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Research Article

Application of 3d Models in Preoperative Planning of Tibial Plateau Fractures: Can We Expect Changes?

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Abstract

Introduction: Tibial Plateau fractures are complex lesions that require deep understanding of the lesion morphology. Computed tomography (CT) is essential for preoperative planning. Studies have shown clinical benefits in surgical management with the application of 3D models. The aim of the study is to analyze changes in preoperative planning by using 3D printing vs CT.

Hypothesis: The use of 3D models generates important changes in preoperative planning of tibial plateau fractures.

Material and Method: A descriptive observational study was performed. Patients with Schatzker V and VI tibial plateau fracture were included in the same center, with CT images in the local DICOM system. Patients who did not have a complete set of images or 3D reconstruction were excluded. The models were generated using Meshmixer version 3.5.4 software, printing each case using Creality version CR-10 max printer.

Preoperative planning surveys were completed by knee surgeons, using 3D models evaluating four variables (number of plates, surgical approach, position of the patient, use of bone graft). The survey was repeated a week later, using the respective CT, anonymizing each case. A descriptive analysis was performed and the intraobserver agreement was calculated by Cohen's Kappa test using Excel 16.70 for each independent variable and then, for each complete case.

Results: Ten patients with tibial plateau fractures were evaluated by ten knee surgeons separated in two groups, according to less or more than 10 years of experience (five surgeons in each group). The agreement for the number of plates, surgical approach, position of the patient and use of bone graft, had a kappa value of 0.31, 0.16, 0.53 and 0.49 respectively, obtaining an overall result of 0.37. 80% of the cases had at least one change within the 4 variables studied from the use of 3D models with a Kappa Cohen value of 0. The agreement in the group of surgeons with less than 10 years of experience had an average Kappa value of 0.34 and the group with more than 10 years an average of 0.39.

Conclusion: The application of 3D models in tibial plateau fractures presents a high rate of changes in preoperative planning, especially in the choice of plate number and surgical approach.

Keywords: 3D Printing; Tibial Plateau Fracture; Preoperative Planning; Level of Agreement

Highligths

- The application of 3D models has gained interest in the scientific community due to the significant clinical benefits it has shown.
- 3D models can help knee surgeons in planning Tibial plateau fractures, changing important aspects with its use.
- The variables that change the most in the surgical planning are the number of plates and the surgical approach.
- Less experienced surgeons (less than ten years of practice) tend to change more than more experienced surgeons.

Introduction

Tibial plateau fractures are complex lesions, corresponding to 1% of all fractures and generally associated with high energy trauma [1]. The prognosis of these lesions depends on multiple variables, where the configuration of the fracture stands out [2], being in the majority of cases of surgical management, due to articular involvement among other reasons [3]. The main objective of the surgery in these lesions is to restore joint congruence and maintain a correct alignment producing the least possible damage to soft tissues [4]. To achieve this, a good understanding of fracture morphology by the surgeon is required, with planning prior to surgery essential, which is usually based on the use of x-rays and computed tomography (CT) scans [5] mainly through 3D reconstruction, as it allows a high detection rate and facilitates the classification of fractures [6]. It has been studied that when comparing surgical planning between conventional CT vs 3D reconstruction, no significant differences have been evidenced [7]. In addition, it also has some limitations, since, although 3D reconstruction manages to demonstrate the spatial orientation of fracture fragments, the preoperative design still considers a 2D visualization of each image, which hinders satisfactory anatomical reduction during surgery [8].

Nowadays we have more advanced technologies, including 3D printing; this consists of printing through digital models the required objects with plastic material, which can be of real size [9]. This technology has been applied recently in the area of health, such as in the dental area where the printing of small and custom-made implants is required [10].

On the other hand, in the medical field, it has generated great expectations, as for example in regenerative medicine and tissue engineering, with the bioprinting of complex organs, such as the heart, kidney, liver, among others [11,12].

Undoubtedly, a field specialty of medicine in which it is generating great interest, is in the field of Orthopedics and Traumatology, by printing orthoses/prostheses, surgical instruments and anatomical models [13-15], demonstrating benefits in the surgical management of different lesions, where the tibial plateau fracture is found. Regarding this lesion, there has been evidence of shorter surgical times, less blood loss, less use of intraoperative radiographs, among others [16].

