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HIP ARTHROPLASTY

Fixation of a modular curved revision stem with a taper of 2° in the femur

Bernd Fink[1,2] · **Uli Buntenbroich**[1] · **Damian Oremek**[1]

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Abstract

Introduction Modular revision stems with a short distal component can prevent the bypassing of the femoral isthmus and hereby theoretically have advantages concerning risk of periprosthetic fractures, breakage of the junction and a technically easier revision procedure.

Materials and methods Radiological evaluation of 202 stem revision operations with the modular curved revision stem "Revitan Curved" with a 2° taper was carried out after a mean follow-up period of 7.44 ± 2.09 years (3–13 years) to investigate whether short-stem combinations are effective in Paprosky 2 and 3A defects with respect to rate of subsidence and loosening.

Results Sixty of 62 endofemoral (96.8%) and 137 of 140 transfemoral implantations (97.9%) involved the short, 140 mm distal component. Significant subsidence was seen in 3.3% of cases following endofemoral implantation and in 2.1% of cases following transfemoral implantation. Neither aseptic loosening nor periprosthetic fracture were observed.

Conclusion The use of combinations of short modular components leads to reproducibly good outcomes in femoral revision with respect to subsidence and loosening.

Keywords Revision arthroplasty · Tapered stem · Fixation · Modular revision stem

Introduction

Distally fixed, cementless tapered revision stems represent a successful concept for the revision of hip prostheses [1–8]. This type of revision stem is available in a monobloc form or in a modular version, the former with a straight stem and the latter with a straight or curved stem. A common feature for all versions is that a conical reamer (for a straight stem) or a conical rasp (for a curved stem) is used to create a conical anchorage bed in the femur. The conical stem is inserted into this bed so that a firm cone-in-cone fixation is achieved. There are, however, differences in the degree of taper, i.e. in the angle of the taper: For example, the revision stems Wagner SL, Revitan (ZimmerBiomet GmbH, Winterthur, Switzerland), the MP prosthesis (Waldemar Link, Norderstedt, Germany), and the conical distal component of the Restoration stem (Stryker Orthopaedics, Mahwah, NJ, USA), all have a taper of 2°, the Reclaim stem (DePuy Synthes, West Chester, Pennsylvania, USA) a taper of 2.5°, the revision stem Arcos (ZimmerBiomet, Warsaw, IL, USA) a taper of 3°, and the ZMR prosthesis (ZimmerBiomet, Warsaw, IL, USA) a taper of 3.5°. These differences result in a variation in the localization of the cone-in-cone anchorage of the conical part of the stem in the femur [9, 10].

A cadaver study with the modular revision stems Revitan Straight and Revitan Curved revealed that, using a transfemoral approach to implant these stems with a 2° taper, a circular press-fit fixation in the femoral isthmus at the tip of the stem can be achieved. Endofemoral implantation of the Revitan Curved stem, on the other hand, results in a so-called three-surface fixation with conical anchorage of three edges of the octagonal surface in the cortical bone at both lower contact areas of the distal component (Fig. 1a, b) [11]. The advantage of this method of fixation is that combinations of short stem components can be selected that do not extend beyond the femoral isthmus. As a consequence, the risk of periprosthetic fracture should

✉ Bernd Fink
bernd.fink@okm.de

[1] Clinic of Joint Replacement, General and Rheumatic Orthopaedics, Orthopaedic Clinic Markgröningen gGmbH, Kurt-Lindemann-Weg 10, 71706 Markgröningen, Germany

[2] Orthopaedic Clinic, University-Hospital Hamburg-Eppendorf, Martinistrasse 52, 20246 Hamburg, Germany

