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In-Hospital manufacturing of patient specific 3D-printed guides

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Abstract

Introduction
Patient specific instrumentation is a novel aid the industry has been implementing in our hospitals during the last years. However, the cost of the process and the impossibility to discuss face to face with the manufacturer the needs of the particular cases may favor the in-hospital production of these devices.
We present the design and manufacturing process of three patient-specific devices to treat complex common situations in orthopaedic surgery, such as intramedular tumor resections, long bone pseudarthrosis and malunions of articular fractures.
Material and Methods
CT scans of the region of interest were performed to all the patients. Horos® software was used to isolate the affected bone region, whereas Meshmixer® software was used to create the patient specific guides. An Ultimaker 2+® 3D printer was used to print the guide, in a biocompatible material (SmartFil® Medical). The printing parameters included a nozzle of 0.6 mm and a layer height of 0.1 mm.
There was one case of a low-grade chondrosarcoma in which we created a guide to resect enough cortical bone to make an extended curettage of the lesion. Phenol and PMMA were used as adjuvants after the curettage. We used the same guide to obtain an exact replica of allograft which was later placed in position.
We had a femur diaphyseal atrophic pseudarthrosis in a patient with achondroplasia, in which the guide permitted the resection of the affected bone with a saw and posterior osteosynthesis with an anterior LCP plate.
Finally, in an intraarticular malunion of a distal radius Die-Punch fracture we used the guide to make an osteotomy of the affected articular portion and correct the articular surface. Bone autograft was added prior to the osteosynthesis with a plate.
Results
Mean design time was 6.3 hours. Mean printing time was 5.2 hours. The price of the filament used for each guide was under 10 USD. The mean time from the CT-Scan and

the surgery being performed was 2.7 months. In all cases the patient specific guides fitted in the bone and permitted the planned resection/osteotomy.
All the surgeries fulfilled their purpose.
Conclusions
Patient specific guides are easy to design in a local setting with the aid of free software. Design time still needs dedication although it permits the manufacturing of the guides following surgeon needs. The use of self-designed and printed guides is safe and accurate, with a low cost for the institutions.

1 Introduction

Patient specific instrumentation is a novel aid the industry has been implementing in our hospitals during the last years. However, the cost of the process and the impossibility to discuss face to face with the manufacturer the needs of the particular cases may favor the in-hospital production of these devices.
Surgical applications of 3D self-manufactured models are wide and involve preoperative planification(1–3), osteotomy guides (4) and patient specific instrumentation for articular prosthetic replacements (5). Other applications of 3D printing involve patient specific implants. However, the costs of the hardware needed for their manufacturing make it available to only a few hospitals such as the Hospital for Special Surgery.

2 Objectives

We present the design and manufacturing process of three patient-specific devices to treat complex common situations in orthopaedic surgery, such as intramedular tumor resections (6), long bone pseudarthrosis and malunions of articular fractures (7). The novelty for the presented cases include the design and manufacturing by the orthopaedic surgeons within the department of trauma surgery in partial articular malunions.

3 Materials and Methods

All the procedures presented were performed within the hospital facilities of University Hospital del Río Hortega, in Valladolid, Spain. CT scans of the region of interest were performed to all the patients and data acquihired as axial Kernel 30 cuts. Horos® software was used to isolate the affected bone region, whereas Meshmixer® software was used to create the patient specific guides as needed, using the bone cortex as a template for the future PSI-Bone contact zone. An Ultimaker 2+® 3D printer was used to print the guide, in a biocompatible ABS material (SmartFil® Medical Filament). The printing parameters included a nozzle of 0.6 mm and a layer height of 0.1 mm. Supports were used for hanging structures above 75 degrees.

