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Technical Note

3D Printed New Surgical Tool For Complex Spinal Surgeries:A Technical Note

Kompleks Omurga Cerrahileri için 3 Boyutlu Yazıcı ile Yapılmış Yeni Cerrahi Alet

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Abstract: 3 dimensional (3D) printing technology is being used for preoperative evaluation of surgical anatomy and development of medical tools. This technology is thought to improve the surgical success by preoperative simulation of the surgical approach. Unique 3D printed models for every patient appears to decrease the peroperative complications. In this technical note, a novel angle meter tool obtained with 3D printing is proposed. The designing steps and use of this tool are desciribed. With the combined use of 3D printed anatomical model and angle meter, surgical orientation of the surgeon appears to be improved. There were no complications or malpositioned screws on the described patient. Therefore, together with the previous experiences of us on using 3D printed models intraoperatively, these models may be beneficial for decreasing screw malposition and operative duration.

Keywords: surgical planning, pilot hole, 3D printer, angle meter

Özet: Günümüzde 3 boyutlu (3B) baskı teknolojisi, hastaların cerrahi anatomisinin preoperatif değerlendirilmesinde ayrıca medikal alet geliştirilmesi için kullanılmaya başlamıştır. Bu teknolojinin kompleks cerrahi yaklaşımların preoperatif simülasyonunu sağlayarak cerrahi başarıyı artırabileceği düşünülmektedir. Hastaya özgü 3B modeller, cerraha preoperatif olarak cerrahi planlama ve uygulama imkânı sunarak peroperatif komplikasyonları azaltabilir. Bu teknik notta kompleks spinal cerrahilerde yeni tasarlanıp üç boyutlu model üzerinde kullanılan açı ölçüm aparatlarının tasarlanması ve kullanımı tanımlanmıştır. Bu model ve açı ölçüm aparatı sayesinde cerrahın vakaya daha iyi hâkim olması beklenmiştir. Vaka olarak tanımlanan hastada vida malposizyonu, veya başka bir komplikasyon olmamıştır. Bu tarz vakalardaki önceki tecrübelerimizi de göz önünde bulundurursak benzeri 3B modellerin kullanımı, ameliyat öncesi simülasyon yapma becerisini artırarak cerrahlara avantajlar sunabilir. Vida malpozisyonu azaltmada ve ameliyat süresini kısaltmada etkili olabilir.

Anahtar Kelimeler: cerrahi planlama, pilot deliği, 3B yazıcı, açı ölçer

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1.Introduction

Neurosurgeons and orthopaedic surgeons deal with complex spinal pathologies including deformities, tumors, infections, traumatic injuries and degenerative diseases. An adequate anatomical knowledge is crucial in order to perform these complex surgeries. The better understanding of surgical anatomy requires theoretical knowledge as well as practical experience (1-4). Therefore, the learning curve is somewhat steep, resulting inevitable complications especially for younger surgeons. New technologies like intraoperative computed tomography (CT) and 3D flouroscopy have being used in order to avoid these complications. However, they result in longer operative duration, higher doses of ionising radiation and higher costs. Additionally, neuronavigation technology is also been widely used, without added radiation related issues(5,6).

Spinal tumors operated without instumentation may cause spinal deformities in following months / years after the operation. These deformities result in more challenging reoperations and higher complication rates. There are several advantages of surgical stabilisation in such cases. First of all sagittal and coronal balance can be pereserved and even be corrected in some. The corrections may aid decompression of affected neuronal structures. Additionally, by preserving the balance the stabilisation prevents hyperkyphosis(6,7).

3D printing technology is being used for preoperative evaluation of surgical anatomy and development of medical tools. This technology is thought to improve the surgical success by preoperative simulation of the surgical approach. The surgeon finds an opportunity to understand the anatomy both by seeing and touching the model. So, the unique models ease the preoperative orientation and preparedness(1,8-10). Furthermore, the patients perception of her/his disease and planned surgery may be improved.

In our institution, preoperative surgical planning is used for complex spinal surgeries using 3D printed models. An angle meter as a novel tool for complex spinal surgeries is developed and printed via 3D printer. With that tool, intraoperative measurement of insertion angles of the pedicle screws becomes a reality. In this paper, the technique is described.

