Research Article

The Prevalence of Alveolar Bone Dehiscence and Fenestration among untreated patients with different patterns of vertical growth using cone-beam computed tomography

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ABSTRACT

Introduction: Alveolar bone dehiscence and fenestration are generally present within the area of the mal-position tooth which complicates the orthodontic treatment. With the advancement of radiology, Cone-beam computed tomography (CBCT) is preferred to identify alveolar bone dehiscence and fenestration among dental patients prior to orthodontic treatment.

Aims and objectives: The purpose of this study was to determine the prevalence of alveolar bone dehiscence and fenestration among patients having different patterns of vertical growth using CBCT.

Materials and Method: CBCT images of 141 patients ranging from 18 to 30 years old were used to measure alveolar bone dehiscence and fenestration. According to the vertical growth pattern of these patients, they were further divided into three groups: hyper-divergent group, normo-divergent group and hypo-divergent group. All the data were measured in Materialise Mimics 21.0 software and statistically analyzed.

Results: The alveolar bone dehiscence and fenestration were found in 48.3% and 14.91% respectively. Pearson chi-square test showed statistically significant association between alveolar bone dehiscence and fenestration with the patient with different vertical growth patterns ($p<0.001$). Both dehiscence and fenestration were prevalent in hyperdivergent and normodivergent growth patterns compared to hypodivergent growth patterns. Dehiscence was more prevalent in maxillary first premolar (9.58%) and mandibular central incisors (8.64%) while fenestration was more prevalent in maxillary canine (21.22%) and mandibular lateral incisors (16.47%).

Conclusion: Alveolar bone dehiscence and fenestration were prevalent among all three vertical growth patterns group. Among these three vertical growth pattern groups, hypo-divergent group had lesser incidence of alveolar bone dehiscence and fenestration owing to comparatively thick alveolar bone in this group.

KEYWORDS: Alveolar Bone Defect, Dehiscence, Fenestration, Vertical growth pattern, Cone-Beam Computed Tomography (CBCT)

INTRODUCTION

Alveolar bone is the primary structure of the dentition, as it develops along with the tooth. It continuously remodels itself to accommodate the functional and physiological needs of the dentition. Alveolar bone dehiscence is the V shaped defect located along the alveolar bone margin toward the apex on the buccal and lingual side of a tooth.[1] On other hand, fenestration can be described as localized defects of the alveolar bone covered only by periosteum and gingiva or occasionally exposed underlying root structure.[1] Previous studies have reported dehiscence and fenestration are commonly found in the alveolar bone with mal-positioned teeth or buccally prominent teeth and considered as non-pathological conditions.[1,2] In malocclusion, alignment of teeth is deflected from normal relation within the arch or to the opposing arch during teeth development.[3] Orthodontic treatment is done for the correction of the malocclusion for proper function of teeth, esthetic and maintaining the overall oral health. As tooth movement in orthodontics is a continuous process of remolding of alveolar bone, there is high risk of development of alveolar bone defect especially dehiscence and fenestration which can cause decrease in tooth support.[4] Presence of dehiscence and fenestration restrict certain movement of tooth which complicate the orthodontic treatment.[5-7]

Cone-beam computed tomography (CBCT) is a digital three-dimensional radiograph. Conventional radiography has significant limitation in detection of alveolar bone dehiscence and fenestration mainly because of superimposition of anatomical structures.[8-10] Hence CBCT is widely used to view alveolar bone morphology and has a diagnostic value in detection of naturally occurring alveolar bone defect.[11-19]

In previous studies alveolar bone dehiscence and fenestration has been evaluated using dry skull and after orthodontic treatment but there have been only few studies evaluating alveolar bone dehiscence and fenestration among untreated patients according to vertical growth pattern using CBCT.[20,21] The predictability of the prevalence of alveolar bone dehiscence and fenestration in different growth pattern before orthodontic treatment can help the dental professionals in formulating effective treatment plan and preventing unwanted complication during the treatment along with long-term stability of the treatment.[19,21] The present study aimed to determine the prevalence of alveolar bone dehiscence and fenestration among untreated patient having different patterns of vertical growth using CBCT.

