EPiC Series in Health Sciences
Volume 3, 2019, Pages 422–427
CAOS 2019. The 19th Annual Meeting of the International Society for Computer Assisted Orthopaedic Surgery

Patient specific surgical guide improve the accuracy of acetabular component placement in total hip arthroplasty with dysplastic acetabulum

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Abstract

To investigate the accuracy of a novel 3D CT scan-based preoperative planning software linked to patient-specific instrumentation (PSI) for placing acetabular components planning in patients with acetabular dysplasia undergoing total hip arthroplasty (THA). A total of 30 consecutive patients were prospectively enrolled and the accuracy of placement of the acetabular component was measured using post-operative CT scans. There was good reproducibility of preoperative and postoperative position of reconstructed rotation center. The mean absolute deviation from the planned inclination and anteversion was 6.2° and 4.8°, respectively. In 90% of cases the planned target of +/-5° was achieved for both inclination and anteversion. And 95% of cases of planned target of +/-3mm were achieved for vertical height of rotation center. Accurate placement of the acetabular component can be achieved using patient-specific guides and is superior to free hand techniques.

1 Introduction

Hip osteoarthritis secondary to acetabular dysplasia (AD) is one of the most common reasons for total hip arthroplasty (THA) (Gala, Clohisy, & Beaule, 2016). Those dysplastic acetabulum in generally present with a shallow and steep socket, bony insufficiency in posterior or anterior wall, and prominent osteophytes (Fujii, et al., 2010), which increase the difficulty of achieving balance in restoration of the anatomical hip center, accuracy of cup orientation, sufficient host bone-cup coverage, and minimizing lower limb discrepancy (Rogers, Garbedian, Kuchinad, Backstein, Safir, &

[*] Designed and perform the study, provided the software, wrote and revised the manuscript.
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Gross, 2012) (Dapuzzo & Sierra, 2012) (Sakellariou, Christodoulou, Sasalos, & Babis, 2014) (Hartofilakidis & Karachalios, 2004).

Hip replacement for patients with AD is safe and effective, although implant revision rates are higher than those in patients without AD. It is up to 29% -53% revision rates of the cemented reconstruction with or without structural bone grafts for patients with AD in 1970s-1990s (MacKenzie, Kelley, & Johnston, 1996) (Shinar & Harris, 1997) (Stans, Pagnano, Shaughnessy, & Hanssen, 1998) (Watts, Abdel, Hanssen, & Pagnano, 2016) (Chougle, Hemmady, & Hodgkinson, 2005). Pagnano et al. revealed that excessive superior and lateral cup placement associated with relative higher revision rate compared to those in an anatomic position (Pagnano, Hanssen, Lewallen, & Shaughnessy, 1996). Surgeons should therefore take special surgical techniques and more cautions during placement of the acetabular component in patients with AD.

Our aim was to assess the accuracy of a new 3D printed patient-specific guides designed to optimize the placement of the acetabular component in patients with AD undergoing THA.

2 Method

2.1 Patients

The study protocol and consent forms were approved by the local ethical committee. Between May 2018 and January 2019, a total of 30 patients (30 hips) were included in this study, including 6 males and 24 females, of which 6 were Crowe type I, 20 were Crowe type II, and 4 were Crowe type III. Patient age ranged from 51 to 78 years, with an average of 61.4 (±7.3) years old.

2.2 Acetabular Preoperative planning

All the included patients had pre- and post-operative CT scans and routine X-ray examination. Model reconstruction and surgical planning were both performed using BOHOLO software (version, Fengsuan Ltd. Shanghai China). A preoperative CT scan from the iliac wing to the less trochanter was performed using a standard CT scanning system (Toshiba, Tokyo, Japan) with a slice thickness of 0.5 or 0.8 mm and pixel dimensions from 0.459 to 0.912 mm.

Preoperative 3-D planning of acetabulum component placement was conducted to determine the optimal cup size, orientation, and location. The cup size was adjusted so as to fit the distance between anterior and posterior acetabular walls. The target ranges of cup orientation were set as 30°-50° of inclination and 10°-25° of anteversion (Lewinnek, Lewis, Tarr, Compere, & Zimmerman, 1978). The goals for cup placement were to restore the center of rotation of the native acetabulum and to achieve at least 70% of host bone-cup coverage, which were based on generally accepted standards from previous reports (Dapuzzo & Sierra, 2012) (Watts, Abdel, Hanssen, & Pagnano, 2016). The planned distance of upward displacement was measured using the inter-teardrop line as reference line. A patient-specific guide was designed to give the planned orientation. Each guide and acetabular model was 3D printed from RUBY using Digital Light Processing (Figure 1).

