Evaluation of Relationship Between Maxillary Sinus Volume and Nasolacrimal Canal Dimension Using Cone Beam Computed Tomography

Maksiller Sinüs Hacmi ile Nazolakrimal Kanal Boyutu Arasındaki İlişkinin Konik Işınlı Bilgisayarlı Tomografi İle Değerlendirilmesi

Selin YEŞİLTEPE[1] https://orcid.org/0000-0002-6857-1411
Hande SAĞLAM[2] https://orcid.org/0000-0001-7792-5106
Suayip Burak DUMAN[3] https://orcid.org/0000-0003-2552-0187
Ibrahim Sevki BAYRAKDAR[2] https://orcid.org/0000-0001-5036-9867
Yasin YASA[4] https://orcid.org/0000-0002-4388-2125
Numan DEDEOĞLU[3] https://orcid.org/0000-0003-0892-3654

[1] Aydın Adnan Menderes Üniversitesi, Diş Hekimliği Fakültesi, Ağız, Diş ve Çene Radyolojisi Ana Bilim Dalı, Aydın
[2] Eskişehir Osmangazi Üniversitesi, Diş Hekimliği Fakültesi, Ağız, Diş ve Çene Radyolojisi Ana Bilim Dalı, Eskişehir
[3] İnönü Üniversitesi, Diş Hekimliği Fakültesi, Ağız, Diş ve Çene Radyolojisi Ana Bilim Dalı, Malatya
[4] Ordu Üniversitesi, Diş Hekimliği Fakültesi, Ağız, Diş ve Çene Radyolojisi Ana Bilim Dalı, Ordu

Atıf/Citation: Yeşiltepe S., Sağlam H., Duman S.B., Bayrakdar İ.S., Yasa Y., Dedeoğlu N., (2022). Evaluation of Relationship Between Maxillary Sinus Volume and Nasolacrimal Canal Dimension Using Cone Beam Computed Tomography. Ege Üniversitesi Diş Hekimliği Fakültesi Dergisi,43(3), 169-173.

ABSTRACT

Introduction: The objective of this study was to evaluate a possible relationship between maxillary sinus volume (MSV) and the diameter and length of the nasolacrimal canal (NC) using cone beam computed tomography (CBCT) data.

Methods: In this retrospective study, CBCT scans of 93 patients were evaluated. The maxillary sinuses and NCs were evaluated separately using Fujifilm-Synapse 3D software. 186 measurements of NC and maxillary sinuses were made in 93 patients.

Results: The total mean patient age was 38.2 ± 15.2 years. There were no significant differences between genders in terms of MSV, length, and diameter of NC. No statistically significant differences were found between the two sides in terms of MSV, length, and diameter of NC. While a negative correlation was detected between MSV and NC diameter, a positive correlation was found between MSV and NC length.

Discussion and Conclusion: As the maxillary sinus medial wall forms the lateral border of the nasal cavity, the recognition and preservation of the nasolacrimal canal is essential for better postoperative results in surgical procedures to be applied to this area. In our study, it was found that as MSV increased, the diameter of the NC decreased and its length increased.

Keywords: *Maxillary sinus volume, Nasolacrimal canal, Cone Beam Computed Tomography*

ÖZ

Giriş ve Amaç: Bu çalışmanın amacı, maksiller sinüs hacmi (MSH) ile nazolakrimal kanal (NK) çapı ve uzunluğu arasındaki olası ilişkiyi konik ışınlı bilgisayarlı tomografi (KIBT) verilerini kullanarak değerlendirmektir.

Yöntem ve Gereçler: Bu retrospektif çalışmada 93 hastanın KIBT taramaları değerlendirildi. Maksiller sinüsler ve NK'ler Fujifilm-Synapse 3D yazılımı kullanılarak ayrı ayrı değerlendirildi. 93 hastada 186 NK ve maksiller sinüs ölçümü yapıldı.

Bulgular: Toplam ortalama hasta yaşı 38.2 ± 15.2 yıldı. MSH, NK çapı ve uzunluğu açısından cinsiyetler arasında anlamlı fark yoktu. MSH, NK çapı ve uzunluğu açısından iki taraf arasında istatistiksel olarak anlamlı fark bulunmadı. MSH ile NK çapı arasında negatif korelasyon saptanırken, MSH ile NK uzunluğu arasında pozitif korelasyon bulundu.