MATERIALS AND METHOD

Initial CBCT images of 141 study participants' (101 female and 40 male) who were offered orthodontic treatment were obtained from the Department of orthodontics, West China Hospital of Stomatology, Sichuan University, China. The Ethical approval for the use of patient data was obtained from the Ethical Committee of West China Hospital of Stomatology, Sichuan University (WCHSiEB-CT-2020-416). Based on a study by Yang et al[22] in 2015, which reported a prevalence of 8.51% for alveolar bone dehiscence in Chinese population, with 95% confidence level and 5% of margin of error, a sample size of 120 was required for the reliability and generalizability study. Following the inclusion and exclusion criteria the CBCT images were selected.

Inclusion Criteria:

- Age between 18 and 30 years
- Permanent dentition without congenitally abnormal or missing teeth
- Without extracted teeth except third molar
- No previous orthodontic treatment
- Absence history of head or neck trauma

Exclusion Criteria

- Age <18 and >30 years• Congenitally teeth abnormalities or missing teeth.
- Present of severe periodontitis
- History of previous orthodontic treatment.
- History of naso- respiratory complex surgery
- Naso-maxillary complex deformity

Sella-Nasion to manibular plane (SN-MP) angle was measured for the determination of the vertical growth pattern. According to vertical growth pattern the patients were divided into Hyper-divergent (SN-MP angle is greater than or equal to 37°), Normo-divergent (SN-MP angle is less than or equal to 26°) and Hypo-divergent (SN-MP angle is within 26°and 37°)[23] There were 39 patients in hyper-divergent, 57 patients normo-divergent and 45 patients in hypo-divergent group.

The CBCT measurement of alveolar bone dehiscence and fenestration were done in Materalize Mimics research 21.0.24 fig 1) For measurement of alveolar bone dehiscence, the distance from cement-enamel junction and alveolar bone was measured in buccal and palatal surfaces. Simultaneously for alveolar bone fenestration interruption in buccal and lingual cortical plates were noted and the distance of exposed root was measured. Dehiscence was considered to be present if the distance measured between the cement-enamel junction and alveolar bone was more than 2 mm whereas fenestration was present if there is isolated defect of 2.2 mm or more as recommended by Sun et al.[12] According to severity of the alveolar bone dehiscence and fenestration was classified into mild, moderate and severe types. We considered the range of 2mm-3mm as mild, 3mm-4mm as moderate and >4mm as severe for alveolar bone dehiscence. Subsequently, for fenestration the range of mild was 2.2mm-3mm, moderate was 3mm-4mm and severe was >4mm.[20]

Statistical analyses were performed with the statistical package for social science (SPSS) version 18.0. Percentage of Incidence of alveolar bone dehiscence and fenestration according to vertical growth pattern in different tooth was calculated. Pearson chi square was performed and the statistical test was concluded to be significant when the p value was less than 0.05. To evaluate the stability and consistency of the measurement, test-retest reliability was calculated using intra-class correlation coefficient (ICC).

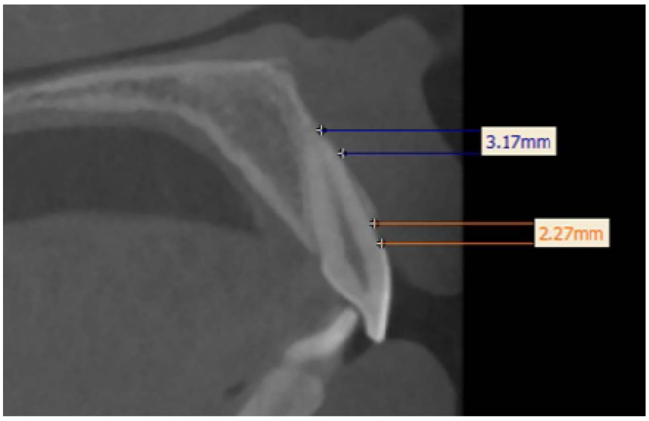

Figure 1: Measurement of dehiscence and fenestration in Materalise Mimics research 21.0

RESULTS

In 141 patients with mean age of 23.33±3.89, 3948 teeth were evaluated in which incidence of dehiscence and fenestration was 48.3% and 14.91% respectively. Alveolar bone dehiscence in hyper-divergent group was 15.55%, in normo-divergent group was 20.89% and hypo-divergent group was 11.85%. However, fenestration was present 5.11% in hyper-divergent, 6.71% in normo-divergent and 3.09% in hypo-divergent group (Table 1).

