

NO SIGNIFICANT EFFECT OF 3D MODELLING ON SURGICAL PLANNING IN SPINAL DEFORMITIES

NENHUM EFEITO SIGNIFICATIVO DA MODELAGEM 3D NO PLANEJAMENTO CIRÚRGICO EM DEFORMIDADES DA COLUNA VERTEBRAL

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ABSTRACT

Objective: To evaluate the effect of 3d printed models on surgical pre-operative planning of complex spinal deformities. **Methods:** In our study, five orthopedic surgeons made surgical planning of 5 patients with severe spinal deformity in three conditions: X-ray with computer tomography (X-ray-CT), 3D-computed tomography (3dCT), and 3d printed spine models. Operation plans were examined according to the level and number of instrumentations, osteotomy level, and time required for decision-making. **Results:** X-ray-CT, 3dCT, and 3d modeling methods were compared, and no statistically significant difference was observed in the number of screws and osteotomy score to be used in operation. The time required for decision ranking is 3d Model, 3d CT, and Xray-CT. **Conclusions:** 3d printed models do not influence the operative plan significantly; however, it reduces surgical planning time at pre-op duration, and those models gave some opportunities to practice with implants on a patient's 3d spine model. **Level of Evidence III; Diagnostic Studies - Investigating a Diagnostic Test.**

Keywords: Biomedical Engineering. Image-Guided Surgery. Orthopedic Surgery. Simulation. Biomechanics.

RESUMO

Objetivo: Avaliar o efeito de modelos 3D impressos no planejamento pré-operatório cirúrgico de deformidades complexas da coluna vertebral. **Métodos:** Em nosso estudo, 5 cirurgiões ortopédicos fizeram o planejamento cirúrgico de 5 pacientes com deformidade espinhal grave em três condições: raio-X com tomografia computadorizada (raio X-CT), tomografia computadorizada com reconstrução 3D (3dCT) e modelo de coluna vertebral impressa (modelo 3d). Os planos de operação foram examinados de acordo com o nível e número de instrumentos, nível de osteotomia e tempo necessário para a tomada de decisão. **Resultados:** Foram comparados os métodos de modelagem de raio X-CT, 3dCT e modelo 3d e nenhuma diferença estatisticamente significativa foi observada no número de parafusos e escore de osteotomia a serem utilizados na operação. O ranking do tempo necessário para a tomada de decisão foi de modelo 3d, 3d CT e raio X-CT. **Conclusões:** Os modelos impressos em 3d não influenciam significativamente o plano operatório, porém reduzem o tempo de planejamento cirúrgico no pré-operatório e esses modelos deram algumas oportunidades de praticar com implantes no modelo de coluna 3d do paciente. **Nível de evidência III; Estudos de Diagnóstico - Investigando um Teste de Diagnóstico.**

Descritores: Engenharia Biomédica. Cirurgia Guiada por Imagem. Cirurgia Ortopédica. Simulação. Biomecânica.

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INTRODUCTION

In complex spinal deformities, preoperative surgical planning and preparation are vital for fruitful treatment of the problem. The correction procedure is often very challenging as unexpected pedicle absence and vertebral rotations can be discovered intraoperatively, posing great risk of neurovascular lesions during the operation.¹ With advances in both medical imaging and computer programming, two

dimensional axial images can be processed in to other reformatted views (sagittal and coronal) and three-dimensional (3D) virtual models that represent a patients' own anatomy.² Three-dimensional print models for orthopedic conditions can improve understanding of anatomy and pathology by way of tactile and visual experience for both the surgeon and patient to complement images displayed on a computer monitor.³ There are studies

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in literature on many fields such as complex neoplasm and cardiac anomaly surgeries, deformity, fracture or spinal deformities with promising results for almost all of them, especially in reducing the operation period.³⁻¹⁴

However, careful review of the literature revealed no study on the effectiveness of 3D printed models on pre-operative planning. So, the present study was conducted to search the effects of 3D models on preoperative planning of complex spinal deformities with special reference to the level of instrumentations and osteotomies.

MATERIALS AND METHODS

Five patients (1 male and 4 females) who underwent operation for their severe spinal deformities between 2010-2015 were included in the study. All patients had severe scoliosis, kyphosis or kyphoscoliosis deformity. Preoperational X-rays and CT images were obtained from the archives. Ethics committee Approval Number; 2015/11-06. 3D CT's were produced as follows: spines were scanned using computer tomography (Somatom Definition Flash; Siemens Healthcare) with a spatial resolution of 0.3 mm. Data were reconstructed out of the axial plane with a slice thickness of 0.6 mm, matrix size of 512 9 512, and a field of view of 154 mm 9 154 mm.