2.Materials and Methods

There are several steps for 3D pirnted model creation. The source data obtained from CT images, traditionally visualized in 2D. After this data is processed, the 3D anatomical images are produced. The following steps were used for image acquirement, image processing and 3D printing the material.

The quality of imaging affects the quality of the printed object in 3D printing. Therefore 1 milimeters sliced CT images obtained preoperatively. The images were recorded as DICOM (Digital Imaging and Comunications in Medicine) format.

Segmentation is performed on the DICOM files using 3D Slicer. Afterwards, postprocessing conducted for surface improvements. The processed image is saved as STL (Surface Tesselation Language) format and got prepared for 3D printing procedure.

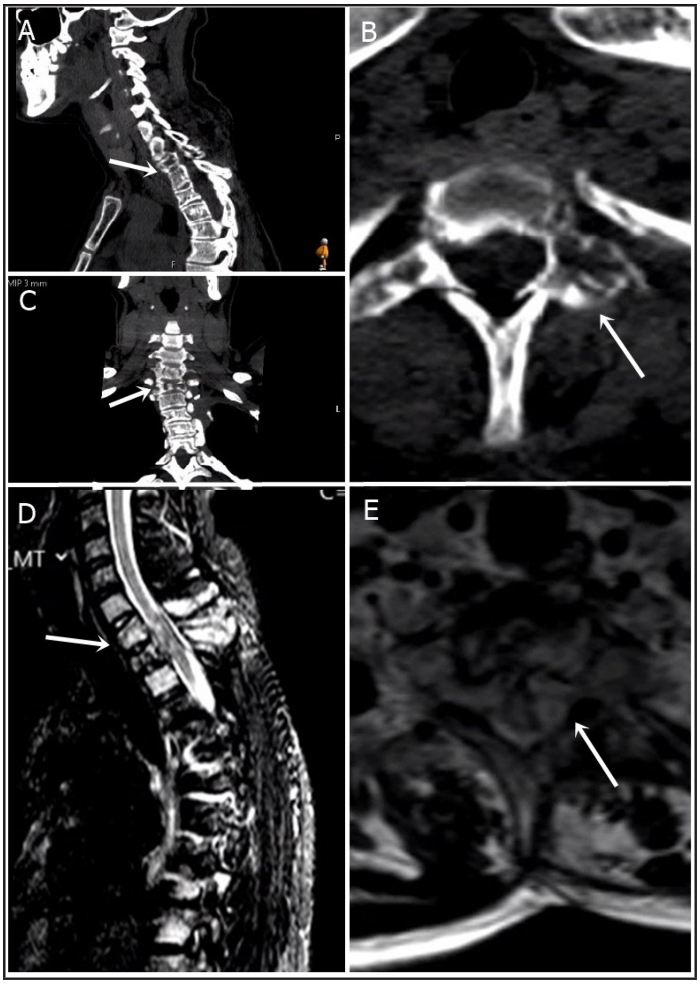

Figure 1: Kyphoscoliosis and lytic lesions are seen due to involvement of C7-T1 and T2 vertebrae (A, B, C). STIR sequence MRI demonstrates bone marrow edema in C6-C7-T1 and T2 vertebrae and loss of vertebral height in T1 (D). Axial T2 sequence shows epidural spread of a mass lesion compressing the spinal cord.

STL file was obtained in slices using CAD data with Meshmixer, an open source slicing software (Autodesk, San Rafael, USA). G-Code data is collected and sent to 3D printer using a thermoplastic material. Polylactic acid (PLA), a thermoplastic material, was used in printing process. A Fused Deposition Modelling technique-capable 3D printer was utilized.

Blender v2.91 (Amsterdam, Netherlands) and Meshmixer softwares were used in order to design and edit a novel angle meter tool. The models were printed in the same way described previously.

All models were taken to the sterlisation unit of our institution. Ethylene oxide was used fort his purpose. Therefore prepared for intraoperative use.