Tartışma ve Sonuç: Maksiller sinüs medial duvarı, nazal kavitenin lateral sınırını oluşturduğundan, bu bölgeye uygulanacak cerrahi işlemlerde daha iyi postoperatif sonuçlar için nazolakrimal kanalın tanınması ve korunması esastır. Çalışmamızda, MSH arttıkça NK çapının azaldığı ve uzunluğunun arttığı bulundu.

Anahtar Kelimeler: *Maksiller sinüs hacmi, Nazolakrimal kanal, Konik Işınlı Bilgisayarlı Tomografi*

Sorumlu yazar/Corresponding author*: dt_selin@yahoo.com
Başvuru Tarihi/Received Date: 01.11.2021
KabulTarihi/Accepted Date: 08.12.2021

INTRODUCTION

The nasolacrimal canal (NC) is located in front of the inferior lateral wall of the orbit and connected to the inferior nasal meatus.[1] Tear fluid is drained by this duct which extends through the nose exiting under the inferior turbinate.[2] The nasolacrimal drainage system obstruction causes epiphora. There can be congenital or acquired obstruction in this system. Bartley classified acquired lacrimal duct obstruction as primary and secondary.[3] While the secondary obstruction etiology includes trauma, neoplasm, surgery, sarcoidosis and granulomatosis, the exact etiology of primary acquired nasolacrimal duct obstruction (PANDO) is uncertain, but some anatomical factors have been identified.[4] Causal factors proposed include chronic inflammation and fibrosis in the nasolacrimal duct.[3] Race and gender differences in facial skull sizes may result in narrow nasolacrimal ducts.[3,5]

The maxillary sinus is the largest and the first to develop of the paranasal sinuses.[6] It develops as a mucosal evagination of the nasal cavity middle meatus in the third month of intrauterine life. Maxillary sinus volume (MSV) is 6-8 mm^3 during birth, which increases in several directions including the zygomatic process, the nasal cavity, the infraorbital wall, and the alveolar process. Subsequent growth is mainly downward, and after the upper teeth eruption, the maxillary sinus size reaches the maximum volume usually by puberty.[7] In adults, the mean volume of the maxillary sinus is 14-18 cm^3. When both sexes get older, it will decrease after the maximum growth period.[8]

Maxillary sinus topography is variable due to the range of anatomical bony structures that make up this cavity. It may show anatomical variations, such as pneumatization, hypoplasia, antral septa, and exostosis. An atypical structure of the maxillary sinus presents difficulties during operations in this cavity.[9]

Cone beam computed tomography (CBCT) is applied in dentistry as an important diagnostic image modality. It may be preferred due to its higher resolution, low radiation dose, and low scanning time, compared to computed tomography (CT), which has been the gold standard for imaging paranasal sinuses. CBCT provides three-dimensional cross-sectional imaging that eliminates distortion and superpositions.[10,11]

Our study aimed to evaluate a possible relationship between MSV and the diameter and length of the NC using CBCT data.

MATERIALS and METHODS

In this retrospective study, with approval from the local ethics committee of İnönü University (Decision No: 2020/2-205), CBCT scans of 93 patients (62 females and 31 males) were evaluated. The study was carried out in full compliance with the Helsinki Declaration. CBCT data used in this study were randomly selected from archive of the Oral and Maxillofacial Radiology Department, İnönü University and no additional CBCT images were taken for this study. CBCT images were excluded if it was not possible to evaluate both maxillary sinuses and NCs. Additional exclusion criteria were patients with any type of sinus pathology, craniofacial syndrome, prior history of maxillofacial trauma, paranasal sinus surgery, and those under 20 years of age. CBCT imaging was performed with the same device (NewTom 5G, Quantitative Radiology, Verona, Italy) in the standard supine position (110 kVp, 1-11 mA, 3.6 s). To ensure the consistency of the sagittal images, Frankfort horizontal planes of all patients were placed perpendicular to the table.

Table 1. Distribution of patients by gender.

	N	Minimum	Maximum	Mean	Std. Deviation
Female	62	21	94	37.71	15.59
Male	31	21	70	39.19	14.58
Total	93	21	94	38.20	15.20

The maxillary sinuses and NCs were evaluated separately; 186 measurements of NC and maxillary sinuses were made in 93 patients. All measurements were performed by the same radiologist with nine years of experience (S.B.D.) Fujifilm-Synapse 3D software (Fujifilm Medical Systems, Stamford, CT, USA) was used to evaluate the CBCT images. NC measurements were made using the study data obtained by editing axial images in parallel with the orbital base in the volumetric data file. At the axial section, the largest transversal diameter was identified, and the diameter of the NC was measured (Fig 1). NC length measurements were made in the sagittal section with a thickness of 0.25 mm. In the obtained sagittal section, the distance between the midpoints of lines crossing the upper and lower anterior and posterior walls of the NC was recorded as the length of the canal (Fig 2). Then, the patients' MSVs were measured using Fujifilm-Synapse 3D software (Fujifilm Medical Systems, Stamford, CT, USA). The software's "calculate 3D" tool was used to calculate MSVs automatically (Fig 3).

