MINIMUM TEN-YEAR FOLLOW-UP OF COMPUTED TOMOGRAPHY BASED, CUSTOM CEMENTLESS STEM AFTER INTERTROCHANTERIC OSTEOTOMY FOR DYSPLASTIC HIPS

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Abstract : Background: During fixation of total hip arthroplasty (THA) after osteotomy, it is difficult to obtain a good cement mantle with a cemented stem and to obtain good fit along the medullary canal with a ready-made stem. We developed a CT-based custom stem, which was inserted after osteotomy in THA.
Methods : We investigated 32 hips in 28 patients. The mean patient age at surgery was 62 and the mean follow-up period was 13 years. The previous osteotomy was intertrochanteric varus femoral osteotomy in 14 hips, intertrochanteric valgus femoral osteotomy in 17, and Schanz osteotomy in one. CT studies were obtained with a 5 mm slice intervals and 2 mm slice width. We produced stems made of Ti-6Al-4V. The stems did not have collars and the proximal third was coated with a 400-μm-thick porous coating covered with 20-μm-hydroxyapatite (HA) coating.
Results : The Harris Hip Score improved from a preoperative mean of 49.9 points to a postoperative mean of 82.7 points. One patient complained of postoperative thigh pain. Fractures occurred in two hips. Dislocation occurred in three patients. To date, no patient has reqired revision of the stem due to aseptic loosening. There was bone-ingrown fixation in all hips. Severe stress shielding was found in 14 hips (44%)
Conclusion: Stable fixation was achieved with the proximal press-fit of the custom stem. Although stress shielding was observed in 14 hips, excellent results were obtained over a follow-up period of 10 years with this custom stem system for hips after intertrochanteric femoral osteotomy.

Key words : primary total hip arthroplasty, femoral osteotomy, CT based custom stem, fixation, stress shielding

INTRODUCTION

The main pathogenesis of osteoarthritis in Japan is hip dysplasia. Since Pauwels[1] described the biomechanical theory of intertrochanteric femoral osteotomy, the procedure has been routinely performed to treat arthritic hips, and we have used it at our institution, especially to treat dysplastic hips. However some hips worsened, and we did not achieve favorable results with cemented total hip arthroplasty (THA).

Cementless femoral stems, which have been manufactured since the early 1980s[2], were developed to fit the endosteal architecture of the femur in tall, well-built patients in the United States and Europe. However, the majority of Japanese patients with coxarthrosis are short and slender and have a femoral morphology that is much less likely to achieve a good fit with ready-made components after osteotomy. Therefore, we designed and produced custom stems based on computed tomography (CT) data and have used these stems in Japanese patients since 1995[3]. In the present study, we report the results of a minimum of 10-years' follow-up of patients with dysplastic hips who underwent intertrochanteric femoral osteotomy and insertion of a custom stem.

METHOD

From March 1995 to October 2005, primary THA using a cementless custom stem was performed on 41 dysplastic hips after intertrochanteric varus or valgus osteotomy at our institution. Of these, 32 hips in 28 patients (2 hips in 2 males and 30 hips in 26 females), were investigated in the present study. The sex distribution of the patients reflects the high rate of hip dysplasia in Japanese females. Of the original 41 primary total hip arthroplasties, 2 patients underwent stem revision because of alumina-ceramic fracture of a ceramic-on-ceramic acetabular cup, 4 patients died for unrelated reasons, and 3 patients were lost to follow-up. The mean age at surgery was 62 (range, 29-77) and mean height and weight 1.50 m (range, 1.27-1.65 m) and 55 kg (range, 37-76 kg), respectively. The mean follow-up period was 13-years (range, 10-19 years) and the follow-up rate was 82%. All patients had coxarthrosis secondary to dysplastic hip. The previous osteotomy was intertrochanteric varus femoral osteotomy in 14 hips, intertrochanteric valgus femoral osteotomy in 17, and Schanz osteotomy in one. The mean interval between osteotomy and THA was 25 years (range, 14-36 years).

