The Vomer Bone Pattern Variations in Dentofacial Discrepancy using three-dimensional Analysis

Üç Boyutlu Analizler Kullanılarak Dentofasiyal Yetersizliğinde Vomer Kemik Örneğindeki Varyasyonlar

Ammar Mohi[1,] , Kadir Beycan[2], Şebnem Yalçınkaya[3]

[1] Specialist Dentist, Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Baghdad University, Baghdad, Iraq.
[2] Assistant professor, Department of Orthodontics, Faculty of Dentistry, Marmara University, Istanbul, Turkey.
[3] Professor, Chairman and Head of Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Marmara University, Istanbul, Turkey.

ORCID IDw of the authors: A.M. 0000-0003-1394-5743

Cite this article as: Mohi A., Beycan K., Yalçınkaya Ş. The Vomer Bone Pattern Variations in Dentofacial Discrepancy using three-dimensional Analysis. Clin Exp Health Sci 2018; 8: 284-290.

ABSTRACT

Objectives: Objective: The aim of this study was to evaluate the spatial and dimensional morphometric changes of the vomer bone in relation to the mid face deficiency.
Methods: The CBCT images of 96 patients in Marmara University / Faculty of Dentistry/ Orthodontic department patients cases archive were there images evaluated within age between 16 to 30 years old, with normal occlusion and Angle Class III malocclusion. Patients CBCT images analyzed with Steiner analysis using linear and angular reference planes of 13 skeletal points selected. The 3D reconstructive models of vomer bone dimension were built and measured using MIMICS 19.0V software and all data analyzed statistically
Results: There was a statistically significant relationship in both linear and angular measurements of the vomer bone where the anterior values ($p < 0.01$) and the posterior value of ($P < 0.05$). Also the correlation was highly significant ($p < 0.01$) in males and severe (type C) group of mid-face insufficiency. The 3D reconstructive models of vomer bone appeared wider and longer in dimensions when they measured in the severe (type C) group to be statistically different from other groups ($p < 0.01$).
Conclusion: The results of this study found the active role of vomer bone in mid-face region in all planes and its effect on Mid-face malocclusion.
Keywords: MIMICS, Orthodontics, Vomer Bone, Mid-Face Deficiency.

ÖZ

Amaç: Bu çalışmanın amacı, 1) Orta-yüz yetersizliği olan bireylerde vomer kemiğinin konumsal ve boyutsal morfometrik değişimlerini değerlendirmek.
Gereç ve Yöntem: Marmara Üniversitesi Diş Hekimliği Fakültesi Ortodontik A. D. arşivinden seçilmiş, normal okluzyonu ve Angle Sınıf III malokluzyonu olan 16-30 yaş arasındaki 96 hastanın CBCT görüntüleri değerlendirildi. Steiner analiziyle hastalar üç gruba ayrıldı, 13 iskeletsel nokta seçilerek doğrusal ve açısal referans düzlemleri çizildi. Vomer kemiğinin 3B rekonstrüktif boyutları, MIMICS 19.0V yazılımıyla ölçüldü ve veriler istatistiksel olarak analiz edildi.
Bulgular: Lineer ve açısal ilişkide vomer kemiğinin anterior ($p < 0.01$) ve posterior ($P < 0.05$) düzeysel parametreleri arasında istatistiksel olarak anlamlı ilişki olduğu saptandı ve bu korelasyonun erkeklerde ve şiddetli (tip C) orta-yüz yetersizliği grubunda daha belirgin olduğu görüldü ($p<0.01$). Vomer kemiğinin 3B rekonstriktif modelinin şiddetli (tip C) grupta daha geniş ve daha uzun şekilde ölçüldüğü ve istatistiksel olarak diğer gruplardan farklı olduğu saptandı ($p<0.001$).
Sonuç: çalışmanın bulguları tüm düzlemlerde orta-yüz bölgesinde, vomer kemiğinin aktif rolünün önemini göstermektedir.
Anahtar Sözcükler: MIMICS, Ortodonti, Vomer Kemik, Orta-Yüz Yetersizliği.

