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The Effects of 3D Modeling on Planning of Maxillofacial Surgery: A Preliminary CBCT Study#

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Research Article

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History

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ABSTRACT

Objectives: The aim is to evaluate the contribution of 3D modeling data to the planning of the maxillofacial surgery and to determine the indications of 3D modeling.
Materials and Methods: In this preliminary study, CBCT images of 2 patients with the Kodak 9000 3D (Kodak Carestream Health, Trophy, France) system were used. The segmentation procedures of the pathologies were performed manually, and was followed by the construction of the 3D models. A questionnaire was prepared by consensus of the research team, including the parameters which are critical in preoperative maxillofacial surgery planning. Five oral and maxillofacial surgeons independently evaluated both the traditional CBCT data and 3D model assisted data under the same viewing conditions. The extent of their decision change was scored using a 2 point Likert scale. Conventional (pre 3D model) versus 3D model assisted data (post 3D model) scores were analyzed. Pair-wise comparisons were completed using Fisher's exact test. Kappa was used to measure inter-observer agreement.
Results: In both of the evaluation sessions (pre and post 3D model), operation time, defect size and complication risk factors showed the highest variation for both patients. The difference between the decision change proportions for the variables of pre and post 3D model sessions were not statistically significant. Except 2 observers with excellent agreement for both evaluations, the agreement rates were fair without statistical significance.
Conclusions: The results showed that personalized 3D modeling constructed by CBCT data may lead to changes in surgical treatment planning protocol of complex cases.
Keywords: 3D Modeling, CBCT, Dental Radiology, Maxillofacial Surgery Planning, Questionnaire

Maksillofasiyal Cerrahide 3 Boyutlu Modellemenin Etkisi: Bir KİBT Ön Çalışması#

Bilgi
 # Bu çalışma 23-25 Kasım 2021 tarihleri arasında düzenlenen 'Sivas Cumhuriyet Üniversitesi 1. Uluslararası Diş Hekimliği Kongresi'nde sözlü bildiri olarak sunulmuştur.

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ÖZ

Amaç: Çalışmanın amacı, konik ışınlı bilgisayarlı tomografi (KIBT) kesitlerinin segmentasyonu sonucunda oluşturulan 3 boyutlu modellerin maksillofasiyal cerrahi planlamasına katkısını değerlendirmek ve 3 boyutlu modellemenin kullanım alanlarını belirlemektir.
Yöntem: Bu ön çalışmada, Kodak 9000 3D (Kodak Carestream Health, Trophy, Fransa) KIBT cihazı kullanılarak çekilmiş 2 farklı hastanın görüntüleri kullanılmıştır. Görüntüler her kesitte değerlendirilerek segmentasyonu manuel olarak tamamlanmış ardından 3 boyutlu modellere çevrilmiştir. Cerrahi planlama açısından önemi sebebiyle seçilen 8 parametre kullanılarak araştırma ekibi tarafından gözlemci anketi oluşturulmuştur. Gözlemci olarak seçilen beş oral ve maksillofasiyal cerrah, aynı görüntüleme koşulları altında önce sadece geleneksel KIBT verilerini değerlendirerek, ardından ise 3 boyutlu model ile oluşturulan verileri bağımsız olarak inceleyerek aynı anketi iki kere doldurmuştur. Cerrahların karar verme mekanizmaları üç skorlu Likert ölçeği kullanılarak puanlanmış, geleneksel ve 3 boyutlu model kullanılarak yapılan planlama puanları karşılaştırılarak analiz edilmiştir. İki yöntemin karşılaştırılması için Fisher's Exact testi, gözlemciler arası uyumu ölçmek için ise Kappa testi kullanılmıştır.
Bulgular: Yöntemler karşılaştırıldığında (3 boyutlu model ve geleneksel yöntem), her iki hastada en çok değişkenlik gösteren faktörlerin operasyon süresi, defekt boyutu ve komplikasyon riski olduğu gözlendi. İki yöntem arasındaki karar verme mekanizması incelendiğinde, yöntemlerin sonuçlarının benzer olduğu görüldü. Gözlemciler arasındaki uyum değerlendirildiğinde ise yalnızca 2 gözlemci arasında tam bir uyumun olduğu gözlenmekle birlikte, diğerleri arasında istatistiksel olarak anlamlı olmayan orta düzeyde bir uyumun bulunduğu belirlendi.
Sonuçlar: Çalışmanın sonuçları, KIBT verileriyle oluşturulan, kişiye özgü 3 boyutlu modellemenin karmaşık vakaların cerrahi tedavi planlama protokollerinde değişikliğe yol açabilir.
Anahtar Kelimeler: 3B Modelleme, KIBT, Maksillofasiyal Cerrahi Planlaması, Dental Radyoloji, Anket.

