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3D surgical printing for preoperative planning of trabecular augments in acetabular fracture sequel

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ABSTRACT

We describe the methodical and possibilities of 3D surgical printing in preoperative planning for a total hip arthroplasty in acetabular deformity after acetabular fractures, showing a case of a 43-year-old with posttraumatic arthritis after both column fracture of the left acetabulum that was treated non operatively, supporting the do it yourself mode.

Introduction

Displaced acetabular fractures constitute a surgical challenge for the orthopaedic surgeon. An anatomical congruence between the femoral head and the acetabulum is essential for good long-term results in these fractures. Residual displacements greater than 2 mm lead to early coxarthrosis and poor functional outcomes [1]. When a grossly displaced acetabular fracture is treated non-operatively the chance to develop a disabling arthrosis in a short period of time is extremely high and the residual anatomy can limit the use of regular implants when considering a total hip arthroplasty, forcing us to use revision arthroplasty technics for primary procedures [2].

Lately, the advances in three-dimensional reconstruction of radiological studies have provided tools for virtual surgical planning, obtaining reconstructions that are easier to interpret, even by less experienced surgeons. From the diagnostic images of the case, the study can be rendered software, and can even be exported as a three-dimensional mesh to obtain a real model in a 3D printer. This 3D preoperative impression allows a more effective diagnosis and helps in the simulation of the surgical procedure. Thanks to the improvement of the domestic computers, more intuitive development of the software and decrease of its cost, access to several formative platforms and to domestic 3D printers, all this process can be realized by the final user, in such a way that has facilitated the “Do It Yourself” (DIY) style, even in our daily practice as orthopaedic surgeons [3].

The goal of this paper is to describe a methodology for applying 3D technology thru a DIY processing, analyzing advantages and potential drawbacks in total hip arthroplasties after acetabular fractures treated non-operatively. We describe our method thru a clinical case that underwent surgical treatment at our institution.

Materials and methods

We present the case of a 43-year-old male who attended our outpatient clinic reporting severe progressive constant pain in the left side of the groin, compromised functionality and shortening of 3 cm. 5 months before, after a fall from a height of ten meters, he suffered several fractures (pelvis, spinal, elbow, metatarsal) that were managed non operatively at that time and a left diaphyseal femoral fracture that was treated with an intramedullary nail.

The patient’s walking ability was very limited and he required a wheelchair to get around. Tapentadol 200 mg every 12 h was not able to relieve the pain. On examination, the affected leg showed apparent shortening of 3 cm upon inspection with functional impairment and limited hip range of motion with a marked tendency of external rotation while flexing the hip (Fig. 1). The patient related that distal nerve was initially affected but a spontaneous recovery was achieved.

X-ray and CT scan evidenced severe deformity of the left acetabulum with proximal migration of the femoral head and clear images of coxarthrosis, a consequence of the acetabular fracture (Fig. 2). After discussing treatment alternatives, the patient decided to undergo total hip replacement.

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Fig. 1. Limited range of motion with obvious predisposition of external rotation while flexing the affected hip.

In order to create our preoperative surgical planning, we used the DICOM archives of the standard multislice CT performed to the patient (Philips Brilliance 64, 0.625 mm slice thickness). The CT study was loaded into the radiological post-processing software OsiriX® (MD version 7.5.), using a Macintosh personal computer (Apple Computers, Cupertino, CA). Once we segmented, with automatic and semiautomatic tools, the sacrum, lumbar spine, both femurs, and contralateral hemipelvis, 3D surface rendering was made to obtain the isosurface mesh that was then exported as a 3D object in STL format and then imported to the printer software (Cura®, version 2.7.) (Fig. 3). The total time to obtain the final post-processing STL archive was 11 min. The inspection and repair of the virtual model and its supports, as well as the slicing, took 15 min. The mold impression was printed with the Ultimaker 2+ Extended printer using polylactic acid (PLA) for fused deposition modeling, with a retail price of 2.000 euros. The printing time was 21 h and 37 min, consuming 245 g of this material, with an approximate cost of 6 euros (Fig. 4). In order to optimize the ratio quality of the mold and time of impression we stabilized, in the basic the configuration of the printing software (Cura®, version 2.7), 0,3 mm for the layer height, a fill density of 8% and a shell thickness of 1,2 mm (3 layers of 0.4 mm each thickness). This layer height represents a low quality in 3D printing standard but is enough to achieve an optimal result in bone impressions, besides reducing the printing time considerably. With a fill density of 8% and a shell thickness of 1,2 mm we generate a light object with high strength, while we minimize the material waste.

