References

1. Horner KA, Behrents RG, Kim KB, Buschang PH. Cortical bone and ridge thickness of hyperdivergent and hypodivergent adults. *Am J Orthod Dentofacial Orthop.* 2012; 142: 17–178. https://doi.org/10.1016/j.ajodo.2012.03.021
2. Sassouni V. Diagnosis and treatment planning via roentgenographic cephalometry. *Am J Orthod.* 1958; 44: 433. https://doi.org/10.1016/0002-9416(58)90003-4

3. Schudy FF. Vertical growth versus anteroposterior growth as related to function and treatment. *Angle Orthod* 1964; 34(12): 75–93.
4. Masumoto T, Hayashi I, Kawamura A, Tanaka K, Kasai K. Relationships among facial type, buccolingual molar inclination, and cortical bone thickness of the mandible. *Eur J Orthod* 2001; 23: 15–23. https://doi.org/10.1093/ejo/23.1.15
5. Tsunori M, Mashita M, Kasai K. Relationship between facial types and tooth and bone characteristics of mandible obtained by CT scanning. *Angle Orthod* 1998; 68: 557–562.
6. Park S, Lee YJ, Jeong SH, Kwon TG. Density of the alveolar and basal bones of the maxilla and the mandible. *Am J Orthod Dentofacial Orthop* 2008; 133: 30–37. https://doi.org/10.1016/j.ajodo.2006.01.044
7. Fuh LJ, Huang HL,Chen CS, Fu KL, Shen YW, Tu MG, Shen WC, Hsu JT. Variations in bone density at dental implant sites in different regions of the jawbone. *J Oral Rehab* 2010; 37: 346–351. https://doi.org/10.1111/j.1365-2842.2010.02061.x
8. Choi JH, Park CH, Yi SW, Lim HJ, Hwang HS. Bone density measurement in interdental areas with simulate placement of orthodontic miniscrew implants. *Am J Orthod Dentofacial Orthop* 2009; 136: 766. https://doi.org/10.1016/j.ajodo.2009.04.019
9. Fayeda MMS, Pazerab P, Katsaros C. Optimal sites for orthodontic mini-implant placement assessed by cone beam computed tomography. *Angle Orthod*. 2010; 80: 939–951. https://doi.org/10.2319/121009-709.1
10. Baumgaertel S, Hans B. Buccal cortical bone thickness for mini-implant placement. *Am J Orthod Dentofacial Orthop*. 2009; 136: 230–235. https://doi.org/10.1016/j.ajodo.2007.10.045
11. Marquezan M, Lau TCL, Mattos CT, Cunha AD, Nojima LI, Santanna EF, Gomes de Souza MM, Arau MT. Bone mineral density, Methods of measurement and its influence on primary stability of miniscrews. *Angle Orthod.* 2012; 82: 62–66. https://doi.org/10.2319/031811-192.1
12. Miyawaki S, Koyama I, Inoue M, Mishima K, Sugahara T, Takano-Yamamoto T. Factors associated with the stability of titanium screws placed in the posterior region for orthodontic anchorage. *Am J Orthod Dentofacial Orthop.* 2003; 124: 373–378. https://doi.org/10.1016/S0889-5406(03)00565-1
13. Fritz U, Diedrich P, Kinzinger G, Al-said M. The anchorage quality of mini implants towards translatory and extrusive forces. *J Orthofac Orthoped.* 2003; 64: 293–304. https://doi.org/10.1007/s00056-003-0304-9
14. Ozdemir F, Tozlu M, Cakan GD. Quantitative evaluation of alveolar cortical bone density in adults with different vertical facial types using cone-beam computed tomography. *Korean J Orthod* 2014; 44(1): 36–43. https://doi.org/10.4041/kjod.2014.44.1.36
15. Raadsheer MC, Kiliaridis S, Van Eijden TM, Van Ginkel FC, Prahl-Andersen B. Masseter muscle thickness in growing individuals and its relation to facial morphology. *Arch Oral Biol* 1996; 41: 323–332. https://doi.org/10.1016/0003-9969(95)00136-0
16. Ingervall B, Helkimo E. Masticatory muscle force and facial morphology in man. *Arch Oral Biol* 1978; 23: 20–206. https://doi.org/10.1016/0003-9969(78)90217-0
17. Kiliaridis S. Masticatory muscle influence on craniofacial growth. *Acta Odont Scand.* 1995; 53: 196–202. https://doi.org/10.3109/00016359509005972
18. Lione R, Franchi L, Noviello A, Fanucci E, Cozza P. Three-Dimensional Evaluation of Masseter Muscle in Different Vertical Facial Patterns: A Cross-Sectional Study in Growing Children. *Ultrason Imaging.* 2013; 35: 37. https://doi.org/10.1177/0161734613502468
19. Nomura Y, Watanabe H, Honda E, Kurabayashi T. Reliability of voxel values from cone-beam computed tomography for dental use in evaluating bone mineral density. *Clin Oral Implants Res.* 2010; 21: 558–562. https://doi.org/10.1111/j.1600-0501.2009.01896.x
20. Orenstein IH, Synan WJ, Truhlar RS, Morris HF, Ochi S. Bone quality in patients receiving endosseous dental implants: *Implant Dent*. 1994; 3: 90–94. https://doi.org/10.1097/00008505-199405000-00004