SPSS software (SPSS Inc., Chicago, IL) was used for all statistical analyses. Descriptive statistics were assessed with Mann Whitney U, $\chi 2$, and Spearman correlation tests. $p<0.05$ was considered to be statistically significant. The intraclass coefficients were 0.85–0.92 for all measurements.

Table 2. Distribution and statistical analysis of the maxillary sinus volume, length and diameter of nasolacrimal canal by gender.

	Gender	N	Mean	Std. Deviation	Mean Rank	P
Length of nasolacrimal canal (mm)	Female	124	15,14	1,89	94,69	0.671
	Male	62	15,03	2,12	91,13	
	Total	186	15.10	1.96		
Diameter of nasolacrimal canal (mm)	Female	124	4,17	0,84	95,36	0.505
	Male	62	4,12	0,91	89,78	
	Total	186	4.16	0.87		
Volume of maxillary sinus (mm^3)	Female	124	9,79	5,19	91,28	0.426
	Male	62	10,84	6,21	97,94	
	Total	186	10.14	5,56		

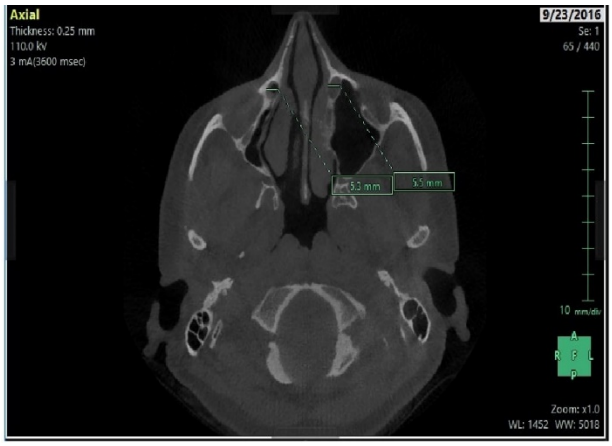

Figure 1. NC diameter measurement in the axial section.

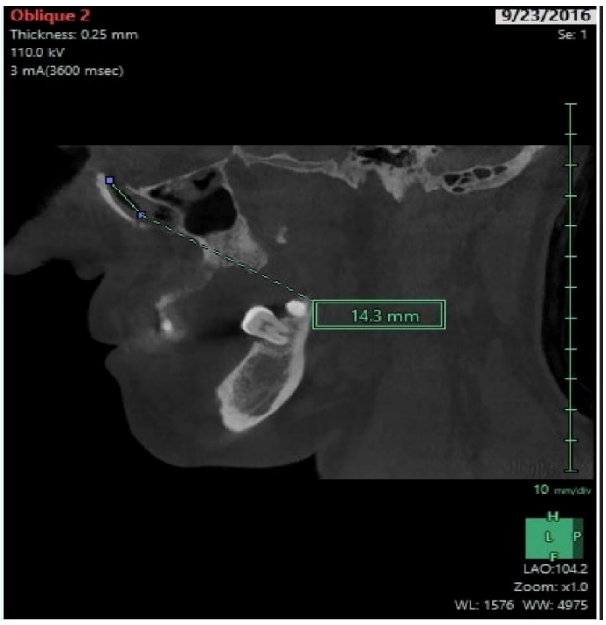

Figure 2. NC length measurement in the sagittal section.

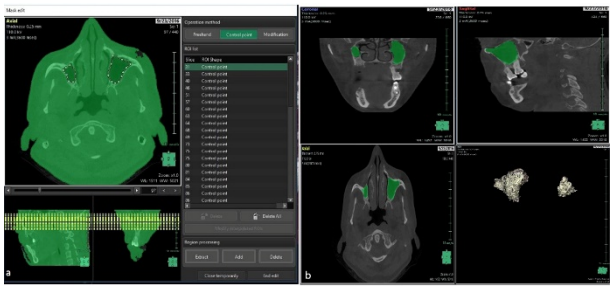

Figure 3. **a)** Clipping the maxillary sinus borders **b)** Three-dimensional reconstruction of the maxillary sinuses.

