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Simulation with Three Dimensional Modeling Before Spinal Surgery and its Effects on the Surgery

Spinal Cerrahi Öncesi Üç Boyutlu Modelleme ile Simülasyon ve Cerrahiye Etkileri

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Abstract: Three dimensional printers which are among the popular innovations of today are used increasingly more in medical field as in every field of life and they make the surgical operation easier. When customizable materials are combined with technology, we have successful results and fewer complications. The objective of our study was to demonstrate the advantages provided by three dimensional modeling methods in neurosurgery practice for both the surgeon and the patient. We reached the conclusion that 3D printing techniques were the practically and anatomically correct methods for the production of patient-specific models for surgical planning, simulation and training, tissue engineering implants and the secondary devices. Thus, the progress of this technology may contribute to the progress of neurosurgery field in several aspects.
Keywords: Neurosurgery, spinal surgery, three dimensional modeling

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Özet: Günümüzün popüler yenilikleri arasında yer alan üç boyutlu yazıcılar, yaşamın her alanında olduğu gibi tıp alanında da giderek daha fazla kullanılıyor ve cerrahi operasyonları kolaylaştırıyor. Özelleştirilebilir malzemeler teknolojiyle birleştirildiğinde başarılı sonuçlar ve azalmış komplikasyon oranları ortaya çıkarıyor. Çalışmamızın amacı, hem cerrahi hem de hasta için beyin cerrahisi uygulamalarında üç boyutlu modelleme yöntemlerinin sağladığı avantajları göstermekti. 3D baskı tekniklerinin; cerrahi planlama, simülasyon ve eğitim, doku mühendisliği implantları ve sekonder aletler için hastaya özel modellerin üretimi için pratik ve anatomik olarak doğru yöntemler olduğu sonucuna ulaştık. Bu nedenle, bu teknolojinin gelişimi nöroşirürji alanının ilerleyişine farklı açılardan katkıda bulunabilir.
Anahtar Kelimeler: Beyin cerrahisi, spinal cerrahi, üç boyutlu modelleme

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1. Introduction

First inscriptions on spinal trauma were discovered in Edwin Smith Papyrus dating back to 3000 and 2500 BC (1). Hippocrates who is among the founders of scientific medicine dealed with vertebra anatomy and physiology and defined paraplegia which is a clinical finding around 400 BC (2). While spinal traumas among the severe health problems in the society were treated through supportive methods in the past, surgical treatment providing better planning through radiological imagings replaced it today with the advancement of implant characteristics.

Three dimensional printers which are among the popular innovations of today are used gradually more in medical area as in every field of life. With the help of a three dimensional printer, producing spine models which are exactly the same with the patients using computer aided modeling through CT (Computed Tomography), the surgeon is provided the change of preoperative simulation. For patients with spinal trauma history, computer aided spinal models will be formed with direct graphy, computed tomography and 3 dimensional computed tomography and they will be produced by 3 dimensional printers and surgical plans will be made by different surgeons (Figure-1) (3).

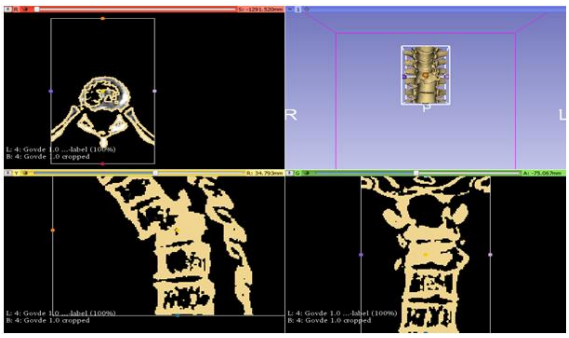

Figure 1.
Modeling the spine structure in 3DSlicer program.

Transpedicular screw applications with conventional technique are highly related to personal clinical experience. Pedicular screw malpositions with ratios changing between 21.1% and 39.8% were reported (4). With the support of three dimensional printers, radiological imagings were turned into physical objects and thus the duration of the surgery was shortened with pre-surgical planning. Shortening of scopy use duration during the surgery is a two-sided gain protecting both the patient and the surgeons.

The objective of our study was to produce identical spinal models of the patients with the help of 3 dimensional printer using computer aided modeling of CT in patients referring to our clinic and to perform pre-operative surgical planning on the model and make the surgical operation easier (Figure-2).

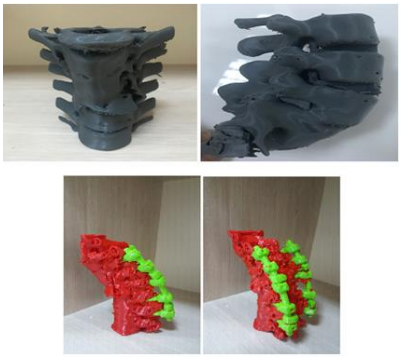

Figure 2.
Stratified modeling produced preop and postop spondylolisthesis spine models.

