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Review

Application of 3D Printers in Neurosurgery

3B Yazıcıların Nöroşirurji Pratiğinde Kullanımı

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Abstract: Utilisation of 3D printers has increased in medicine as well as other fields thanks to developing technology. There are lots of opportunities to utilize them in the medical field. There are several steps consisting image acquisition to surface post processing in 3D printing. In neurosurgery, there are lots of topics which can utilize 3D printing technology. Education of young neurosurgeons, preoperative planning and preperation, orientation to intraoperative anatomy, surgeon-patient communication and better understanding of informed consent period, design and production of new surgical instruments are among them. Besides, there are some drawbacks like, long duration of printing process, possible costs and resolution and texture quality of acquired models waiting for possible solutions. 3D printing is a promising technology in medical field. It has a potential to revolutionize surgical treatment as becomes widespread and cheaper.

Keywords: 3D printer, Neurosurgical education, Neurosurgery

Özet: Her an gelişmekte olan teknoloji ile birlikte tıp alanında da 3B yazıcıların kullanımı doğal olarak bir artış göstermiştir. Tıp alanında kullanımlarını sağlayacak pek çok fırsat yer almaktadır. 3B yazımda görüntü eldesinden yüzey iyileştirmeye kadar izlenecek pek çok basamak yer almaktadır. Nöroşirurji pratiğinde 3B yazıcıların kullanılabileceği çok sayıda alan vardır. Bunlar arasında genç nöroşirurjiyenlerin eğitimi, preoperatif planlama ve hazırlık, intraoperatif anatomiye oryantasyon, cerrah-hasta iletişimi ve aydınlatılmış onam sürecinin daha anlaşılır ve verimli hale getirilmesi, yeni cerrahi alet tasarım ve üretimi gibi başlıklar yer almaktadır. 3B yazıcıların bu faydalarına rağmen basım sürecinin uzun zaman alması, olası maliyetler ve elde edilen modellerin çözünürlük ve doku kaliteleri gibi çözülmeyi bekleyen problemleri de vardır. 3B yazıcı teknolojisi tıp alanında gelecek vaat etmektedir. Bu teknolojini yaygınlaşmasıyla maliyetleri daha da düşebilecek olup cerrahi hasta tedavisinde yenilikler getirebilme potansiyeline sahiptir.

Anahtar Kelimeler: 3B yazıcı, Nöroşirurji eğitimi, Nöroşirurji

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1.Introduction

3 dimensional (3D) printing, creates a three dimensional structure consisting consequent layers with the help from computer aided design (CAD). Utilisation of 3D printers has increased in medicine as well as other fields thanks to developing technology. However, currently an established standard printing technique is not available for patient treatment and medical research. In this review, we will describe the necessary steps for 3D model creation, different applications of 3D printers in the field and discuss the setbacks of this technology which we hope for a better understanding of it.

2.Steps in 3D Model Creation

The raw data (computed tomography, magnetic resonance imaging data etc.) should be obtained in high resolution (1 milimeters of slice thickness at least), high quality and with least artefacts possible in order to create a better 3D model. The data should be recorded in Digital Imaging and Comunications in Medicine (DICOM) format. Segmentation and surface processing steps follows the image recording. Payed or open-source softwares are available for this purpose. After all these steps Surface Tesellation Language (STL) file can be obtained. This file can be recognized processed by a 3D printer, therefore the model is ready to be printed.

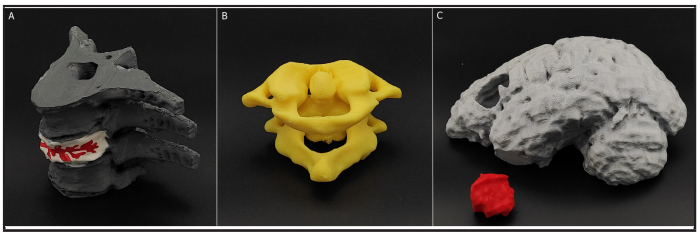

Figure 1: 3D printed models of thoracic vertebra farcture (A), C1 and C2 (B) and left frontal opercular glioma with rest of the hemisphere (C) are seen.

3.Applicaiton of 3D Printers in Neurosurgery

In 1990, Mankocih introduced 3D printer capabilities to the medical field by using the technology in a craniomaxillofacial surgery (1). The first appearance of this technology in neurosurgery occured in 1999 by D'Urso (2). Afterwards it demostrated the talents in several surgeries: Open or endovascular treatment of intracranial aneurysms, intracranial tumor surgeries and surgeries with instrumentation. Visual-tactile perception combined rather then visual only, can be revolutionize the preoperative planning, surgical education and research thanks to the 3D printed models. Novel surgical tools can be designed and printed, additionally with further development in material sciences 3D printed implants may be developed and used in patients; all contributing a new and wider perspective to surgical treatment.