For 3D printing, soft tissues were erased just to get spine itself. Two freeform surfaces were represented by triangular tessellation and exported as STL (stereolithography) files, respectively. The STL files of both the collecting system and the Spine model outer shape were checked for anatomical correctness and then imported to Geomagic Studio 12.0 (Geomagic Inc. US) (Figure 1). Surface modification was done on 3D spine model and then imported to Cura 2.0 (Ultimaker, The Netherlands) to print the spine model with a 3D printer (Ultimaker 2 Extended, The Netherlands)

Three different sets (X-ray - CT, 3D CT and 3D Model) were prepared for each patient. This means, a total of 15 sets were ready for five patients. Then five surgeons who were at least 20 years of experience in spinal surgery were included in the study. Fifteen sets were presented randomly presented to these surgeons and they were asked to make surgical planning for deformity correction and mark the level osteotomy and screws. Additionally, time required for decision making was also noted. 3D model of a patient is displayed in (Figure 2).

The results were analyzed by Friedman test.

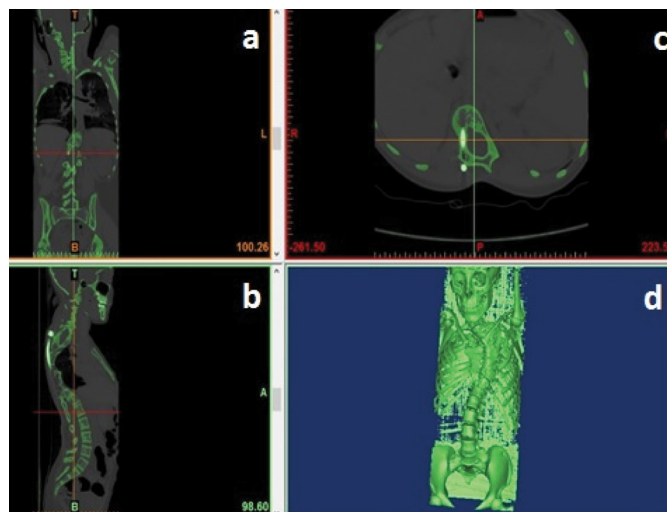


Figure 1. Workflow for getting 3D model of the spine on a software (Mimics 17). CT imaging data of a human spine as acquired (a) frontal view and (b) sagittal view. (c) The collecting system is used as the inner mold. Image segmentation for each slice to get the best solution for each spine. (d) CT images were constructed to the 3D model.

RESULTS

Surgical plannings of five surgeons for five patients with severe vertebral deformity were analyzed in terms of level and number of instrumentations, level of osteotomy and time required for decision making.

Compared to X-ray CT, 3D CT and 3D modeling methods, no statistically significant difference was observed regarding the distribution of the number of screws to be used in the operation. The statistical distribution of the number of screws is ($p=0.072$) (Table 1).

The results of statistical evaluation of the number of osteotomies to be performed in the operation turned out to be similar to those of X-ray - CT, 3D CT and 3D model. ($p=0.803$).

Time required for surgical planning with regard to the methods is statistically different ($p<0,001$) (Table 2). According to multiple comparison tests, while required time in X-Ray is longer than in 3D CT and 3D model and it is statistically significant; time-length in 3D CT is longer than in 3D model, which is also statistically significant.

DISCUSSION

In orthopedic procedures, surgeons have to mentally integrate all preoperative two-dimensional images and formulate a 3D surgical plan. This preoperative planning is particularly difficult in areas that have complex anatomy and severe deformity.² 3D

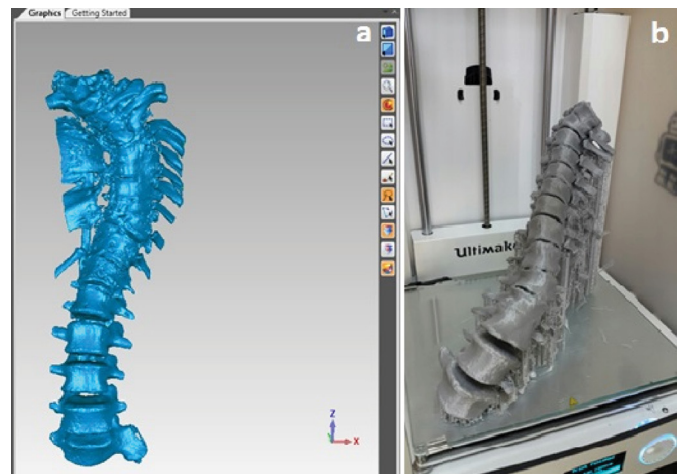


Figure 2. Workflow for building a 3D spine model. (a) The surface modification of the spine model is done by the software (Geomagic 12.0) to ease the 3D printing. (b) spine model is 3D printed with an ultimaker PLA material to obtain 3D surgical evaluation spine model for complex spinal deformities.

