Objective evaluation for initial stability of highly porous cup without screws in total hip arthroplasty for femoral neck fracture

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ABSTRACT

Background: The purpose of this study was to objectively investigate the initial fixation of highly porous cups in THA for femoral neck fractures.

Methods: THA for displaced femoral neck fractures was performed in 52 consecutive patients. We objectively measured the rotational torque for cup stability, and the primary endpoint was the success rate of press-fit fixation without screws.

Results: The success rate of press-fit fixation without screws was 96.1%. No specific complications were occurred.

Conclusion: The initial stability of highly porous cups was excellent for femoral neck fractures with a high success rate of press-fit fixation without screws.

1. Introduction

Initial stability of a cementless acetabular cup is important to prevent early cup loosening in total hip arthroplasty (THA). The factors that contribute to initial stability include the surgical technique, type of acetabular component, supplemental fixation, and bone quality.¹ The press-fit technique in cementless THA has been shown to have good clinical results.^{2–5} Initial stability of a press-fit cup ideally minimizes micromotion and involves bone ingrowth between the cup and acetabular bone. Various methods have been considered to achieve press-fit initial fixation.^{6–9} Kaneko et al.² reported that torque measurement was useful for cementless cups without screws. Engh et al.³ reported good results using spiked cups. Press-fit and supplemental screw fixation has been confirmed to be a principal technique for good initial fixation.⁵

In recent years, an acetabular component using a metal cup with a highly porous surface was developed because increased surface roughness helps to improve initial fixation.¹⁰ A highly porous cup has a higher friction coefficient than a standard cup and provides excellent initial fixation.¹ Salemyr et al.¹¹ reported that porous cups demonstrated good results in terms of initial fixation and clinical outcomes in patients with primary hip osteoarthritis. However, whether highly porous cups provide good fixation for the non-osteoarthritis acetabulum, as in patients with femoral neck fractures due to osteoporosis, remains unclear.

Several authors have reported on the benefit of THA for displaced femoral neck fractures with low bone quality. Burgers et al.¹² and Wang

et al.¹³ reported that THA is superior to bipolar hemiarthroplasty in terms of the hip pain, function, and revision rates. However, the safety of THA remains unclear, and how to perform the operation more safely is still a major concern. Blomfeldt et al.¹⁴ reported a longer duration of surgery and increased intraoperative blood loss in THA than bipolar hemiarthroplasty. Press-fit fixation without screws in a cementless cup might reduce the blood loss and operation time. However, whether the press-fit technique using a cementless cup is possible for osteoporotic acetabular bone has not been clarified.

Therefore, we hypothesized that the use of a highly porous cup in press-fit fixation without screws is effective when THA is performed for displaced femoral neck fractures due to osteoporosis. The purpose of this study was to objectively investigate the initial fixation of a highly porous cup without screws in THA for femoral neck fractures.

2. Patients and methods

2.1. Patients

This was a retrospective study. Institutional review board approval was obtained before reviewing any medical records. From June 2015 to December 2018, 52 patients with displaced femoral neck fractures due to osteoporosis were admitted to our hospital. Informed consent was obtained from all patients. THA was performed in 52 patients with 52 hips (male, 11 hips; female, 41 hips). The patients' average age was 80.4 years (range, 62–96 years).

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Fig. 1. Highly porous acetabular cup (Pinnacle™ Gription®; DePuy Orthopaedics, Warsaw, IN).

2.2. Operative procedure

The direct anterior approach using fluoroscopy was performed in all patients. A standard surgical table was used until 2017,¹⁵ and a novel mobile traction table (Surgical Alliance, Tokyo, Japan) was used beginning in 2018.¹⁶ Osteotomy was performed after cutting the articular capsule in the supine position by intermuscular penetration of the tensor fasciae and sartorius muscle.¹⁷ Intraoperative control of the cup and shaft positioning was always performed by fluoroscopy and adjusted as needed to ensure optimal positioning. All patients were allowed full weight bearing immediately after THA. All patients received highly porous cups (Pinnacle™ Gription®; DePuy Orthopaedics, Warsaw, IN) (Fig. 1). The diameter of the ceramic inner head was 32 mm in 47 hips and 28 mm in 5 hips. For the stems, 42 patients received cementless tapered-wedge femoral components (TRI-LOCK®; DePuy Orthopaedics) with a circumferential plasma spray coating and hydroxyapatite. Ten patients received a cementless fit-and-fill stem with a full hydroxyapatite coating and collar (ACTIS®; DePuy Orthopaedics).

