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Influence of stem length on component flexion and posterior condylar offset in revision total knee arthroplasty

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ABSTRACT

Background: Hyperextension of the femoral component and excessive slope of the tibial component may delay the cam–post engagement in semi-constrained revision total knee arthroplasty (TKA). Further, it may compromise the posterior condylar offset (PCO). No prior study has determined whether a short 50-mm stem, or longer stems (100 mm and 150 mm) lead to less hyperextension of the femoral component or excessive slope and its influence on the posterior condylar offset.

Methods: Flexion/extension of the femoral component with respect to the sagittal femoral anatomic axis of the distal diaphysis (SFAA) and the tibial slope were measured from rotationally controlled lateral X-rays of 126 consecutive patients with a one- or two-stage revision TKA. Stems of 50 mm, 100 mm and 150 mm were analyzed. Further, reconstruction of the PCO with respect to stem length and component flexion was evaluated.

Results: The average flexion (+) or extension (−) of the femoral component in the sagittal distal anatomical axis was $-4.1° \pm 2.8°$ (mean ± std) for components, which have been implanted with 50-mm stems and $1.1° \pm 1.1°$ for components with 100- or 150-mm stems, respectively ($P = 0.0001$). The average slope of the tibial was $2.6° \pm 1.5°$ for tibial trays with 50-mm stems, which was more than the $1.3° \pm 1°$ for trays with 100-mm stems ($P = 0.0001$). The average PCO ratio was 0.8 ± 1.7 for femoral components with 50-mm stems, which was less than the 1.0 ± 1.7 for trays with 100-mm stems ($P = 0.0001$).

Conclusions: Because 50-mm stems resulted in about three degree hyperextension of the femoral component with respect to the SFAA compared to 100-mm or 150-mm stems, the longer stems do not alter the natural femoral flexion and a delay of the cam–post engagement may be avoided. Further, a better reconstruction of the PCO may be archived with the use of longer stems.

1. Introduction

With increasing numbers of primary total knee arthroplasties (TKAs), numbers of revision TKAs are increasing as well [1]. The major reasons for revision TKA are still postoperative instability and altered knee kinematics [2]. The outcome in revision knee revision TKA is inferior compared to TKA [3]. In revision TKA, components are attempted to be placed perpendicular to the mechanical axis. However, in the sagittal plane the ideal component position is not clearly defined yet. It is known, that flexion/extension of the femoral component and the tibial slope in patients treated with one-stage or two-stage revision arthroplasty is crucial, because

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there is a concern that hyperextension of the femoral component and excessive tibial slope delays the cam–post engagement in semi- or fully constrained revision TKAs [4]. Abnormal knee kinematics are associated with postoperative patient dissatisfaction and altered implant survival. Placing the femoral component in hyperflexion might lead to an anterior impingement of the components as well [5]. A greater reduction in tibial slope after TKA is associated with less paradoxical medial femoral condylar movement, as well as less instability [6]. Further, it was shown previously that five degrees of tibial slope may cause a delay of the cam -post engagement of 18° higher compared to a neutral slope [4]. The important role of the posterior condylar offset (PCO) in primary TKA has been reported many times before [6–8]. Three recent studies report an inferior outcome in revision knee arthroplasty, if the PCO is reduced [9–11]. The reconstruction of the PCO is often tricky due to posterior bone loss. A reduction of