CT studies were performed with 5 mm slice intervals and a 2 mm slice thickness. Two circles were drawn along the internal margins of the medial-lateral cortical bone. A line was drawn between these two circles and the tapered stem was produced with this line as the anterior and posterior side. To obtain proximal fixation, the distal aspect was gradually tapered. Anteversion of the femoral neck was measured using the slice through the femoral condyle as the base. Rotation at the femoral neck was adjusted during stem preparation for patients with excessive anteversion or retroversion.

The stems produced were made of Ti-6Al-4V (Expert System Version 1, Kyocera, Osaka, Japan). They did not have collars and the proximal third was coated using a 400-μm-thick porous coating covered with 20 μm hidroxyapatite (HA) coating. The center third was coated

Fig. 1. Frontal view photograph of a custom-made stem

using sand blasted coating. The average stem length was 10.5 cm (range, 8.9-18.8 cm) (Fig.1).

All stems were implanted via a standardized posterolateral surgical approach without trochanteric osteotomy. The custom stem was directly inserted following confirmation of the direction using an elevatorium without a reamer or broach. A rasp was required to ream the neo bone.

Patients returned for yearly follow-up. At each follow-up visit, Harris Hip Score[4], range of motion, and postoperative thigh pain were recorded and antero-posterior and lateral radiographs were obtained. Images were evaluated using Engh classifications for stem fixation[5] and stress shielding[6], and were further evaluated for spot welds formation, pedestal formation, and cortical hypertrophy.

Statistical analysis of range of motion was performed using the Wilcoxon signed-ranks test.

RESULTS

Harris Hip Score improved from a preoperative mean of 49.9 points (range, 19-79 points) to a postoperative mean of 82.7 points (range, 65-100 points). One patient complained of postoperative thigh pain. The range of motion was significantly greater at the final follow-up than preoperatively for all joint actions except adduction and external rotation (Table 1).

The mean preoperative anteversion of the femoral neck was 34.4 degrees (range, 0-62.5 degrees) and a mean of 20 degrees derotation (range, -5-35 degrees) was implemented for correction of excessive anteversion. Intraoperative fractures occurred in 2 hips at the completion of insertion. One was stabilized with cerclage wiring and the other was stabilized using a Dall-Miles cable grip (Stryker Corp., Kalamazoo, MI, USA).

Dislocation occurred in 3 patients. A posterior dislocation in a male patient occurred 3 years after varus femoral osteotomy and was treated with closed reduction; since then his hip has dislocated once. A posterior dislocation in a female patient occurred 7 years after varus femoral osteotomy and was treated with closed reduction; since then her hip has dislocated twice. Finally, a posterior dislocation in a female patient occurred 10 years after Schanz osteotomy

Table 1. Preoperative and Postoperative Range of Motion

	Preoperative angle (degrees)	Preoperative angle (degrees)	p value
Flexion	58.5±23.4	75.5±15.0	0.000697
Extension	-2.1±5.08	-0.2±0.73	0.03
Abduction	13.5±11.1	24.4±6.56	0.000125
Adduction	15.2±4.19	14.6±3.58	0.679
External rotation	32.1±15.7	28.1±11.3	0.27
Internal rotation	1.0±17.9	21.0±13.9	0.0000182

and was treated with closed reduction. She has not experienced hip dislocation since then.