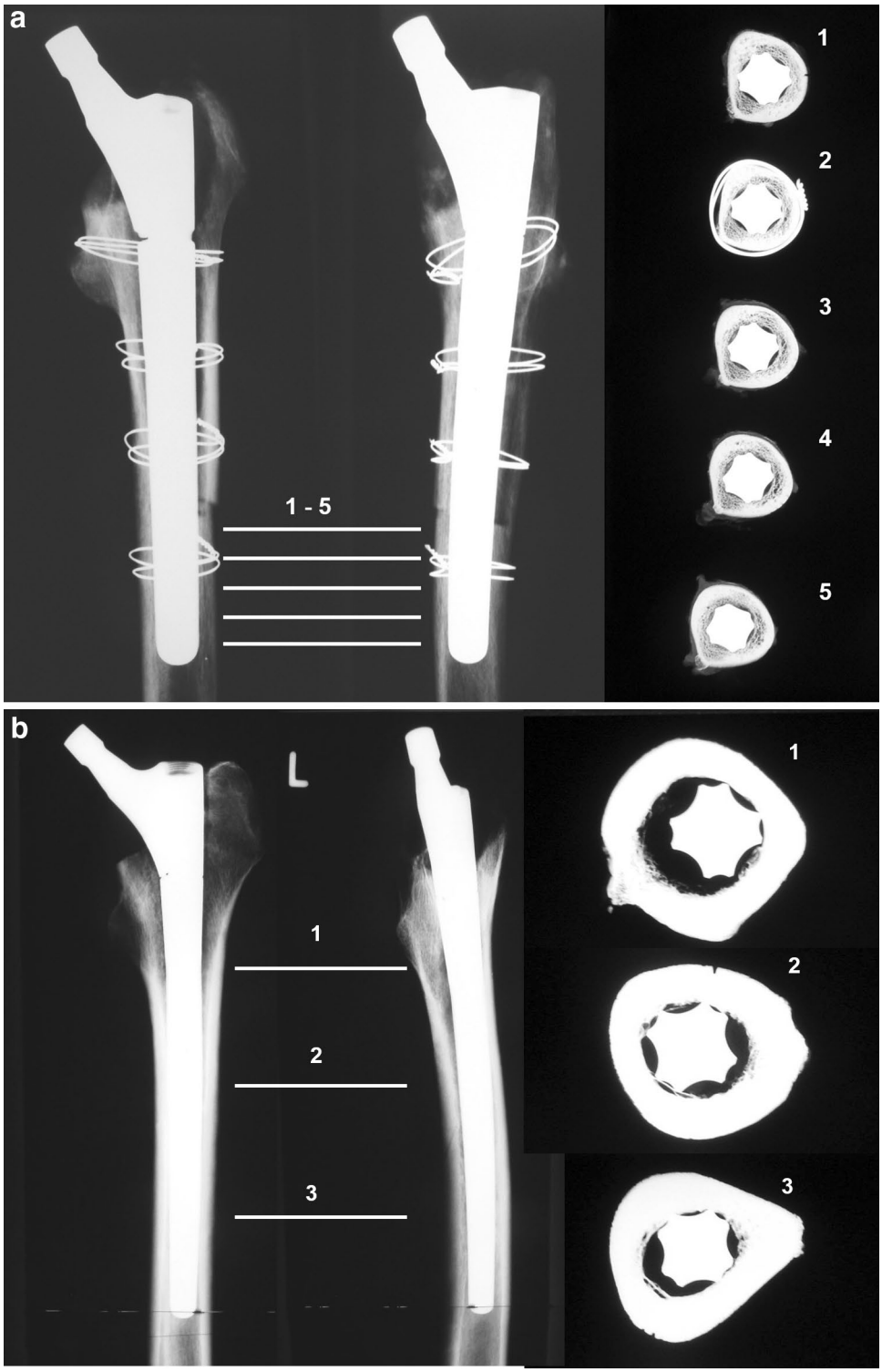

Fig. 1 **a** Illustration of the distal cone-in-cone press-fit anchorage in the femoral isthmus with a transfemorally implanted Revitan Curved stem (taken from Fink et al. [11]). Contact autoradiographs of a transfemorally implanted Revitan Curved stem in two planes (a.p., left image third; lateral, middle image third) with marked levels of the cross-sections (lines with numbering) and contact autoradiographs of cross-sections of the circular fixation zone in the femoral isthmus of the transfemorally implanted Revitan Curved stem (right image third with corresponding numbering from proximal to distal). **b** Illustration of the three-surface fixation of an endofemorally implanted Revitan Curved stem with cone-in-cone fixation in the two distal fixation zones (taken from Fink et al. [11]). Contact autoradiographs of the endofemorally implanted Revitan Curved stem in two planes (a.p., left image third; lateral, middle image third) with marked levels of the cross-sections (lines with numbering) and contact autoradiographs of cross-sections of the three contact zones of the endofemorally implanted Revitan Curved stem (right image third with corresponding numbering from proximal to distal)

