Results of primary THA using 36 mm femoral heads on first-generation highly cross-linked polyethylene in patients less than 60 years of age: Minimum 10-year follow-ups

Myung-Rae Cho, Chung-Mu Jun, Kyung-Tae Kim, Suk Kyun Song and Won-Kee Choi

Abstract

Purpose: Long-term results of total hip arthroplasty (THA) using highly cross-linked polyethylene (HXLPE) and metal femoral head with more than 10 years of follow-up have already been reported. However, most studies included results with a head size of 28 mm that could affect wear rates. The aim of this study was to evaluate the results of 36-mm metallic femoral heads on first-generation HXLPE in patients less than 60 years of age with a minimum follow-up of 10 years.

Methods: Retrospective analysis included 54 cases from 47 patients. The mean age at the time of surgery was 47.22 years and the mean follow-up period was 131.04 months. Porous-coated cementless acetabular cups (Trilolgy®; Zimmer Inc., Warsaw, Indiana, USA) and HXLPE acetabular liners (Longevity®; Zimmer Inc.) were used for all cases. Acetabular cup abduction angles, anteversion angles, and wear rates of liner were measured using polyWare pro 3D distal version 5.10.

Results: The average modified Harris hip score at the final follow-up was 88.48 (range 80–96). Average Merle d’Aubigne and Postel score was 15.57 (range 14–18). There was no acetabular cup or femoral stem failing due to aseptic loosening. The average steady-state wear rate determined using radiographs taken at 1 year postoperatively and at the latest follow-up was 0.053 ± 0.025 mm/year. There were no statistically significant differences in liner wear rate with respect to age, variety of the femoral stem, or liner thickness.

Conclusion: Results of THA with 36-mm metallic femoral heads on first-generation HXLPE in patients less than 60 years of age were satisfactory.

Keywords
highly cross-linked polyethylene, 36-mm femoral head, total hip arthroplasty, wear

Date received: 12 February 2019; Received revised 29 November 2019; accepted: 3 December 2019

Introduction

Instability and osteolysis around the implant due to conventional polyethylene wear are major causes for revision total hip arthroplasty (THA).1,2 Dislocation is an early and serious postoperative complication of THA. Although the use of large-sized femoral head is one of the backup plans for preventing dislocation, it might increase the wear rate.3,4 Highly cross-linked polyethylene (HXLPE) as a bearing surface has been used to decrease the wear rate.5,6 However, there have been some debates on the mechanical...
strength caused by the remelting process for the reduction of free radicals. There are more concerns over thin plastic since liners with relatively smaller depth are used in combination with large-sized femoral heads. In addition, large-sized femoral heads are reluctantly used in young-aged patients with high activity. In our medical center, we have used 36 mm metal femoral heads in combination with highly cross-linked liners from 2004. They have relatively lower wear rates compared to conventional liners in performing THA regardless of patients’ age or activity. Our results can be compared to the results of in vivo study of first-generation HXLPE. Long-term results of THA using HXLPE and metal femoral head with more than 10 years of follow-up have already been reported.9–11 We already reported long-term clinical and radiological results of 20 cases using 36-mm metallic femoral heads on first-generation highly cross-linked liners (Longevity®; Zimmer Inc., Warsaw, Indiana, USA) as a bearing surface in patients aged less than 40 years as case series.13 In this time, we report long-term clinical and radiological results of using 36-mm metallic femoral heads on first-generation highly cross-linked liners (Longevity) as a bearing surface in patients aged less than 60 years with follow-up of more than 10 years.

We hypothesized that articulation of 36 mm metallic femoral heads on first-generation highly crosslinked liners (Longevity) might have lower wear rates than 0.1 mm/year in steady-state period during a minimum follow-up of 10 years in patients less than 60 years old with high activity compared to a similar result reported in an in vivo study.

Materials and methods

Patient population

Patients less than 60 years old who underwent primary THA from 2004 to 2008 by the same one surgeon using 36 mm diameter femoral heads and first-generation HXLPE with a minimum follow-up of 10 years were enrolled in this study. During this period, we performed 79 cases of THA except for acute trauma as a cause. Five cases were more than 60 years old. Eight cases were operated with a 28-mm metal head and 12 cases were not followed up with a minimum of 10 years. The retrospective analysis included 54 cases from 47 patients. This study was approved by the Institutional Review Board at the author’s institution. Causes for surgery included avascular necrosis of the femoral head (18 cases), dysplastic hip (12 cases), osteoarthritis (12 cases), rheumatoid arthritis (7 cases), ankylosing spondylitis (3 cases), pathological fracture of the femoral neck (1 case), and coxarthroses caused by slipped capital femoral epiphysis (1 case). The mean age at the time of surgery was 47.22 years (range 21–59 years) and the mean follow-up period was 131.04 months (range 120–162 months; Table 1).