INTRODUCTION

In modern Orthognathic assessment, the cartilaginous or bony part of the midface complex is normally determined by accurate evaluation and proper treatment plan. (1)

Correspondence Author/Sorumlu Yazar: Ammar Mohi **E-mail/E-posta:** ammar_19_80@yahoo.com

This controversy in diagnosis and treatment appeared how to treat underdeveloped maxillary region with a dentofacial discrepancy. (2-4) although there are various morphometric evaluation modalities for treatment of the midfacial hypoplasia still continues to present a great challenge. (5)

The vomer bone as one component of septal cartilage (SC) in nasomaxillary complex represents the most common site in the reconstruction surgery because it lies within the surgical field and the relative flatness, thickness, and hardness of the vomer make it need more evaluation. (6)

The vomer is thickest at its posterior alar portion connected to the Perpendicular Plate of Ethmoid (PPE) and the presphenoidal joint and always markedly thicker than the PPE and the septum due to its bilaminar origin. (7, 8) That fact of pattern variations have definite clinical implications. (9)

Many studies have quantified the site, proportion and outline of vomer bone available for grafting in clefts. (10) However, these studies have had several limitations either study of human cadavers or the samples were few in number and age not in adult time. (11-13)

In a radiological evaluation studies, Cone beam computed tomography (CBCT) provide an accurate analysis with an orthographic view but required reconstruction through additional procedures. (14) CBCT imaging demonstrates precise views of skeletal tissues and routinely provides sagittal images have the high quality of resolution used in evaluation by distinguishing the border outline of the bony structure at minimal cost. (15)

This is the first study using 3D vomer bone CBCT analysis to evaluate the vomer bone differences in relation to the dentofacial discrepancy and its implication in Orthodontics and Orthognathic implications. The aim was to clarify the components variations of the vomer bone in different dentofacial patterns in three different type groups. Thereby this study provides the data that will be helpful for the orthodontic and esthetic midfacial surgery.

Methods

The study was designed as a retrospective study and was carried out on the patient CBCT records that selected from the archives of the Orthodontics Department/ Faculty of Dentistry ethic committee consent with a protocol number of 2016-32.

When Patients' CBCT records of ninety-six patients were thirty-six of Angle class I (normal) occlusion and sixty of Angle class III malocclusion patients. In total 44 (45.8%) were female and 52 (54.2%) were male. The mean age was 23.23 ± 3.92 year – old. Patients were divided into three groups:

1. The "type A" of Angle Cl I normal occlusion 37.5% (n = 36) with a maximum interocclusal (ANB) angular relation value above (4°< ANB >1°).
2. The "type B" of Angle Cl III malocclusion 18.8% (n = 18) with an edge to edge interocclusal (ANB) angular relation value (1°< ANB >-1°).
3. The "type C" of Angle Cl III malocclusion 43.8% (n = 42) with an inverse interocclusal (ANB) angular relation value (< – 1°).

When the patients' CBCT records were taken, the focal spot diameter was 0.3 mm x. The CBCT device (Iluma Imtec; 3M Company, St Paul, Minn. USA). The minimum voxel size of the tomography device is 0.4 mm, the pixel size is 0.290 mm, and the cross-sectional area is 0.299 mm and the device 120 KVp and 1.0mA current.

The Ninety-six patients' images who were worked on a desktop computer and then a computer software Mimics version 19.0 (Mimics®, Materialise, Leuven, Belgium) was transferred images module to the Digital Imaging and Communications in Medicine (DICOM) module preparing for the suitable preoperative analysis of modeling for each patient.

Firstly, the threshold of bone scale selected before cropping for skeletal observation representing by the bone Hounsfield Units (HU) was chosen with a minimum limit of (-1024) Hounsfield Units (HU) and a maximum of (1650) HU. The threshold (bone scale threshold) is important to create first separation of the involved anatomical structures landmarks of the vomer bone.