There was one case of a low-grade chondrosarcoma in which we created a guide to resect enough cortical bone to make an extended curettage of the lesion. Phenol and PMMA were used as adjuvants after the curettage. We used the same guide to obtain an exact replica of allograft which was later placed in position. A LISS plate was applied for bone protection. (Fig. 1)

There was one case of femur diaphyseal atrophic pseudarthrosis in a patient with achondroplasia. The previous fracture was treated with a LISS plate. In this case, the guide permitted the resection of the affected bone with a saw and posterior osteosynthesis with an anterior LCP plate. The LISS plate was left for support (changing the position of proximal screws). (Fig. 2)

Finally, there was one case of intraarticular malunion of a distal radius Die-Punch fracture. We used the guide to make a proper osteotomy of the affected articular portion and correct the articular surface. Bone autograft was added prior to the osteosynthesis with a volar plate. (Fig. 3)

4 Results

Mean design time was 6.3 hours. Mean printing time was 5.2 hours. The price of the filament used for each guide was under 10 USD. The mean time from the CT-Scan and the surgery being performed was 2.7 months. In all cases the patient specific guides fitted perfectly in the bone and permitted the planned resection/osteotomy. All the surgeries fulfilled their purpose with bone union in all cases.

5 Conclusions

Patient specific guides are easy to design in a local setting with the aid of free software. Design time still needs dedication, although it permits the manufacturing of the guides following surgeon needs. The use of self-designed and printed guides is safe and accurate, with a low cost for the institutions.

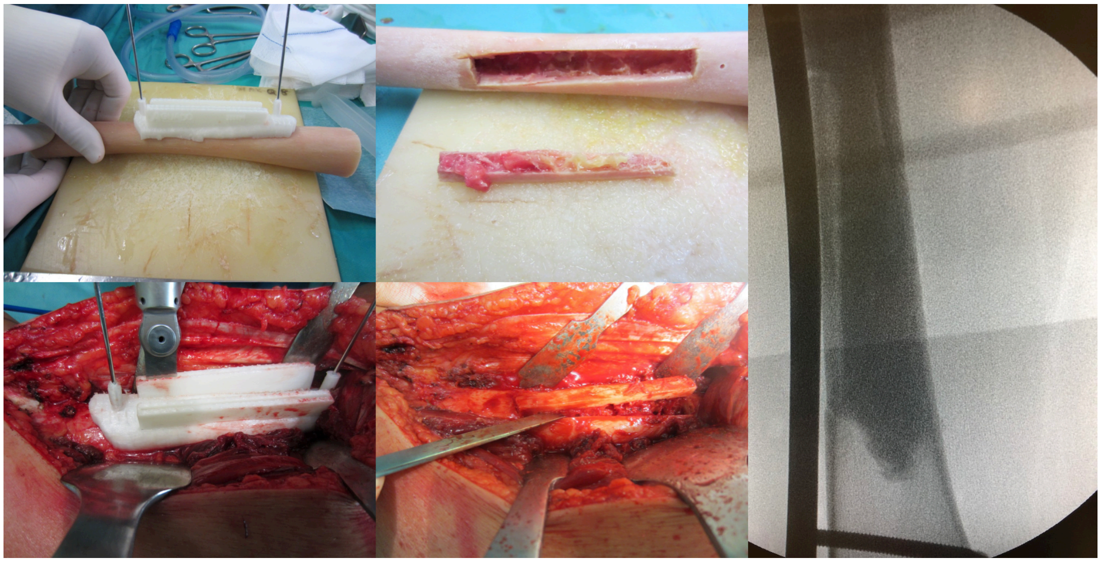

Figure 1: Curettage of a low-grade chondrosarcoma.