be reduced and the risk of breakage of the junction of modular stems lowered because the short distal components are positioned more distal in the femur and so are subject to greater medial bone support [10]. The question now arises as to whether these theoretical considerations concerning short-stem combinations and the observations from cadaver studies can all be translated into a realizable clinical application. Therefore the current study using the modular revision stem Revitan Curved (ZimmerBiomet GmbH, Winterthur, Switzerland) addressed the following questions:

1. Which combinations of distal and proximal stem components were chosen?
2. How long were the contact zones of the distal component in the femur?
3. What were the clinical outcomes of the stem combinations with respect to subsidence and loosening?
4. What complications were observed?

Materials and methods

This study included 245 cementless modular revision stems Revitan Curved that had been implanted between July 2004 and April 2013. Earlier studies reported the clinical outcomes and survival rates of 101 and 66 of these stems [5, 12]. The data were retrospectively evaluated from a prospectively created database concerning stem revisions. Cases were selected from this group in which bone defects of type Paprosky 2 and 3A [13, 14] with a sufficiently long fixation zone in the isthmus of the femur were present, and therefore no additional interlocking screws had been used as an additional fixation technique (as previous studies have shown) [15, 16]. Since stem subsidence is observed within the first two postoperative years [1, 5, 17], cases were chosen with a minimum follow-up of 3 years. Three patients (with 3 revision stems) died from causes unrelated to the revision operation before the 3-year minimum follow-up period was reached, so that a total of 202 stems from 200 patients were examined. This patient cohort comprised 116 females and 84 males with an average age of 69.04 ± 9.09 (44–95) years. The mean follow-up period was 7.44 ± 2.09 years (3–13 years). Informed consent was obtained from all individual participants in the study.

The modular cementless revision system Revitan™ Curved (ZimmerBiomet GmbH, Winterthur, Switzerland) is based on the principles of the Wagner SL-stem and consists of a distal curved component with a thickness ranging from 14 to 28 mm (in 2 mm steps) and lengths of 140, 200 and 260 mm which can then be combined with the proximal component with a length ranging from 55 to 105 mm (in 10 mm steps). The curved distal component has an octagonal cross-section and is tapered at an angle of 2°. The rotational stability of the implant is achieved by the spline peaks of the octagonal form that run along the whole length.

Of the 202 stem revisions, 62 were carried out via the endofemoral approach and 140 by the transfemoral approach (38 of which involved a periprosthetic fracture). Endofemoral implantation was carried out via a posterolateral approach. The transfemoral approach was carried out using a previously published modified Wagner technique [18, 19]. The indication for a transfemoral approach was determined during preoperative planning. First, it was decided whether the stem could be revised with or without osteotomy. The transfemoral approach was always chosen in cases of broken endoprosthesis stems or only partially loosened cementless stems with a coarsely porous structure. In cases of cemented stems, where the cement could not be completely removed using the endofemoral approach, the transfemoral approach was also adopted for the surgical operation. A transfemoral approach was also chosen during preoperative planning when the femoral axis was so deformed by loosening of the prosthesis that it had to be corrected by osteotomy. In these cases a revision without osteotomy would have carried the risk of femoral perforation or fracture. This was especially true for femurs showing obvious osteolysis or thinning of the cortical bone. Furthermore, the periprosthetic fracture, where the implant is loose, can be regarded as a transfemoral approach that has, to a large extent, already been prepared for revision. In septic two-stage revisions, the transfemoral route was used to remove the infected but well-anchored cementless stems or well-cemented stems with septic osteolysis. In these 66 cases, the transfemoral approach was reopened in the second stage to replace the spacer with the Revitan Curved implant.