Table 1. Comparison of Instrumentation Levels with 3 Different Methods.

Instrumentation Level	Mean	Median(Min-Max)
X-ray - CT	11,4	13 (3-9)
3D CT	11,0	12 (3-20)
3D Model	9,9	11 (0-15)

* $p=0,072$.

Table 2. Comparison of time required for surgical planning levels with 3 Different Methods.

Time required for surgical planning	Mean	Median (Min-Max)
X-ray - CT	4,9	5,0 (2,0-10,0)
3D CT	3,5	3,2 (1,3-7,0)
3D model	2,2	2,0 (1,0-4,0)

$p<0,001$. Friedman test.

modeling seems to overcome these problems. Careful review of the literature revealed a number of studies on application of 3D modeling in orthopedics.^{2-7,9}

Because of referring a new method of diagnosis and treatment, these are generally expert opinion articles. In the experience of bone fractures, pediatric deformities and complex spinal deformity, 3D modeling reported an incredible improvement. However, there was no statistical evaluation in those articles.

3D modeling is thought to facilitate the perception of the existing pathology, and it is obvious that experienced surgeons and orthopedic residents will benefit most from it. Bizzotto et al. 2015, examined different fracture models by experienced surgeons and residents. They observed a clear improvement in both groups, but it was not mentioned whether there was a difference between the groups.⁵ Considering the production process, it is more logical to use 3D modeling in specific cases rather than its routine usage. Wang et al., made preoperative planning of complex spinal disorders with 3D modeling can be cited as a successful application of that.⁶ Real size spinal models allow determination of deformity corrective interventions in the preoperative period. Martijn van Dijk et al., determined osteotomy and resection levels by using real size implants and had a chance to test custom-made implants in-vitro environment.⁹ In the literature, there are two articles published on this subject and they are about high tibial osteotomy and cubitus varus surgeries. Pérez-Mananes et al., applied 3D modeling to high-tibial osteotomy surgery and they determined that it shortened the surgery time, reduced the use of scopy and decreased the margin of error.⁴ Takeyasu and colleagues treated supracondylar fractures of the cubitus varus deformities with custom-made surgical templates and three-dimensional corrective osteotomy with the use of a custom-made surgical template that is designed and produced on the basis of computer simulation is a feasible and useful treatment option for cubitus varus deformity.⁷

Review of the literature revealed several studies concerning complex spinal problems.⁹⁻¹⁴ In most of these studies, the authors had

prepared templates in order to perform more accurate osteotomies or instrumentation and reduce the operation period.⁹⁻¹⁴ However, none of these studies focused on the contribution of 3D models on preoperative decision making as compared to conventional methods such as x rays, CT or 3D CT. We designed our study on the basis of this gap in the literature and aimed at determining a supporting method for the decision-making process of daily practices of surgeons dealing with spinal deformities.

This can be interpreted that 3D models can lead to fundamental changes under some conditions. It is obvious that this change is important given the financial size of the intervention, the risks of complications that may arise from the operation, especially the psychosocial status of the patient with a surgical intervention.

In the present study, the level of the osteotomy and instrumentation were not affected by 3D CT or 3D model ($p=0,803$ and $0,072$ respectively). So, conventional x rays and CT seems enough for surgical decision making.

In our study, required time for surgical planning were 4.9 minutes with Xray-CT, 3.5 minutes with 3D CT and 2.2 minutes with 3D model and that difference was statistically significant. Rapid preoperative planning with 3D models can be the result of having detailed knowledge by examining the model in concrete. On the other hand, although statistically significant ($p<0,001$) in reality, three or four minutes have no importance especially in nonemergency surgeries, such as correction of spinal surgeries. Moreover, considering the production process of a spine model with the existing technology, the practical usability of 3D modeling is debatable.

CONCLUSION

In conclusion, the results of the present study indicate that 3D printed models do not influence the operative plan significantly. On the other hand, it is probable that surgeons may feel more confident with 3D models. We also conclude that larger series with different groups of patients may allow more strict conclusions.

AUTHORS' CONTRIBUTION: Each author contributed individually and significantly to the development of this article. OG: conception and design of the study, analysis and interpretation of the data, writing of the article, HO: construction of the models and data analysis, IG: conception and design of the study, final approval of the manuscript.

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