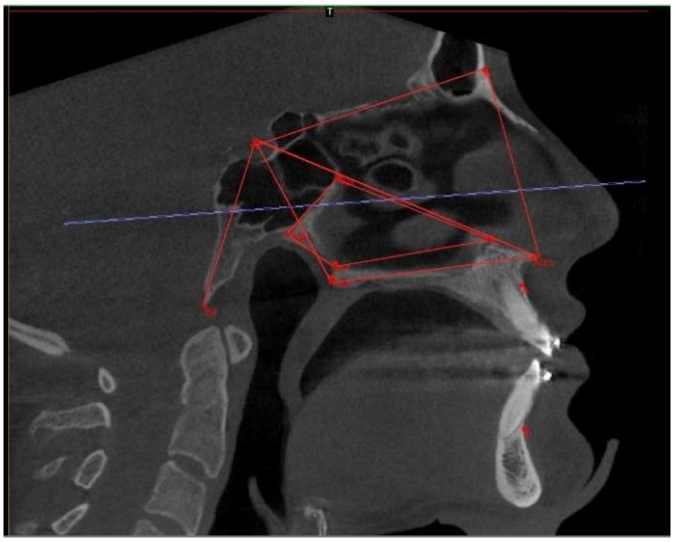

Figure 1. Landmarking and Dimensional Determination.

The vomer bone scale was launched by using thresholding between (-1000) to (1000) Hounsfield Units (HU) for better image resolution.

Secondly, the vomer bone anatomical landmarks were determined and the skeletal planes of the vomer bone were measured and outlined by using the cropping and segmentation tools of the Mimics 19.0 version. (Figure. 1 and 2).

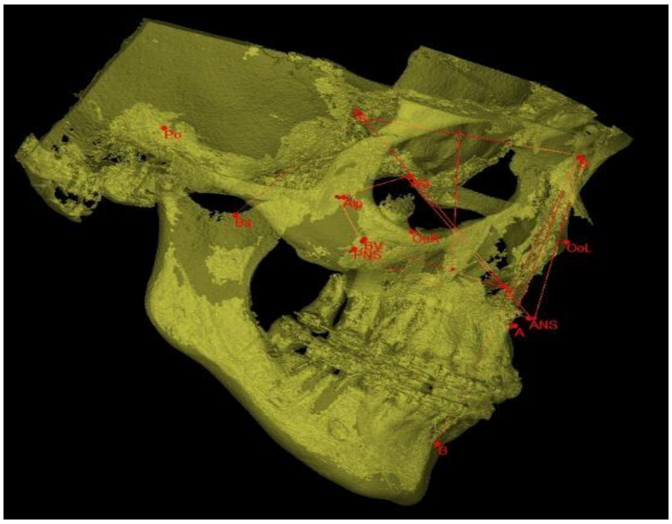

Figure 2. Horizontal and Vertical Coordination Planes.

The coordination for both horizontal and vertical performed for symmetry purpose preliminary to the vomer bone outline.

Finally, the three dimensional (3D) models of the full head and vomer bone were reconstructed and separated from each other based on splitting mask tool for determination of landmarks and planes of the vomer bone among three different study (A, B and C) groups respectively for each patient's records CBCT. (Figure.3 and 4) (Table.1)

Table. 1 The Study Skeletal Landmarks

Landmark	Definition
Nasion (N)	The junction between the nasal and frontonasal sutures
Sella (S)	The center of the Sella turcica on the midsagittal plane
Basion (Ba)	The most anterior curve of foramen magnum
Anterior nasal spine (ANS)	The most anterior point on the floor of nose
Orbitale Right (OoR)	The most inferolateral point of Right inferior orbital margin
Orbitale Right (OoL)	The most inferolateral point of Left inferior orbital margin
Posterior nasal spine (PNS)	The most posterior point on the floor of nose
A point (A)	The deepest point between ANS and prosthion at the midsagittal plane of upper alveolus of upper incisors
B point (B)	The deepest point between pogonion and the alveolus of the lower incisors on the midsagittal plane
Vomer apex (C)	The most anterior and medial point at upmost opening of nasopalatine canal corresponding to canine eminence point CE bilaterally
Vomer base(BV)	The most posterior and medial point of maxilla at lowermost opening of sphenopalatine fissure opening corresponding to point PNS medially
Vomer ala anterior (Ala)	The most superior and medial point at uppermost level of anterior sphenoid body.
Vomer ala posterior (Alp)	The most posterior and medial point at lowermost level of anterior sphenoid body.

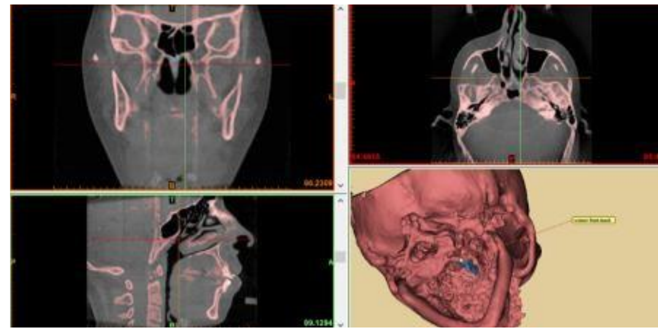

Figure 3. Full Skull 3D model Reconstruction.

