



# Clinical and Radiological Outcomes of Rectangular Tapered Cementless Stem According to Proximal Femoral Geometry in Elderly Asian Patients

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**Purpose:** A retrospective analysis of mid- to long-term clinical and radiological outcomes of Korean patients over 60 years of age who underwent hip arthroplasty using a cementless rectangular tapered stem according to Dorr proximal femur geography.

**Materials and Methods:** From January 2007 to December 2013, 107 patients (112 hips) underwent hip arthroplasty using the C2 stem. The mean age of patients was 77.4 years (range, 60-91 years) and the mean follow-up duration was 91.1 months (range, 60-116 months). All patients were evaluated clinically and radiologically with special attention to Dorr femoral bone classification, implant fixation, radiolucent line (RLL), and thigh pain.

**Results:** All implants demonstrated radiographic evidence of stable fixation by bone ingrowth without any change in position. The mean Harris hip score improved from  $65.5 \pm 16.0$  (preoperative) to  $90.5 \pm 15.9$  (final follow-up) ( $P < 0.001$ ). Incidence of RLLs, stress shielding, and thigh pain was highest in patients with Dorr type A (RLL,  $P = 0.021$ ; stress shielding,  $P = 0.030$ ; thigh pain,  $P < 0.001$ ). One stem revision was performed due to deep infection. The Kaplan–Meier survival rate of the femoral stem was 97.6%.

**Conclusion:** The overall survival rate of the C2 stems was greater than 97%; there were no significant differences in survival of the C2 stem according to the Dorr classification. The incidences of RLL of thigh pain and RLL were significantly different among Dorr classifications and (highest in patients with Dorr type A).

**Key Words:** Hip, Femur, Hip replacement arthroplasty, Femoral stem, C2 stem

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## INTRODUCTION

Hip arthroplasty has emerged as one of the most successful orthopedic interventions. Many long-term follow-up studies have reported clinical success including patient satisfaction, pain reduction, functional improvement, and the absence of further surgery<sup>1)</sup>. Various cementless stems have been developed to improve clinical outcomes and promote firm fixation<sup>1-3)</sup>. Cementless rectangular tapered stems, which are fixed at the femoral metaphyseal-diaphyseal junction and provide stability mediated by three-point fixation in the proximal part of the diaphysis, have shown excellent clinical

results<sup>4-6</sup>). Recent studies have shown that cementless rectangular tapered stems are associated with improved clinical outcomes compared with cemented stems<sup>7,8</sup>). Importantly, however, proximal radiolucency, calcar resorption, stress shielding, and thigh pain remain possible adverse events when cementless stems are used<sup>9-11</sup>). The C2 stem (LimaCorporate SpA, Udine, Italy) is a rectangular tapered stem. To date, there have been no published clinical trials for the C2 stem among elderly Asian patients.

This study was designed to retrospectively evaluate the mid- to long-term clinical and radiological outcomes in Korean patients over 60 years of age who underwent hip arthroplasty using a cementless rectangular tapered stem; we hypothesized that these outcomes may vary depending on the proximal femur geometry.

## MATERIALS AND METHODS

The design and protocol of this retrospective study were approved by the Institutional Review Board of Inha University Hospital (IRB No. INHAUH 2018-12-025-001). Informed consent was waived due to its retrospective nature.

### 1. Patients

A total of 107 patients (112 hips) who received hip arthroplasty using a C2 cementless femoral stem between January 2007 and December 2013 were enrolled in this retrospective study. There were 27 men (27 hips) and 80 women (85 hips) of mean age 77.4 years (range, 60-91 years). The preoperative diagnoses were fracture (n=99), avascular necrosis (n=7), and osteoarthritis (n=6). Bipolar hemiarthroplasty was performed in 90 patients and total hip arthroplasty was used in 22 hips using ceramic bearing couples (DELTA-PF cup; LimaCorporate SpA). All primary hip arthroplasties were performed through the posterolateral approach by a single experienced surgeon. The mean follow-up duration was 91.1 months (range, 60-116 months).