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Introduction

The advent of 3D technology has revolutionized medical imaging. 3D modeling has been used to improve diagnostic accuracy, plan complex interventions, and aid in medical student and resident understanding of disease.[1] It has been particularly helpful with regard to complex anatomic structures and disorders that are not easily captured or understood in two dimensions.[2] New technological advances have also revolutionized the field of oral and maxillofacial surgery. Advanced imaging techniques, software and computerized manufacturing techniques have made three-dimensional (3D) computer models available not only for research and development, but also for routine clinical applications.[3] Clinicians frequently operate in areas of the face and jaws which cannot be directly observed prior to a procedure, and consequently risking damage to critical structures such as nerves and blood vessels. 3D models are particularly useful for planning maxillofacial surgeries, because the anatomy and procedures in this region are especially complex (Figure 1).

Studies evaluating the efficacy of 3D biomodels in craniofacial and maxillofacial surgeries showed that three-dimensional models contributed positively to diagnosis, operative planning, and informed consent.[4]

Image acquisition and processing are the first steps to create a 3D model. Considering the fact that complex surgical procedures in maxillofacial region injuries require meticulous preoperative planning, it is important to utilize imaging modalities that provide detailed information that can ensure accurate diagnosis and good clinical outcomes.[4,5,6] At this point, cone beam computed tomography (CBCT) has become a mainstay in oral and maxillofacial surgery for many surgeons by offering 3-dimensional and multi-planar views for a more accurate diagnosis and treatment without the financial burden and radiation exposure of conventional computed tomography (CT) scans.[7-9] A number of studies have evaluated the performance of imaging modalities in the surgical treatment of maxillofacial pathologies.[10-15] However, it is noteworthy that most of these studies presented conventional computerized tomography and MRI images for 3D modeling of preoperative planning of maxillofacial pathologies.[13,15,16,17] The number of studies using CBCT images for this purpose is quite scarce.[12,18-22] In addition, it was observed that most of CBCT studies were case reports and there were no clinical studies investigating the effect of 3D modeling on decision of surgical treatment planning using CBCT images.[18-21]

The aim of this preliminary retrospective study was to determine and compare the preoperative surgical treatment decisions of oral surgeons for maxillofacial pathologies by using either CBCT images alone or by personalized 3D model supported surgical treatment planning in order to assess the indications for 3D modeling in surgical treatment planning.

Materials and Methods

Cases

CBCT data obtained from 2 patients with lesions localized in the mandibular posterior region and close relationship with adjacent teeth and vital tissues were included to this retrospective preliminary study. All data were retrieved from the radiology archive and patient files. The first patient was a 49-year-old female with an expansive radiolucent lesion extending from the distal root of mandibular 2nd molar to the 1st molar region involving the periapical tissues of 2nd molar teeth. The second patient was a 47 year-old female with a large tooth extraction cavity in the mandibular 2nd molar region.

Radiographic Technique

CBCT examinations were performed using the Kodak 9000 3D (Kodak Carestream Health, Trophy, France) system and the imaging parameters were 10 mA and 70 kVp with 2.5 mm Al equivalent filtration. CBCT image acquisition of each patient was completed after a single 360° rotation with 10.8 s scan time, and a volume with a spatial resolution of 76 µm (isotropic voxel) was reconstructed using the dedicated software of the imaging system (Kodak Dental Imaging Software v3.10.9). Both patients CBCT images revealed multilocular lesions with radiolucent content located in the mandibular posterior area with indistinct boundaries (Figure 2).