Table 1. Patient demography.

| Variables                  | Numbers           |
|----------------------------|-------------------|
| Sex                        | Total 47 patients |
| Male                       | 17                |
| Female                     | 30                |
| Age                        | 47.22 years (21–59) |
| Durations of follow-ups    | 131.04 months (120–162) |
| Method of femoral stem fixation | Total 54 cases  |
| Cemented                   | 15                |
| Uncemented                 | 39                |
| Acetalular cup sizes       | 53.33 mm (50–60)  |
| HXLPE liner thickness      | 6.19 mm (5.80–8.90) |
| Preoperative modified HHS  | 35.18 (18–59)     |
| Preoperative Merle d’Aubigne and Postel score | 9.68 (7–11) |

HXLPE: highly cross-linked polyethylene; HHS: Harris hip score.

Prosthesis and operation

Porous-coated cementless acetabular cups (Trilology®, Zimmer Inc.) and HXLPE acetabular liners (Longevity) were used for all cases. Longevity polyethylene liners were manufactured from GUR 1050 polyethylene (Zimmer Inc.) with compressive-molded techniques. These liners were launched after a 9.5-Mrad electron beam irradiation process to increase cross-linking and strength, a remelting process for irradiated plastic to eliminate remaining free radicals that might cause oxidation, and an aseptic process using gas plasma technology. Acetabular components had a mean outer diameter of 53.33 mm (range 50–60 mm). Fiber metal stem (Zimmer Inc.) components were used in 39 cases for cementless femoral fixation while Heritage Versys (Zimmer Inc.) components were used in 15 cases for cemented femoral fixation. All cementless stems were inserted using standard press-fit techniques to insure longitudinal and rotational stability while all cemented femoral stems were inserted using meticulous third-generation cementing techniques. All surgical procedures were performed by one surgeon using a modified Harding’s approach with patient in a lateral position. Patients were allowed to sit on the first postoperative day and stand with support according to their ability after blood drainage removal. There was no range of motion limitation immediately after surgery. No abduction pillow was used in any patient.

Clinical follow-ups

Patients were followed at 6 weeks, 3, 6, and 12 months postoperatively and yearly thereafter. Clinical radiographic examinations were performed by another orthopedic
surgeon. Clinical follow-ups included specific assessments of possible dislocation. In addition, the modified Harris hip score (HHS) and Merle d'Aubigne and Postel score were evaluated.

**Radiologic follow-ups**

Radiographic examinations included an anteroposterior (AP) view of the pelvis centered over the pubis and an axial view by a shoot through lateral of the hip. For cases of uncemented fixation, the status of fixation of femoral component was assessed using the method of Engh et al. For cases with cemented fixation, femoral components were assessed for the amount of cement filling using the method of Barrack et al. Based on immediate postoperative radiographs. Acetabular cup abduction angles, anteversion angles, and wear were measured using polyWare pro 3D distal version 5.10 software (Drafware Developers Inc., Vevay, Indiana, USA).

**Measurement of wear rates**

Using PolyWare pro 3D distal version 5.10 software, wear rates were obtained as average of values measured twice by a single rater with a period of 4 weeks. Assuming that the bedding-in period was 1 postoperative year, we measured annual wear rate during the steady state by comparing pelvis AP films of 1 year after surgery and those of the last follow-up session.

**Statistical analysis**

Differences in liner wear rates according to age, femoral stem type (cemented and uncemented), and liner thickness were compared using the Mann–Whitney test. SPSS version 18.0 (SPSS Inc., Chicago, Illinois, USA) was used for all statistical analyses. A $p$ value of less than 0.05 was considered statistically significant.