### 2. Stem

The C2 femoral stem used in this study has a rectangular section with sharp edges and consists of a titanium alloy (Ti6Al4V) component (6% aluminum and 4% vanadium); the entire stem surface was sandblasted except for the neck region (Fig. 1). The microstructure of such a rough surface is designed to better induce bone ingrowth<sup>12,13</sup>). This stem is classified as a C3-type stem according to

the Mont classification<sup>5,14</sup>).

### 3. Clinical Outcome Assessment

Patient follow-up was conducted at six weeks, six months, one year, and annually thereafter. We estimated Harris hip score (HHS), thigh pain, complications, and stem survival rate by reviewing patient charts just after surgery (i.e., postoperative) and at final follow-up. Thigh pain was assessed by hip physicians at follow-up visits, with a particular focus on starting pain and walking pain.

### 4. Radiological Outcome Assessment

One observer who had not been involved in the surgical procedures evaluated all radiographs. Preoperative radiographs were evaluated for Dorr type<sup>15</sup>, calcar-canal



**Fig. 1.** C2 stem (LimaCorporate SpA, Udine, Italy); the titanium alloy (titanium, 6% aluminum, 4% vanadium) implant used in this study. © 2016 - LimaCorporate SpA.

(CC) ratio, and cortical index (CI)<sup>16)</sup>. Osteolytic lesions were recorded when they were detected during follow-up. Radiologic results (i.e., fit and fill, percentage of the canal filled by the stem at four levels) were evaluated using anteroposterior-view radiographs conducted at the five-year follow-up. These levels were named by Dorr et al.<sup>17)</sup> as calcar fill, metaphyseal fill, midstem, and distal fill. The presence of radiolucent lines (RLLs) and stress shielding were evaluated at final follow-up. The presence and extent of RLLs at the bone implant were measured according to Gruen criteria<sup>18)</sup>. Stress shielding of the proximal femur was categorized into degrees of severity using Engh's classification<sup>19)</sup>.

## 5. Statistical Analysis

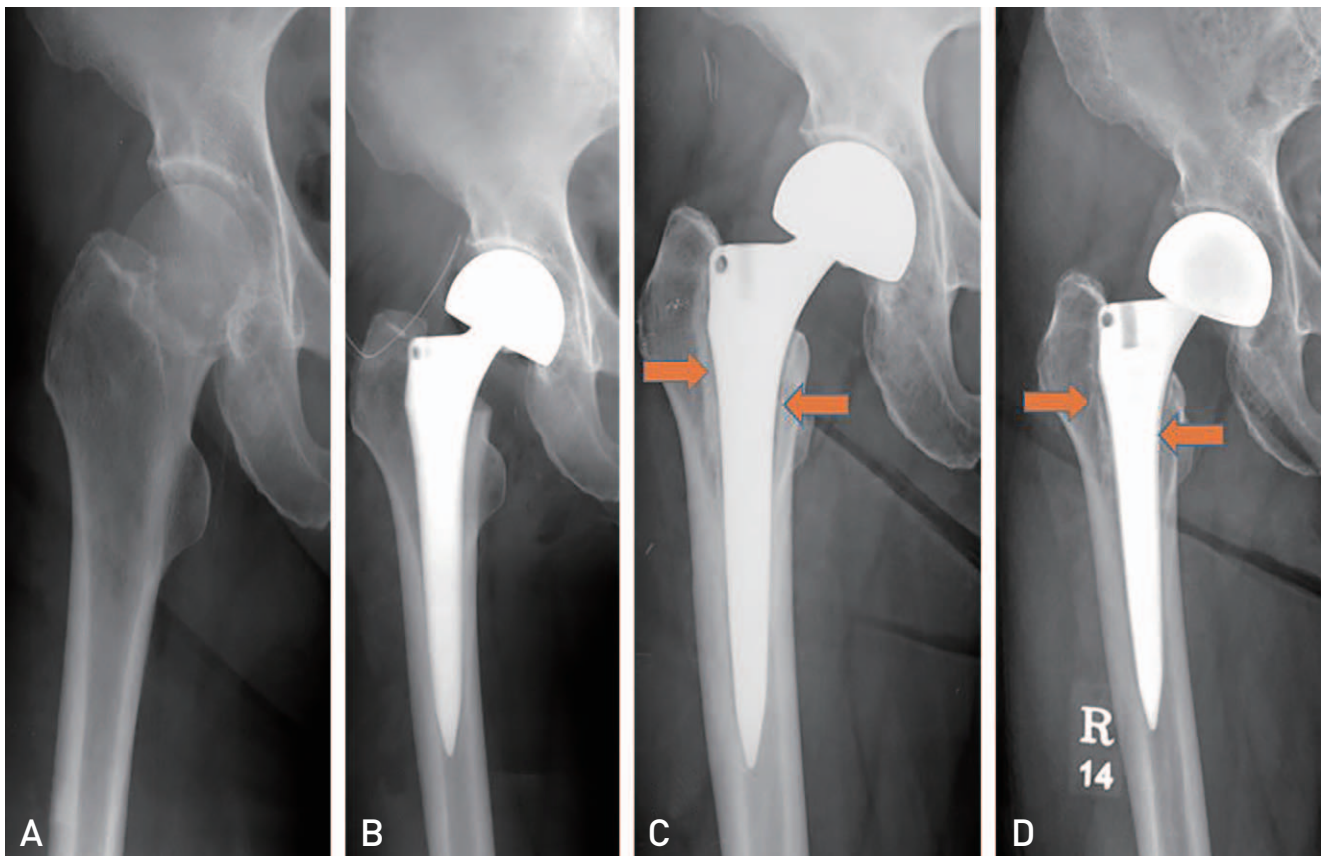
Kaplan–Meier survival analysis was performed with the end point of revision time for any reason. Statistical analysis was performed using the ANOVA test for the results of the three Dorr-type groups. Preoperative and