Post-operatively, the leg was subjected to partial weight-bearing by loading with 10 kg for a period of 6 weeks. Thereafter the weight bearing was slowly increased up to full weight bearing after 3 months. In the case of transfemoral approach, the hip joint was not allowed to be flexed by more than 70° for 6 weeks following the operation to avoid movement of the bony flap.

Radiological evaluations were carried out prospectively before the operation, and 3 months, 6 months, 1 year, 2 years and 3 years post-operatively. Standardized radiographs of the hip joint with the femur in two planes (the antero-posterior view was performed in a standing position) were carried out with a standard tube-to-cassette distance of 115 cm. All measurements in a sequence of radiographs were corrected for magnification using the prosthetic head diameter as a reference as described by Nunn et al. [20]. All radiographic evaluations were performed separately by two experienced examiners. Reliability for the radiographic examination data was high, with an intrarater, intraclass correlation coefficient of 0.98 and of 0.97 between raters, respectively.

Osseous defects were classified according to the system of Paprosky et al. [13, 14]. There were 58 type-2 defects and 146 type-3A defects (all transfemoral approaches had type 3A defects after the osteotomy). The fixation zone of the stem was determined by radiography immediately after the operation according to Fink et al. [5, 11, 15] by analysing the length of direct contact of the stem with the cortical bone at the isthmus in the transfemoral group and of the whole diaphyseal zone for the endofemoral group. Subsidence of the stem was assessed by comparing all the postoperative radiographs using the technique described by Callaghan et al. [21] and McInnis et al. [15]. Hereby, vertical subsidence of the

femoral component was measured as the change in the distance from the inferior margin of the component neck and the most proximal point on the lesser trochanter and from the proximal lateral end of the component body and the tip of the greater trochanter (Fig. 2a, b). Any subsidence greater than 5 mm was classified as significant in accordance with Pattyn et al. [3] and van Houwelingen et al. [6].

Results

In transfemoral implanted stems, fixation was always achieved at the tip of the distal component in the isthmus of the femur (Fig. 2a). A distal component of length 140 mm was selected 137 times (97.9%) and the length 200 mm selected 3 times, the latter being combined 3 times with a proximal component of length 65 mm. In 60 of the 62 endofemoral implanted stems (96.8%), a distal component of length 140 mm was combined with proximal components of different lengths (Fig. 2b). A distal stem component of 200 mm length was used only twice, which was then combined with a proximal component of 55 mm length. Figure 3 shows the length distribution of the endofemoral and transfemoral implanted stems.

The mean length of the fixation zone of the endofemoral implanted stems (i.e. both distal fixation zones of the 3-surface fixation zone as described by Fink et al. [5, 11, 15]) amounted to 7.93 ± 1.48 cm (5.2–10.5 cm) and the mean circular press-fit fixation zone at the tip of stems implanted via the transfemoral approach was 4.11 ± 0.92 cm (3.0–5.6 cm). The mean length of the flap created during the transfemoral approach was 17.6 ± 3.2 cm (11.2–23.0 cm).

The prostheses of 6 patients were explanted as a result of a delayed periprosthetic infection. Four of these patients exhibited new infections 4.5, 5 and 6 years after revision surgery and the 2 others suffered a recurrence of their infections 3 and 5 years after a cementless, 2-stage, septic revision operation. No aseptic loosening was observed within the patient cohort. However, loosening of the acetabular component required revision in 5 cases (4, 5, and 6, 8 and 10 years later).

Significant subsidence of 5 mm or more was observed in two cases (3.3%) following endofemoral implantation (both of 7 mm) and in three cases (2.1%) following transfemoral implantation (of 6.6 and 7 mm). These patients did not exhibit any symptoms. Thus significant subsidence occurred in 2.5% of all cases and all occurred during the first 2 years following revision surgery. The fixation zone of the endofemoral implanted stems was 52 and 60 mm and in the transfemoral implanted stems 30 mm in all three cases.