**Results**

**Clinical results**

Preoperative modified HHS at final follow-up was 35.18 (range 18–59) and preoperative Merle d’Aubigne and Postel score was 9.68 (range 7–11). At the final follow-up, average modified HHS was 88.48 (range 80–96) and Merle d’Aubigne and Postel score was 15.57 (range 14–18; Table 2). Among 54 cases, 1 case underwent revision THA due to multiple dislocations. THA survival rate on average postoperative 131.04 months was 98.14%.

**Radiologic results**

Radiographic final follow-up exams showed fibrous or bony ingrowth stable fixation in all patients with uncemented femoral components and Barrack type A or B in all patients with cemented femoral components. Mean acetabular cup abduction and anteversion angles were 49.50° (range 41.50–57.30) and 9.42° (range 1.00–24.20°), respectively. Mean thickness of the polyethylene liner at 45° was 6.19 mm (range 5.80–8.90 mm). There was no radiographic evidence of osteolysis in the pelvis or proximal femur. There was no acetabular cup or femoral stem failing due to aseptic loosening either.

**Liner wear rates**

Intraobserver reliability for values of acetabular cup abduction and anteversion and the total amount of liner wear from 1 year after surgery until the last follow-up session measured using PolyWare pro 3D was 0.8 or over for all cases (Table 3). The average steady-state wear rate determined using radiographs taken at 1-year postoperatively and at the latest follow-up was 0.053 ± 0.025 mm/year.

**Steady-state wear rates according to age**

When dividing the 54 cases by age standard of 40, 20 cases with age younger than 40 showed an average wear rate of 0.059 ± 0.01 mm/year while 34 cases with age older than 40 showed an average wear rate of 0.050 ± 0.02 mm/year, showing no statistically significant difference between the two groups ($p = 0.425$).

**Table 2.** Summary of the clinical and radiographic outcomes.

| Parameter | Values     |
|-----------|------------|
| Modified HHS | 88.48 (80–96) |
| Merle d’Aubigne and Postel score | 15.57 (14–18) |

**Table 3.** ICCs of radiographic measurements.

| Parameters | Intraobserver reliability |
|------------|--------------------------|
| Acetabular cup abduction | 0.879 (0.677–0.958) |
| Acetabular cup anteversion | 0.943 (0.839–0.980) |
| Total amount of liner wear | 0.834 (0.574–0.941) |

ICC: intraclass correlation coefficient.
Steady-state wear rates according to femoral stem type

The average wear rate of 15 cases using cemented femoral stems was $0.045 \pm 0.02$ mm/year and that of 39 cases using non-cemented femoral stems was $0.056 \pm 0.02$ mm/year, showing no statistically significant difference between the two groups ($p = 0.132$).

Steady-state wear rates according to liner thickness

Liners with a thickness of 5.8 mm were used in 39 cases while those with a thickness of 6.9–8.9 mm were used in 15 cases. The average wear rate of the 15 cases was $0.065 \pm 0.02$ mm/year while that of the 39 cases using 5.8-mm thick liners—the thinnest—was $0.049 \pm 0.02$ mm/year, showing no statistically significant difference in wear rate between the two groups ($p = 0.064$).