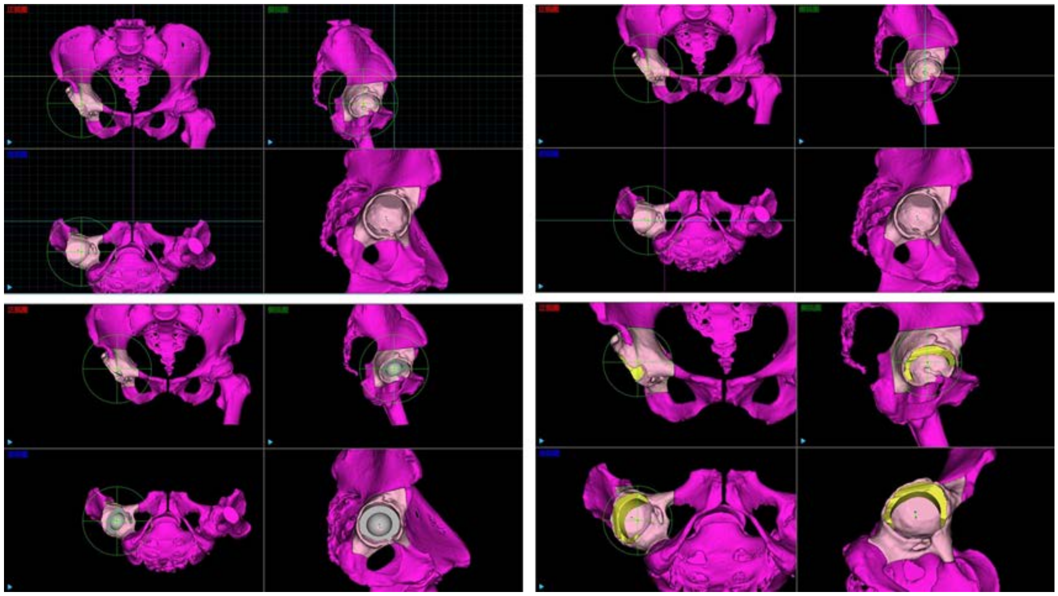

Figure 1. Simulation of the cup component implantation. a. Align the pelvis on the anterior pelvic plane ; b. Identify and align the lower margin of acetabulum; c: Simulation of the cup placement size: 50mm; bone-cup coverage:81%, Inclination = 40°; Anteversion = 20°; height of rotation center from the inter-teardrop line; d. A patient-specific guide was designed to give the planned orientation.

2.3 Operative procedure

Posterolateral surgical approaches were used in all cases. The acetabular labrum was completely removed, and the acetabular bony rim was sufficiently exposed. The guide was placed rigidly into the acetabulum ensuring that the guide matched with the articular surface of the acetabular. The surgeon marked the inner margin of the guider on the articular surface of the acetabulum using an electrotome. The surgeon reamed within the marked margin down to medial wall with a 40 mm diameter reamer, and expansion step by step to get acceptable acetabular dome coverage by checking the width of uncovered part which had been planned and provided to the surgeon preoperatively. (Figure 2)

All acetabular cup implantations were performed by one senior surgeon (LWM) and the cementless acetabular component was chosen by the surgeon (The brand of cup was Pinnacle, Depuy, Warsaw, IN)