Alveolar bone dehiscence can be seen mainly in 1st premolar (9.58%), followed by 1st molar (9.26%) in maxilla and central incisor (8.64%) followed by 2nd premolar (7.69%) in mandible. Fenestration is mostly found in canine (21.22%) followed by lateral incisor (20.03%) in maxilla and lateral incisor (16.47%) followed by central incisor (7.47%) in mandible (Table 2).

Severity of dehiscence was found mild in nature, while moderate severity was seen in fenestration. we found that mild, moderate and severe degree of severity was seen in 63.35%, 21.14%, 15.51%, while that in fenestration was 22.62%,44.35%,33.03% respectively. (Table 3)

Pearson chi square test was performed to test the association between alveolar bone dehiscence and fenestration with different vertical growth patterns (Table 1). There was a significant association between alveolar bone dehiscence and fenestration with different vertical growth pattern dX2= 3814, fX2 =1178 and p < .001) This shows that the prevalence of alveolar bone dehiscence and fenestration was different among patients with different vertical growth patterns. The ICC was estimated to be 0.93 (95% confidence Interval: 0.88-0.97) were calculated using SPSS statistical package version 18 based on single-rating, absolute agreement, 2-way random effects model.

Table1: Percentage of Incidence of Alveolar bone dehiscence and fenestration in different vertical growth pattern

Vertical Growth patterns	Dehiscence (n=1907)	dX^2	P value	Fenestration (n=589)	fX^2	P value
Hyper-Divergent	15.55	3814	<0.001	5.11	1178	<0.001
Normo-Divergent	20.89			6.71		
Hypo-Divergent	11.85			3.09		
Total	48.3			14.91		

Pearson chi square for dehiscence dX^2

Pearson chi square for fenestration fX^2

Table2: Percentage of Incidence of Alveolar bone dehiscence and fenestration in different vertical growth pattern according to Tooth

Alveolar defect									
Dehiscence									
Jaw	Vertical Growth patterns	Central incisor	Lateral incisor	Canine	First premolar	Second premolar	First molar	Second molar	Total
Maxilla	Hyper-Divergent	0.83	1.73	1.83	3.30	3.04	2.98	2.35	16.07
	Normo-Divergent	1.67	2.83	2.3	4.19	3.51	4.24	3.82	22.61
	Hypo-Divergent	0.73	1.67	1.99	2.09	1.62	2.04	2.20	12.38
	Total	3.23	6.23	6.12	9.58	8.17	9.26	8.37	51.06

Mandible	Hyper-Divergent	2.77	2.04	1.88	2.41	2.30	2.41	2.25	16.1
	Normo-Divergent	3.46	2.62	2.72	3.35	3.4	3.04	2.04	20.67
	Hypo-Divergent	2.41	1.83	1.57	1.83	1.99	1.25	1.25	12.17
	Total	8.64	6.49	6.17	7.59	7.69	6.7	5.54	48.94
Fenestration									
Maxilla	Hyper-Divergent	1.02	6.45	6.11	3.9	0	1.36	1.02	19.86
	Normo-Divergent	1.36	8.66	9.85	5.94	0.68	0.51	1.19	28.19
	Hypo-Divergent	0.34	4.92	5.26	1.86	0.51	0	0.17	13.06
	Total	2.72	20.03	21.22	11.7	1.19	1.87	2.38	61.11
Mandible	Hyper-Divergent	2.72	5.26	2.55	2.38	0.68	0.51	0.17	14.27
	Normo-Divergent	3.23	7.47	2.55	2.04	1.19	0.34	0.17	16.99
	Hypo-Divergent	1.52	3.74	1.86	0.17	0.17	0.17	0	7.63
	Total	7.47	16.47	6.96	4.59	2.04	1.02	0.34	38.89

Table3: Percentage of severity of the Alveolar bone dehiscence and fenestration according to Vertical growth pattern

Jaw		Maxilla			Mandible			
Alveolar defect	**Degree of severity**	**Hyper-Divergent**	**Normo-Divergent**	**Hypo-Divergent**	**Hyper-Divergent**	**Normo-Divergent**	**Hypo-Divergent**	**Total**
Dehiscence	Mild (2mm≤d≤3mm)	10.01	14.68	8.6	9.3	12.06	8.7	63.35
	Moderate (3mm<d≤4mm)	4.24	5.5	2.7	3.2	3.8	1.7	21.14
	Severe (d>4mm)	1.31	2.5	1.2	3.7	4.9	1.9	15.51
fenestration	Mild (2.2mm≤f≤3mm)	2.72	4.92	2.72	5.09	4.07	3.1	22.62
	Moderate (3mm<f≤4mm)	7.8	12.4	3.74	6.5	9.67	4.24	44.35
	severe(f>4mm)	9.3	11.03	6.96	2.54	2.7	0.5	33.03