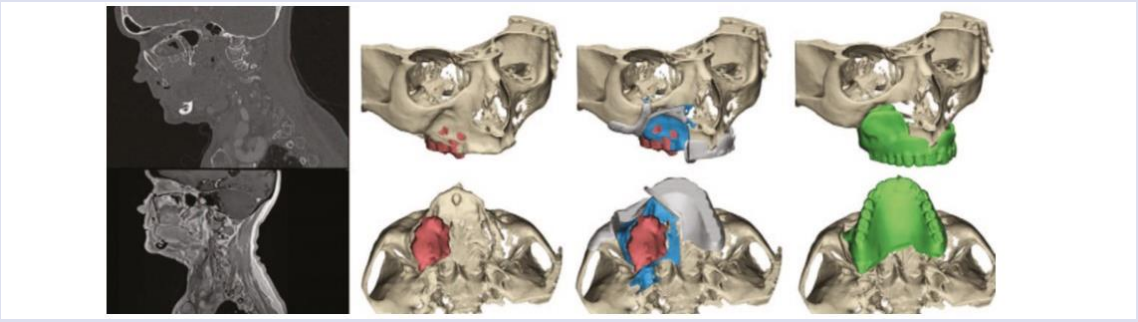

Figure 1. In a case of maxillary malignant lesion (red), CT and MRI data are used for preoperative 3D planning of bone resection (blue), guide design (gray) and obturator (green) (Glas 2020).

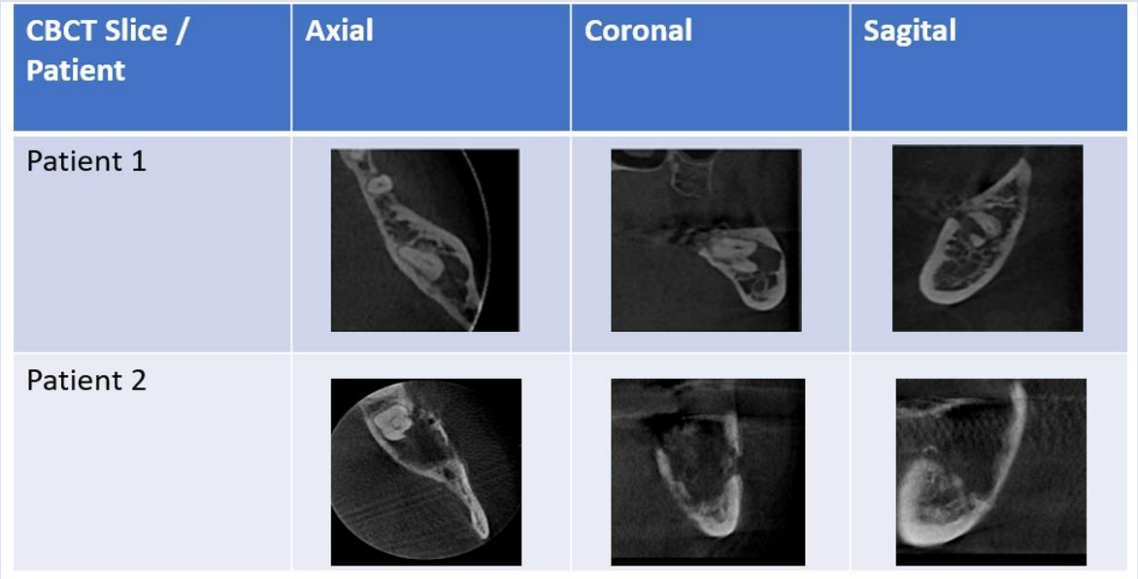

Figure 2. CBTC images of the patients, presenting the pathologies with indistinct borders, penetrating to the cortical plates, and causing erosions of bone.