There was one case of prosthesis junction breakage in a 69-year old patient with a BMI of 36.4, 5 years after an endofemoral stem revision with a Paprosky type-2 defect. The X-ray showed satisfactory osteointegration of the distal component of 140 mm length but there was insufficient medial bone support of the proximal prosthesis component at the calcar of the femur, so that the bending stress point was at the level of the junction of the components. Furthermore, there were two cases of revision of the head component because of recurrent dislocation. These cases have already been described in an earlier publication [5]. Other complications included 5 dislocations that could be treated conservatively and one case of thrombosis. No periprosthetic fractures were observed.

Discussion

This study was designed to investigate whether the consistent use of short-stem combinations is possible for revision hip arthroplasty with an intact isthmus of the femur, and to determine the outcomes of using these short-stem combinations. We could show that with an intact isthmus, i.e. with defect types of Paprosky 2 and 3A, short-stem combinations with the short distal component of 140 mm length can be used on a regular basis to achieve reproducibly good results with regard to aseptic loosening and subsidence of the stem. This corresponds to the observations of de Menezes et al. [22], which showed that in 100 straight Revitan stems implanted via the transfemoral approach, the subsidence rate was significantly lower in short stems with fixation at the tip of the prosthesis stem than in longer stems. Moreover, Russell et al. [23] concluded in a biomechanical study that 1.5–2.5 cm cone-in-cone fixation at the tip of a tapered revision stem seems to result in sufficient stability. We showed for the clinical use of the Revitan Curved stem, that the minimum fixation zone seems to be 3 cm [5, 15].

The use of longer stems does not lead to a cone-in-cone fixation with a longer fixation zone, but rather to a fixation zone of the same length as with shorter stems, but further away from the tip of the stem (Fig. 4). The subsidence rate of 2.5% we observed in the present study and the aseptic loosening rate of 0% are both within the range of the best results reported in publications on modular revision stems, in which, as a rule, significantly longer tapered revision stems were used [2–8]. Thus, the use of short revision stems leads to rates of subsidence and loosening that are at least as low as those reported for long revision stems.

The use of shorter stems has the advantage that fixation takes place in the isthmus of the femur, so that the stem does not extend beyond this region which, in turn, results in a reduced risk of periprosthetic fracture. In fact, our study clearly showed that the combination of shorter stems with the consistent use of the transfemoral approach in femurs at risk of fracture was associated with a total lack of periprosthetic fractures. Furthermore, the use of short revision stems