DISSCUSION

Alveolar bone defect is inevitable in every person, only may have difference degree of occurrence. By evaluating 141 patients CBCT before orthodontic treatment we found Alveolar bone defect was seen in all patients which is similar to studies by other researchers.[20,25] The definite mechanism of alveolar bone defect is still evolving. Alveolar bone defect jointly consists of dehiscence and fenestration. Study has been done on alveolar bone defect with different vertical growth. [20,21] Enhos et al. found the prevalence of dehiscence and fenestration was 8.35% in hyper-divergent group, 8.18% in normo-divergent group and 6.56% in hypo-divergent group. [21] Prevalence of alveolar bone dehiscence and fenestration according to skeletal classification has been carried out.[26-30] However, studies on prevalence in dehiscence and fenestration among untreated patient according to vertical growth patterns using CBCT is still less.

CBCT is a routine dental radiography, efficient in identification of alveolar bone defect along with other periodontal disease. Compared to other conventional radiography CBCT is highly accurate in detection of alveolar bone dehiscence and fenestration.[11,12] Even some study reported that CBCT overestimate the presence of alveolar bone defect,[11-13] it is clinically used due to three-dimensional visualization and low in radiation. We used CBCT to find the Prevalence of alveolar bone dehiscence and fenestration among patients having different patterns of vertical growth.

Dehiscence was commonly seen than fenestration since natural defects have more gradual and tapering margins along with thin alveolar bone which might easily expose alveolar bone to inflammatory process.[4,11] Watson et al also said that Alveolar bone dehiscence might be formed due to inflammatory processes induced by Chronic gingivitis.[3] While fenestration is isolated defect exposing the underlying root which is more related with the position of tooth.[5] In our study, the prevalence of dehiscence was also seen higher than fenestration.

In study done by Enhos et al. in patients with different vertical pattern dehiscence andwas prevalent in normo -divergent group (8.18%) and hyper-divergent group (8.35%). whereas fenestration was prevalent in hypo-divergent and hyper-divergent groups[21]. Studies have found that higher the alveolar bone density, lower the alveolar bone defects. The thickness of alveolar bone is higher in hypo-divergent compared to hyper-divergent growth pattern.[20,32,33] By evaluating 141 patients CBCT before orthodontic treatment we found alveolar bone dehiscence and fenestration was noticeably increased in normo -divergent group and hyper-divergent group than hypo-divergent group. Sun et al.did study in class I patients with normality pattern found the prevalence of dehiscence (27.46%) and fenestration (26.91) suggesting as common finding.[14] The main factors for occurrence of alveolar bone defect are position of tooth along with alveolar bone thickness. The thickness of cortial plates varies significantly from tooth to tooth throughout the arches. Tooth position in arch such as buccoversion, linguoversion, superuption, supereruption, intrusion etc appears to be the major determinant of cortical plate thickness and contour.[32,33] In our study the difference in number of patients included in normo-divergent group is comparatively high than hyper-divergent and hypo-divergent which contribute in increase in prevalence of the alveolar bone dehiscence and fenestration in normo-divergent group. Overall the prevalence of alveolar bone dehiscence and fenestration were prevalent notably in all hyper, normo and hypo divergent group of vertical growth pattern.

In accordance to severity of the defect, we have found alveolar bone dehiscence was predominantly mild in nature in all types of vertical growth patterns. While we found fenestration in hyper-divergent group was mild in nature whereas normo-divergent and hypo-divergent alveolar bone defect was of moderate type in all types of vertical growth pattern. Sun et al divided the alveolar bone dehiscence into mild cases (62.69%) moderate cases (10.95%) and severe cases (26.37%). Similarly, alveolar bone fenestration was divided into mild cases accounted for 57.36%, moderate cases accounted for 35.53% and severe were 7.11%.[20] These result shows that the alveolar bone prevalent in untreated patient are mainly mild in nature.