The use of these 3D models in tibial plateau fractures has been studied primarily for intra- and postoperative outcomes, however, we currently do not count, as far as we know, with studies evaluating the variation in preoperative planning that could occur using 3D printing. The aim of this study is to analyze the changes that occur when comparing preoperative planning of a tibial plateau fracture by using 3D models versus CT. The main question of the study, therefore, is: does the use of 3D models generate important changes in preoperative planning?

Materials and Methods

Type of study and patient selection

A descriptive observational study was conducted including patients with Schatzker V and VI tibial plateau fractures, between 2019 and 2021, all from the same center, with CT images in the local DICOM (Digital imaging and communications in Medicine) system.

Those patients without a complete set of images or 3D reconstruction in the system and those who did not have the completed surveys by the evaluators were excluded.

Construction of 3D models

The raw CT file of each selected patient was extracted from the DICOM system and then imported into a 3D reconstruction image reading program "InVesalius" version 3.1.9, which exports a STL (Standard Triangle Language) file. Subsequently the model was cleaned of any non-useful image, selecting in turn the segment necessary for its printing, using a modeling program "Meshmixer" version 3.5.4. The generated model was transferred to a 3D printing software "Ultimaker Cura" (Figure 1) version 4.11.0, which exports a G-code file that contains all the necessary instructions (both media, speed, temperature, as well as density and filling form), which by means of a micro-SD card introduced in a 3D printer "Creality" version CR-10 max (Figure 2), is read to materialize the object. The printing is carried out with a polylactic acid (PLA), which is a thermolabile bioplastic that hardens when cooled forming the part.

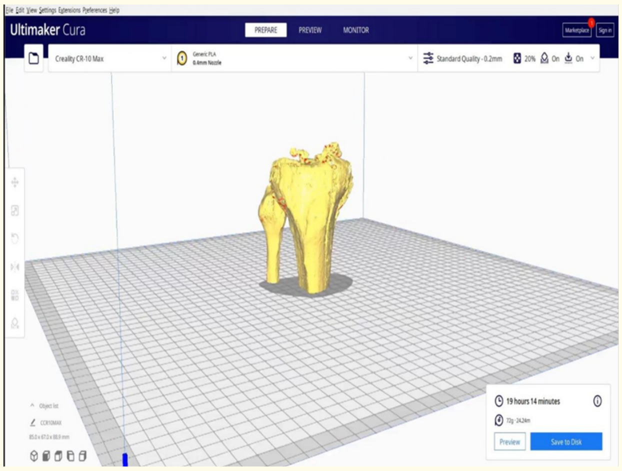

Figure 1: 3D Printing software "Ultimaker Cura".

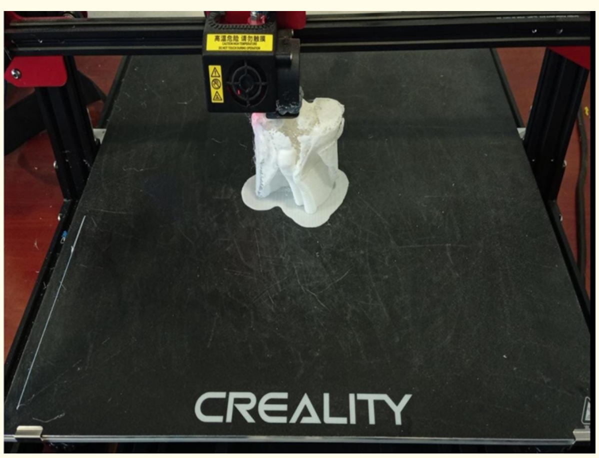

Figure 2: 3D printer "Creality".

Nombre
Años de Cirujano de Rodilla

Caso

	1	2	3			
Número de placas						
	Antero-medial	Medial	Postero-medial	Lateral	Postero-lateral	Posterior
Abordajes						
	Supino	Prono	Lateral			
Posición						
	Si	No				
Injerto						

Figure 3: Survey completed by knee surgeons.

