Joint line position in revision total knee arthroplasty: the role of posterior femoral off-set stems

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ABSTRACT
Background: Elevation of the joint line frequently occurs in revision total knee arthroplasty (RTKA) because of a wider flexion space than extension space. One solution to balance this flexion-extension space involves the introduction of couplers between the stem and femoral components, and the use of posteriorly offset femoral stems that we hypothesized would improve gap balancing and facilitate joint line restoration.

Methods: We retrospectively reviewed a selected series of 43 RTKA. Postoperative joint line height was subtracted from intended height using postoperative lateral radiographs. The value was negative if the joint line position was lowered, and positive if raised.

Results: Forty knees were followed for a mean of 3.5 years. Mean postoperative joint line position change from intended position was 1.5 mm (range −2.5–7.5 mm). In 28 knees (70%), the joint line position was restored to within ±2 mm of the intended position; in eight knees (20%), from 2–4 mm; and in four knees (10%), >4 mm. Joint line position was raised in 32 knees (80%) and lowered in eight (20%). In the offset stem knees, the intended joint line position was 0.9 mm (range −1.2–3.4 mm) as compared with 3.2 mm (range −2.5–7.5 mm) for the straight stem knees.

Conclusions: A coupler system between the femoral stem and femoral component restored the joint line in 70% of cases. The posterior offset stem provided increased posterior condylar offset, addressed the wider flexion space, provided better positioning of the stem, and restored the joint line.

Level of evidence: Therapeutic Study Level IV
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1. Introduction

In revision total knee arthroplasty (RTKA), elevation of the joint line is a frequent occurrence associated with lower clinical and functional outcomes[1–5]. The basis of this evidence is rooted in the difficulty of balancing the flexion-extension space that, in most cases, results in a proximalization of the distal femur to compensate for the disproportionate wider flexion space [6]. To avoid joint line elevation and fill the flexion space, some solutions have been previously posited. One solution is the use of a larger femoral component; however, a larger component has a wider mediolateral diameter resulting in soft tissue impingement and pain. The alternative method is to bring the femoral component as posterior as possible, but the use of a femoral stem dictates the anteroposterior position of the implant and results in anterior seating of the femoral component and also increased flexion space [6]. Another solution is the use of a smaller cemented stem that has less of a tendency of forcing the femoral component anteriorly thus allowing positioning of the femoral component slightly posterior and in slight flexion to compensate for the wider flexion space.

Recently, a new solution has been suggested to balance the flexion-extension space in RTKA via the introduction of couplers between the stem and the femoral component and, more predominantly, the use of posteriorly offset femoral stems that restore the posterior femoral condylar offset (PFCO). This method should provide a better flexion-extension soft tissue balance [7,8]. In this way, the femoral component may be displaced as posteriorly as necessary to balance the flexion gap and avoid joint line elevation.

To date, there are no reports in the literature describing the accuracy of restoration of the joint line with this new system. Thus, the purpose of our study was to retrospectively analyze joint line restoration and the clinical outcomes in 43 RTKA patients treated using modular offsets of variable length and direction. We hypothesized that the posteriort offset femoral stems would provide a better gap balancing and therefore, in turn, facilitate joint line restoration.

2. Materials and methods

We retrospectively reviewed the results of a selected series of 43 total knee revisions performed in 41 patients with the modular revision system (Legion; Smith & Nephew, Memphis, TN) at the authors’ institution from April 2007 to December 2011. All patients required revision of the tibial and femoral components with or without patellar revision.

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Patients who had indications for revision included those with aseptic loosening, arthrofibrosis, femoral component malposition, and second-stage procedure for infected TKA. Contraindications for revision were for patients with severe instability or periprosthetic fractures. All patients or their legal representative signed informed consent forms that were approved by the Institutional Review Board.

The revision surgeries were performed for the following reasons: aseptic loosening (29), infection (10), femoral component malposition (2), and stiffness with pain (2). This operation represented the first revision procedure to the knee in 33 cases (31 patients). Ten knees had undergone one previous surgery consisting of the complete removal of the component for reasons of infection.

2.1. Surgical technique

All procedures were performed by two of the authors (M.I., R.C.). In each procedure, the surgeon used the same modular knee revision system (Legion; Smith & Nephew, Memphis, TN) which provides press-fit straight stems that can be connected to the femoral and tibial components with or without a 2 mm, 4 mm or 6 mm offset displacement in a 360° arc. The stems are available in 80 mm, 120 mm, 160 mm, and 220 mm lengths, with a 2 mm increment in 10–24 mm diameters.

A pneumatic tourniquet was applied around the upper thigh and inflated to approximately 250 mmHg in all cases. The tourniquet was released after the cement had set to allow hemostasis before wound closure. All operations were performed through the previous approach with patellar eversion.