In accordance to type of tooth, in maxilla we found dehiscence was prevalent in maxillary first premolars (9.58%) and mandibular central incisors (8.64%). Fenestration was prevalent in maxillary canines (21.22%) and mandibular lateral incisors (16.47%). Similar kind of study done by Enhos et al. found dehiscence was prevalent in mandible central incisors and maxillary canines whereas Fenestration was prevalent in maxilla and mandible lateral incisors.[21] Jin et al. investigated the bone thickness of canine and premolars in normal occlusion and found that the thickness of canine and first premolar were was lower than 2mm in relation to second premolars.[32,33] In mandible central and lateral incisors were mainly present with the alveolar bone defect compared to posterior teeth as a result of presence of thin anterior alveolar bone compared to posterior alveolar bone. [9,32]

LIMITATIONS

The limitation of the current study is its dependence on only one observer in detecting bone defects using CBCT images therefore inter-observer reliability in detecting these alveolar bone defects was not evaluated. As inter-observer reliability in interpreting CBCT images when diagnosing orthodontic-related problem can significantly affect the diagnosis accuracy of the imaging technique.[34]

CONCLUSION

The dehiscence and fenestration are innately prevalent in all three hyper-divergent, normo-divergent, and hypo-divergent groups. The prevalence of alveolar bone dehiscence and fenestration were less in hypo-divergent group compared to hyper-divergent and normo-divergent group. Dehiscence was more prevalent in first premolar in maxilla and central incisors in mandible. Fenestration was more prevalent in canine in maxilla and lateral incisors in mandible.