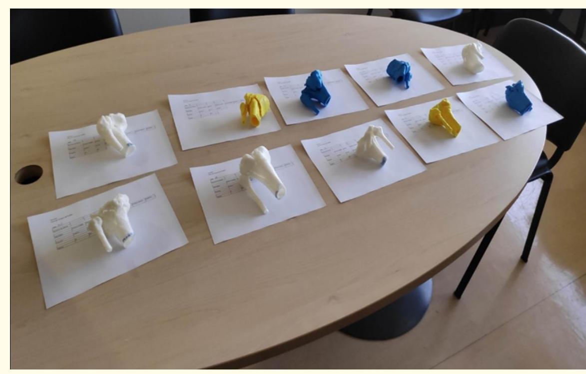

Figure 4: 3D models of Tibial Plateau fractures.

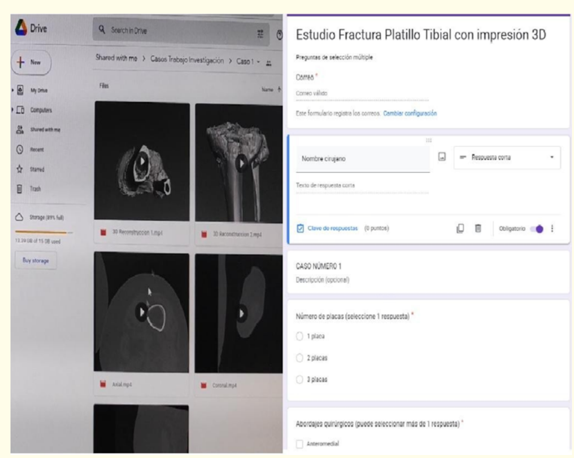

Figure 5: Survey and images in Google Forms.

Data collection

Preoperative planning surveys were conducted by knee surgeons, where the four variables shown in figure 3 were recorded.

The survey was first conducted using the printed 3D models (Figure 4), asking the evaluators to fill them out at once, with no set time limit. Then the same survey was repeated a week later, using the Google Forms platform, this time with the CT and its respective 3D reconstruction of each case, randomized and anonymized. The survey was sent through a link by email, to be completed also at once and with no set time limit (Figure 5).

Statistical analysis

We performed a descriptive analysis of the data obtained and calculated the intraobserver agreement using the Cohen´s Kappa test for each variable of the independent survey, calculating next the overall average. The same test was used to calculate the intraobserver agreement for each complete case, defining it as "agreement" when the four variables of the same case did not present changes between the surveys of 3D models versus the CT.

The results obtained among the evaluators were compared according to years of experience as a knee surgeon (older than and younger than 10 years).

The analysis was done with Microsoft Excel 16.70

Results

Ten patients were enrolled with all available images in the system and ten knee surgeons completed all surveys with 3D and CT models.

The result of the Kappa test obtained for each variable of the survey and the overall average is summarized in table 1. The degree of agreement is described according to Landis., *et al*. (Table 2).

Variable	Kappa Cohen Test	Interval	Strength of agreement
Number of plates	0.31	-0.25-0.65	Fair
Surgical approach	0.16	-0.01-0.29	Slight
Position	0.53	0,01-1	Moderate
Bone graft	0.49	0-1	Moderate
Global	0.37		Fair

Table 1: Results of the Kappa test.

Agreement Measures for Categorical Data	
Kappa Statistic	**Strength of Agreement**
<0.00	Poor
0.00-0.20	Slight
0.21-0.40	Fair
0.41-0.60	Moderate
0.61-0.80	Substantial
0.81-1.00	Almost Perfect

Table 2: Strength of agreement according to Landis., *et al.*

At least one change in the four variables was seen in 80% of the cases when planning was compared using a 3D versus CT model, which corresponded to a Kappa Cohen value of 0.

Regarding the years of experience according to the evaluator, the group with less than 10 years had an average Kappa value of 0.34 and the group with more than 10 years an average of 0.39.

Discussion

From this study, where four relevant variables were compared at the time of planning a tibial plateau fracture surgery, important changes when using 3D models versus CT were evidenced.

The printing of 3D models facilitates the understanding of the anatomy in fractures of pelvis, femur, tibia, tibial plafond, talus, calcaneus, etc. in addition to the planning of the positioning of reduction clamps, screw entry sites and their respective trajectories [17-21].

It has been studied that 3D models facilitate understanding between surgeons and preoperative planning in cases of trimalleolar ankle fractures [22], collaborate to a better positioning of plates in complex pelvic surgeries [23], help in the generation of cutting guides and application of plates in traumatic hand-wrist surgery [24-26], among other benefits presented by these models.