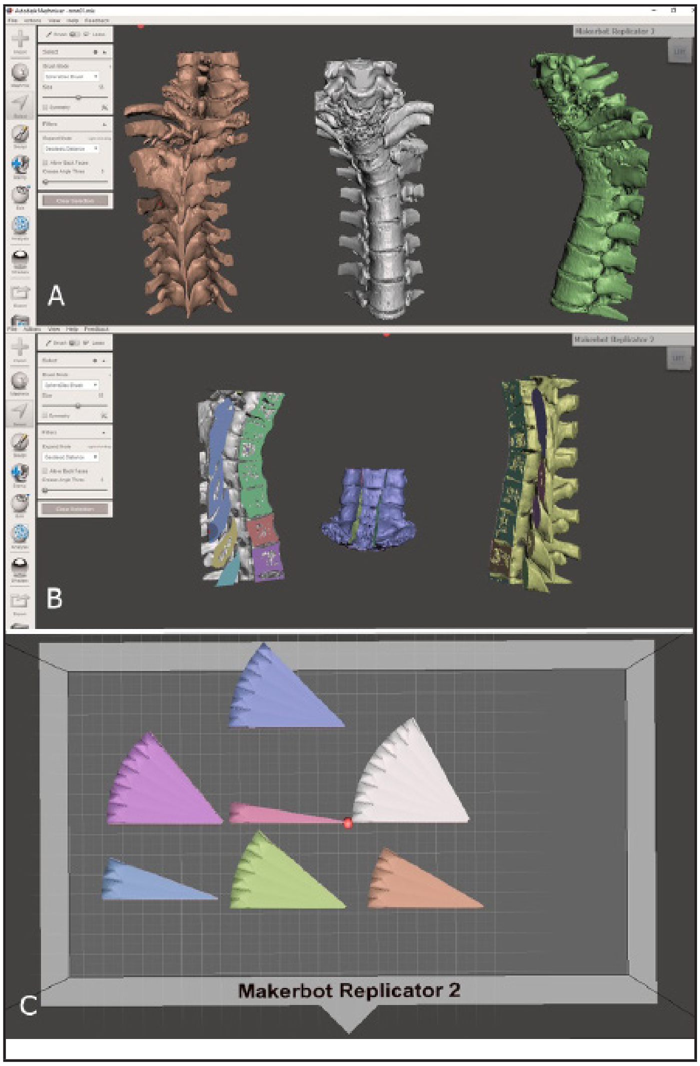

Figure 2: Sliced and postprocessed 3D anatomical model and angle meter tools are seen on Meshmixer software (A, B, C).

The case demonstrated in this technical note is a patient with neuroblastoma of cervico-thoracic origin showing cervical and thoracal bone and epidural spread. He has history of 4 operations regarding the tumor, consisting 2 spinal and 2 thoracic, chemotherapy and radiotherapy. He presented with progressive neurological deterioration. Disease progression at C7-T1-T2 levels were demosntrated on imaging and surgery was planned.

3.Results

The 3D printed model of the anatomy was evaluated together with CT images. Pedicle screw trajectories and angles were determined. Pilot holes on 3D model were created and proceeded deeper down inside the model just like a pedicle screw via drilling. Thus, the entry points and trajectories almost perfected on the model. Additionally CT images were used in order to calculate the angles of trajectories according to midline. These calculated values were used in conjunction with novel 3D printed angle meter tools.

Both 3D printed model with pilot holes and angle meter were used intraoperatively to determine best entry points and trajectories on the bone itself. The operation conducted without any complications. Postoperative CT scan demonstrated almost perfect placement of all pedicle screws.

4.Discussion

At first, 3D printing technology was used for preoperative surgical planning in complex spinal cases. Later on, intraoperative use of these models was increased and patient-specific models aided as screw guides(2,6-9). In this technical note, design and use of 3D printed angle meter tools in conjunction with 3D printed anatomical model for spinal surgery was demonstrated.

When compared with intraoperative CT, neuronavigation and other image-guided techniques, intraoperative use of 3D printed models seem to enhance the anatomical perception of the surgeon better.

Free hand technique is the oldest one used in order to insert pedicle screws. Screw malposition and complication rates vary between 3-55%(8). Thanks to recent technological advancements, surgeons may use new techniques and devices to overcome this problem.

Guo et. al. compared free hand technique with 3D printed template use in patients undergone upper cervical pedicle screw placement. In 3D printed template group screw malposition was reported as 6%, whereas 30% in free hand technique group(8). Duration of operation and flouroscopy time were lower in 3D printed template group.