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REFERENCES

1. Klokkevold, Perry & Newman, M.G. & Takei, Henry & Carranza, Fermin. (2018). Newman and Carranza's Clinical Periodontology.
2. Nimigean VR, Nimigean V, Bencze MA, Dimcevici-Poesina N, Cergan R, Moraru S. Alveolar bone dehiscences and fenestrations: an anatomical study and review. Rom J MorpholEmbryol. 2009;50(3):391-7. PMID: 19690764.
3. Watson WG. Expansion and fenestration or dehiscence. Am J Orthod. 1980 Mar;77(3):330-2. doi: 10.1016/0002-9416(80)90086-x. PMID: 6987880.
4. Coşkun İ, Kaya B. Appraisal of the relationship between tooth inclination, dehiscence, fenestration, and sagittal skeletal pattern with cone beam computed tomography. Angle Orthod. 2019 Jul;89(4):544-551. doi: 10.2319/050818-344.1. Epub 2019 Feb 11. PMID: 30741575; PMCID: PMC8117187.
5. Cha C, Huang D, Kang Q, Yin M, Yan X. The effects of dehiscence and fenestration before orthodontic treatment on external apical root resorption in maxillary incisors. Am J OrthodDentofacialOrthop. 2021 Dec;160(6):814-824. doi: 10.1016/j.ajodo.2020.06.043. Epub 2021 Sep 2. PMID: 34481683.
6. Gaffuri F, Cossellu G, Maspero C, Lanteri V, Ugolini A, Rasperini G, Castro IO, Farronato M. Correlation between facial growth patterns and cortical bone thickness assessed with cone-beam computed tomography in young adult untreated patients. Saudi Dent J. 2021 Mar;33(3):161-167. doi: 10.1016/j.sdentj.2020.01.009. Epub 2020 Feb 6. PMID: 33679110; PMCID: PMC7910683.
7. Guo QY, Zhang SJ, Liu H, Wang CL, Wei FL, Lv T, Wang NN, Liu DX. Three-dimensional evaluation of upper anterior alveolar bone dehiscence after incisor retraction and intrusion in adult patients with bimaxillary protrusion malocclusion. J Zhejiang Univ Sci B. 2011 Dec;12(12):990-7. doi: 10.1631/jzus.B1100013. PMID: 22135148; PMCID: PMC3232432.
8. Bagis N, Kolsuz ME, Kursun S, Orhan K. Comparison of intraoral radiography and cone-beam computed tomography for the detection of periodontal defects: an in vitro study. BMC Oral Health. 2015 May;15:64. DOI: 10.1186/s12903-015-0046-2. PMID: 26016804; PMCID: PMC4446848.
9. Nahm KY, Kang JH, Moon SC, Choi YS, Kook YA, Kim SH, Huang J. Alveolar bone loss around incisors in Class I bidentoalveolar protrusion patients: a retrospective three-dimensional cone beam CT study. DentomaxillofacRadiol. 2012 Sep;41(6):481-8. doi: 10.1259/dmfr/30845402. Epub 2011 Dec 19. PMID: 22184474; PMCID: PMC3520391.
10. Arvind Tr P, Jain RK. Computed tomography assessment of maxillary bone density for orthodontic mini-implant placement with respect to vertical growth patterns. J Orthod. 2021 Dec;48(4):392-402. doi: 10.1177/14653125211020015. Epub 2021 May 31. PMID: 34053366.
11. Leung CC, Palomo L, Griffith R, Hans MG. Accuracy and reliability of cone-beam computed tomography for measuring alveolar bone height and detecting bony dehiscences and fenestrations. Am J OrthodDentofacialOrthop. 2010 Apr;137(4 Suppl):S109-19. doi: 10.1016/j.ajodo.2009.07.013. PMID: 20381751.
12. Sun L, Zhang L, Shen G, Wang B, Fang B. Accuracy of cone-beam computed tomography in detecting alveolar bone dehiscences and fenestrations. Am J OrthodDentofacialOrthop. 2015 Mar;147(3):313-23. doi: 10.1016/j.ajodo.2014.10.032. PMID: 25726398.
13. Ising N, Kim KB, Araujo E, Buschang P. Evaluation of dehiscences using cone beam computed tomography. Angle Orthod. 2012 Jan;82(1):122-30. doi: 10.2319/020911-95.1. Epub 2011 Jul 27. PMID: 21793713; PMCID: PMC8881042.
14. Pan HY, Yang H, Zhang R, Yang YM, Wang H, Hu T, Dummer PM. Use of cone-beam computed tomography to evaluate the prevalence of root fenestration in a Chinese subpopulation. IntEndod J. 2014 Jan;47(1):10-9. doi: 10.1111/iej.12117. Epub 2013 May 24. PMID: 23701176.
15. Ozcan G, Sekerci AE. Classification of alveolar bone destruction patterns on maxillary molars by using cone-beam computed tomography. Niger J ClinPract. 2017 Aug;20(8):1010-1019. doi: 10.4103/1119-3077.180074. PMID: 28891547.
16. Braun X, Ritter L, Jervøe-Storm PM, Frentzen M. Diagnostic accuracy of CBCT for periodontal lesions. Clin Oral Investig. 2014 May;18(4):1229-1236. doi: 10.1007/s00784-013-1106-0. Epub 2013 Sep 19. PMID: 24048949.
17. de FariaVasconcelos K, Evangelista KM, Rodrigues CD, Estrela C, de Sousa TO, Silva MA. Detection of periodontal bone loss using cone beam CT and intraoral radiography. DentomaxillofacRadiol. 2012 Jan;41(1):64-9. doi: 10.1259/dmfr/13676777. PMID: 22184627; PMCID: PMC3520280.
18. Castro LO, Castro IO, de Alencar AH, Valladares-Neto J, Estrela C. Cone beam computed tomography evaluation of distance from cementoenamel junction to alveolar crest before and after nonextraction orthodontic treatment. Angle Orthod. 2016 Jul;86(4):543-9. doi: 10.2319/040815-235.1. Epub 2015 Sep 17. PMID: 26379114; PMCID: PMC8601496.
19. Sun L, Yuan L, Wang B, Zhang L, Shen G, Fang B. Changes of alveolar bone dehiscence and fenestration after augmented corticotomy-assisted orthodontic treatment: a CBCT evaluation. ProgOrthod. 2019 Feb 18;20(1):7. doi: 10.1186/s40510-019-0259-z. PMID: 30773604; PMCID: PMC6378319.
20. Sun L, Mu C, Chen L, Zhao B, Pan J, Liu Y. Dehiscence and fenestration of Class I individuals with normality patterns in the anterior region: a CBCT study. Clin Oral Investig. 2022 May;26(5):4137-4145. doi: 10.1007/s00784-022-04384-2. Epub 2022 Mar 7. PMID: 35254527; PMCID: PMC9072473.
21. Enhos S, Uysal T, Yagci A, Veli İ, Ucar FI, Ozer T. Dehiscence and fenestration in patients with different vertical growth patterns assessed with cone-beam computed tomography. Angle Orthod. 2012 Sep;82(5):868-74. doi: 10.2319/111211-702.1. Epub 2012 Feb 23. PMID: 22356702; PMCID: PMC8823119.

