Femoral Components: Outcome with a Tapered, Polished, Anatomic Stem

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Introduction

Failure of a cemented total hip arthroplasty (THA) is a rare event even in the long term. With improved cementing techniques, excellent and consistent long-term outcome has been achieved with a number of different femoral stem designs [1, 11, 21, 25, 32, 36, 37, 42]. However, some implants seem to perform better than others [32] and some very different design and anchorage philosophies [24, 40] can be identified (▶ chapter 7.1). A modern stem design should be easy and reproducible to implant for any surgeon including the trainee, but should also forgive minor mistakes and provide long-term survival of at least 95% after 10 years [33]. For long-term survival a complete cement mantle of adequate thickness [19, 28, 29] is of significant importance. There is no doubt that a thin or deficient cement mantle can lead to cracks, which create a pathway for wear particles to induce osteolysis and loosening [24, 26, 31]. Hence, it is considered important to create not only a sound cement interlock, but also an optimal cement mantle around the femoral stem at operation. It is the surgeon who »manufactures« the cement mantle, which also depends on a variety of factors (▶ chapter 5.2) including femoral anatomy, bone preparation, stem design and size and centralizer usage [10].

Most stem designs are straight and an obvious dilemma exists, if one considers the femoral anatomy in the lateral plane, which is curved [15]. Accordingly, a typical sagittal »mal-alignment« pattern of straight stems has been identified both clinically and experimentally [10, 15, 35] on lateral radiographs. This inevitably leads to areas at risk for producing thin cement mantles [10].

To address this anatomical fact and to minimise the risk of a deficient cement mantle, the Olympia hip stem, an anatomical, tapered and highly-polished design, has been developed and used clinically since 1996. This chapter describes the 9-year survival and radiographic outcome of the Olympia stem in the first 120 consecutive cases implanted between 1996 and 1998.

Design Rationale

The Olympia stem (Biomet UK Ltd.) is tapered, of anatomic shape (left and right), with a highly-polished surface finish with a mean surface roughness (Ra) of 10 nm. (Fig. 8.23). The modular design is manufactured from forged high Nitrogen Stainless Steel (to ISO 5832 part 9) and has a 12/14 neck taper.

- *Anatomic shape:* The stem is anatomically shaped (Fig. 8.23) and available in 7 sizes (0 to 6), separated for the right and left side. The standard CCD is 134–137° depending on the stem size with a standard true offsets ranging from 40 to 46,55 mm. Lateralised offset stems are also now available (CCD 129–133°) with an incremental offset from 43 to 50,4 mm. The reduced neck diameter ensures an improved range of motion and minimises the dislocation risk to due to impingement
- *Polished*: The highly-polished surface (Ra 10 nm) reduces tensile stresses and cement abrasion at the stem-cement interface. Current evidence suggests that all stems, regardless of their design features, debond eventually and move within the cement mantle. With minimal distal migration of the stem, the tapered shape provides wedge fixation and loading of the surrounding cement in compression.
- *Tapered design:* The stem is 3-dimensionally tapered: the oval metaphyseal part provides rotational locking. A double reduced taper limits subsidence and increases intrinsic rotational stability.

- *In-built anteversion:* The 3-dimenstional geometry follows the natural femoral torque and provides a natural anteversion within the implant. As a consequence the proximal oval diameter even provides an even cement mantle
- *Centralizer:* Although a natural centralisation of the stem in the femoral canal is afforded by virtue of the shape of the stem, additionally a set of 4 distal PMMA centralizers, to prevent stem tip bone contact, is provided with each stem sizes to allow a selection depending on the canal diameter.
- *Cement mantle friendly:* The anatomic shape in both planes (reduced shoulder and proximal curve in lateral view) reduces the risk of thin cement mantles in all Gruen zones. The stem has no corners, which could act as a stress riser for the cement mantle. Templates with 2 and 3 mm outlines ensure stem size selection to produce a minimal cement mantle thickness of 2–3 mm distally and 4–7 mm proximally (medial calcar).
- *Abductor and approach friendly:* The stem shape and the simple instruments protect the abductors, especially in an antero-lateral approach, and allow MIS techniques.

