3D Printed Models Can Reduce Costs and Surgical Time of Complex Proximal Humeral Fractures: Planning and Training

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INTRODUCTION:

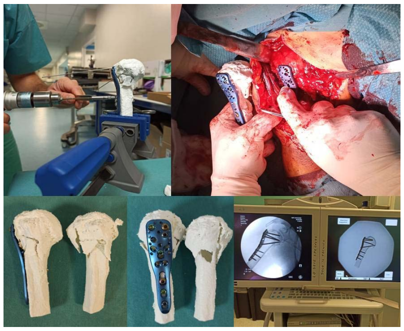
Three-dimensional (3D) printing is a technology capable of creating solid objects based on the reproduction of computerized images. In the medical field the 3D reconstruction of anatomical models guarantees an accurate approach to deformities, offering revolutionary impacts on surgical practice. In trauma surgery, a 3D printed anatomical model can provide a direct and interactive visualization of fracture characteristics, ensuring preoperative planning and practical training.

We report applications and opportunities of 3D printed anatomical models reproduction for complex proximal humeral fractures (Neer Classification 3-4) treated with open reduction and internal fixation (ORIF).

METHODS: Twenty consecutive patients treated surgically for complex proximal humeral fractures were included in a prospective, randomized case-control study. All the patients underwent X-ray and CT scan in the emergency room and were randomly divided into two groups. Patients enrolled in the Group B (10 controls) were treated with standard method without further pre-operative investigations. Patients in the Group A (10 cases) were investigated more deeply: anatomical full-touch/real-size plastic 3D models were made from the CT images to study joint implication, localization and quality of bone fragments. In-fact, once the senior surgeon and the residents fully understood the fracture and predicted how severe the involvement of the vascular component was, they simulated "*in vitro*" on-the-table the operation, planning the correct sequence to reduce fragments and selecting and applying the most appropriate plate size and its positioning, length and orientation of the screws. The 2-factor ANOVA for repeated measures has been used to investigate the differences in mean of operative time (from incision to suture of the skin), the number of intraoperative X-Rays and blood loss between Group A and Group B.

RESULTS: Planning the surgical procedure for Group A patients was more complex. The printing time was between 4 and 6 hours for each single full-touch anatomical model in full size. Unpretentious costs were recorded for the production of these anatomical full-touch real-size models: less than 5 euros per model as regards the material (PLA), less than 1000 euros as regards the hardware (commercial laptop and printer). The sterilization of 3D models did not involve any additional cost, nor was there a reduction of sterilized instrument to perform the interventions of Group A compared to Group B. The mean duration of surgery in Group A (71.28 ± 10.03 min.) was significantly lower ($p < 0.05$) than in Group B (84.03 ± 12.08 min.), saving about 15% of the surgical time. No statistically significant difference was found in blood loss, while a significantly higher number of intraoperative x-rays were recorded in Group B (11.45 ± 1.8 vs 8.76 ± 2.1).

DISCUSSION AND CONCLUSION: The lower number of intraoperative radiographic controls, the reduction of the procedures time and the advanced patient compliance allow the reduction of X-Ray exposure for patients and healthcare professionals and optimize surgical outcomes. At the same time, the 15% reduction in surgical times leads us to conclude that the savings obtained on less use of the active operating room was about 300 euros per operation, but we are not still able to provide a suitable follow-up of these patients to certify even better clinical outcomes. In addition, the introduction of this method during residency programm in the orthopaedic surgical area could practically involve the trainees and improve training satisfaction and quality of learning.



Prospective, randomized case-control study			
	Group A (10 cases)	Group B (10 controls)	
Surgical procedure	10 ORIF	10 ORIF	
Surgical time	71.28 ± 10.03 min	84.03 ± 12.08 min. (+15%)	*p< 0.05
Blood loss	268.75 ±67.81 mL	271 ±50.10 mL	*p> 0.05
X-Rays intraoperative	10.12 ±1.9	13.02 ±2.4	*p< 0.05

* 2-factor ANOVA using repeated statement