The reconstruction was commenced by re-establishing the proximal tibia, because any change in the tibial height would affect the extension and flexion symmetrically. The goal of the tibial reconstruction was to position the cutting blocks. The thickness of the extension space was measured using spacer blocks, and, where necessary, one or more augment blocks in the distal femur were used to establish extension space. The knee was then flexed to approximately 90° and the flexion space was evaluated. Rotational positioning of the femoral component was guided by the epicondylar axis. In cases where the flexion space was too loose, the knee was stabilized by increasing the femoral component size, applying posterior augments and simultaneously changing the femoral rod offset. The offset option allowed for optimized flexion space relative to the extension space so that the dimensional change occurs only in flexion, thereby avoiding sacrifice of the joint line (Fig. 2).

All tibial and femoral components were positioned with cement fixation on the non-stemmed portion of the implant in the metaphysis and using the press-fit fixation of the titanium stems. The intramedullary canal was reamed until a tight press-fit was obtained in the diaphysis. The length of the stem was chosen so that there was adequate diaphyseal engagement past the metaphyseal–diaphyseal junction. Metal augment blocks were used as needed on both the femoral and tibial components to address bone defects, balance the flexion and extension spaces, and restore the joint line position. The orientation of the femoral offset was recorded intraoperatively. A posterior offset femoral stem was used in 27 knees (62.7%) and a straight stem in 16 knees (37.3%). In all cases we used constrained tibial insert.

2.2. Postoperative evaluation

We performed clinical and radiographic assessments before surgery and at the latest follow-up. The Knee Society rating system was used for
the clinical evaluation [10]. Radiographs were taken preoperatively, postoperatively, 4 weeks postoperatively and then yearly after surgery. The images included an AP view (weight bearing) and a true lateral view with the femoral condyles overlying each other. The height of the reconstructed joint line was measured from the lateral radiographs. The position of the joint line was determined as the distance from a line through the distal aspect of the femoral condyles perpendicular to the long femoral axis and the upper level of the tibial tubercle. Postoperative joint line height was subtracted from intended height to obtain the change in millimeters from the intended height (Fig. 3); the value was negative if the joint line position had been lowered, and positive if it had been raised.

Orientation of the intramedullary femoral stem within the femoral canal was measured by the angle between the anterior cortex of the femoral shaft and the axis of the stem. Flexion of the stem was defined as a positive value, while recurvatum was defined as a negative value.

Preoperative and postoperative posterior condylar offset was evaluated on true lateral radiographs by measuring the maximal thickness of the posterior condyle projected posteriorly to the tangent of the posterior cortex of the femoral shaft. A ratio between the posterior condylar offset and implant anteroposterior thickness was determined.

Radiolucent lines were measured in millimeters in each designated zone for the femoral and tibial prostheses in the coronal and sagittal planes according to the Knee Society rating system.

2.3. Data analysis

All measurements were performed by a single observer on digital 8-bit grayscale TIFF images with EazyDraw 10.4 software (Dekkorpa Optics, Poinette, WI). Intraobserver error was evaluated by repeating the radiographic measurements on a single patient, which resulted in standard errors of 1.37% for intended joint line, 1.23% for measured joint line and 1.78° for stem angle [11]. Statistical analysis was performed using Wilcoxon signed rank test to analyze preoperative to postoperative changes in clinical scores and joint line measures. We compared the postoperative clinical scores, joint line, stem inclination and condylar offset of straight and offset femoral stems using an independent sample t test. All statistical analyses were performed using Stata™ Version 6.0 (StataCorp, College Station, TX).

3. Results

The patients in this series were followed for a mean of 3.5 years (range 0.7–5.5 years). Three patients (three knees) were lost to follow-up and one patient died at 2 months after revision for reasons unrelated to the surgery. In these patients, post-operative X-rays were not available and the patients had to be excluded from the study. Overall, 40 knees (38 patients) were available for inclusion in the current study: 25 (62.5%) with posterior offset femoral stem and 15 (37.5%) with a straight stem. The mean age of the patients at the time of the revision surgery was 68.8 years (range 43–87 years). Twenty-nine knees were from females and 11 were from males.

3.1. Clinical scores

At the final follow-up, the knee score improved from an average of 33 points (range 21–45) to 83 (range 62–95) (p = 0.09). The functional score improved from 31 points (range 0–55) to 82 points (range 55–98). The mean total flexion arc improved from 54° (range 10–95°) preoperatively to 108° (range 55–140°) at the time of the latest follow-up. There was no statistically significant difference in the postoperative clinical scores between straight and offset femoral stems.

3.2. Joint line

The mean postoperative joint line position change from the intended position was 1.5 mm (range −2.5–7.5 mm). In 28 of the 40 knees (70%) the postoperative joint line position was restored to within ± 2 mm of the intended position; in 8 knees (20%), from 2 to 4 mm; and in 4 knees (10%), more than 4 mm. The joint line position was raised in 32 knees (80%) and lowered in 8 (20%).

In the offset stem knees, the intended joint line position was 0.9 mm (range −1.2–3.4 mm) compared with the straight stem knees where the position was 3.2 mm (range −2.5–7.5 mm). There was a statistically significant difference in the restoration of the joint line between the straight and offset femoral stems (p = 0.046).