postoperative HHS were compared using a two-sample *t*-test. A comparison of fit and fill between with and without RLLs was conducted using an independent *t*-test. A *P*-value <0.05 was considered statistically significant. IBM SPSS ver. 19.0 statistical software (IBM Corp., Armonk, NY, USA) was used to analyze the data.

## RESULTS

### 1. Radiological Outcomes

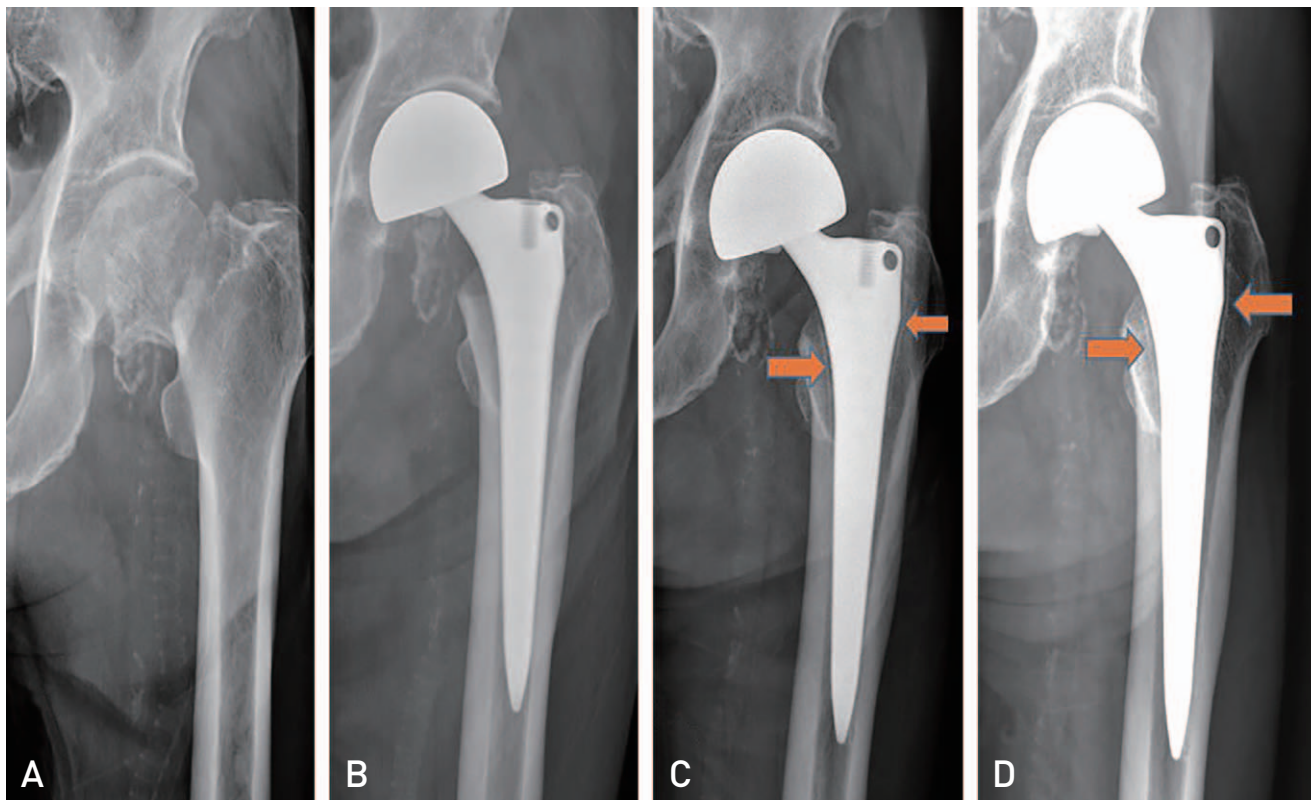
Preoperative femoral geometry was classified using the Dorr classification system (type A [n=20], type B [n=49], type C [n=43]). RLLs were observed in Gruen zones 1, 2, and 7 in 15 hips (13.4%). Generally, the lines appeared 2 to 12 months after arthroplasty (Fig. 2, 3). After the appearance of RLL, five hips (33.3%) remained unchanged with gradual sclerotic change of the outer margin. RLLs according to Dorr type are as follows: type A (n=6), type B (n=7), and type C (n=2). Patients with Dorr



**Fig. 2.** (A) A 72-year-old female patient with Dorr type A. (B) The patient underwent hip arthroplasty for femur neck fracture. (C) Radiolucent lines in Gruen zone 1, 2 and 7 appeared one-year after hip arthroplasty. (D) Radiolucent lines had not progressed until seven-year after hip arthroplasty.

type C had significantly fewer RLL (4.7%) compared to types A (30.0%) and B (14.3%) ( $P=0.021$ ) Stress shielding was observed in 48 cases and there was a significant

difference between Dorr types: 12 in type A (60.0%), 24 in type B (49.0%), and 12 in type C (27.9%) ( $P=0.030$ ) (Table 1, Fig. 4).



**Fig. 3.** (A) A 75-year-old male patient with Dorr type B. (B) The patient underwent hip arthroplasty for femur neck fracture. (C) Radiolucent lines in Gruen zone 1 and 7 initially appeared six-month after hip arthroplasty. (D) Radiolucent lines had not progressed until six-year after hip arthroplasty.