Figure 4. Vomer bone 3D model analysis.

Statistical analysis of the data was performed using SPSS statistics program for Windows (version 22.0, SPSS, Chicago, IL, USA). The Shapiro-Wilk normality test was applied. Also Statistical Investigations NCSS (Number Cruncher Statistical System) 2007 (Kaysville, Utah, USA) program was used for statistical analysis. Student t-test was used in two group comparisons of the variables that showed normal distribution in comparison of descriptive statistical methods (mean, standard deviation, median, frequency, ratio, minimum, maximum) as well as quantitative data. Mann Whitney U test was used in two group comparisons of non-paired It was used. The Kruskal Wallis test and the Mann Whitney U test were used in the comparison of the three groups with no normal distribution. Spearman's Correlation Analysis was used to evaluate inter-variable relationships. The Fisher-Freeman-Halton Test was used for the comparison of qualitative variables. Significance was assessed at $p < 0.05$.

Results

When the dimensional measurements according to the type of groups were examined. There was no statistically significant difference between the mean ages of cases according to study groups ($p > 0.05$). Whereas; there was a statistically significant difference between male and female ($p<0.01$). The incidence of Type C (severe group) in males is significantly higher than females. There were highly significant differences ($p<0.01$) between all skeletal parameters among different study groups as shown in (Table.2).

Table.2 The Dimensional Analysis of Study Groups

Cranial		Type			*p*	
		A (n=18)	B (n=9)	C (n=21)		
ANS – PNS	Min-Max (Median)	45,42-58,79 (54,3)	43,88-50,26 (46,2)	41,71-71,33 (48,4)	***0,001*****	A>B=C
	Mean±SDs	53,17±4,41	46,15±1,89	48,96±6,41		
Midfacial						
C-ANS	Min-Max (Median)	7,22-15,6 (11)	9,82-14,12 (13,7)	5,53-20,13 (14,6)	***0,002*****	B=C>A
	Mean±SDs	11,13±2,48	12,93±1,5	14,17±3,00		
AC	Min-Max (Median)	6,37-15,11 (10,1)	11,42-14,85 (13,9)	9,9-30,21 (14,3)	***0,001*****	B=C>A
	Mean±SDs	10,50±2,85	13,60±1,24	15,84±4,72		
	Mean±SDs	18,20±2,27	15,74±1,87	20,54±7,23		
Ala-BV	Min-Max (Median)	15,24-27,66 (21,7)	15,31-22,46 (21,8)	18,11-29,72 (23,7)	***0,049****	C>A
	Mean±SDs	21,20±3,40	20,73±2,41	23,65±3,18		
CBV	Min-Max (Median)	34,33-46,03 (41,7)	29,17-37,72 (34,4)	25,91-41,58 (34,8)	***0,001*****	A>B=C
	Mean±SDs	41,27±3,54	33,35±2,81	35,22±4,45		
C-Alp	Min-Max (Median)	52,24-67,54 (60,7)	44,2-57,41 (49)	33,21-60,98 (55,1)	***0,001*****	A>C>B
	Mean±SDs	60,50±5,52	50,06±4,46	53,81±5,90		
C-Ala	Min-Max (Median)	41,23-54,58 (46,4)	33,32-51,33 (42,1)	26,16-51,04 (43,7)	***0,025****	A>B=C
	Mean±SDs	47,01±4,23	41,32±6,60	42,94±5,92		

ANS-PNS: Maxilla base plane, **C-ANS**: Anterior maxilla plane, **A-C**: Anterior dentoalveolar plane, **C-Alp**: Full length of vomer bone, **C-Ala**: mattress of vomer bone, **Ala-BV**: Height of vomer bone, **C-BV**: Vomer bone base
Kruskal Wallis Test *p<0,05 **p<0,01

Table. 3 The Correlation of Vomer Bone Variables with Skeletal Parameters.