RESULTS

In this study, CBCT scans of 93 patients, 62 females and 31 males—a total of 186 maxillary sinuses and NCs—were evaluated. The total mean patient age was 38.2 ± 15.2 years—37.7 years for females and 39.2 years for males. (Table 1) No significant differences were between genders in terms of MSV, length, and diameter of NC. (Table 2) The two sides did not show any statistically significant differences in terms of MSV, length, and diameter of NC. (Table 3) While a negative correlation was detected between MSV and NC diameter, a positive correlation was found between MSV and NC length ($p < 0.01$). In other words, as MSV increased, the diameter of the NC decreased and its length increased. (Table 4)

DISCUSSION

The lacrimal system consists of two principal parts—the secretion system and the drainage system. There is a close anatomical relationship between the lacrimal drainage system and the nose and paranasal sinuses. The bone structure of the NC extends within the maxillary

sinus medial wall and opens to the inferior meatus. Narrowing of the lacrimal canal is the leading cause of development of epiphora. Epiphora is a common disease of the lacrimal passage system and can be treated with various surgical methods.[12] Information about the morphometry of the lacrimal drainage system provides ophthalmologists with precise information for the operation and avoids unnecessary interventions.

Table 3. Distribution and statistical analysis of the maxillary sinus volume, length and diameter of nasolacrimal canal by sides.

	Side	N	Mean	Std. Deviation	Mean Rank	P
Length of nasolacrimal canal (mm)	Right	93	15,11	10,80	93,67	0.966
	Left	93	15,10	1,97	93,33	
	Total	186	15,10	1,96		
Diameter of nasolacrimal canal (mm)	Right	93	4,19	0,87	96,26	0.484
	Left	93	4,12	0,86	90,74	
	Total	186	4,16	0,87		
Volume of maxillary sinus (mm^3)	Right	93	9,57	5,50	87,73	0.144
	Left	93	10,71	5,58	99,27	
	Total	186	10,14	5,56		

An NC obstruction can be congenital or acquired. In spite of unclear exact etiology of PANDO, there may many associated situations, such as a history of dacryocystitis, maxillofacial trauma, and smoking.[5] Another etiological factor described is a relatively smaller diameter of the NC. Small changes in NC bone diameter can affect tear flow and cause congestion.[13,14] In this study, we evaluated the possible relationship between MSV and NC diameter and length.

There are several studies in the literature that use CBCT to assess the NC's diameter and system.[15,16] In one radiologic study, Lee et al.[14] studied 228 CT images and reported the NC smallest diameter to be 3.2 mm while men and women did not show any difference. Bulbul et al.[17] compared the anatomical differences between PANDO and non-PANDO patients in diameter of NC bone and did not detect significant differences in their measurements in terms of gender.

Table 4. Correlation between maxillary sinus volume and nasolacrimal duct diameter and length.

		Length of nasolacrimal canal	Diameter of nasolacrimal canal	Volume of maxillary sinus
Length of nasolacrimal canal (mm)	Correlation Coefficient	1.000	.115	.351**
	P	.	.059	**.000**
Diameter of nasolacrimal canal (mm)	Correlation Coefficient	.115	1.000	-.205**
	P	.059	.	**.003**
Volume of maxillary sinus (mm^3)	Correlation Coefficient	.351**	-.205**	1.000
	P	**.000**	**.003**	.

In some recent studies, gender differences in NC size have been reported, suggesting that PANDO is more common among the female patients over 40 years of age, which can be explained by anatomical differences.[13,18] Janssen et al.[13] reported the orifice diameter to be 3.0 mm in their nasolacrimal duct obstruction group, a smaller diameter than in their control group. They posited that having a small canal diameter was an etiological factor in

nasolacrimal duct obstruction. Shigeta et al.[18] suggested that there may be association between increased obstruction frequency of primary nasolacrimal duct in women and both smaller head-to-face configuration and smaller diameter of the duct in women than in men.

Our study shows that no significant difference was found between genders in terms of MSV and the length and diameter of the NC. The two sides did not show any statistically significant differences in terms of MSV, length, and diameter of NC.

The maxillary sinus, which has anatomical proximity to the dental structures, is the region which dentists are mostly interested in. Various imaging methods have been used in the literature to evaluate paranasal sinuses, and differing results may be due to disparity of imaging methods.