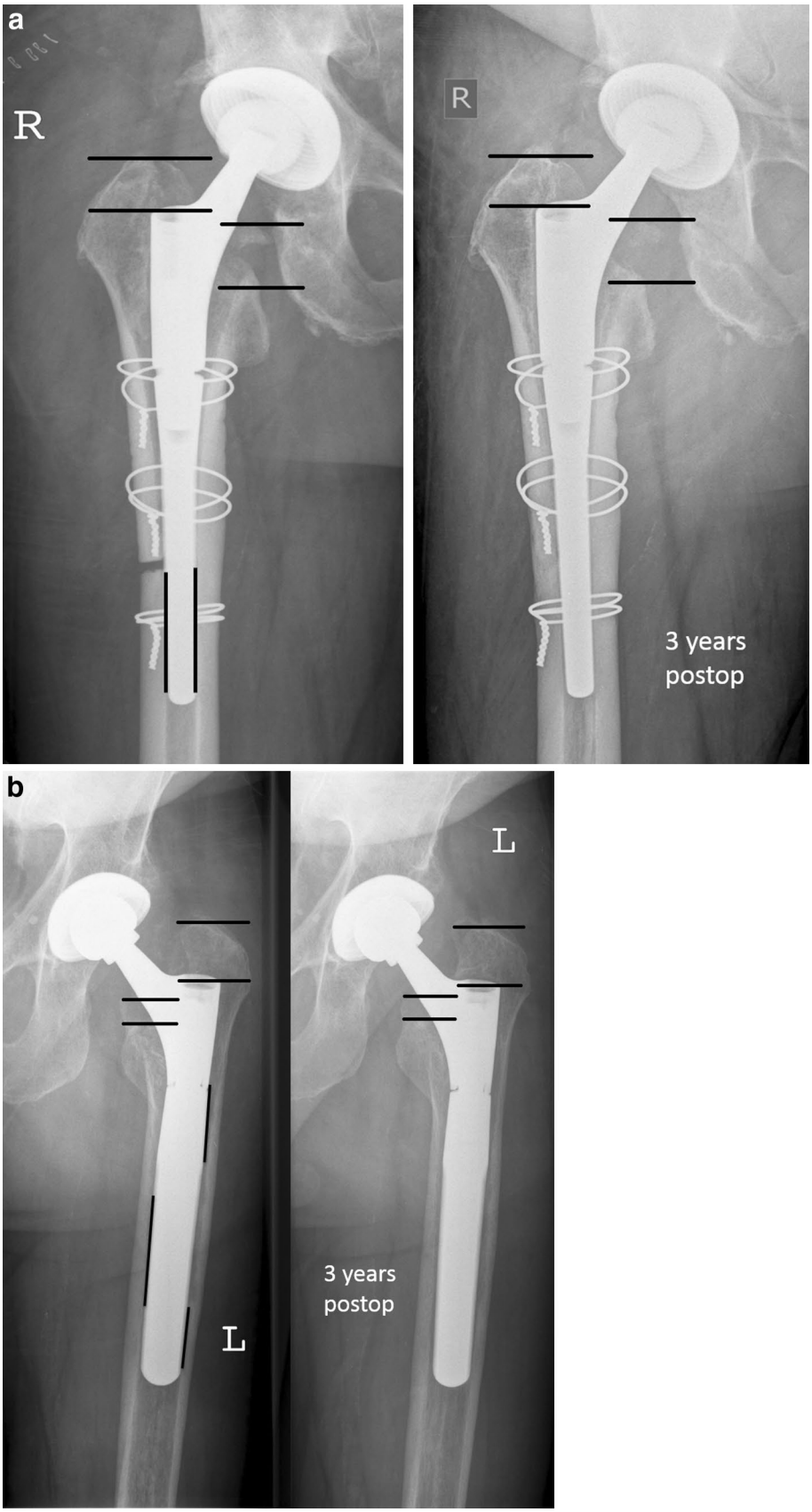

Fig. 2 **a** Postoperative X-ray of a transfemorally implanted revision stem Revitan Curved with distal fixation zone marked in the isthmus of the femur as well as vertical lines showing the method of measuring possible subsidence. **b** Postoperative X-ray image of an endofemorally implanted revision stem Revitan Curved with fixation zones of the three-surface fixation marked in the femur as well as vertical lines showing the method of measuring possible subsidence

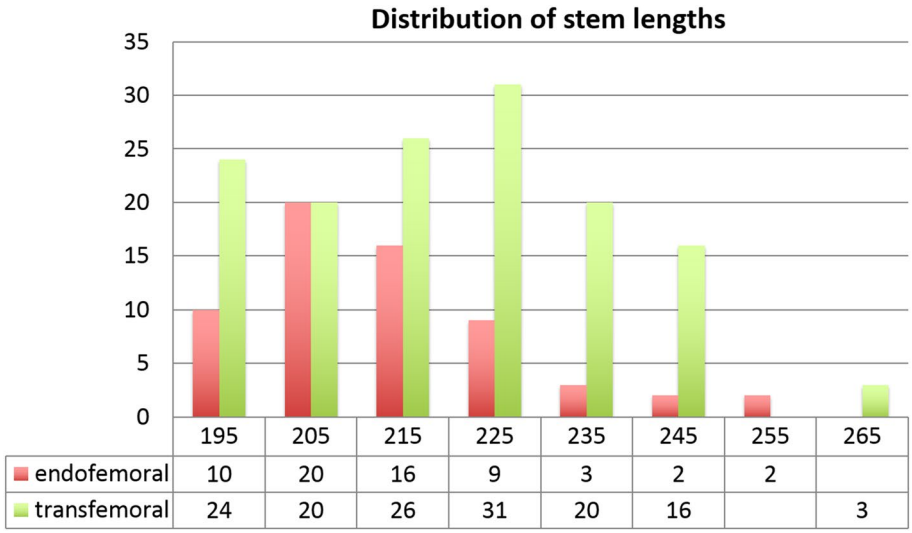

Fig. 3 Distribution of stem lengths of the endofemoral and transfemoral implanted Revitan Curved revision stems