Patients

Between November 1996 and October 1998 the first author implanted 120 Olympia stems in 111 consecutive patients at King Edward VII Hospital Midhurst (Fig. 8.24). There were 40 males and 71 females (mean age 74,2 years; range 51–91). Preoperative diagnoses consisted of 116 primary osteoarthritis (OA), 3 femoral neck fractures and

Fig. 8.23. Photograph of Olympia stem indicating the anatomical shape in both planes

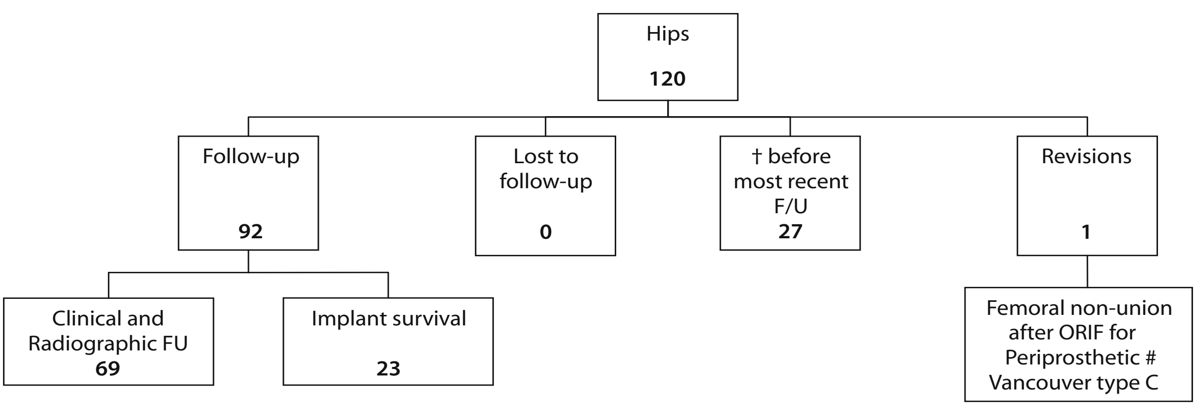


Fig. 8.24. Patient follow-up data

1 posttraumatic OA. No patient had undergone previous hip surgery.

All operations were performed in a laminar flow theatre with a three dose prophylactic antibiotic regime, the same first assistant and anaesthetist being present at all operations. Using a lateral transgluteal Hardinge approach in lateral decubitus position, all Olympia stems were implanted with Palacos–Gentamicin cement using a modern cementing technique with distal femoral cement restrictor, pulsatile jet lavage and proximal pressurisation. In this initial series, no distal centralizers were used (not available). A stem size was chosen to allow a minimum cement mantle of 4–5 mm proximally-medially and 2–3 mm distally (templates). Size 3 (34%) and size 4 (30%) stems were used in the majority of cases. Modular metal head diameters were used: 28 mm (80%), 32 mm (16%) and 22 mm (4%). Both cemented and cementless acetabular cups had been implanted: cemented Ogee (11%), cemented Elite (56%) (DePuy International Ltd) and cementless Spotorno's expansion cup (33%) (Zimmer Inc., Warsaw).

Methods

This is a consecutive, prospective series of the first 120 Olympia stems ever implanted and includes therefore the learning curve with this design. All patients were traced for follow-up (FU), but some were unwilling to attend for radiographic review due to travelling time and 'inconvenience'. None had pain and all were still satisfied with their hip. There was no patient lost to follow-up regarding implant survival (Fig. 8.24).

Clinical evaluation was done using the Harris hip score [23] and patient functional assessment using Oxford hip questionnaire [16]. Radiographs taken before, after operation and at final review and were examined by an independent experienced reviewer [M.S.]. The radiograph of the latest follow-up was also examined for any radiolucent lines at the cement/bone interface, measurable stem subsidence and significant cup migration. The integrity of the cement mantles was graded according to the Barrack classification [7]. Cement mantle was examined for cement fractures and cement mantle thickness was measured ap and lateral in all 14 Gruen zones [22, 27]. The stem was checked for varus/valgus and sagittal malalignment of the stem, which was defined as a deviation from the longitudinal axis of 3 or more degrees [29]. Osteolysis was defined as a newly developed, cystic lesion with endosteal scalloping [12].