Fig. 3. Torque meter (Model FTD16N2-S; TONICHI Engineering, Tokyo, Japan).

2.3. Protocol and objective evaluation of initial stability

The operative protocol is shown in Fig. 2. After exposure on the acetabular side, the same size of reaming was performed in all cases. After cup implantation, a torque meter (Model FTD16N2-S; TONICHI Engineering, Tokyo, Japan) was attached to the connector, and the theoretically required instability torque, which was calculated by the implant head size and body weight,² was applied (first torque measurement) (Figs. 3 and 4). If the cup retained its stability under application of the theoretically required torque, the procedure was defined as successful (i.e., adequate initial stability was achieved). If adequate initial stability was not achieved by the first torque measurement, soft tissue removal around the acetabular edge and reaming with the same-size reamer were repeated. The cup was then re-implanted, and a second torque measurement was performed. If the cup retained its stability under application of the theoretically required torque, the procedure was also defined as successful (i.e., adequate initial stability was achieved). If adequate initial stability was not achieved by the second torque measurement, the procedure was defined as a failure (i.e., adequate initial stability was not achieved). In cases of failure, additional screws or a cemented cup was implanted.

Fig. 2. The operative protocol in this study.

Fig. 4. Illustrative image of the torque measurement in this study.

2.4. Calculation of theoretically required stability torque

The theoretically required stability torque was calculated as previously reported.^{2,18} The formula was $T = R \times f \times L$, where T is the necessary theoretical rotation torque, R is the femoral head radius, F is the coefficient of friction, and L is the load. Concerning the polyethylene liner and femoral head, the femoral head radius was 16 mm (32-mm head) and the coefficient of friction was 0.1–0.2. The body weight ranged from 32 to 90 kg. The load was indicated as follows: $32\text{--}90\text{ kg} \times 9.8\text{ N} = (314\text{--}882)\text{ Nkg}$. We assumed a four-times higher value in consideration of safety. Thus, the rotation torque, which occurs in the cup with a postoperative normal gait, was expressed by the following numerical formula: $T = 0.016 \times (0.1\text{--}0.2) \times (314\text{--}882\text{ kg}) \times 4$. Therefore, the theoretical rotation torque ranged from 2.0 to 11.2.

2.5. Evaluation

The primary endpoint was the success rate of press-fit fixation without screws. The secondary endpoints were the presence of an initial gap on the immediate postoperative X-ray, postoperative acetabular cup translation, acetabular fracture, dislocation, infection, periprosthetic fracture, and revision surgery for any reason. The initial gap was measured using the method described by Cameron et al.¹⁹ An implant–bone interface gap of $\geq 2.0\text{ mm}$ was defined as the presence of an initial gap. Translation of the acetabular cup by $\geq 1.0\text{ mm}$ was defined as cup translation as reported by Pijls et al.²⁰ Immediate postoperative and weekly X-ray examinations during hospitalization were performed to identify acetabular fractures.

3. Results

The theoretically required torque based on the patient's body weight ranged from 8 to 12 N. The success rate of press-fit fixation without screws was 96.1%. Two failures were observed in our series, and additional screws for cup fixation were necessary in those cases. Among the successful cases (50 hips), adequate torque was confirmed by the

first attempt in 94.2% (49 hips). No initial gap or cup translation was observed in any case. No acetabular fractures occurred, and all patients underwent rehabilitation with full weight bearing. No revision surgery was performed for any reason. No dislocation, periprosthetic fracture, or infection was observed postoperatively.

