Minimum ten-year outcome of a triple-tapered femoral stem implanted with line-to-line cementing technique

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Abstract

Background

A triple-tapered polished femoral stem was implanted with line-to-line cementing technique. The purpose of this study was to determine the survivorship, loosening rate, stem subsidence, radiologic changes and clinical outcomes in the minimum ten-year follow-up.

Methods

This was a retrospective study done in three institutes. Finally, 118 hips in 97 patients could be followed-up at the mean follow-up period of 126.9 months. The survivorship, radiological and clinical outcomes were investigated.

Results

Radiologically, 107 hips (90.7%) were categorized to Barrack cementing grade A, and 108 stems (91.5%) were inserted in neutral position. All hips were not loose and were not revised due to aseptic loosening. Survival with revision for any reason as the endpoint was 100% after 10 years. At the last follow-up, the mean subsidence was 0.41 mm, and the subsidence was less than 1 mm in 110 hips (93.2%).

JOA hip score improved from 42.7 ± 9.2 points preoperatively to 92.9 ± 6.8 points at the last follow-up. No patient complained thigh pain.
Conclusions

Line-to-line cementing technique with use of a triple-tapered polished stem was effective to achieve good cementation quality and centralization of the stem. The subsidence was small, and the minimum ten-year results were excellent without any failures related to the stem.

Trial registration: Retrospectively registered

Keywords: Total hip arthroplasty, Triple-tapered polished femoral stem, Line-to-line cementing technique, Subsidence
Background

Since the cement fixation system of femoral stems for total hip arthroplasty (THA) was established in the 1960s, a variety of different concepts have been applied to the development of the femoral stems. In these concepts, main topics are stem design and cement mantle thickness.

In terms of stem design, cemented femoral stems can be broadly divided into two designs that achieve fixation as a composite beam and those that function as a taper-slip device [1]. Recent studies of polished tapered cemented stems have reported superior long-term clinical outcomes from the systematic review [2], and significant survival advantages in the registry data [3]. Originally, double-tapered polished stems, such as the Exeter stem and the CPT stem, were developed. Their long-term good clinical results have been previously reported [4-6], while the bone loss in the calcar region around double-tapered stem was concerning [7]. A triple-tapered cemented stem was designed with the intention of loading the proximal femur, thereby reducing proximal bone loss [8]. Buckland et al. [9] measured bone mineral density (BMD) around a triple-tapered stem. The marked loss in BMD occurred in zone 1 and 7 within 9 months postoperatively, while zones 6 and 7 showed a recovery in BMD between 9 and 24 months postoperatively, and zones 1 and 3 showed more
delayed recovery in BMD at 18 months.

The second topic of cemented stem is cement mantle thickness. It is still unclear whether thickening the cement mantle leads to better outcomes. Many studies have reported good outcomes for a cement mantle thickness of at least 2mm [10-13], while a favorable outcome with a thin cement mantle was also reported as 'French paradox' [14, 15]. Line-to-line cementing technique means preparation of the femoral canal using the largest possible broach and implantation of a stem with the same dimensions as the broach. It is reported that line-to-line cementing technique in human cadaver femora resulted in a mean thickness of cement of 3.1 mm, and the cement was directly supported by cortical bone or cortical bone with less than 1 mm of cancellous bone interposed in over 90% of thin cement mantle areas [16]. This technique also can achieve the pressurization of the cement into cancellous bone during insertion of the implant [17]. These results indicate that both polished tapered stem design and line-to-line cementing technique might bring about successful long-term outcomes.

The purpose of this study was to determine the survivorship, loosening rate, stem subsidence, radiologic changes and clinical outcomes in the minimum ten-year follow-up of a triple-tapered polished stem implanted with line-to-line cementing
technique. These results were compared with those of the other polished tapered stems.

Materials and Methods

The research protocol of this retrospective study was in compliance with the Helsinki Declaration. The institutional review board of Osaka Saiseikai Nakatsu Hospital approved this study. Informed consent was obtained from all patients who participated in this study.

From February 2009 to October 2010, consecutive 186 hips in 162 patients underwent THA with a femoral stem (Trilliance, B.Braun Aesculap, Tuttlingen, Germany) fixed with line-to-line cementing technique. This stem was made of CoCr with a highly polished surface (Ra 0.01 mm) and a quadrangular section (Fig. 1).