		Type Groups					
		TypeA		TypeB		TypeC	
Vomer	*Skeletal*	r	*p*	r	*p*	r	*p*
Ala-BV	**AC**	0,457	0,056	-0,169	0,664	0,125	0,589
	ANS-PNS	0,701	0,001**	0,142	0,715	0,066	0,775
	C-ANS	0,492	0,038*	-0,151	0,698	0,137	0,553
CBV	**AC**	0,067	0,791	0,177	0,648	0,165	0,474
	ANS-PNS	0,695	0,001**	0,527	0,145	-0,082	0,724
	C-ANS	0,061	0,810	0,479	0,192	0,274	0,229
C-Alp	**AC**	0,259	0,299	0,244	0,527	0,131	0,571
	ANS-PNS	0,917	0,001**	0,317	0,406	0,092	0,693
	C-ANS	0,059	0,817	0,226	0,559	0,328	0,147
C-Ala	**AC**	0,129	0,610	0,034	0,932	0,504	**0,020***
	ANS-PNS	0,858	0,001**	0,400	0,286	0,346	0,124
	C-ANS	0,065	0,798	0,142	0,715	0,106	0,648

ANS-PNS: Maxilla base plane, **C-ANS**: Anterior maxilla plane, **A-C**: Anterior dentoalveolar plane, **C-Alp**: Full length of vomer bone, **C-Ala**: mattress of vomer bone, **Ala-BV**: Height of vomer bone, **C-BV**: Vomer bone base

r: Spearman's Correlation Coefficient *p<0,05 **p<0,01

Almost of the vomer bone skeletal parameters in relation to the maxilla base plane (ANS-PNS) skeletal parameter were diminished in both mild and severe malocclusion (B and C) groups by values of (44,2±-57,41, 33,21±60,98) mm respectively. While the vomer perpendicular height (Ala-Bv) parameter were increased inversely proportional. (Table.2)

There were significant differences between the vomer bone length parameter represented by (C-Alp) and the vomer base parameter represented by (C-BV) with the severity of class III malocclusion (Type C) were (p< 0.01) respectively. (Table.2)

A positive correlation was shown also between the vomeral mattress parameter (C-Ala) and anterior dentoalveolar base parameter (A-C) variables (0,504/0,020*) in severe group (Type C). In contrast, there was no correlation between other vomer bone components. (Table.3)

The dimensional change of 3D reconstruction models of the vomer bone appeared highly significant differences in different groups in relation to the severity of malocclusion by values of (2090,3) mm^3 that the vomer bone became larger in size in severe group (Type C). (Table.4)

Discussion

Maxillary orthopedic is an essential topic in the treatment of the malocclusion with surprising concept because of its interrelationships with the various distinct anatomical architectures. (16-18) Last decades, a low-cost CBCT is not worthy used in craniofacial applications (19, 20) but nowadays are widely used for analysis of a broad spectrum of dentofacial discrepancy like midface complex. (21)

Conventional cephalometrics 2D analysis can give a general idea of the problem in most cases. However, unambiguous craniofacial deformities are not clearly diagnosed and treatment planning alone suffices the defects. Especially in Orthognathic surgery planning, the position, size and relationships of craniofacial structures need to be determined more precisely. In order to solve this problem, although many investigators try to make three-dimensional reconstructions based on using two-dimensional posteroanterior and lateral cephalograms, the reproducibility of measurements and sensitization has not been adequately used. (22)

In this study, unlike previous studies that used a 2D conventional cephalometrics alone or CBCT 3D image analysis with misdiagnosed vomer bone.(23) Firstly, the parameter measured by using 2D cephalometrics landmarks and planes determination then after the vomer bone outline observed for the reconstruction of the 3D models without errors using algorithmic tools of Mimics 19.0 version software. Superposition of anatomical structures or different magnifications in different regions, have not been observed frequently in the examining of the skeletal craniofacial structures. By that method facilities, the analyzing of the midface complex revealed a precise image in three dimensional reality.(24) Therefore, before orthodontic and orthognathic surgery procedures; The CBCT analysis can be used to evaluate incoming changes that might be reported with no complication and with steady treatment's outcome later. (25)

When the dimensional changes of skeletal parameters evaluated, the vomer bone components (Length, Mattress, Base and Height) (C-Alp, C-Ala, C-BV and Ala-BV) shown with values (53,81±5,90, 42,94±5,92, 23,65±3,18, and 35,22±4,45) respectively highly proportional and significant differences with maxillary length (ANS-PNS) parameters among different study groups. However, The anterior maxilla plane (ANS-