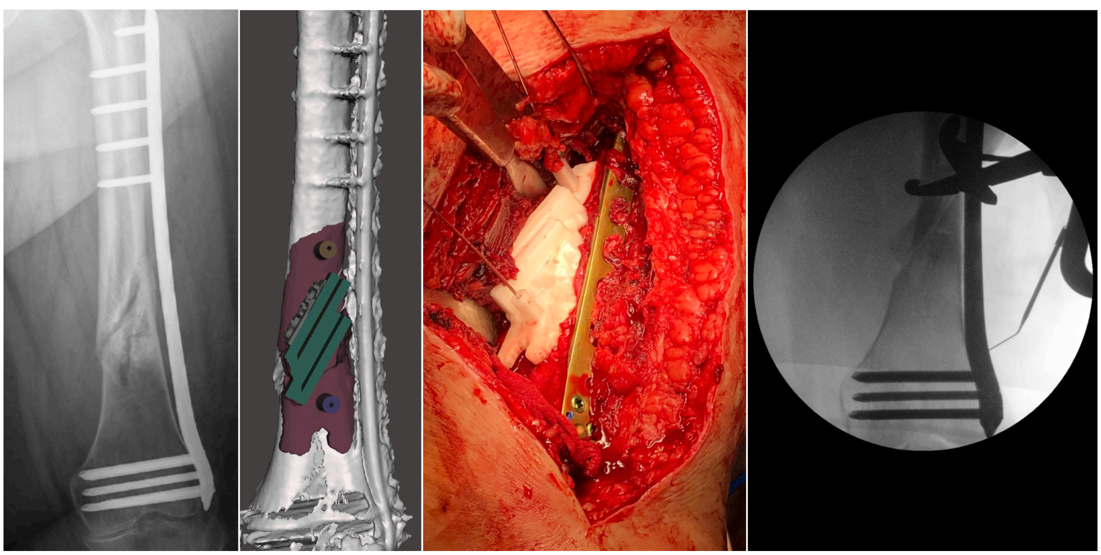

Figure 2: Resection of the pseudarthrosis and posterior stable osteosynthesis with an anterior plate. Lateral plate was left for protection purposes.

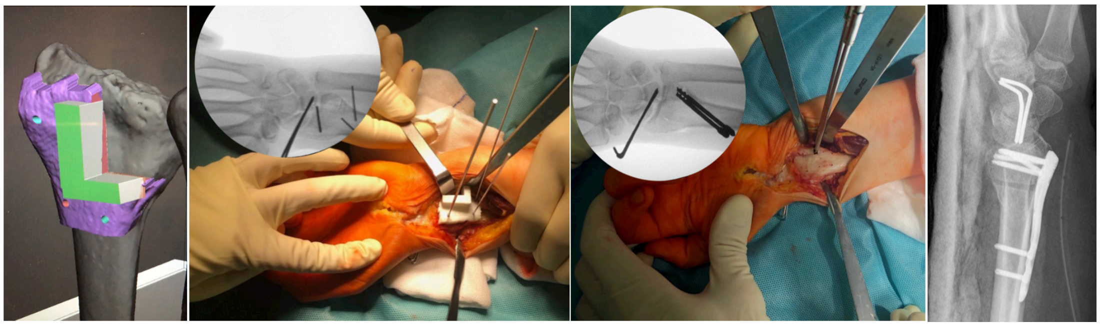

Figure 3: Design of a patient specific guide for a malunion of a distal radius fracture. Intraoperative views of the articular osteotomy.

6 References

1. Lal H, Patralekh MK. 3D printing and its applications in orthopaedic trauma: A technological marvel. J Clin Orthop Trauma. 2018 Sep;9(3):260–8.
2. Tack P, Victor J, Gemmel P, Annemans L. 3D-printing techniques in a medical setting: a systematic literature review. Biomed Eng Online. 2016 Oct 21;15(1):115.
3. Kang HJ, Kim BS, Kim SM, Kim YM, Kim HN, Park JY, et al. Can Preoperative 3D Printing Change Surgeon's Operative Plan for Distal Tibia Fracture? Biomed Res Int. 2019;2019:7059413.
4. Arnal-Burró J, Pérez-Mañanes R, Gallo-Del-Valle E, Igualada-Blazquez C, Cuervas-Mons M, Vaquero-Martín J. Three dimensional-printed patient-specific cutting guides for femoral varization osteotomy: Do it yourself. Knee. 2017 Dec;24(6):1359–68.
5. Nabavi A, Olwill CM, Do M, Wanasawage T, Harris IA. Patient-specific instrumentation for total knee arthroplasty. J Orthop Surg (Hong Kong). 2017;25(1):2309499016684754.
6. Wang F, Zhu J, Peng X, Su J. The application of 3D printed surgical guides in resection and reconstruction of malignant bone tumor. Oncol Lett. 2017 Oct;14(4):4581–4.
7. Shintani K, Kazuki K, Yoneda M, Uemura T, Okada M, Takamatsu K, et al. Computer-Assisted Three-Dimensional Corrective Osteotomy for Malunited Fractures of the Distal Radius Using Prefabricated Bone Graft Substitute. J Hand Surg Asian Pac Vol. 2018 Dec;23(4):479–86.