Twelve patients died, 14 patients could not visit due to the comorbid disorders, 18 patients could not visit due to long distance to the institutes, and 21 patients were lost to follow-up. Finally, 118 hips in 97 patients could be followed-up at longer than ten years postoperatively (Fig. 2). The patients demographics, diagnosis, and surgical approaches were shown in Table 1. No patient received prior surgery to the hip. A type of cup and bearing materials were chosen according to the surgeons’ preference (Table 2). The heads used were 22, 26, 28 and 32 mm in diameter. Femoral
canal was prepared using the largest possible broach, and bone plug or polyethylene cement plug was placed at 1 cm distal to the stem tip. After pulse lavage, vacuum mixed bone cement was introduced in a retrograde fashion. The femoral stem was inserted without a distal centralizer.

Clinical and radiological evaluation was undertaken preoperatively and at 3 weeks (baseline radiograph) and every year. At each follow-up visit, the patients had a physical examination by the operating surgeons and the functional results were evaluated using Japanese Orthopaedic Association hip score (JOA hip score, full mark=100) [18]. Anteroposterior radiograph of the pelvis with the patient supine position was obtained, and all the radiographs were examined independently by the three authors. The cementing technique was assessed using the grading of Barrack et al. [19]. The alignment of the stem was referenced from the axial alignment of the femur, and the alignment was assumed to be neutral within 3 degrees from colinearity. On the final radiographs, the presence and evolution of radiolucent lines and cortical thickening in any of the seven zones described by Gruen et al. [20] was evaluated. Loosening of the femoral component was defined according to the criteria of Harris et al. [21] which included subsidence of the stem greater than 3 mm, fracture of the cement mantle, and a complete radiolucent line greater than 2 mm or
a radiolucent line in zone 1 greater than 2 mm in width. Periprosthetic cystic or
scalloped lesions larger than 2 mm in diameter which had not been present on the
immediate post-operative radiograph were defined as osteolysis. Subsidence of the
stem was measured on magnified images calibrated using the known size of the
femoral head. The radiological landmarks were the greater trochanter, the
proximolateral cement mantle and the shoulder of the prosthesis, as described by
the Exeter group [22].

All data were collected and analyzed using the Microsoft Excel Software (Microsoft
Corporation, Redmond, WA). Kaplan-Meier survival analyses (EZR, Saitama
Medical Center, Jichi Medical University, Saitama, Japan) were used to evaluate the
cumulative stem survivorship and performed for any reasons, and aseptic loosening.

Results

According to the Barrack cementing grade, 107 hips were categorized to grade A, 11
hips were categorized to grade B. Stem was inserted in neutral position in 108 hips,
in valgus in 7 hips, and in varus in 3 hips. Radiolucent lines and osteolysis were not
observed in any hips. All hips were not loose and were not revised due to any reasons
(Fig. 3). Cortical thickening was observed in one hip at zones 3 and 5. Fracture of
the cement mantle was not observed. No post-operative complication occurred, such
as deep venous thrombosis, and heterotopic ossification.

Survival with stem revision for any reasons as the endpoint was 100%. At the last follow-up, the mean subsidence was 0.41 mm (0 mm to 1.9 mm). In most of the hips, the subsidence was less than 1 mm (Table 3).

JOA hip score improved from 42.7 ± 9.2 points preoperatively to 92.9 ± 6.8 points at the last follow-up. No patient complained thigh pain.

Discussion

In this study, survival with revision for any reasons as the endpoint was 100%. The most widely used polished tapered femoral component, Exeter stem, showed that the survival rate for all-cause revision of the stem was 96.8%, and that for aseptic loosening as the endpoint was 100% at 13.5 years [5]. From the report of C-stem, there were no revision for stem loosening but two stems was revised for fracture at a mean follow-up of 13 years [23]. CMK stem, implanted with line-to-line cementing technique, marked the cumulative survival rate with revision of either component for any reason as endpoint of 90.5% at 17 years [15]. Our long-term results would be comparable to those of polished tapered stems.

Line-to-line cementing technique has some advantages. It can achieve the pressurization of the cement into cancellous bone during insertion of the implant.
While grade A cementation quality described by Barack was recognized in 49.6% and 73.6% when using the Exeter stems [5, 24], grade A was achieved in 90.7% in our study. Other advantage is centralization of the stem. Scheerlinck et al. reported line-to-line stems without a distal centralizer were better aligned than undersized stems fitted with a centralizer [17]. Cortical point contact during stem insertion may improve alignment of the stem into the proximal medullary cavity. In our study, 91.5% was inserted in neutral position, and the CMK stem that was also implanted with line-to-line cementing technique, was in a neutral position in 80.5% [15]. In contrast, 65.3% was inserted within 2 degrees of varus or valgus in the Exeter stem [24], and 61.7% was in a neutral position in the C-stem [25]. The mean subsidence was 0.41 mm at the mean follow-up period of 126.9 months. It was reported that the mean subsidence of Exeter stem was 1.2 mm at a minimum of 10-year follow-up [5]. The subsidence of C-stem AMT was reported to be 1.28 mm at two years [26]. A hollow polymethylmethacrylate centralizer was placed on the tip of these stems. The use of centralizer and thick cement mantle might allow these stems for subsidence. Subsidence remains a fundamental principle of the design of taper-slip stem, which produces tensile hoop forces in the cement and compressive stress at the cement-bone interface. On the other hand, the mean subsidence was
0.63 mm in CMK stem, that had no centralizer and was implanted with line-to-line cementing technique [15].