C) and dentoalveolar impaction plane (A-C) parameters increased inversely (14,17±3,00), (15,84±4,72) when the vomer bone backward displaced and impacted in the sever group malocclusion (Type C).(26)

Thus, a new finding of this study emphasized a strong correlation of the anterior midfacial pattern with vomer bone anterior parameters under the biodynamic effect of the skeletal dimensional changes of the vomer bone. The displacement range of all vomer bone parameters were between (3-5) mm in all planes with near value of (±4,72) mm. That results appeared to be parrallel with the Bacilli's study with confidential evidence to the anatomical feature of anterior portion of maxilla segments. (Table 3) (27, 28)

Due to the vomer bone morphology of the "Y" shape, the anterior proximal segments has a close relation to the septo-vomeral traction that narrower anterior segment of the medial directional displacement of the maxilla line occurs. These observational findings appeared clearly with highly significant increase and positive correlation in the anterior maxilla region (ANS-PNS), (ANS-C), (A-C) parameters in relation to the full length of vomer bone and its basal plane parameters were diminished in backward displacements toward the severity of malocclusion. (29) (Table.2) (Table.3)

On the other hand, the interesting interrelations of the vomer bone with midfacial architecture using 3D CBCT analysis not reveal accurately previously. In this study, the application of the possibility of creating 3D reconstruction model of the full skull and vomer bone models provide the opportunity to analyze the vomer bone with great

Table. 4 The 3D Model Variables of The Full Face and Vomer Bone.

Variable		**Type**			***p***	
		A (n=36)	**B (n=18)**	**C (n=42)**		
Face Model	Min-Max (Median)	313310,6-568871,2 (359786,3)	307725,2-465322,3 (421677,7)	307725,2-568111,4 (493231,8)	***0,001****	C>A=B
	Mean±SDs	411827,53±94680,17	395089,79±54770,1	482389,16±74392,88		
Vomer Model	Min-Max (Median)	888,1-1784,3 (1208,6)	993,6-2119,7 (1889,5)	1073,6-2843,3 (2090,3)	***0,001****	C>B>A
	Mean±SDs	1253,64±263,46	1656,64±477,78	2249,77±457,69		

r: Spearman's Correlation Coefficient *p<0,05 **p<0,01 accuracy and reproducibility. The analysis of this study 3D models were developed by defining landmarks and planes initially then converted from 2D to 3D masks for accurate finding analysis. As a result the vomer bone seemed to be significantly larger in relation to the increase of severity among different study groups. (30)

That vomer bone components analysis were reported with a meaningful limitation of this study retrospectively and less sample account. However, that study fact have an important orthodontic and surgical implementation because the pattern of anomalies and facial disharmony appeared almost varied between individuals even though a little dentofacial difference may be seen between each others.

According to the findings of this study, the dimensional change and 3D pattern variations of vomer bone were shown to be highly significant and correlated with a meaningful displacement to the skeletal dentofacial discrepancy by using 3D CBCT image analysis.

Conclusion

Under the limits of this study it can be concluded that: Three-dimensional analysis of the vomer bone segments provide the clear evidence of the midface pattern discrepancy with malocclusion. To create an ideal treatment plan the morphometric analysis for malocclusion with different dentofacial pattern should be evaluated. In order to evaluate a more reliable relationship of vomer bone with midface hypoplasia and dentofacial pattern discrepancy, further studies are still needed to be conducted. Ethics Committee Approval: This study was approved by Clinical Researchs Ethic Comittee of Marmara University, Faculty of Dentistry.

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Peer-review: Externally peer-reviewed.

Author contributions: Concept - A.M., K.B., Ş.E.Y.; Design - A.M., K.B., Ş.E.Y.; Supervision A.M., K.B., Ş.E.Y.; Materials – A.M., K.B., Ş.E.Y.; Data Collection and/or Processing - A.M., K.B., Ş.E.Y.; Analysis and/or Interpretation - A.M., K.B., Ş.E.Y.; Literature Search A.M., Ş.E.Y.; Writing A.M., K.B., Ş.E.Y.; Critical Reviews - A.M., K.B., Ş.E.Y.