4. Discussion

We believe that use of a highly porous cup is an excellent option for patients with displaced femoral neck fractures due to osteoporosis. Our study demonstrated that press-fit fixation without screws was achieved in 96.1% of cases. This is a considerably high rate, implying that this technique may contribute to reduced blood loss, a shortened operative time, and a lower complication rate. Although some authors have reported that cup stability depends on the strength of screw fixation,^{21–23} we confirmed adequate initial stability of highly porous cups in patients with bone fragility by a quantitative and objective method involving torque measurement. The Pinnacle™ Gription® is highly porous cup with a rougher surface that sinters the three-dimensional structure of pure titanium on the surface of plasma titanium spray cup with a pore size of $300\text{ }\mu\text{m}$, a coefficient of friction of 1.2, and 80% surface volume porosity.¹ Therefore, the Pinnacle™ Gription® cup has a friction coefficient 1.2 times higher than that of the conventional titanium spray cup (Pinnacle™ Porocoat®). Yoshimoto et al.²⁴ reported that the highly porous titanium cups had a higher mean maximum torque than the titanium-sprayed cups in all bone defect models of their study.

Our study demonstrated both the utility and safety of highly porous cups. No specific complications associated with this cup occurred, such as acetabular fracture or initial gaps. Hasegawa et al.²⁵ reported that 0.4% of periprosthetic fractures of the acetabulum were seen in postoperative computed tomography images taken an average of 1 week after surgery. These fractures might be a source of unexplained groin pain after THA.²⁶ In our series, full weight bearing was allowed immediately postoperatively. However, groin pain was not observed in all patients. Under the utilization of intraoperative and postoperative X-ray examinations with immediate full weight bearing, it was difficult to consider that acetabular fractures had occurred in our patients.

The relationship between a highly porous cup with a pore size of $300\text{ }\mu\text{m}$ and formation of an initial gap has not been described in the literature. However, Springer et al.²⁷ reported the relevance of a porous cup with a pore size of $250\text{ }\mu\text{m}$ and initial gap. They reported that 38.7% of cases (133 of 343 hips) had a $\geq 1\text{-mm}$ initial gap in zone 2 on the first postoperative radiograph. This discrepancy between our result and their report raises several considerations other than the difference in materials among different types of highly porous cups. First, the same size reaming technique was used for the final reaming in our study (i.e., a 48-mm-diameter reamer was used for a 48-mm implanted cup). We found that with a 1-mm undersized reaming technique (47-mm-diameter reamer was used for a 48-mm implanted cup), it was difficult to impact the cup and contact the bottom of the acetabulum because of the high friction of the cup surface. Other reports have shown that under-reaming by $> 2\text{ mm}$ increases the risk of iatrogenic intraoperative fracture^{25,26} and improper seating.²⁷ Clarke et al.²⁸ reported that excessive under-reaming carries a risk of acetabular fracture. Second, fluoroscopy is very useful to check whether the cup is adequately implanted to the bottom of the acetabulum. In our experience, because of the high friction of the cup surface, a hammering sensation without adequate implantation of a very rough cup mimics a well-implanted standard cup. Without fluoroscopy, it is difficult to determine whether the cup is adequately implanted with no initial gap. We believe that fluoroscopy is very useful to eliminate the gap between the cup and the bottom of the acetabulum. We recommend performing imaging studies to determine whether the highly porous cup is correctly implanted.

The torque measurement that we used in this study was a simple and reliable method to evaluate the initial fixation. We believe that the torque test is effective for evaluation of press-fit fixation in the clinical

setting. Yoshimoto et al.²⁴ reported quantification of the initial stability of a highly porous titanium cup using an acetabular bone defect model with the rotational torque test.

This study had several limitations. First, no control group was used. However, our aim was not to compare the stability among cups but to quantitatively and objectively investigate the initial fixation of highly porous cups without screws in THA for femoral neck fractures. Second, four surgeons with different experience levels participated in this study, which might have influenced the results. However, in the actual clinical setting, operations for femoral neck fractures are performed by surgeons with different levels of experience. Third, only rotation torque measurement, not the lever-out test, was performed. During in vivo testing, however, dual evaluations of cup stability (rotation torque test and lever-out test) might influence the achieved cup stability; thus, we chose to perform only a single torque test.

5. Conclusion

The initial stability of highly porous cups was excellent for femoral neck fractures with a high success rate of press-fit fixation without screws.

Conflicts of interest

No funds were received in support of this study. No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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