2. Material and Method

A systematic review was performed for the literature to evaluate the current use of 3D printing in neurosurgery field. Three medical databases (Compendex, Google Scholar, Pubmed) were searched using keywords for the related literature.
Inclusion criteria include articles both referring to "three dimensional printing" and "neurosurgery" in addition to the common variations of these terms. Results were manually filtered based on more specific criteria and human studies on spinal reconstruction were examined.

3. Discussion

The number of studies is limited on the 3 dimensional printers which became popular with the use in different fields in recent years. The studies especially performed by orthopedics and brain surgery clinics in the medical field were examined and it was observed that tangible data based on radiological images was acquired. Joshua P. Klein et al determined a route on spine imagings in the article they published in 2015. In the article, they mentioned that spine imaging methods are commonly used and for the correct interpretation of these images, a systematic approach is required (5). In the study they examined the efficiency of computed tomography in understanding three dimensional deformities, Jae-Young Hong et al measured vertebral rotation, rib humb index and sternal shift rates in all spinal direct graphies and computed tomographies before and after the operation and they stated that computed tomography was a useful method for determining three dimensional deformities, treatment planning and the evaluation of surgical results (6).

With the support of three dimensional printers, radiological imagings were turned into physical objects and thus the duration of the surgery was shortened with pre-surgical planning. Shortening of scopy use duration during the surgery is a two-sided gain protecting both the patient and the surgeons. In the article published by Laine et al in Euro Spine in 2000, malposition with a ratio of 13.4% was shown with conventional technique and with a ratio of 7.1% with computed tomography aided technique (7). Perez-Mananes et al. applied 3 dimensional modeling in orthopedics clinic and compared surgical time, scopy usage duration and deformity correction rates with this method. As a result, they showed that pre-operative modeling decreased error margin while shortening the surgery time (8).

Klein et al determined a route on spine imagings in the article they published in 2015. In the article, they mentioned that spine imaging methods are commonly used and for the correct interpretation of these images, a systematic approach is required. In the study made by Minyi Yang et al, Group A included 76 patients operated with traditional free hand technique and Group B included 62 patients treated with pedicular fixation supported by 3B printing. A significant difference wasn't detected in the clinical results of any of the follow-up time points related to JOA- VAS or NDI scores among the two groups. On the other hand, when compared to Group A, Group B had better results for atlantoaxial pedicular fixation (P=0.003) and a shorter operation time (P=0.001) and less blood loss were detected (P = 0.037). Contrary to the navigation system which is expensive for most hospitals, a 3D-printed model can be used as a common tool to provide significant guidance for Upper cervical surgery (9). In the study by Hyun Jin Park et al, an experienced surgeon gave instructions to two inexperienced surgeons who didn't have any experience on free hand pedicle screw instrumentation and on a total of 20 3D print models of 10 volunteering patients, each surgeon located 10 pedicle screws on the 3D model for every lumbar spine and the results of the second 10 spine models were compared to those of previous 10 models to evaluate the learning effect. A total of 37/200 screws (18.5%) perforated the pedicle cortex 1.7 mm in average (range 1.2-3.3 mm). On the other hand, it was detected that the second half of the models invaded less than the first half (10/100 vs. 27/100, p <0.001). In spine model, 10 pedicle screw instrumentation time was 42.8 ± 5.3 min. in the first 10 spine models and 35.6 ± 2.9 minutes in the last 10 spine models. In the last 10 spine models, significantly less time was spend compared to previous 10 models (p <0.001). As a result, real-dimensioned 3D printed spine model was observed as a perfect tool for pedicular screwing for free hand pedicle beginners (10).

In a study investigating the printing of spine models using three dimensional printers, it was shown that this printing could be used as a safe

method. It was stated that with the extensive production of three dimensional spine models, a good alternative was provided for the researchers in subjects with limited facilities such as cadaver provision (11). On the plans for the future, individual fusion materials were produced experimentally in experimental studies and it was stated that this method would enable the individual implant production in the future (12).

With the support of three dimensional printers, radiological imagings were turned into physical objects and thus the duration of the surgery was shortened with pre-surgical planning. Shortening of scopy use duration during the surgery is a two-sided gain protecting both the patient and the surgeons. Models produced by three-dimensional printers supported by radiological imagings allow both the doctors and the patients to understand the present pathology and to make preoperative plan.

4. Conclusion

Surgical planning was performed thanks to pre-operative modeling with the support of radiological imagings and a chance was provided for the stimulation of the operation. Thanks to the increasing of model production speed and decreasing costs through the improvements in three dimensional print technology, preop planned surgical simulations using 3 dimensional printed models and intraoperative guide use may become routine applications.

In recent publications, a series of applications were defined for 3D printing in different sub specialties of neurosurgery. These fields include cerebrovascular, neuro-oncological, spinal, functional and endoscopic neurosurgery. 3D printing was applied in each field to improve surgical planning, training and treatment. We think that the production with 3D printers in addition to the current diagnosis methods with the help of improving technology would lead the way of the surgeons who will perform the operation.

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