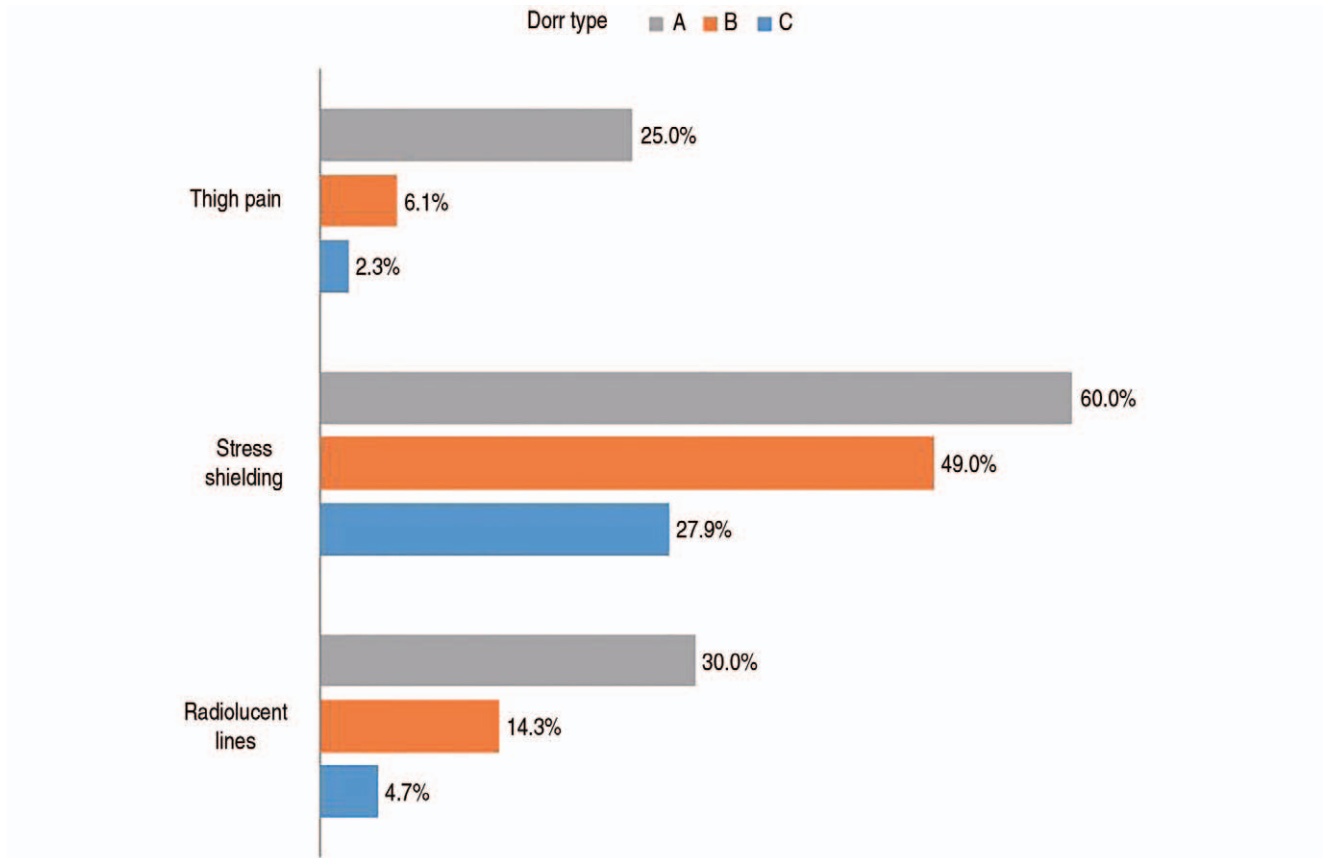
**Table 1.** Clinical and Radiological Results between Dorr Types

Parameter	Dorr proximal femoral type			P-value
	A (n=20)	B (n=49)	C (n=43)	
<b>Clinical outcome</b>				
Pre HHS	67.1±17.0	65.6±15.2	64.6±15.9	0.135
Post HHS	90.0±15.5	90.1±16.1	91.2±16.5	0.232
Thigh pain	5 (25.0)	3 (6.1)	1 (2.3)	0.006
<b>Radiological outcome</b>				
Radiolucent line	6 (30.0)	7 (14.3)	2 (4.7)	0.021
Stress shielding	12 (60.0)	24 (49.0)	12 (27.9)	0.030
Calcar-canal ratio	0.54±0.05	0.55±0.03	0.57±0.02	0.660
Cortical index	0.57±0.05	0.54±0.04	0.53±0.04	0.452
Calcar fill (%)	92.05±2.85	94.47±3.47	95.40±3.28	0.466
Metaphyseal fill (%)	93.36±3.87	96.27±1.95	96.33±2.11	0.387
Midstem fill (%)	86.08±3.07	80.93±7.85	79.88±4.04	0.383
Distal fill (%)	84.64±6.40	62.69±9.67	69.32±10.88	0.064
Lateral proximal fill (%)	82.05±8.80	79.95±8.42	82.53±8.58	0.927

Values are presented as the mean ± standard deviation or number (%).  
HHS: Harris hip score.