Conflict of Interest: The authors have no conflict of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

Etik Komite Onayı: Bu çalışma Marmara Üniversitesi Diş hekimliği Fakültesi Klinik Araştırmalar Etik Kurulu tarafından onaylanmıştır.

Hasta Onamı: Bu çalışmaya katılan hastalardan yazılı onam formu alınmıştır.

Hakem Değerlendirmesi: Dış Bağımsız.

Yazar Katkıları: Fikir – A.M., K.B., Ş.E.Y.; Tasarım A.M., K.B., Ş.E.Y.; Denetleme - A.M., K.B., Ş.E.Y.; Kaynaklar– A.M., K.B., Ş.E.Y.; Malzemeler – A.M., K.B., Ş.E.Y.; Veri Toplanması ve/veya işlemesi A.M., K.B., Ş.E.Y.; Analiz ve/veya Yorum – A.M., K.B., Ş.E.Y.; Literatür taraması - A.M., Ş.E.Y.; Yazıyı Yazan - A.M., K.B., Ş.E.Y.; Eleştirel İnceleme - A.M., K.B., Ş.E.Y.

Çıkar Çatışması: Yazarlar çıkar çatışması bildirmemişlerdir

Finansal Destek: Yazarlar bu çalışma için finansal destek almadıklarını beyan etmişlerdir.

References

[1] Rohrich RJ, Ahmad J. Open technique rhinoplasty. In: Warren RJ, Neligan PC, editors. Plastic surgery. 3rd ed. New York: Saunders Elsevier 2012; p.387-412.

[2] Masucci C, Franchi L, Defraia E, Mucedero M, Cozza P, Baccetti T. Stability of rapid maxillary expansion and facemask therapy: A long-term controlled study. Am J Orthod Dentofacial Orthop. 2011;140:493–500.[PubMed]

[3] Ferro A, Nucci LP, Ferro F, Gallo C. Long-term stability of skeletal class III patients treated with splints, class III elastics, and chincup. AmJOrthod Dentofacial Orthop 2003;123:423–34. [PubMed]

[4] Rey D, Angel D, Oberti G, Baccetti T. Treatment and posttreatment effects of mandibular cervical headgear followed by fixed appliances in Class III malocclusion. Am J Orthod Dentofacial Orthop. 2008;133:371–8. [PubMed]

[5] 5 .Marcus AF, Corti M, Loy A, Naylor GJP, Slice DE, editors. Advances in morphometrics. New York: Plenum. NATO ASI Series A: Life Sciences 1996.Vol. 284, 587 p.

[6] Sajjadian A, Rubinstein R, Naghshineh N. Current status of grafts and implants in rhinoplasty: part I. Autologous grafts. Plast Reconstr Surg 2010;125:40e-9e.

[7] Rohrich RJ, Hollier LHJ, Landecker A. Harvesting cartilage grafts for primary rhinoplasty. In: Gunter JP, Rohrich RJ, Adams WPJ, editors. Dallas rhinoplasty: nasal surgery by the masters. 2nd ed. St. Louis, MO: Quality Medical Pub 2007;p.177-86.

[8] Daniel RK. Rhinoplasty: an atlas of surgical techniques. New York: Springer-Verlag; 2001.

[9] Miles BA, Petrisor D, Kao H, et al. Anatomical variation of the nasal septum: analysis of 57 cadaver specimens. Otolaryngol Head Neck Surg 2007;136:362-8.

[10] Kim JS, Khan NA, Song HM, et al. Intraoperative measurements of harvestable septal cartilage in rhinoplasty. Ann Plast Surg 2010;65:519-23.

[11] Kim IS, Lee MY, Lee KI, et al. Analysis of the development of the nasal septum according to age and gender using MRI. Clin Exp Otorhinolaryngol 2008;1:29-34.

[12] Kim JS, Jang PY, Choi TH, et al. The dimension of the septal cartilage using the cadaver study. J Korean Soc Aesthetic Plast Surg 2006;12:29-32.

[13] Kim J, Cho JH, Kim SW, et al. Anatomical variation of the nasal septum: Correlation among septal components. Clin Anat 2010;23:945-9.

[14] Basili C, Otsuka, T, Kubota M, Slavicek R, Sato S. Three-dimensional CT analysis of vomer bone in the architecture of craniofacial structures in caucasic human skulls. International journal of stomatology & occlusion medicine 2009; 2(4), 191-204.