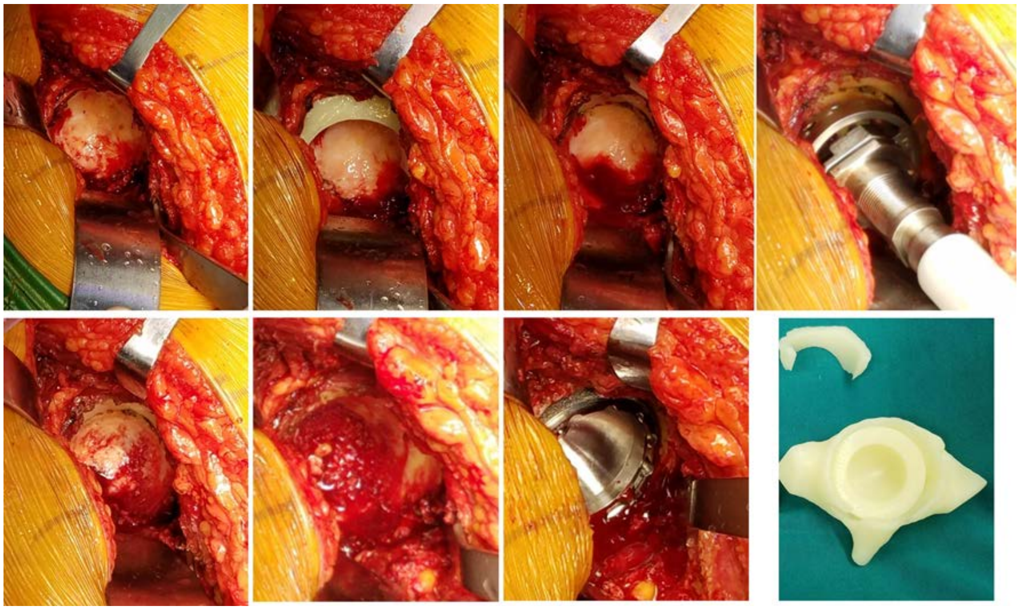

Figure 2. Operative procedure with using a patient-specific guide. a. Sufficiently expose the acetabular bony rim; b. The guide was placed rigidly into the acetabulum ensuring that the guide matched with the articular surface of the acetabular; c.The surgeon marked the inner margin of the guider on the articular surface of the acetabulum using an electrotome; d,e.The surgeon reamed within the marked margin down to medial wall with a 40 mm diameter reamer; f. Expansion the reaming step by step to reach the target size; g. Insertion of the cup component; h. the patient-specific guide and the patient's acetabulum model for intraoperative confirmation of cup placement.

2.4 Postoperative evaluation

We measured the postoperative cup anteversion and inclination angles, vertical distance between rotation center and inter-tear drop line, horizontal distance between rotation center and ilioischial line on the postoperative reconstructed acetabular images.

2.5 Statistical Analysis

SPSS 20.0 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. Paired-sample T tests were used for preoperative and post-operative comparisons. The two-tailed level of significance α was 0.05.

3 Results

There was good reproducibility of preoperative and postoperative position of reconstructed rotation center. The mean absolute deviation from the planned inclination and anteversion was 6.2° and 4.8°, respectively. In 90% of cases the planned target of +/-5° was achieved for both inclination and anteversion. And 95% of cases of planned target of +/-3mm was achieved for vertical height of rotation center

4 Discussion

We found that the accuracy of placement of the acetabular component using specific instrumentation was satisfactory. There were a total of 3 outliers in this series. Outliers were malpositioned greater than 5° from pre-planned orientation in one plane. There were two cases of increased height of rotation center. This accuracy of placement is comparable with previous reports of both robotic and navigated techniques and is vastly better than free hand techniques (Kalteis, Handel, & Bathis, 2006) (Parratte & Argenson, 2007) (Sugano, Nishii, & Miki, 2007). We used our historical control group of THA in patients with DDH with the free hand technique to show the superiority of the patient-specific technique.

The main finding of this study was that the preoperative CT-based 3-D templating made it possible to predict accurate cup size and achieve reproducible cup position in patients with dysplastic acetabulum. Moreover, 3-D templating enables the surgeon to adjust the acetabular components into their proper positions in the 3-D space and balance in restoration of the rotation center, sufficient host bone-cup coverage, and minimizing lower limb discrepancy. Especially, in dealing with the cases with steep acetabular dome, reconstruction at the anatomical level would cause a large uncovered overhang portion on cup component, and the slight superior placement of the uncemented acetabular component could be reproduced intraoperatively according to the preoperative plan. It is a safe and effective surgical procedure of using patient-specific instrument to avoid structural bone graft and achieve good bone coverage of the acetabular component and lead to excellent clinical outcome in short-term follow up.

In conclusion, accurate placement of the acetabular component in THA with dysplastic acetabulum can be achieved by preoperative CT-based 3-D templating and using patient-specific guide.

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