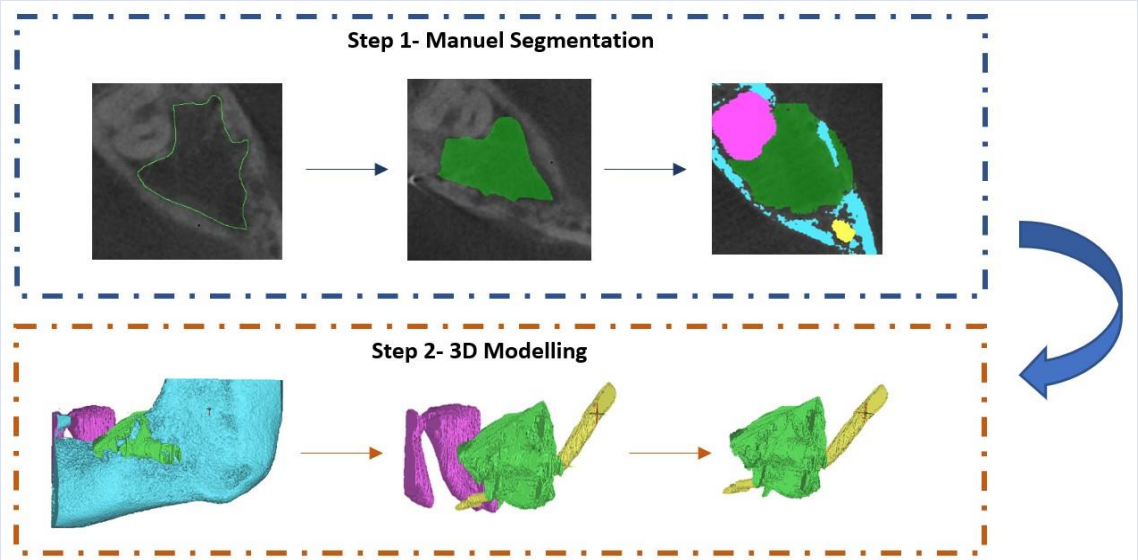

Figure 3. Manuel segmentation and 3D modelling workflow.

Segmentation and Reconstruction

CBCT sections of the patient were imported to "3D Slicer (version 4.8.1 r26813)" software. The region was segmented and recorded by determining the appropriate threshold values. Manual segmentation was performed using cross-sectional images of CBCT images in 3 different (axial + sagittal + coronal) planes by one oral radiologist and converted into 3D model (Figure 3). The slice thickness was 0.076mm in each section. The tooth, related lesion, mandible cortical layer, mandibular canal masks were used. The 3D model in stl format has been smoothed by opening it with the free software "Autodesk Meshmixer (version 3.5.474)".

Evaluation Procedure

Following a thorough literature review about 3D modelling in surgical planning, a questionnaire including 8 parameters [1.Estimated operation time, 2.Anesthesia type (local-general), 3.Intervention direction (extraoral-intraoral), 4.Osteotomy boundaries/defect size, 5.Additional material requirement (plate-graft-membrane), 6.Relationship with vital tissues, 7.Requirement of postoperative medication, 8.Risk of complications] which are critical for preoperative maxillofacial surgery planning was prepared by consensus of the research team.

Five oral and maxillofacial surgeons independently evaluated both the traditional CBCT data and 3D model assisted data under the same viewing conditions. At first,

each surgeon evaluated only the CBCT data and made a traditional planning (pre 3D model). Then, he/she made a new planning by examining the 3D modeling data (post 3D model) within a week after the traditional planning. Both questionnaires for CBCT and 3D modeling data were compared. The inconsistency between the two maxillofacial surgery planning (pre and post 3D model) for each parameter was scored using a 3-point Likert scale (1-decision is not changed, 2- changed).To evaluate whether the maxillofacial surgeon's decision for each parameter changed after using the 3D modeling, this process was performed in both patients.

Statistical Evaluation

Conventional (pre 3D model) versus 3D model assisted data (post 3D model) scores were analyzed with SPSS version 15.0 (SPSS, Chicago, Illinois, USA). In all tests, p-value less than 0.05 was considered statistically significant.

Fishers Exact test was used for pair-wise comparisons of two different evaluation data (pre and post 3D model) including 8 parameters which are critical for preoperative maxillofacial surgery planning. Five observers evaluated both of 2 cases and the interrater reliability of 5 observers was tested by Cohen's kappa coefficient (k) using the Landis and Koch scale scored as: 0.01, poor; 0.01-0.20, slight; 0.21-0.40, fair; 0.41-0.60, moderate; 0.61-0.80, substantial; and 0.81-1.00, almost perfect.

Results

Cohen's kappa coefficient (k) showed that there was a significant agreement between Observer 2 and 5 for both evaluations (p=0.036), while the agreement between other observers was not significant (p>0.05) (Table 1). The mean change values of the scores of eight parameters for both patients are presented in Table 2.