3.a Education of young neurosurgeons and intraoperative orientation

Surgeons-in-education get their training mostly in form of observation and getting participated in the surgery itself step by step. If enough opportunity is given, training outside the operating room beforehand and acquiring necessary knowledge and abilities in a simulated environment should be considered. Animal tissue samples, cadavers and plastic models have been used for this purpose. With 3D printing technology, using the appropriate materials a realistic 3D printed model with desired anatomical detail and texture characteristeics can be created. Bartikian et al. 3D printed human skull bones with a high resolution printer. They stated that the detail on complex bones like sphenoid or temporal bone were precise and preserved (3). Surgical demonstrations can be performed on such models with ease and they are reproducible. Lin et al. created a tuberculum sella meningioma model. They performed a pre-training test to the participants, afterwards divided them into two groups: 3D model group and anatomy atlas group. After training with given materials, both groups given a post-training test. They demonstrated that, improvement in 3D model group was higher and statistically significant (4). With 3D printing ability, preoperative demosntration of the surgery and determination of possible adverse events are possible. Given that the cost is comparebly lower, the surgical steps can be done several times ex vivo. The outcome of that practice could be seen as lower complication rates, lower intraoperative blood loss and lower duration of surgery and anesthesia at the real operation (5).

3.b Preoperative planning

A patient-specific 3D printed model can help the surgeon for better understanding of surgical anatomy preoperatively. For example one can have a grasp of the localisation of an intracranial tumor, its relation with surrounding gyri, sulci and vascular structures. Or in a spinal surgery, the perfect screw trajectory can be easily determined preoperatively. With a better 3D perception, intraoperative complications can be reduced. Kizmazoglu et al. presented a case series with 6 patients having upper thoracic vertebrae fracture. They produced 3D models for every patient in order to evaluate the pedicle anatomy and determine the best screw entry point and trajectory possible (Figure 1, A). They reported no screw malposition (6). Uzunoglu et

al. produced a 3D model for a patient with odontoid fracture. They preoperatively planned the screw trajectories and entry points performed C1-C2 fixation (Figure 1, B) (7). Kalemci et al. created 3D models of cortically located intracranial tumors in a case series of 9 patients (Figure 1, C). They stated that the preoperative evaluation was helpful for determining intraoperative corticotomy site (8).

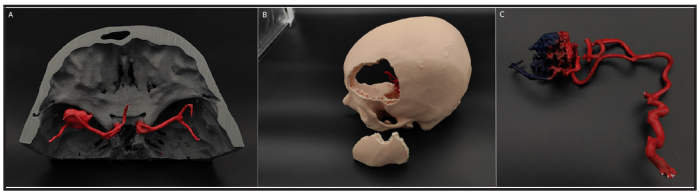

Figure 2: 3D printed models of left middle cerebral artery bifurcation aneurysm (A), left frontal craiotomy (B), an AVM model (C) are seen. These models are used for each patient exclusively to demostrate their own diseases and possible approaches to them.

3.c Surgeon-patient communication

With a 3D printed model surgeon could explain the patient his disease, its location, planned surgical approach and operative risks better. Therefore, an informed consent could be more appropriately acquired by enhanced communication and perception of disease (Figure 2).

3.d Surgical tools

As mentioned earlier, models that can ease the understanding of the anatomy and specific surgical tools for selected surgeries can be produced with 3D printing. With this ability hospitals themselves may find an opportunity to manufacture their own surgical instruments. Therefore they will seek systems inspecting the quality, reliability and biocompatibility of the products. These systems will benefit not only neurosurgery but also all surgical subspecialities. Evins et al. formed craniectomy models in a cadaveric study. After imagings acquired 3D printed graft materials were obtained for each defect specifically. They mentioned that the whole process from image acquisitiontill the end of sterilisation takes ,relatively short period of time, between 155-180 minutes (9). Kizmazoglu et al. preoperatively determined the screw trajectories and drilled onto the 3D printed models in patients with thoracic vertebra fractures. After sterilisation, they used the models intraoperatively and aimed for lower complication and screw malposition rates (6).

4.Constraints of 3D Printed Models

3D printing process is somewhat a process that takes long time. Must of the time production of a model can take up to 1 day. This issue prevents the use of 3D printed models in patients needing emergency surgery. Additionally, the learning curve of the software requires practice and time. Converting DICOM files into fine STL files takes several steps. Model designing time gets increased especially for new user as each step needs some experience.

Although low cost 3D printers are available in the market, Professional highly capable printers are still on the costly side. Particularly the raw materials used in professional printers may cost higher prices depending on the used material.

In order to obtain a highly detailed and precise 3D pirnted model every slice most be as thin as possible. To achieve this, the noosle diameter of the printer should be thinner therefore increasing the resolution on the other hand increasing the printig duration.

5.Conclusion

3D printing is a promising technology in medical field. With its complex 3D anatomy and ability to use instrumentation makes neurosurgery particularly suitable for application of this kind of technology. As discussed throughout this review there are several applications in our field. As more neurosurgeons get the knowledge about this technology and the technology develops, 3D printing will become more widely used.

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