Due to the complexity of the model, supports were generated in order to maintain the model to the printing bed during the printing process. The bone model itself presents many cavities, in addition to an acetabular joint surface disrupted by the defect lines, caused by the old fracture lines, so different supports were needed in this area in order to reproduce reliably the STL model. It was also especially important to place the STL model properly in the bed of printing in order to reproduce all the shapes during printing, that is the reason vertical the areas that required more detail since the resolution is greater in the vertical direction than in the plane.

After obtaining the printed hemipelvis (Fig. 5), we proceeded with the implant size selection (Trabecular Metal®; Zimmer) that matched the characteristics of the defect, using the trials available in the set. Two augments were used to fill the superior cavity (size 54–15 and 54–10) and a cup trial of 56 mm was placed supported by the remaining inferior part of the acetabular columns. The plastic model was labeled and sterilized thru standard circuits

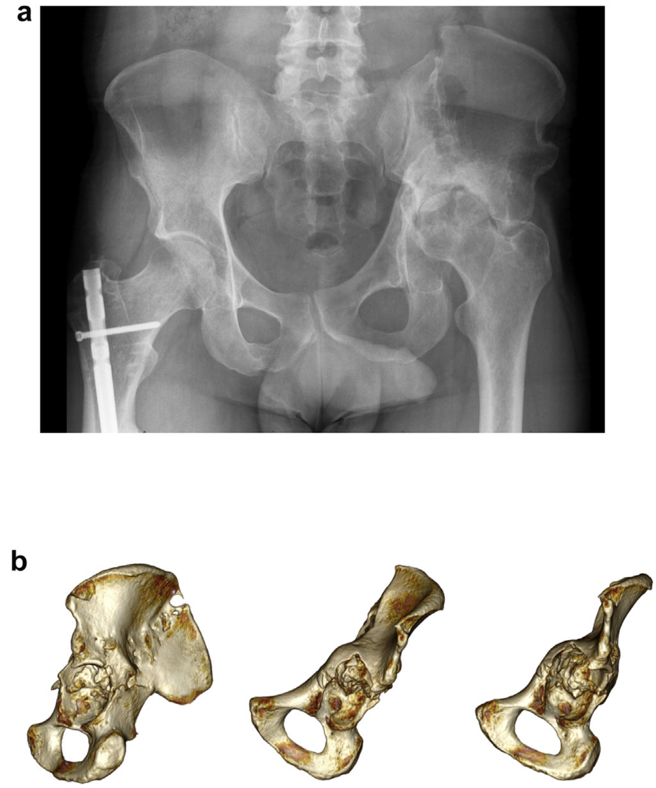

Fig. 2. A. X-ray A-P view shows clear high centre of rotation of the left hip with severe post-traumatic arthrosis. B. CT scan images after 3D volumetric rendering showing deformity after both column acetabular fracture.

using ethylene oxide with a temperature of 55° and was available during the definitive surgical procedure to check the concordance of the planned trials with the definitive implants (Fig. 6).

The patient was admitted on the same day of the procedure and placed under intrathecal anesthesia in the lateral decubitus position, using a standard hip posterolateral approach. The gluteus medius was easily identified and elevated to enable access. As the short rotators could not be individually identified, they were separated by blunt dissection using Cobb dissectors. After identifying the femoral neck, we performed in situ femoral osteotomy, avoiding dislocation and taking care not to damage the anterior column. We continued distal dissection from the upper rim of the acetabulum towards the obturator foramen, clearing away fibrosis and osteophyte residue from the lower rim of the native acetabulum. The fracture healing was checked. Once the fibrotic tissue was removed by curettes the acetabular bone loss, type of deficiency and remaining bone stock was analyzed and it was considered as a severe segmental and cavitary defect according to the AAOS classification [4]. All the findings matched the surface of the printed model. The acetabulum superior cavity was prepared with a high-speed burr in order to reach the desire-bleeding surface in which to fit the planned augments and maximize the contact area with native bone. The hip centre was recognized and sequentially acetabular reamers were used with a progressive increase of 2 mm up to 58 mm in the desired location, to size and shape the acetabulum for the trabecular metal revision shell. Once the acetabular trials were checked we inserted the definitive components. We pressed fit two trabecular metal augments (size 54–15 and 54–10) in the superior defect. The femoral head resected was used to fill the augments as morselised cancellous bone autograft. A film of palacos-G® bone cement was applied on the medial surface of the augments in order to create a unique element. Then trabecular metal revision cup (Trabecular