Despite the fact that the surgery duration, osteotomy boundaries/defect size, and complication risk parameters exhibited the highest variance after oral surgeons analyzed 3D modeling for both patients, the differences between the parameters were not statistically significant (p>0.05) and the decisions of the surgeons regarding the other parameters were not affected by 3D modeling (Table 2). There was no statistically significant difference between the two patients in terms of tested parameters (p>0.05) (Table 2).

Discussion

The design of maxillofacial surgery has improved significantly after presentation of 3D virtual planning methods.[5,22] This approach has provided priceless preoperative information to select the most appropriate surgical and reconstructive techniques, and to decide the resection margins, the region of osteotomies, the places for placement of osteosynthesis/graft materials and implants.[17,23] Considering that dental rehabilitation is a vital step of reconstruction, 3D virtual planning becomes particularly useful to hasten the process of oral rehabilitation.[17,24,25]

With the aid of digital technology/3D modeling, personalized operation and reconstruction could be performed[5,24,26,27], and better outcomes than traditional surgery could be achieved.[6,24,26] Even though personalized maxillofacial surgery has been used frequently, a more patient tailored approach using 3D print technology shall be preferred for more accurate reconstruction. [17] On the other hand, 3D modeling based surgical planning requires time and expertise, and this can be named as the disadvantage of this method.[6,24,28]

Although the reduction of the operation duration with 3D modeling and imprinted surgical guides has been reported in the literature[5,6,24,28-31], the impact of 3D modeling on the decision of surgical treatment planning has not been investigated. Therefore, we could not meet any studies in the literature to compare our results. In the present study, 3D modeling changed the decision of oral surgeons with respect to the duration of the operation time, the defect size estimation and influenced the planning of the surgery. In a recent study, Kuralt *et.al.*[27] showed implementation of 3D modeling in periodontal surgery and implantology for better treatment outcomes and reduced risk of complications. Similarly, Jaron *et.al.*[32] revealed the efficacy of 3D modeling and printing in surgical removal of impacted mandibular third molars in order to overcome the high risk of postoperative problems.

The major limitation of this investigation is the number of the cases, which could be the reason of insignificance of the differences; currently we are increasing the study sample size. The other limitation may be the lack of the use of 3D printing, which would additionally effect the preoperative planning process of the surgeons.[32] Spatial evaluation of a case after meticulous segmentation of CBCT images during 3D modeling and precise 3D printing would contribute to the performance of the surgeon and outcome of the surgery.[32]

Table 1. Inter-observer agreement values by Cohen's kappa test (* refers statistical significance, p<0.05).

Cohen's kappa	P value
G1*G2	0.280
G1*G3	0.086
G1*G4	0.146
G1*G5	0.949
G2*G3	0.182
G2*G4	0.383
G2*G5	0.036*
G3*G4	0.383
G3*G5	0.849
G4*G5	0.146

Table 2. The mean change values of the scores of the parameters.

Parameters	Scores for decision change in surgery planning			P
	Patient 1	Patient 2	Mean score for decision change	
Estimated operation time	0.60	0.80	0.70*	0.4
Anesthesia type (local/general)	0.00	0.20	0.10	1.0
Intervention direction (extraoral-intraoral)	0.00	0.20	0.10	1.0
Osteotomy boundaries (defect size)	0.60	0.80	0.70*	0.4
Additional material requirement (plate-graft-membrane)	0.00	0.00	0.00	1.0
Relationship with vital tissues	0.40	0.40	0.40	1.0
Requirement of postoperative medication	0.20	0.40	0.30	0.4
Risk of complications	0.80	0.40	0.60*	1.0

*Revealed the highest change between the pre and post-operative decision-making processes.

Conclusions

In conclusion, 3D modeling may affect the surgeons preoperative decision-making processes, especially regarding the operation duration, osteotomy boundaries/defect size and complication risk. In complex cases, this novel methodology can be utilized in order to provide a better surgical outcome both for the surgeons and the patients. The findings of this preliminary study need validation on larger sample groups, with addition of 3D printing process to the present test protocol.

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None to declare

Conflicts of Interest Statement

The authors deny any conflicts of interest related to this study.

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