To date, none of our patients has undergone revision of the stem for aseptic loosening. Spot welds formation was observed in 18 hips, pedestal formation in 6 and cortical hypertrophy in 7. In addition, distal densification was observed in 11 hips. According to the radiologic classification system of Engh et al.[5], there was bone-ingrown fixation in all hips (Fig.2). Stress shielding was Engh grade 1 in 2 hips, grade 2 in 16, grade 3 in 13, and grade 4 in 1 hip. Severe stress shielding (Engh's grade 3 or 4) was found in 14 hips (44%). Thigh pain and severe stress

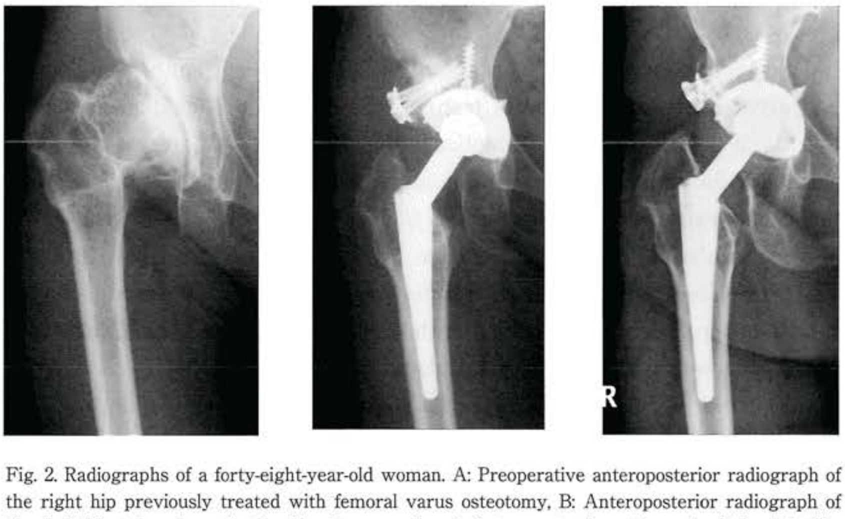

Fig. 2. Radiographs of a forty-eight-year-old woman. A: Preoperative anteroposterior radiograph of the right hip previously treated with femoral varus osteotomy, B: Anteroposterior radiograph of the right hip, taken immediately after the operation, C: Anteroposterior radiograph of the right hip, taken 15 years after the operation. The femoral component was well fixed at the latest follow-up.

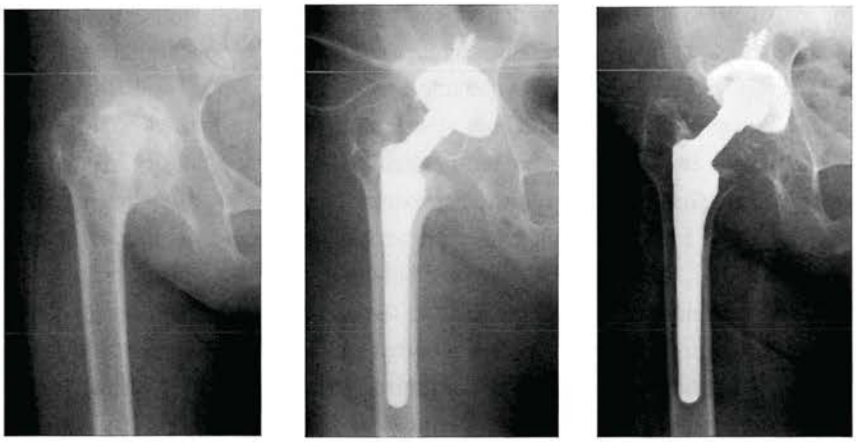

Fig. 3. Radiographs of a sixty-one-year-old man. A: Preoperative anteroposterior radiograph of the right hip previously treated with femoral valgus osteotomy, B: Anteroposterior radiograph of the right hip, taken immediately after the operation, C: Anteroposterior radiograph of the right hip, taken 12.5 years after the operation. Severe stress shielding is observed.

shielding (Engh grade 4) occurred in 1 hip (Fig.3).

DISCUSSION

Modern cementing techniques have led to excellent long-term results, including for patients with previous femoral osteotomy, of primary THAs using a cemented stem[7]. However intertrochanteric femoral osteotomy can leave the femoral medullary canal with an abnormal shape; excessive or too little anteversion; granulation tissue; neo bone; a residual plate or screws; a large bone defect after plate removal preventing good cement pressure; osteoporosis; and covering greater trochanter after varus osteotomy. Our custom stems were able to fit an abnormal medullary shape, correct anteversion with derotation at the neck, and maintain good fixation for a mean of 13 years after surgery.