Statistical Analysis

Survival analysis was performed using life-table analysis as detailed by Armitage and Berry [4]. The endpoint was defined as revision surgery with implant removal for any reason. All statistical calculations were performed with SPSS Version 12.0 (SPSS Inc., Chicago, Illinois).

Implant Survival

119 of the original 120 implants were not revised at latest follow-up. 25 patients (27 implants) had died, but their implants were in situ at the time of death. Mean implant survival was 6,7 years (range 0,2–9 years; median 7 years).

There were no dislocations or infections, but 3 reoperations were performed for periprosthetic fractures after a fall with adequate trauma. All 3 fractures were subprosthetic and classified class C according to the Vancouver-Classification [9] with the implants all well fixed. All fractures were treated with plate fixation. One fracture went on to non-union and removal of the well fixed stem was necessary for revision to a distally locked, long uncemented stem.

Overall-survival for aseptic loosening was 100% after 7–9 years and 99.2% for implant survival for all reasons (Fig. 8.25; standard deviation for cumulative surviving 0,0092%).

At the time of review no stem was considered at risk for loosening. There have been no revisions for acetabular cup loosening or wear to date.

Clinical Results

Harris Hip Score

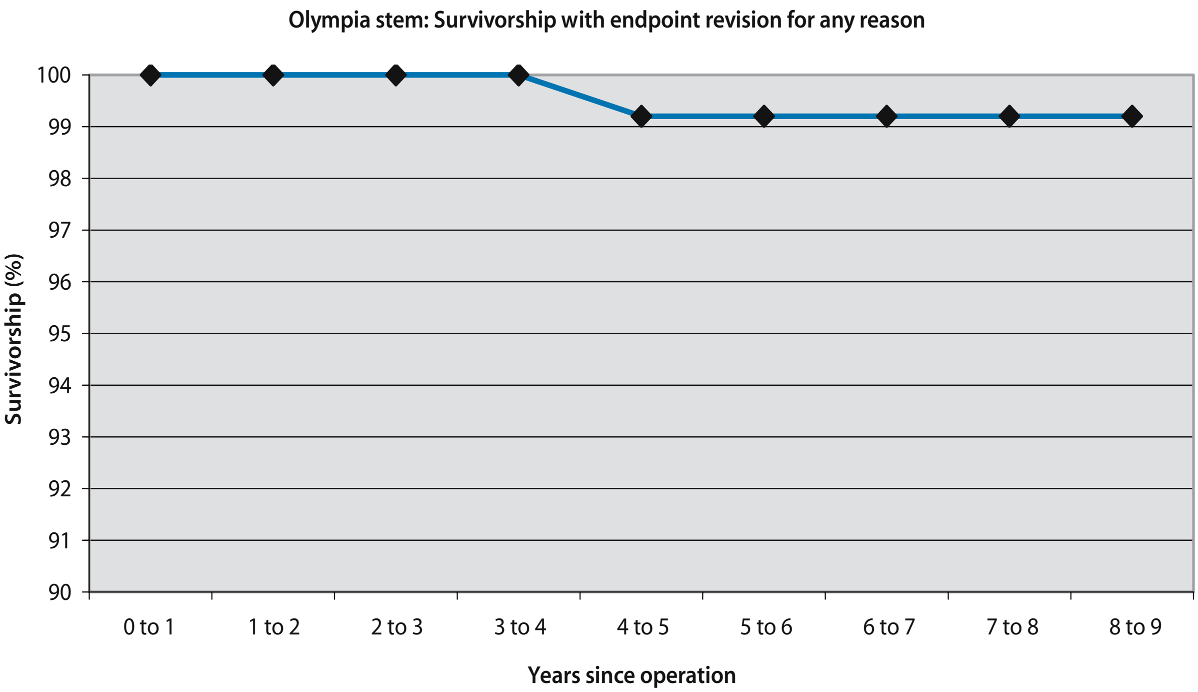
The score for the reviewed patients was a mean of 87.4 (range 67–91± 5.31). 52% of patients had a score above 90 with 92% scoring 80 or greater.