Cortical thickening was observed in one hip (0.8%) in our study. The rate of cortical thickening was reported from 0.5% to 40.2% [4, 15, 27]. The rate of cortical thickening was lower compared to those reported results. Cortical hypertrophy might reflect the mechanical conditions around cemented femoral components, however, this was not matched to poor outcome, and its clinical relevance is still unclear.

The first limitation of the study is the uncontrolled retrospective study, and there was no control group. Thus, the results were compared with those of the other polished tapered stems. The Exeter stem and the CPT stem were double-tapered stem, and the C-stem was triple-tapered stem. These stems were fixed using distal centralizer with keeping cement mantle. The CMK stem was also double-tapered stem and the line-to-line cementing technique was applied. Secondary, the follow-up period was not enough to compare our results with reported long-term results. For predicting the long-term survival of this femoral stem, we have to continue to investigate the clinical and radiological outcomes.

In conclusion, line-to-line cementing technique with use of a triple-tapered polished
stem was effective to achieve good cementation quality and centralization of the stem. The subsidence was smaller than that of well-established polished tapered stems. The minimum ten-year results were excellent without any failures related to the stem. Further follow-up is needed to compare with results with longer-term follow-up.

Declarations

Abbreviations

THA: Total hip arthroplasty, BMD: Bone mineral density, JOA hip score: Japanese Orthopaedic Association hip score

Ethics approval and consent participate

The research protocol of this retrospective study was in compliance with the Helsinki Declaration. The institutional review board of Osaka Saiseikai Nakatsu Hospital approved this study. Informed consent was obtained from all patients who participated in this study.

Consent for publication

Not applicable.
Availability of data and materials

The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare no conflicts of interest associated with this manuscript.

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Authors’ contribution

HO designed the work, acquired and analysed the data, and was a major contributor in writing the manuscript. SI and IM acquired and analysed the data, and substantively revised the manuscript. All authors read and approved the final manuscript.

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Figure legends

Fig. 1 Three views of a triple-tapered polished cemented stem, Trilliance

Fig. 2 The flowchart of patients in this study

Fig. 3 Post-operative anteroposterior radiographs of 62-year-old woman with dysplastic hip osteoarthritis showing (a) well-aligned stem cemented with line-to-line technique, (b) follow-up at 10 years without measurable subsidence of the stem
Primary THA with Trillian stem
186 hips in 162 patients

Death until ten years after THA
14 hips in 12 patients

Unable to visit
due to comorbid disorders
or long distance
32 hips in 32 patients

Lost to follow-up
22 hips in 21 patients

Complete clinical and radiological follow-up
at a minimum of ten years
118 hips in 97 patients

Fig. 2
Table 1 Patient demographics, diagnosis, and surgical approaches

| Demographics                  |       |
|-------------------------------|-------|
| Number of hips                | 118 hips |
| Age at operation (mean ± SD, range) | 61.0 ± 10.0 (20-84) years |
| Sex                           |       |
| Males                         | 18 hips |
| Females                       | 100    |
| Follow-up period (mean ± SD, range) | 126.9 ± 5.7 (120-139) months |

| Diagnosis                        |       |
|----------------------------------|-------|
| Osteoarthritis                   | 104 hips |
| Idiopathic osteonecrosis of femoral head | 9 |
| Rheumatoid arthritis             | 2     |
| Rapidly destructive coxarthritis | 2     |
| Miscellaneous                    | 1     |

| Approaches                      |       |
|---------------------------------|-------|
| Direct anterior approach        | 97 hips |
| Direct lateral approach         | 20    |
| Transtrochanteric approach      | 1     |

SD: standard deviation
Table 2 Cups and types of articulation used in this study

| Cup          | Articulation               | Count |
|--------------|----------------------------|-------|
| Plasmacup    | Ceramic / Ceramic          | 68 hips |
| Contemporary | Metal / Polyethylene       | 50    |
| Triad HA     |                            | 2     |
| Trident      |                            | 43    |
Table 3 Number of hips in every 1 mm for subsidence

| Subsidence          |     |
|---------------------|-----|
| 0 mm                | 28  |
| 1 mm > S           | 82  |
| 2 mm > S ≥ 1 mm    | 8   |

S: subsidence