Shi et. al. applied an angular scale and used intraoperatively. They measured pedicle-transvers process and pedicle-lateral mass angles on preoperative CT and used them. They reported 91,5% of the screws were in correct position(3).

In our case, 3D printed anatomical model and angle meter tools used manually directly on the patient. We did not encounter any screw malposition or additional complications.

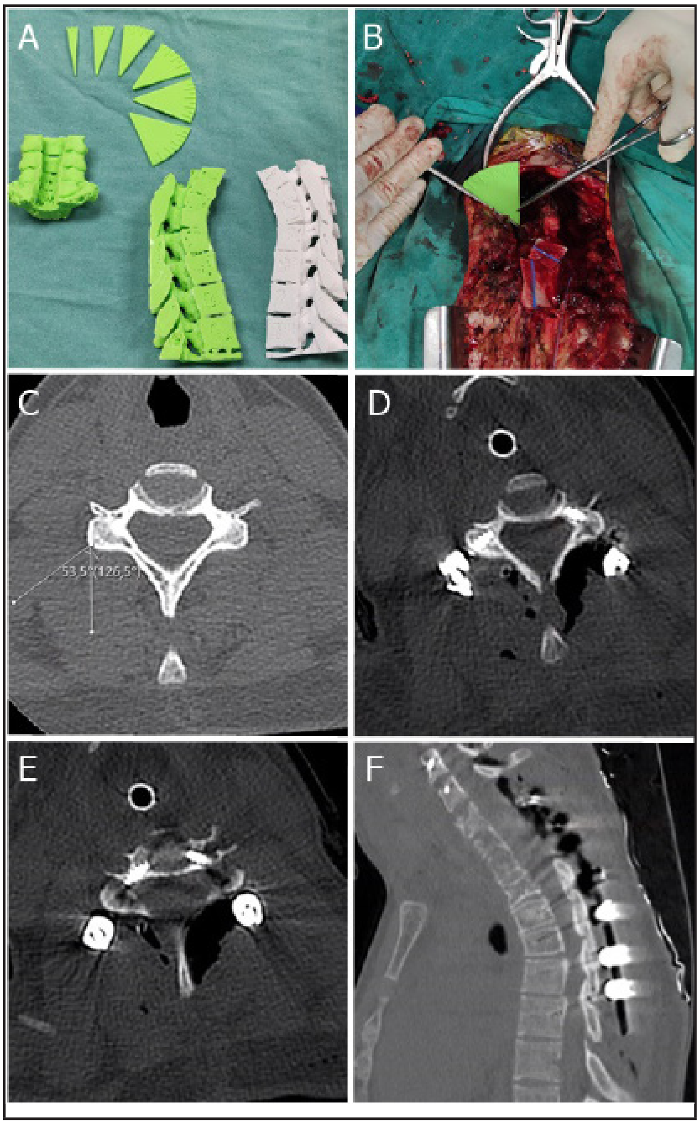

Figure 3: Intraoperative image of 3D anatomical models and angle meter tools (A). Use of angle meter tool intraoperatively (B). Preoperative CT-guided measurement for screw trajectory angle to be used with novel angle meter tools (C). Postoperative CT scan demonstrates satisfactory placement of pedicle screws (D, E, F)

3D printing technology helps the surgeon percieve the 3D anatomy of a pathology, thus improving intraoperative orientation. With a 3D printed model available, a spine surgeon can easily determine the best entry point and trajectory for the pedicle screws. When taken to the operation sterilised, these models would further increase the success rate. Additionally, learning curve for younger surgeons may become less steep thanks to better understanding of operative anatomy and screw trajectories. This may result in better results with less surgical experience.

Lastly, use of these models intraoperatively may decrease the duration of operation and anesthesia. Thus, may decrease sergery-related bleeding and surgical site infections.

5.Conclusion

The planning, image processing, printing and sterilisation of 3D printed models requires coordinated work of different disciplines. Such patient-oriented unique treatment plans can be done with team work. After decision of surgery was made, the work schedule must be flawless. Creation of practical measures with 3D printing technology, will give not only to the complex spinal surgery but also to several different types of surgeries an insight.

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