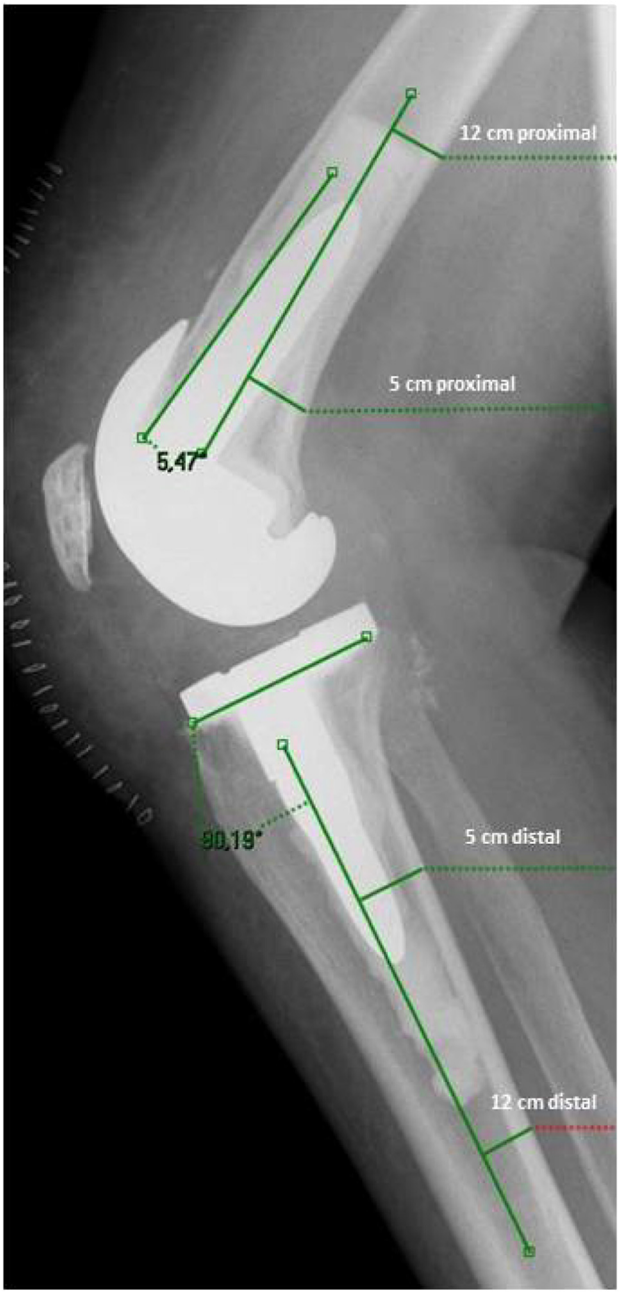

Figure 1. The flexion–extension of the femoral component was measured with respect to the sagittal femoral anatomic axis (SFAA). The SFAA bisects a trapezoid best fit to the distal femoral diaphysis and corresponds to the portion of the femur typically imaged by a lateral radiograph of the knee. The tibial slope was measured with reference to the anatomical axis of the tibia.

the PCO might lead to flexion instability and a reduced range of motion. It was the intention of this study to evaluate the hypothesis that revision TKA performed with 50-mm stems result in more average extension of the femoral component with respect to the sagittal femoral anatomic axis of the distal diaphysis (SFAA) than 100-mm or 150-mm femoral stems and its influence on the PCO ratio. Furthermore, we hypothesized that short tibial stems do not lead to excessive tibial slope.

2. Methods

A total of 126 consecutive revision TKAs with one specific implant were retrospectively analyzed to perform radiographic measurements between October 2014 and April 2016. Included were all patients receiving a one- or two-stage revision in that time period. The quality of the X-rays was analyzed according to Al-Hadithy et al. [12]. Thirty-nine cases were excluded due to inferior quality of the radiographs. Eighty-seven cases were analyzed in this study. In all cases the Stryker Triathlon Total Stabilizer (TS) System was used with a TS or posterior stabilized (PS) onlay. During the surgery, the implants were removed as carefully as possible in order to preserve maximal bone stock. At that stage it was decided whether the collateral ligaments were sufficient. If intact, a TS TKA was used. A pin was inserted into the medial epicondyle, which was used as a reference point to ensure that the joint line and the PCO were restored intra-operatively with the revision prosthesis, using distal and posterior augments if appropriate. The stem length was up to the personal preference of the surgeon. All stems were cemented and aligned intramedullary. All distal cuts were re-cut and distal augments were used in all cases.

In 18 cases, a 50-mm stem was used on the femoral side and 69 received a 100- or 150-mm stem on the femoral side. No offset adapters were used on the femur. All 50-mm stems were cemented. The longer stems were either hybrid fixed or full cemented. Digital X-rays were used for the preoperative planning. The Carestream VuePACS software (Carestream Health Inc.) was used for all measurements.