Tassöker et al.[19] investigated possible correlations of MSV with nasal septal deviation, concha bullosa, and impacted teeth using CBCT images. They observed that the mean sinus volume in men was significantly higher than in women, and that there were no significant differences between MSV and impacted teeth, nasal septal deviation and concha bullosa. Demirtaş et al.[20] evaluated and compared the MSV of patients with a unilateral cleft lip and palate and a control group using CBCT images. They observed that there were no statistically significant differences between the age, gender and side distributions of the groups; a statistically significant difference was in the MSVs of the cleft versus the noncleft side.

Akyüz et al.[21] evaluated the anatomical relationships and variations between NC and maxillary sinus in paranasal sinus tomography sections that are routinely used during preoperative preparations. They observed that the relationship between the maxillary sinus and NC may reflect anatomic variations between individuals, and that the vertical diameter of NC was significantly higher in men, but they found no significant difference between genders of the horizontal diameter.

In our study, while a negative correlation was detected between MSV and NC diameter, a positive correlation was found between volume and NC length. In other words, as the MSV increased, the diameter of the NC decreased while its length increased.

The maxillary sinus has no smooth boundary, which may cause linear measurements to be inaccurate. Therefore, it is emphasized that the segmentation method is the most accurate and reliable for measuring sinus volume.[22] Technological advances have made it possible to use 3D software to perform segmentation on radiographs obtained by methods allowing 3D calculations, including CT, CBCT, and magnetic resonance imaging (MRI). CBCT, which offers images of a similar quality to those of CT, has the following advantages: low cost, much lower radiation doses, easy to perform, and better 3D images of related structures. In this study, MSVs were measured using Fujifilm-Synapse 3D software. Thayyil et al.[23] used 12 kidney, heart, and liver MRI images from various animals to evaluate the sensitivity of the MIMICS program. They reported very good correlation between MIMICS measurements and actual organ volumes. Weissheimer et al.[24] compared the MIMICS, InVivo Dental, Dolphin3D, OsiriX, and Ondemand3D 3D modeling programs. They reported that MIMICS program had the least error-sharing. A recent study by Szabo et al.[25] compared the paranasal sinus volumes obtained with manual and semi-automatic imaging software programs using both CBCT and CT imaging. They found that the CBCT images provided reliable volumetric information of the artificial organ structure, assisting the operator before or during the intervention.

CONCLUSION

Before surgical intervention in the paranasal sinuses and related structures, determining the detailed anatomical structure of the region and possible anatomic variations in the preoperative period can help minimize potential complications. As the maxillary sinus medial wall forms the lateral border of the nasal cavity, the recognition and preservation of the nasolacrimal canal is essential for better postoperative results in surgical procedures to be applied to this area.

REFERENCES

1. Lawrenson JG, Douglas RH. Orbit and Accessory Visual Apparatus. In: Gray H, Standring S. Gray's Anatomy: The Anatomical Basis of Clinical Practice, 41st Ed., Elsevier Limited, New York, 2016, 666-85.
2. Imre A, Imre SS, Pinar E et al. Transection of nasolacrimal duct in endoscopic medial maxillectomy: implication on epiphora. J Craniofac Surg 2015; 26: 616-9.
3. Bartley GB. Acquired lacrimal drainage obstruction: an etiologic classification system, case reports, and a review of the literature. Part 1. Ophthalmic Plast Reconstr Surg 1992; 8 :237-42.
4. Fasina O, Ogbole GI. CT assessment of the nasolacrimal canal in a black African population. Ophthalmic Plast Reconstr Surg 2013; 29: 231-3.
5. Yazici B, Hammad AM, Meyer DR. Lacrimal sac dacryoliths: predictive factors and clinical characteristics. Ophthalmology 2001; 108: 1308-12.
6. Kalabalık F, Ertaş ET. Investigation of maxillary sinus volume relationships with nasal septal

deviation, concha bullosa, and impacted or missing teeth using cone-beam computed tomography. Oral Radiol 2019; 35: 287-95.