Calcar fill, CC ratio, and CI were  $94.39 \pm 3.16\%$ ,  $0.57 \pm 0.03$ , and  $0.53 \pm 0.04$  at five-year follow-up, respectively; these values were not significantly different among patients with Dorr types A, B, and C. Metaphyseal fill, midstem fill, distal fill, and lateral proximal fill were  $95.77 \pm 2.82\%$ ,  $81.45 \pm 5.49\%$ ,  $69.16 \pm 12.58\%$ , and  $81.32 \pm 7.54\%$  at five-year follow-up, respectively (Table 1). In those experiencing RLL, metaphyseal fill, midstem fill, distal fill, and lateral proximal fill were  $94.27 \pm$

$4.60\%$ ,  $83.47 \pm 5.85\%$ ,  $72.69 \pm 14.43\%$ , and  $83.15 \pm 8.24\%$ , respectively. Calcar fill was significantly lower in the group with RLL compared with the non-RLL group ( $P=0.033$ ) (Table 2). There were no significant differences between Dorr types and the focal osteolytic area detected in two hips in Gruen zone 1 at postoperative two years and remained without change in size until final follow-up. No changes in the position of implants, including stem subsidence, were detected in this study.



**Fig. 4.** Incidence of thigh pain, stress shielding, and radiolucent lines was the highest in Dorr type A (thigh pain,  $P \leq 0.001$ ; stress shielding,  $P=0.030$ ; thigh pain,  $P \leq 0.001$ )

**Table 2.** Comparison of Fit and Fill between with and without RLLs

Parameter	RLL (n=15)	Non-RLL (n=97)	P-value
Calcar-canal ratio	$0.57 \pm 0.02$	$0.54 \pm 0.04$	0.275
Cortical index	$0.55 \pm 0.02$	$0.55 \pm 0.05$	0.963
Calcar fill (%)	$91.63 \pm 2.67$	$95.85 \pm 3.07$	0.033
Metaphyseal fill (%)	$94.27 \pm 4.60$	$96.16 \pm 1.51$	0.412
Midstem fill (%)	$83.47 \pm 5.85$	$81.36 \pm 5.86$	0.602
Distal fill (%)	$72.69 \pm 14.43$	$71.84 \pm 12.95$	0.926
Lateral proximal fill (%)	$83.15 \pm 8.24$	$80.20 \pm 7.99$	0.591

Values are presented as the mean  $\pm$  standard deviation.  
RLL: radiolucent line.

## 2. Clinical Outcomes

There was a significant improvement in the mean HHS at final follow-up ( $90.5 \pm 15.9$ ) compared with preoperative values ( $65.5 \pm 16.0$ ) ( $P \leq 0.01$ ). Pre- and postoperative HHS did not vary significantly among Dorr types. Nine patients (8.0%) experienced occasional activity-related thigh pain that was related to Dorr type ( $P=0.006$ ) and RLL ( $P \leq 0.01$ ) (Table 1, Fig. 4). Thigh pain was relieved in all patients within two years of surgery.

## 3. Complications

Two cases of periprosthetic femoral fracture occurred during stem implantation. All hips were treated with circumferential wiring and healed without complication. Hip dislocation was noted in three hips and all cases were treated with closed reduction and hip brace fitting. One stem revision was performed due to deep infection.

## 4. Survival Analysis

All hips achieved stable fixation except for one case of revision surgery due to deep infection. The Kaplan–Meier survival rate for the femoral stem was 97.6%.