Discussion

According to an in vitro study, the development of first-generation HXLPE reduced the wear rate compared to conventional polyethylene liners. Notwithstanding long- and mid-term results of in vivo studies showing superior results with low wear rates, in our study, the steady-state wear rate was $0.053 \pm 0.025$ mm/year on average with minimal follow-up of 10 years. This result is similar to the other previous studies. Except for one patient who had a dislocation, there were no revisions for loosening, trunnion corrosion, or other causes in this study. One laboratory study has reported higher frictional torque with the use of larger femoral head and suggested that this could lead to increased component loosening. However, clinical or possible radiographic loosening of the component was not found in the current study. Since reduction in polyethylene thickness is inevitable when using large femoral heads within the acetabular component (due to space limitations), polyethylene thickness has remained controversial when using larger heads. A high wear rate due to thin polyethylene component by high contact stress has been reported. To have longevity, the remelting process is used in order to eliminate remaining free radicals after the electron beam irradiation process. It can raise concern over polyethylene breakage due to decrease in tensile yield strength and fatigue stress. In 39 (72.2%) cases, we used plastics of 5.8 mm at 45° direction. However, there was no statistically significant difference in liner wear rate according to liner thickness in our study ($p = 0.064$). There was no polyethylene breakage warranted from thinner remelted plastic either, although our study subjects had high activity. This suggests that minimal thickness for the plastic might be 5 mm at 45° direction or less than 6 mm. This result was similar to the results of Aubault’s study. Large femoral heads were introduced to increase stability and decrease the frequency of dislocation after THA. Howie et al. have reported a significant decrease in early dislocation in a multicenter study comparing 28 and 36 mm femoral heads in primary THA. However, one hip developed posterior dislocation during the follow-up period in our study (Figure 1). The patient underwent THA due to secondary osteoarthritis developed at 1 year after internal fixation for acetabular fracture and posterior dislocation of the hip joint. Of course, dislocation may be due to compromised musculature damaged by previous fracture surgery. But, we found out the acetabular anteversion and AP inclination were $8°$ and $46.2°$, respectively. So, we adjusted an acetabular anteversion with poly liner reposition. This suggests the importance of precise implant insertion during surgery. Even 36 mm diameter femoral head may increase the stability of hip joint. There have been several reports of symptomatic trunnion corrosion with hip or groin pain. It is possible that some could have trunnion corrosion with the larger metal femoral heads and mixed metallurgy at taper junction. Computed tomography (CT), magnetic resonance
imaging, and serum cobalt and chromium levels might be valuable methods to predict trunnion corrosion. However, we did not check them for any patients because no patient had the symptom that warranted investigation of metal levels. Although femoral head size may play a role in the development of trunnion corrosion, previous results have shown that the geometry of the taper interface or other factors (e.g., implant alignment and patient factors) are more influential than femoral head size in setting of corrosion and fretting, particularly with smaller head sizes in patients with metal on polyethylene articulation as a bearing surface. In our study of 54 hips with a minimum follow-up of 10 years, there was no revision due to implant-related problems.

This study has several limitations. First, this was a non-randomized retrospective study. Fifteen cases among 54 were cemented cobalt-chromium alloy femoral components. Although our findings may be specific for these implants, few studies have reported the existence of different wear rates caused by different femoral components. Second, we did not measure the volumetric wear rate. Although we were able to evaluate volumetric wear by analyzing plain AP and axial radiographs of the pelvis with polyWare 3D software, measured values in axial radiographs were highly unreliable due to its irregular results. For this reason, we only evaluated linear wear rates by only analyzing AP films. Third, we did not observe osteolytic lesions. A few studies have reported the incidence of osteolytic lesions with first-generation HXLPE and any femoral head size at a minimum follow-up of 10 years. It is difficult to compare our study with these reports due to differences in femoral head size, method of detection, and absolute length of follow-up time. Mall et al. have measured the presence and volume of osteolysis on CT scan in a highly selected group of 48 patients with Longevity XLPE liners at a minimum follow-up time of 5 years (mean 7 years; range 5–11 years). Only 1 (2%) of these 48 patients had an osteolytic lesion seen on CT scan (volume 1.49 cm³). However, we did not have CT of the hip to detect osteolytic lesions. Thus, small osteolytic lesions might have been underestimated. However, we did not find any osteolytic lesions from plain radiographs. It might be explained by a wear rate of less than 0.1 mm/year as a threshold for osteolysis development. This study also has some strengths. First, patients with less than 60 years old were enrolled. In addition, a single surgeon performed all procedures. Acetabular components were identical. Metal femoral heads were from the same manufacturer with a head diameter of 36 mm. The follow-up time was a minimum of 10 years. Moreover, two times of wear measurements were performed by one experienced researcher.

**Conclusion**

Results of THA with 36-mm metallic femoral heads on first-generation HXLPE as a bearing surface in patients less than 60 years old were satisfactory.

**Declaration of conflicting interests**

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

**Funding**

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by the grant of Research Institute of Medical Science, Catholic University of Daegu (2018).