7. Kosko JR, Hall BE, Tunkel DE. Acquired Maxillary Sinus Hypoplasia: A Consequence of Endoscopic Sinus Surgery? Laryngoscope 1996; 106: 1210-3.
8. Demir UL, Akca ME, Ozpar R, Albayrak C, Hakyemez B. Anatomical correlation between existence of concha bullosa and maxillary sinus volume. Surg Radiol Anat 2015; 37: 1093-8.
9. Ali A, Kurien M, Selvaraj KG. Correlation of the ethmoid infundibulum to the medial orbital wall in maxillary sinus hypoplasia: "Infundibular lateralization" a diagnostic CT finding. Ear Nose Throat J 2007; 86: 744-7.
10. Maestre-Ferrín L, Galán-Gil S, Carrillo-García C, Peñarrocha-Diago M. Radiographic findings in the maxillary sinus: comparison of panoramic radiography with computed tomography. Int J Oral Maxillofac Implants 2011; 26: 341-6.
11. Duman SB, Duman S, Bayrakdar IS, Yasa Y, Gumussoy I. Evaluation of radix entomolaris in mandibular first and second molars using cone-beam computed tomography and review of the literature. Oral Radiol 2020; 36: 320-326.
12. Ali MJ, Paulsen F. Etiopathogenesis of primary acquired nasolacrimal duct obstruction: what we know and what we need to know. Ophthalmic Plast Reconstr Surg 2019; 35: 426-33.
13. Janssen AG, Mansour K, Bos JJ, Castelijns JA. Diameter of the bony lacrimal canal: normal values and values related to nasolacrimal duct obstruction: assessment with CT. AJNR Am J Neuroradiol 2001; 22: 845-50.
14. Lee H, Ha S, Lee Y, Park M, Baek S. Anatomical and morphometric study of the bony nasolacrimal canal using computed tomography. Ophthalmologica 2012; 227: 153-9.
15. Altun O, Dedeoğlu N, Avci M. Examination of nasolacrimal duct morphometry using cone beam computed tomography in patients with unilateral cleft lip/palate. J Craniofac Surg 2017; 28: e725-8.
16. Tschopp M, Bornstein MM, Sendi P, Jacobs R, Goldblum D. Dacryocystography using cone beam CT in patients with lacrimal drainage system obstruction. Ophthalmic Plast Reconstr Surg 2014; 30: 486-91.
17. Bulbul E, Yazici A, Yanik B, Yazici H, Demirpolat G. Morphometric evaluation of bony nasolacrimal canal in a caucasian population with primary acquired nasolacrimal duct obstruction: a multidetector computed tomography study. Korean J Radiol 2016; 17: 271-6.
18. Shigeta K, Takegoshi H, Kikuchi S. Sex and age differences in the bony nasolacrimal canal: an anatomical study. Arch Ophthalmol 2007; 125: 1677-81.
19. Tassoker M, Magat G, Lale B, Gulec M, Ozcan S, Orhan K. Is the maxillary sinus volume affected by concha bullosa, nasal septal deviation, and impacted teeth? A CBCT study. Eur Arch Otorhinolaryngol 2020; 277: 227-233.
20. Demirtas O, Kalabalik F, Dane A, Aktan AM, Ciftci E, Tarim E. Does Unilateral Cleft Lip and Palate Affect the Maxillary Sinus Volume? Cleft Palate Craniofac J 2018; 55: 168-72.
21. Akyüz S, Yıldırım FN, Ersöz N, Başak HS, Karaman CZ. Evaluation of Maxillary Sinus and Nasolacrimal Canal Relationship via Paranasal Sinus Tomography Imaging. Eur J Rhinol Allergy 2019; 2: 71-4.
22. Belgin CA, Colak M, Adiguzel O, Akkus Z, Orhan K. Three-dimensional evaluation of maxillary sinus volume in different age and sex groups using CBCT. Eur Arch Otorhinolaryngol 2019; 276: 1493-9.
23. Thayyil S, Schievano S, Robertson NJ et al. MaRIAS (Magnetic Resonance Imaging Autopsy Study) Collaborative group. A semi-automated method for non-invasive internal organ weight estimation by post-mortem magnetic resonance imaging in fetuses, newborns and children. Eur J Radiol 2009; 72: 321-6.
24. Weissheimer A, de Menezes LM, Sameshima GT, Enciso R, Pham J, Grauer D. Imaging software accuracy for 3-dimensional analysis of the upper airway. Am J Orthod Dentofacial Orthop 2012; 142: 801-13.
25. Szabo BT, Aksoy S, Repassy G, Csomo K, Dobo-Nagy C, Orhan K. Comparison of hand and semiautomatic tracing methods for creating maxillofacial artificial organs using sequences of computed tomography (CT) and cone beam computed tomography (CBCT) images. Int J Artif Organs 2017; 40: 307-12.