Oxford Hip Score

Functional outcome was measured by the patient administered Oxford hip questionnaire. The mean score at 5 years follow up was 13.2 (SD=1.67) with a range of 12–21. 51% of patients scored 12 (excellent) with only 2% scoring >24. Therefore, 98% of patients were classified at good or excellent at 5+ years.

Radiographic Assessment

All patients had AP and lateral radiographs at follow up. At latest follow up, during the study period 2004/05, only 69/92 hips were available for assessment. No measurable stem subsidence or the development of radiolucent lines



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around the stem or cement bone interface was found. There was no femoral or acetabular osteolysis. There were radiolucent lines <2 mm in zone I DeLee and Charnley [17] in 21% of the cemented cups, but no migration of any cemented or uncemented cup. Visual examination and measurements of radiographs did not show any detectable polyethylene wear.

Stem

AP-alignment revealed neutral position ±3° in 76.4% of the reviewed cases, varus in 5.9% and valgus in 17.7%. No stem showed more than 5° deviation from neutral. Alignment on lateral views showed neutral position ±3° in 75.7%, anterior position in 2.7% and posterior tip orientation in 21.6% of the cases.

Table 8.19 shows cement mantle thickness according to Gruen zones 1–14. In more than 4/5 of cases excellent stem alignment with complete cement mantle were documented (Fig. 8.26). In 17.1% there was a thin, but complete cement mantle <2 mm in Gruen zones 8/9 and in 8.6% in zone 12 posterior at the stem tip.

In 67.6% of radiographs examined the cement mantle was classified as Barrack A with the appearance of a complete »white out« and in the remainder as Barrack B (32.4%). There were no poor gradings C or D in this review.

Table 8.19. Postoperative cement mantle thickness (%) in Gruen zones 1–14 [22, 27]

Zone	≥2 mm	<2 mm	≤1 mm
1	100	0	0
2	100	0	0
3	98,5	1,5	0
4	100	0	0
5	91,2	4,4	4,4 (valgus)
6	98,5	1,5	0
7	100	0	0
8	82,9	17,1	0
9	94,3	5,7	0
10	100	0	0
11	100	0	0
12	91,4	8,6	0
13	100	0	0
14	94,3	5,7	0

Discussion

This prospective, consecutive single-surgeon series of the first 120 Olympia stems revealed excellent implant survival, radiographic and clinical outcome. No stem had failed up to 9 years and there was no revision for aseptic loosening. Although no 10-year results are yet available, the likelihood of significantly worse results then, is ex-