The flexion–extension of the femoral component was measured with respect to the SFAA. The SFAA bisects a trapezoid best fit to the distal femoral diaphysis and corresponds to the portion of the femur typically imaged by a lateral radiograph of the knee [13] (Figure 1).

The measurement of the PCO was conducted as described by Bellemans et al. before and a ratio was calculated as described by Johal et al. [8,14]. On true lateral radiographs the maximal thickness of the posterior condyle is used as it projects posteriorly to the tangent of the posterior cortex of the femoral shaft. This measurement technique was used in other studies previously to correct for radiographic magnification and prosthesis sizing [9,15]. The tibial slope was measured with reference to the anatomical axis of the tibia on short leg radiographs (Figure 1).

A sample size calculation was conducted. Assuming that longer stems were used three times more than 50-mm stems, the group size differs. Within first test measurements, an extension of the 50-mm stems of one degree (±1°) was expected. The 100-/150-mm stems were expected to show 0° (±1°). Due to a lack of comparable literature, further orientation points were missing. After a power analysis, a total of 60 patients was calculated. Accordingly, there are 15 or 45 patients for both groups.

All authors, except for H.W. performed the measurements. The reproducibility of the measurements was determined by calculating the intra-correlation coefficient (ICC). The software Prism 6 (Graphpad Software Inc.) was used for statistical analysis. A D'Agostino and Pearson normality test was performed. A Mann–Whitney test was conducted to compare the unpaired data. The *P*-value was set to 0.05. All data are presented as mean and standard deviation.

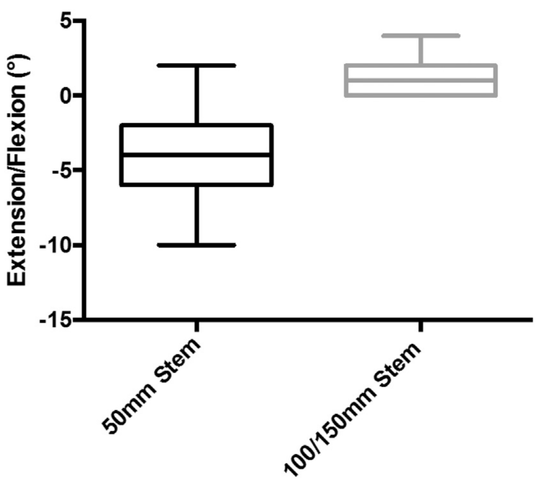

Figure 2. The average flexion (+) or extension (−) of the femoral component in the sagittal distal anatomical axis was −4.1 ± 2.8° for components, which were implanted with 50-mm stems. The average flexion of the femoral component in the sagittal distal anatomical axis was 1.1 ± 1.1° for components with 100- or 150-mm stems ($P = 0.0001$, $P = 0.0001$, respectively).

3. Results

The ICC of 0.91 for measuring the flexion of the sagittal anatomic femoral axis, the ICC of 0.90 for the PCO ratio and the ICC of 0.94 for measuring the slope of the tibial component showed very high (first class) reproducibility.

The average flexion (+) or extension (−) of the femoral component in the sagittal distal anatomical axis was −4.1 ± 2.8° for components, which have been implanted with 50-mm stems. The average flexion of the femoral component in the sagittal distal anatomical axis was 1.1 ± 1.1° for components with 100- or 150-mm stems ($P = 0.0001$, $P = 0.0001$, respectively; Figure 2). The average tibial slope was 2.6 ± 1.5° for tibial trays with 50-mm stems, which was more than the 1.3 ± 1° for trays with 100-mm stems ($P = 0.0001$). The average PCO ratio was 0.8 ± 1.7 for femoral components with 50-mm stems, which was less than the 1.0 ± 1.7 for components with 100-mm stems ($P = 0.0001$; Figure 3).

4. Discussion

The most important finding of this study is that short (50-mm) stems may lead to hyperextension of the femoral component with respect to the distal anatomical femoral axis. Further, hyperextension of the femoral component may lead to a reduced PCO ratio. Concerning the tibial slope, longer stems are more reliable for reducing the slope to zero. The components may end up hyperextended, because the stem does not reach the diaphysis. Thus they move into hyperextension while the cement gets hard.