## DISCUSSION

Cementless stems can be divided into different categories depending on their conceptual approach (i.e., fit and fill, proximal fitting, distal taper). The rectangular tapered stem was designed to fill the proximal femur as much as possible while reducing: i) the force delivered to the distal femur and ii) the biomechanical bending stiffness with the aim of limiting postoperative stress shielding and thigh pain. The Zweymüller stem, a typical rectangular tapered stem designed in Europe, reported to provide initial stability both axially and rotationally<sup>8,12,20</sup>. The Zweymüller stem showed excellent clinical results in older patients with Dorr type B and C femoral geometry<sup>6,11,21,22</sup>. However, other papers reported complications associated with this stem type (e.g., thigh pain, proximal radiolucency, calcar resorption, stress shielding, and subsidence)<sup>9,10,23</sup>.

The C2 stem is very similar to the Zweymüller stem in terms of their design, shape, and surface-coating. The greatest difference between the Zweymüller stem and the C2 stem is that there is no proximal lateral shoulder in the C2 stem. Additionally, the C2 stem has: i) sharp edges

and a rounded section beneath the medial neck side for increased calcar contact area and ii) a distal end with a thinner conical shape compared to other rectangular stems.

In our series, 15 cases (13.4%) experienced RLLs in Gruen zone 1 or 7. Importantly, however, these RLLs did not expand or impact stem stability. The fine motion of the femoral stem causes bone resorption, and the fibrous membrane fills the gap between the femoral stem and inner cortex. This gap appears radiolucent in plain radiography. Choy et al.<sup>24</sup> reported that RLL (zone 3, 4, and 5) was observed in 15% of patients after performing hip arthroplasty in elderly patients using a C2 stem. Although the RLL incidence in our study (13.4%) is similar to this study, there are notable differences in the zones involved. While further studies to better understand this observation are warranted, this difference may be explained by the surgical techniques used. Patients with Dorr type C femoral geometry experienced significantly fewer RLL (4.7%) compared to those with type A (30.0%) and type B (14.3%). Dorr type A femurs have wide metaphysis and narrow diaphysis<sup>15</sup>. Because of these structural features, the rectangular tapered stem does not fit the metaphyseal-diaphyseal junction of Dorr type A femurs, which leads to the fine motion of the femoral stem and RLL.

The most common adverse event following hip arthroplasty is persistent thigh pain<sup>25</sup>. The incidence of thigh pain in patients treated with cementless femoral stems has been reported to range from 10% to 20%<sup>26</sup>. Although the cause of thigh pain has not yet been clearly defined, fixation stability and stress transfer from the femoral stem to the endocortex are two commonly cited hypotheses<sup>25-28</sup>. In our study, nine patients (8.0%) experienced occasional thigh pain that was related to activities. The incidence of thigh pain and RLL varied significantly according to Dorr type (highest in type A). These data suggest that RLL and thigh pain are associated with femoral geometry. The average bone mineral density of the proximal femur among older Asians is lower compared with the Western population<sup>29,30</sup>. Therefore, the use of a small C2 stem for these patients may induce a high probability of micromotion at the proximal femur.

This study has a several limitations. First, this study is a retrospective study and thus may be subject to a selection bias. Specifically, the uneven distribution of Dorr types and over-representation of femur neck fracture among patients might bias the results. Second, this study is limited by the relatively small sample size ( $n=112$ ) and lack of longer follow-up (mean, 91.1 months) to assess implant

survivorship. Despite these noted limitations, we believe that the number of cases and the follow-up length were sufficient to allow for an objective analysis. This study is meaningful in suggesting a relationship between femoral geometry and thigh pain when using this kind of rectangular tapered stem in elderly Asian patients.

## CONCLUSION

The clinical results of hip arthroplasties using a C2 stem revealed a stem survival rate of greater than 97%; survival rates according to Dorr classifications were not significantly different. The incidences of RLL and thigh pain were correlated to femoral geometry (highest for patients with Dorr type A). Special attention is recommended when performing hip arthroplasty using C2 stems in elderly patients with Dorr type A femoral bone classification.

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## CONFLICT OF INTEREST

The authors declare that there is no potential conflict of interest relevant to this article.

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