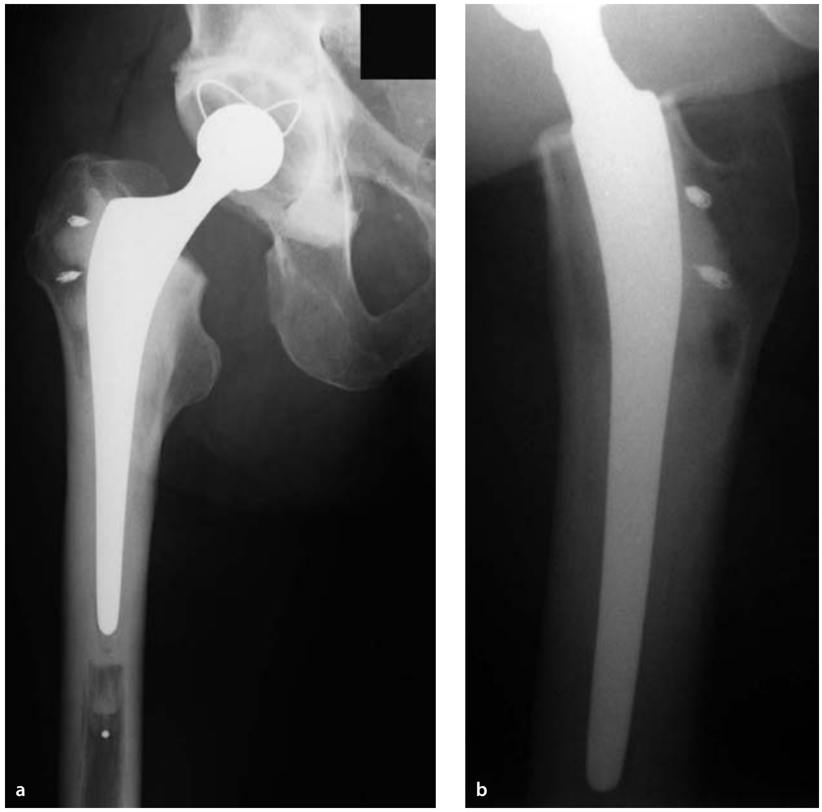

Fig. 8.26. a Postoperative radiograph at FU after 8,5 years with no evidence for subsidence, loosening or osteolysis of the stem. The cup remains well fixed despite a non-progressive radiolucent line in zone I [17]. The lateral radiographic view (**b**) shows optimal alignment and a complete cement mantle even in the anterior Gruen zones 8/9 at the level of the proximal femoral bow. *N.B. The suture anchors were used for reattachment of the vasto-gluteal flap*

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tremely low, in particular as relevant stem subsidence was not detected. It therefore seems justified to expect a survival rate of at least 95% after 10 years (aseptic loosening) as recommended by the NIH [33].

It is certainly not possible to predict whether this anatomic design will show superior survival in its 2nd decade in comparison to straight stem designs. However, this study has provided further radiographic evidence, that an anatomic stem carries a lower risk of thin cement mantles in the sagittal plane (even with antero-lateral approach) in comparison to the published radiographic cement mantle analysis for some straight stem designs [13, 20, 35]. A recent multi-surgeon midterm study with a straight stem design revealed a high incidence (64.2%) of thin/deficient cement mantles in zone 8 on lateral radiographs. At midterm, the thin cement mantles had, however, not led to osteolysis or failure, but the authors had classified this group as »stems at risk« [13].

Surprisingly, a comprehensive cement mantle analysis, which includes the second plane, does not exist for the majority of femoral implants. Conventional stem designs make it difficult to achieve an optimal cement mantle due to the proximal femoral anatomy in the sagittal plane [10, 35, 39]. Even if a distal centralizer is used to centralise the stem tip, which is now done routinely, this has no preventive effect on the proximal/anterior Gruen zones 8/9 [10]. Valdivia et al. [39] also confirmed this relationship in a cadaveric study with 6 different stem designs and identified this as an area »prone to deficient cement mantles«.

Thin or deficient cement mantles can reduce implant survival and are less able to absorb energy and may crack and fail [19, 24, 26, 31]. Only a deficient cement mantle can allow wear particles access to the cement-bone interface. In the presence of wear localised granuloma formation at the cement-bone interface and osteolysis can result as a consequence [3, 26, 31]. In this context, joint-fluid pressure has been found to play an important role for particle migration and osteolysis [5, 6]. Osteolysis is associated with a high risk of periprosthetic fracture, which represents one important mechanism for late failure [8, 14] of THA.

This study has some limitations which have to be considered. Implantation was performed by a single experienced surgeon, who achieved good to excellent cement gradings in all patients. Furthermore, the power of the radiographic analysis is reduced, as radiographs were not available for all patients.

Although we did not find any evidence for stem subsidence, it must be criticised that no Röntgen Stereometric Analysis (RSA) study, which would provide the most accurate measurement method [30], has yet been performed. On the other hand, it has been documented for the polished Exeter stem, that a mean migration of up to 2 mm [2, 38] did not adversely affect survivorship at 8–12 years [41]. Hence, the view that early migration is an indicator of long-term loosening [34] does not seem to be applicable to all femoral stem designs and geometries. It may well be that posterior migration, i.e. retroversion, detected by RSA, will prove to be the more significant predictor [30]. The significance of stem subsidence remains a controversial issue, but it is clear that subsidence may still cause cement mantle damage, which has been confirmed in human retrieval analysis [18]. It seems logical to assume that an undamaged cement mantle increases the chance of long-term performance.

Take Home Messages

- The anatomic Olympia stem revealed excellent radiographic results at 7–9 years and survival of 100% for aseptic loosening and 99.2% for all reasons.
- Radiographic analysis showed a low rate of thin cement mantles, in particular in the high risk Gruen zones 8/9 (on lateral radiographs).
- No measurable subsidence, radiolucent lines or osteolysis were found.
- Based on current results the continued clinical use of this polished, tapered, anatomic design seems justified.

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