[15] Adam GL, Gansky SA, Miller AJ, Harrel WE Jr, Hatcher DC. Comparison between traditional 2-dimensional cephalometry and a 3-dimensional approach on human dry skulls. Am J Orthod Dentofacial Orthop 2004;126(4):397–409.

[16] Deguchi T, Kuroda T, Minoshima Y, Graber TM. Craniofacial features of patients with Class III abnormalities: growth-related changes and effects of short-term and long-term chincup therapy. Am J Orthod Dentofacial Orthop 2002;121:84-92.

[17] McCance AM., Moss JP, Fright WR, James DR., Linney AD. A three dimensional analysis of soft and hard tissue changes following bimaxillary orthognathic surgery in skeletal III patients. British Journal of Oral and Maxillofacial Surgery 1992;30(5), 305-312.

[18] Turvey T. Sequencing of two-jaw surgery: the case for operating on the maxilla first. Journal of oral and maxillofacial surgery: official journal of the American Association of Oral and Maxillofacial Surgeons. 2011;69 doi: 10.1016/j.joms.2010.10.050. [PubMed] [Cross Ref]

[19] Mozzo P, Procacci C, Tacconi A, Martini PT, Andreis IA. A new volumetric CT machine for dental imaging based on the cone-beam technique: preliminary results. Eur Radiol 1998; 8: 1558-64. [Crossref

[20] Mah J, Hatcher D. Three-dimensional craniofacial imaging. Am J Orthod Dentofac Orthop 2004; 126: 308-19. [Crossref]

[21] Hashimoto K, Arai Y, Iwai K, Araki M, Kawashima S, Terakado M. A comparison of a new limited cone beam computed tomography machine for dental use with a multidetector row helical CT machine. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2003; 95: 371-7. [Crossref]

[22] Ludlow JB, Davies-Ludlow LE, Brooks SL, Howerton WB. Dosimetry of 3 CBCT devices for oral and maxillofacial radiology: CB Mercuray, NewTom 3G and i-CAT. Dentomaxillofacial Radiol 2006; 35: 219-26. [Crossref]

[23] Ritto FG, Ritto TG, Ribeiro DP, Medeiros PJ, de Moraes M. Accuracy of maxillary positioning after standard and inverted orthognathic sequencing. Oral surgery, oral medicine, oral pathology and oral radiology. 2014;117:567–574. doi: 10.1016/j.oooo.2014.01.016. [PubMed] [Cross Ref]

[24] Baan F, et al. A New 3D Tool for Assessing the Accuracy of Bimaxillary Surgery: The OrthoGnathicAnalyser. PloS one. 2016;11 doi: 10.1371/journal.pone.0149625. [PMC free article] [PubMed] [Cross Ref]

[25] Turvey TA. Simultaneous mobilization of the maxilla and mandible: surgical technique and results. Journal of oral and maxillofacial surgery: official journal of the American Association of Oral and Maxillofacial Surgeons. 1982;40:96–99. doi: 10.1016/S0278-2391(82)80033-5. [PubMed] [Cross Ref]

[26] Schneider M, Tzscharnke O, Pilling E, Lauer G, Eckelt U. Comparison of the predicted surgical results following virtual planning with those actually achieved following bimaxillary operation of dysgnathia. Journal of cranio-maxillo-facial surgery: official publication of the European Association for Cranio-Maxillo-Facial Surgery. 2005;33:8–12. doi: 10.1016/j.jcms.2004.05.010. [PubMed] [Cross Ref]

[27] Barteczko K, Jacob M. A re-evaluation of the premaxillary bone in humans. Anat Embryol 2004;207(6):417–37.Hansen L, Nolting D, Holm G, Hansen B, Kjaer I. Abnormal vomer development in human fetuses with isolated cleft palate. Cleft Palate Craniofac J 2004;41(5):470–3.

[28] Mooney MP, Siegel MI. Premaxillary-maxillary suture fusion and anterior nasal tubercle morphology in the chimpanzee. Am J Phys Anthropol 1991.85:451–456.

[29] Singh GD, McNamara Jr JA, Lozanoff S. Morphometry of the midfacial complex in subjects with Class III malocclusions: Procrustes, Euclidean and cephalometric analyses 1998. Clin Anat 11:162–170.