The 3 hips that dislocated were all posterior dislocations occurring at 3,7, and 10 years after surgery. Their combined anteversion calculated from the CT taken immediately after surgery were 36.4 degrees, 37.8 degrees and 37.5 degrees[8]. In the case of a posterior dislocation that occurred in a female patient 7 years after varus femoral osteotomy, a large residual osteophyte was detected in the CT taken immediately after surgery. The stems were implanted via a standardized posterolateral approach. Regarding the remaining two dislocation cases, we speculated that the dislocations were due to muscle weakness of the short external rotator muscles. More recently, we have implanted stems via modified Hardinge approach without trochanteric osteotomy[9]. We also speculated that the dislocations were due to bony impingement of the greater trochanter after varus femoral osteotomy.

With regard to fixation, the presence of new endosteal bone formation and distal radiolucent lines is thought to be characteristic of proximal fixation of a cementless stem, and proximal bone atrophy is thought to characterize distal fixation. In the present study, the purpose of using a custom stem was to obtain proximal fixation in dysplastic hips. The stems were designed to press-fit to the medial calcar proximally and to taper distally. However, approximately half of the present patients underwent distal fixation. Engh et al.[10] noted that patients who received an AML stem (Anatomic Medullary Locking Total Hip System, Depuy Synthes Corp., Warsaw, IN, USA) and had stress shielding had a thick stem (> 13.5-mm in diameter). Although Martini et al.[11] reported negligible loss of bone density around CT assisted custom femoral stem, Grant et al.[12] reported proximal bone loss with custom stems compared to standard cemented stems. Parsch et al.[13] reported no stress-shielding with uncemented tapered stems treating failed intertrochanteric osteotomy. In the present study, the 14 hips with severe stress shielding already had porotic femora preoperatively because of long-term pain, weight bearing after osteotomy and thin cortex under the fixation plate. Our stems were coated using sand blasted coating at the central third. The sand blasted coating perhaps caused the stress shielding. Ohishi et al. reported periprosthetic fracture after THA with ready-made cementless stems after previous treatment with femoral osteotomy[14]. Surgeons should therefore be alert to the development of stress shielding.

The main shortcomings of custom-made components are their cost, radiation exposure for CT and the time required for their manufacture. Although Mulier et al.[15] developed intraoperative fabrication of a femoral prosthesis without surface finishing, further clinical trials with this technique were not continued because of early severe subsidence[16]. In the present study, the proximal third of the custom stem was coated using a porous coating covered with HA. Subsidence was <1mm in all cases, suggesting that surface finishing was important for implant fixation.

One advantage of our custom stem is short length, with proximal fitting for abnormal shaped medullary canals after osteotomy in short Japanese patients. The short length is also advantageous for proximal stress shielding and revision surgery. Santori et al.[17] and Kim et al.[18] reported excellent mid-term results of short custom-made stems, but more studies with longer follow-up periods will be required. Another advantage is the ability to standardize the anteversion of the acetabular components. Preoperative adjustment of neck anteversion of the custom stems enabled us to implant the acetabular components with about 20 degrees anteversion. Unfortunately, there were three dislocations in the present study. One reason was the atrophy of the short rotators over the long period following the posterolateral approach. We now perform THA via an anterolateral approach and use a navigation system that allows an ideal location and angle of insertion of the implants.

The limitations of the present study were retrospective study and the lack of a control group.

CONCLUSIONS

We achieved stable fixation with proximal press fitting of our custom stems. Although stress shielding was observed in 14 hips, we obtained excellent results for this custom stem system for hips after intertrochanteric femoral osteotomy over a follow-up period of 10 years.

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