Tibial Plateau fractures are complex lesions that demand great precision and understanding for optimal surgical management. In relation to these fractures, significant intraoperative and postoperative benefits have been evidenced when using 3D models, as demonstrated by Ozturk., *et al*. who showed lower surgical times (89 ± 5.9 mins when using 3D models versus 127 ± 14.5 mins when using CT), lower blood loss (160.5 ± 15.1 ml vs 276 ± 44.8 ml), shorter tourniquet time (74.5 ± 6 mins vs 104.5 ± 5.5 mins) and lower use of intraoperative x-rays (10.7 ± 1.76 times vs 18.5 ± 2.17) [16]. Shen., *et al*. in turn, showed that better reduction rates are achieved in the postoperative controls of tibial plateau fractures by using these models [5].

Our results show great variation by using 3D models when planning surgery on tibial plateau fractures, especially in the variables "number of plates" and "surgical approach", which have a "discrete" and "insignificant" correlation respectively. We believe that the reason for these variables to have presented a higher rate of change lies, in part, in the fact that they present a greater number of options at the time of answering the surveys and not necessarily that they are more difficult variables to analyze. It is also important to consider, in the case of the position on the table, that there is less variation recorded on the survey due to a tendency to choose the well-known supine position, frequently used by surgeons, which presents less intraoperative risks in relation to the prone position or other approaches.

When reviewing the literature, we did not find published papers that make an evaluation similar to this one, so we cannot make a comparison with other groups. Studies that have analyzed results of tibial plateau fractures in relation to preoperative planning have focused on other variables, such as the case of Shen., *et al*. who compared one group with and another without the use of 3D models for old tibial plateau fractures, demonstrating a shorter operating time, blood loss and number of intraoperative fluoroscopy in the group with use of 3D model [5]. Ozturk., *et al*. made a similar comparison in acute fractures of the tibial plateau, in which he found similar results, adding that the quality of the postoperative reduction would be better in the group in which the 3D model was used, however, it is important to note that the group without use of 3D model had fewer patients with complex fractures than the group with 3D models [16]. Xie., *et al.* conducted a systematic review of studies comparing the use of 3D versus CT models in this type of fracture, finding 17 studies with high level of evidence that concluded the same as the aforementioned authors. Furthermore, it stated that the use of 3D models would also have lower consolidation times, making them an important tool to consider when treating these fractures [27].

Within the results of our work, we found that the intraobserver correlation of the "complete case" varied on at least one variable in 80% of the cases studied, with a Kappa value of 0, reflecting a high rate of change in preoperative planning. In this context, the possibility of maintaining the planning with the use of the 3D model is, according to the classification of Landis., *et al*. insignificant. This low Kappa value was expected to be found, considering the low correlation that existed in the variables mentioned and that the term "no agreement" was applied when any variable had a modification.

Finally, our study shows greater intraobserver correlation in the evaluators with more than 10 years of experience (Kappa of 0.39 versus 0.34), which suggests that the experience of the surgeons will cause the general planning to be maintained more frequently, even with the contribution of new technologies.

One limitation of our study we can mention is that only high energy and complex fractures were included, so it is possible that the same evaluator may have had differences in their own preoperative planning by evaluating the same method (only the 3D model or CT) at different times, however, we see that the correlation in general was "discrete" in both groups of evaluators. This makes it reasonable to conclude that the 3D model generates important changes. It is also important to mention that we cannot say with this study that planning with the 3D model is the gold standard or that the planning improves with its use, although it is important to highlight again the comparative studies which show numerous intra- and postoperative advantages when using 3D models for resolving not only tibial plateau fractures. Therefore, our group intends to carry out future clinical evaluations that can compare both methods used and thus validate 3D printing as the gold standard when considering surgical planning in these lesions.

As strengths, we can mention that this is the first work published nationally that studies the impact of 3D models in our medical field and as far as we know, the first internationally to analyze and evaluate changes that occur in preoperative planning for tibial plateau fractures, which involves four variables that are of paramount importance when deciding how to operate them. Taking into account the changes that these models generate, we believe that having 3D models before the surgery can be of great help, so it seems reasonable to recommend their use for complex fractures of the tibial plateau.

Conclusion

The application of 3D models in tibial plateau fractures presents a high rate of changes in preoperative planning when compared with CT, especially in the choice of number of plates and surgical approach. Less experienced surgeons have more planning changes than more experienced surgeons.

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