22. Yang, Yan & Yang, Hui & Pan, Hongyin& Xu, Jue& Hu, Tao. (2015). Evaluation and New Classification of Alveolar Bone Dehiscences Using Cone-beam Computed Tomography in vivo. International Journal of Morphology. 33. 361-368. 10.4067/S0717-95022015000100057.
23. Wada, K.. "A study on the individual growth of maxillofacial skeleton by means of lateral cephalometric roentgenograms." (1977).
24. Yang Z, Fan L, Kwon K, Pan J, Shen C, Tao J, Ji F. Age estimation for children and young adults by volumetric analysis of upper anterior teeth using cone-beam computed tomography data. Folia Morphol (Warsz). 2020;79(4):851-859. doi: 10.5603/FM.a2020.0004. Epub 2020 Jan 13. PMID: 31930465.
25. Braut V, Bornstein MM, Belser U, Buser D. Thickness of the anterior maxillary facial bone wall-a retrospective radiographic study using cone beam computed tomography. Int J Periodontics Restorative Dent. 2011 Apr;31(2):125-31. PMID: 21491011.
26. Yagci A, Veli I, Uysal T, Ucar FI, Ozer T, Enhos S. Dehiscence and fenestration in skeletal Class I, II, and III malocclusions assessed with cone-beam computed tomography. Angle Orthod. 2012 Jan;82(1):67-74. doi: 10.2319/040811-250.1. Epub 2011 Jun 22. PMID: 21696298; PMCID: PMC8881026.
27. Evangelista K, VasconcelosKde F, Bumann A, Hirsch E, Nitka M, Silva MA. Dehiscence and fenestration in patients with Class I and Class II Division 1 malocclusion assessed with cone-beam computed tomography. Am J OrthodDentofacialOrthop. 2010 Aug;138(2):133.e1-7; discussion 133-5. doi: 10.1016/j.ajodo.2010.02.021. PMID: 20691344.
28. Jing WD, Xu L, Li XT, Xu X, Jiao J, Hou JX, Wang XX. Prevalence of and risk factors for alveolar fenestration and dehiscence in the anterior teeth of Chinese patients with skeletal Class III malocclusion. Am J OrthodDentofacialOrthop. 2021 Mar;159(3):312-320. doi: 10.1016/j.ajodo.2019.11.018. Epub 2021 Jan 30. PMID: 33526298.
29. Dos Santos MC, Iwaki LCV, Valladares-Neto J, Inoue-Arai MS, Ramos AL. Impact of orthognathic surgery on the prevalence of dehiscence in Class II and Class III surgical-orthodontic patients. Angle Orthod. 2021 Sep 1;91(5):611-618. doi: 10.2319/062720-590.1. PMID: 33836070; PMCID: PMC8376160.
30. Alsino H I, Hajeer M, Alkhouri I, et al. (March 03, 2022) The Diagnostic Accuracy of Cone-Beam Computed Tomography (CBCT) Imaging in Detecting and Measuring Dehiscence and Fenestration in Patients With Class I Malocclusion: A Surgical-Exposure-Based Validation Study. Cureus 14(3): e22789. DOI 10.7759/cureus.22789
31. Wu SK, Yeh HC, Chan CP. The prevalence and distribution of bone defects in patients with moderate to advanced periodontitis. Chang Gung Med J. 2001 Jul;24(7):423-30. PMID: 11565248.
32. Jin SH, Park JB, Kim N, Park S, Kim KJ, Kim Y, Kook YA, Ko Y. The thickness of alveolar bone at the maxillary canine and premolar teeth in normal occlusion. J Periodontal Implant Sci. 2012 Oct;42(5):173-8. doi: 10.5051/jpis.2012.42.5.173. Epub 2012 Oct 31. PMID: 23185698; PMCID: PMC3498302.
33. Jin, Seong-Ho, Jun-Beom Park, Namryang Kim, Seojin Park, KyungJae Kim, Yoonji Kim, Yoon-Ah Kook and YoungkyungKo. "The thickness of alveolar bone at the maxillary canine and premolar teeth in normal occlusion." Journal of Periodontal & Implant Science 42 (2012): 173 - 178.
34. Al-Homsi, Hala & Hajeer, Mohammad Y. (2015). An Evaluation of Inter- and Intraobserver Reliability of Cone-beam Computed Tomography- and Two Dimensional-based Interpretations of Maxillary Canine Impactions using a Panel of Orthodontically Trained Observers. The Journal of Contemporary Dental Practice. 16. 648-656. 10.5005/jp-journals-10024-1736.