3.3. Stem inclination

The mean stem inclination was 1.47° (range −2–9.5°). The mean stem angle we observed with straight stems (2.99 ± 1.62°) was higher compared with the mean value we observed with offset stems (1.23 ± 1.43°). The difference between the two groups is statistically significant (p = 0.037).

3.4. Condylar offset

The mean postoperative posterior condylar offset ratio was 41% (range 29–56%). A higher posterior condylar offset ratio was observed in knees with an offset stem (47%) compared with knees with a straight stem (37%). The difference was statistically significant (p = 0.042).

3.5. Radiolucency

We observed no postoperative instability or patellar maltracking. One patient developed an infection at 6 months and was treated with a successful two-stage resection and re-implantation. The mean scores for survival were 1.3 (0 to 4) for the femoral and 0.7 (0 to 2) for the tibial components. None of the knees showed progression of these lucencies over time. There was no statistically significant difference in radiological lucency between the straight and offset femoral stems.

4. Discussion

A frequent complication after RTKA is elevation of the joint line, and it is often associated with a decreased range of motion, lowered extensor strength, anterior knee pain, patellar instability and mid-flexion instability [1–5,12,13]. Commonly in RTKA, there is a larger flexion space after component removal compared with the extension space. This occurs because, in revision surgery, the capsuloligamentous structures that are effective in extension are usually much better preserved than those that control the knee in flexion. To obtain a balanced flexion and extension gap, the surgeon may therefore decide to fill up the flexion space by using a thicker insert and perform a compensatory increase of the extension space by proximalizing the femoral component, resulting in elevation of the joint line [6]. Several studies have quantified that 50–80% of RTKA patients have an elevated joint line [1–5].

The use of straight diaphyseal femoral fixation stems may further increase this tendency towards an excessive flexion gap, since these

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Fig. 3. Pre operative X-ray of one case of aseptic loosening (left). Post operative X ray show the use of posterior femoral offset to manage the large flexion space (right).
stems tend to position the femoral component anteriorly and increase the flexion space [6]. To provide stability in flexion and avoid joint line elevation, the surgeon may address the problem by restoring adequate posterior condylar offset. Posterior offset can be increased with the use of an oversized component, a flexed stemmed implant or a shorter cemented stem that allow displacement of the condylar component posteriorly, or a posterior offset stem coupler. However, the use of an oversized component may cause soft tissue impingement, resulting in pain. Flexion of the stem may result in anterior bony impingement between the proximal anterior stem tip and the anterior femoral cortex, which may also contribute to end-stem pain. The use of an offset coupler permits restoration of posterior condylar offset with central stem positioning within the femoral canal.

We therefore asked if the use of a posterior femoral offset stem could allow an appropriate balance of the flexion-extension space and avoid joint line elevation in RTKA. Increased posterior condylar offset and improved alignment of the stem within the intramedullary canal with modular offset of the femoral stem as compared with the modular straight stem was demonstrated by Brilhault and Ries in a series of 126 RTKA [14]. Restoration of the posterior condylar offset with a modular stem avoided the need for resection of any portion of the distal femur and its correlates to allow restoration of the joint line position and stability after RTKA. Furthermore, Mahoney et al. reported an accurate restoration of the joint line within 5 mm of the desired anatomic joint position in a consecutive series of 22 RTKA using modular femoral offset stems.

Some limitations were identified in this study and need to be considered when interpreting these data. First, it was a nonrandomized study of selected rather than consecutive cases, with a potential for patient selection bias. Second, a control group was not available for direct comparison, so we could not show that a non-modular system would have given the same results. We therefore relied on comparisons to published reports to judge the relative adequacy of this implant. Third the small series in this study is under powered to detect meaningful clinical difference or to permit subgroup analyses, nonetheless we are dealing with knee revisions and this is one of the largest series of posterior femoral offset stems. In our series, the joint line was restored within ± 2 mm of the intended position in 70% of cases using a coupler system between the femoral stem and femoral component. The posterior offset stem provided increased posterior condylar offset, balancing a wider flexion space, allowing better position of the stem into the femoral canal, and restoring accurately the joint line. Despite improvements in radiographic parameters, the use of posterior femoral offset does not provide better clinical results. However accurate restoration of the joint line is essential for more physiological range of motion and ligamentous stability during all range of motion. Furthermore, Partington et al. described that only an elevation of the joint line more than 8 mm may have clinical consequences and reduce the clinical score.

To our knowledge, this is the first study where the impact of the new modularity revision system has been evaluated in restoring the joint line position. The desired joint line position before surgery has been evaluated with the use of a ratio between the size of the individual and the femoral width. Previous studies have measured the intended joint line position without considering the large variation depending on the size of the individual. In RTKA, with a flexion space larger than the extension space, we recommend positioning the femoral component as posterior as possible using of a posterior offset-stem to avoid joint line elevation.

**Conflict of interest**

The authors, their immediate family and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article. The authors declare that there are no outside funding or grants received for this study.

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In light of the Italian law, authors are not required to ask for approval of Institutional Review Board or Ethical Committee for this type of study. However, each author certifies that his or her institution has approved the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research.

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