**ORCID iD**

Won-Kee Choi https://orcid.org/0000-0002-4671-5656

**References**

1. Mall NA, Nunley RM, Zhu JJ, et al. The incidence of acetabular osteolysis in young patients with conventional versus highly crosslinked polyethylene. *Clin Orthop Relat Res* 2011; 469: 372–381.
2. Cooper RA, McAllister CM, Borden LS, et al. Polyethylene debris-induced osteolysis and loosening in uncemented total hip arthroplasty. A cause of late failure. *J Arthroplast* 1992; 7: 285–290.
3. Bistolfi A, Crova M, Rosso F, et al. Dislocation rate after hip arthroplasty within the first postoperative year: 36 mm versus 28 mm femoral heads. *Hip Int* 2011; 21: 559–564.
4. Geller JA, Malchau H, Bragdon C, et al. Large diameter femoral heads on highly cross-linked polyethylene: minimum 3-year results. *Clin Orthop Relat Res* 2006; 447: 53–59.
5. McKellog H, Shen FW, DiMaio W, et al. Wear of gamma-crosslinked polyethylene acetabular cups against roughened femoral balls. *Clin Orthop Relat Res* 1999; 369: 73–82.
6. McKellog H, Shen FW, Lu B, et al. Effect of sterilization method and other modifications on the wear resistance of acetabular cups made of ultra-high molecular weight polyethylene. A hip-simulator study. *J Bone Joint Surg Am* 2000; 82: 1708–1725.
7. Rath P, Pereira GC, Giordani M, et al. The pros and cons of using larger femoral heads in total hip arthroplasty. *J Orthop* 2013; 42: E53–E59.
8. Muratoglu OK, Bragdon CR, O’Connor D, et al. Larger diameter femoral heads used in conjunction with a highly cross-linked ultra-high molecular weight polyethylene: a new concept. *J Arthroplast* 2001; 16: 24–30.
9. Howie DW, Holubowycz OT, Middleton R, et al. Large femoral heads decrease the incidence of dislocation after total hip arthroplasty: a randomized controlled trial. *J Bone Joint Surg Am* 2012; 94: 1095–1102.
10. De Ranieri A, Wagner N, Imrie SN, et al. Outcome of primary total hip arthroplasty in Charnley Class C patients with juvenile idiopathic arthritis: a case series. *J Arthroplast* 2011; 26: 1182–1188.
11. Babovic N and Trousdale RT. Total hip arthroplasty using highly cross-linked polyethylene in patients younger than 50 years with minimum 10-year follow-up. *J Arthroplast* 2013; 28: 815–817.
12. Reynolds SE, Malkani AL, Ramakrishnan R, et al. Wear analysis of first-generation highly cross-linked polyethylene in primary total hip arthroplasty: an average 9-year follow-up. *J Arthroplast* 2012; 27: 1064–1068.

13. Choi WK, Kim JJ, and Cho MR. Results of total hip arthroplasty with 36-mm metallic femoral heads on 1st generation highly cross linked polyethylene as a bearing surface in less than forty year-old patients: minimum ten-year results. *Hip Pelvis* 2017; 29: 223–227.

14. Engh CA, Bobyn JD, and Glassman AH. Porous-coated hip replacement. The factors governing bone ingrowth, stress shielding, and clinical results. *J Bone Joint Surg Br* 1987; 69: 45–55.

15. Barrack RL, Mulroy RD Jr, and Harris WH. Improved cementing techniques and femoral component loosening in young patients with hip arthroplasty. A 12-year radiographic review. *J Bone Joint Surg Br* 1992; 74: 385–389.

16. Lee JH, Lee BW, Lee BI, et al. Midterm results of primary total hip arthroplasty using highly cross-linked polyethylene: minimum 7-year follow-up study. *J Arthroplast* 2011; 26: 1014–1019.

17. Ranawat AS, Tsailis P, Meftah M, et al. Minimum 5-year wear analysis of first-generation highly cross-linked polyethylene in patients 65 years and younger. *J Arthroplast* 2012; 27: 354–357.

18. Muratoglu OK, Bragdon CR, O’Connor DO, et al. A novel method of cross-linking ultra-high-molecular-weight polyethylene to improve wear, reduce oxidation, and retain mechanical properties. Recipient of the 1999 HAP Paul Award. *J Arthroplast* 2001; 16: 149–160.

19. Atwood SA, Van Citters DW, Patten EW, et al. Tradeoffs amongst fatigue, wear, and oxidation resistance of cross-linked ultra-high molecular weight polyethylene. *J Mech Behav Biomed Mater* 2011; 4: 1033–1045.

20. Aubault M, Druon J, Le Nail L, et al. Outcomes at least 10 years after cemented PF(R) (Zimmer) total hip arthroplasty: 83 cases. *Orthop Traumatol Surg* 2013; 99: S235–S239.

21. Mistry JB, Chughtai M, Elmallah RK, et al. Trunnionosis in total hip arthroplasty: a review. *J Orthop Traumatol* 2016; 17: 1–6.