There is a concern that hyperextension of the femoral component delays the cam–post engagement in semi- or fully constrained revision TKAs. Fitzpatrick et al. [16] evaluated the cam–post engagement of different PS TKA designs. Depending on the manufacturer, there are significant differences concerning the degree of flexion where cam and post engage. Ideally implanted, certain PS designs engage at 50° of flexion or even later. In combination with a femoral hyperextension or excessive tibial slope, the cam–post engagement would be delayed to 60° of flexion or later [4]. The consequence could be a mid-flexion anterior–posterior instability or altered force introduction to the post with increased wear. Banks et al. reported the mechanism of anterior impingement damage in TKA as a result of a hyperflexion of the femoral component [5]. Hyperflexed components were not observed in this study.

Abnormal knee kinematics are associated with postoperative patient's dissatisfaction and altered implant survival. Instability is still one of the major reasons for revision TKA. A higher tibial slope may delay the cam–post engagement in mid flexion. Thus, a mid-flexion anterior–posterior instability may be the effect. Piazza et al. reported that tilting the tibia by five degrees leads to a delayed cam–post engagement of 18°. In this study, the tibial stem length did not have a big influence on the tibial slope.

The data in this study demonstrate that a hyperextension of the femoral component may lead to a reduced PCO ratio. Three recent studies revealed that the PCO is an independent outcome predictor in revision TKA [9–11]. Johal et al. reported in 2012 that the natural PCO ratio is 0.8 [14], which is the same as we measured preoperatively after primary TKA. Interestingly, Clemet et al. [9] revealed superior results for a PCO ratio of 1.04 compared to 0.86 in a recent study, where two revision TKA systems were compared. This might be due to an opening of the flexion gap when the posterior cruciate ligament is resected in revision TKA. Thus, an increased PCO ratio compared to natural might be achievable.

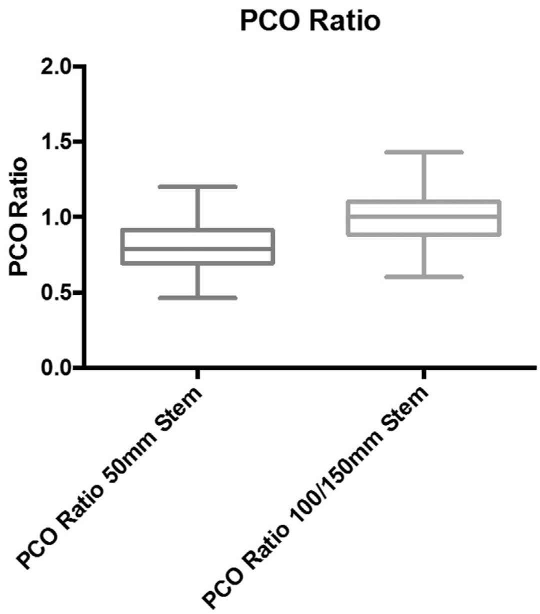

Figure 3. The average PCO ratio was 0.8 ± 1.7 for femoral components with 50-mm stems, which was less than the 1.0 ± 1.7 for components with 100-mm stems ($P = 0.0001$).

This study has limitations. Due to the low number of patients, especially in the 50-mm femoral stem group, only very limited valid statements can be made. A larger number of patients is necessary to confirm or refute the statements. Further, no clinical data is presented in this study. Thus, no conclusion can be drawn concerning the correlation of femoral stem hyperextension and clinical outcome.

5. Conclusion

This study revealed that 50-mm stems resulted in about three degree hyperextension of the femoral component with respect to the SFAA compared to 100-mm or 150-mm stems. In particular, the hyperextension range was significantly larger than for longer stems indicating a lower reproducibility of the correct sagittal alignment. Longer stems do not alter the natural femoral flexion and a delay of the cam–post engagement may be avoided. Further, a better PCO ratio may be archived.

Conflict of interest

All authors have no conflicts of interest to declare.

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