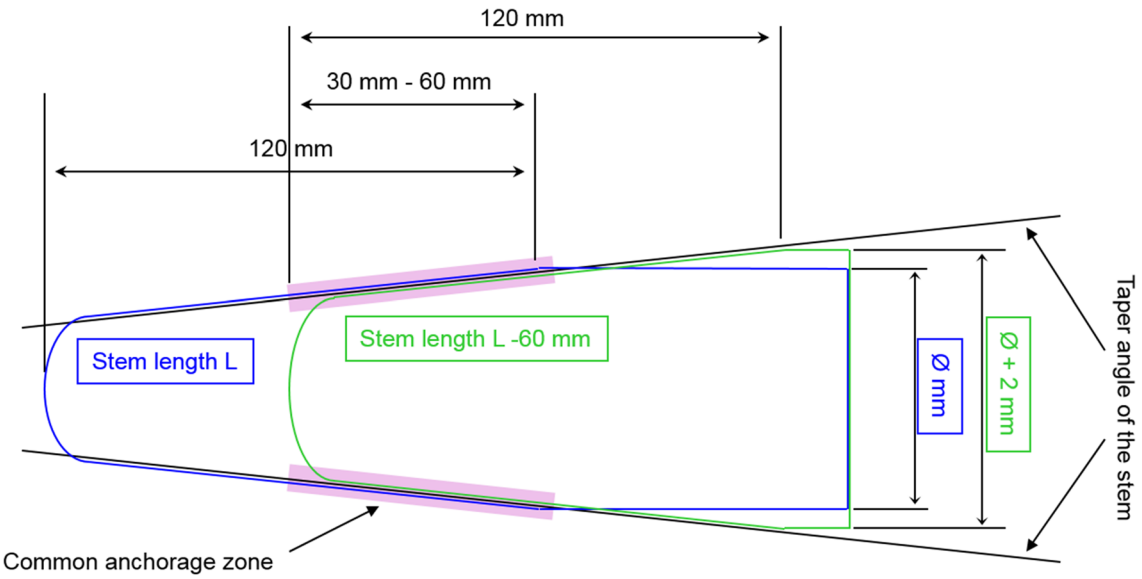

Fig. 4 Schematic diagram of the cone-in-cone fixation zone at the tip of a shorter revision stem and of a longer revision stem above the tip of the stem. The taper (degree of the taper) has been graphically increased here for purposes of better illustration

has the advantage that, if revision surgery is necessary, (e.g. due to a periprosthetic infection), the implant can be revised more easily than long, osteointegrated revision stems. In addition, if a transfemoral approach is necessary, it is possible to remove the revision stem without opening the isthmus completely, which, in turn, has advantages for a reimplantation of a new stem in a two-stage procedure.

This study has some limitations. One is the relatively short period of minimal follow-up observation. However, we suggest that a minimum of 3 years is sufficient for questions posed by the current study. Many other similar studies have shown that subsidence and early loosening occur within 2 years of implantation [1, 5, 17].

In conclusion, it can be said that when the isthmus of the femur is intact, a procedure that involves implanting a modular revision stem with a taper of 2° and the use of short-stem combinations that do not extend beyond the isthmus, regularly leads to reproducibly good outcomes with regard to subsidence and aseptic loosening.

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Compliance with ethical standards

Conflict of interest The authors declare that one of the authors is a consultant of ZimmerBiomet, but no author was supported for this paper.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent Informed consent was obtained from all individual participants included in the study.

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