Comparison of cross-sections of different femoral components for revision total knee replacement

Carmen Zietz, Philipp Bergschmidt, Andreas Fritsche, Daniel Kluess, Wolfram Mittelmeier, Rainer Bader
Department of Orthopaedics, University of Rostock, Rostock, Germany

ABSTRACT

Purpose. To compare the inner contour of the femoral component of 10 total knee replacement (TKR) designs for possible exchange in use.

Methods. Inner contours of the femoral components of 10 cemented, cruciate-retaining TKR designs (e.motion, Genesis, Genia, Innex, LCS, Multigen Plus, NexGen, PFC, Scorpio, Vanguard) were scanned and reconstructed to 2-dimensional contours. Their cross-sections were compared by superimposition and aligning at the distal and anterior cuts. The patellar notch and outer contour were not analysed.

Results. The maximum deviation was 5 mm in the posterior and posterior oblique cuts and 10 mm in the anterior oblique cut. Based on similarity of the inner contour, LCS and Innex was classified as group I, e.motion, Genesis, Scorpio, Vanguard, and Multigen Plus as group II, and Genia, NexGen, and PFC as group III. All 2 designs in group I were not compatible with the other 8 designs. Four of the 5 designs in group II showed good compatibility. All 3 designs in group III significantly differed in the posterior and oblique cuts.

Conclusion. A standardised inner contour of the femoral component can increase compatibility of different TKR systems in revision surgery and reduces the extent of bone resection.

Key words: knee; total knee replacement; revision surgery; implant design

INTRODUCTION

Total knee replacement (TKR) is increasingly popular among younger patients.1-4 Owing to limited survivorship of implants, the number of revision surgeries increases.5,6 Various TKR designs are available; their femoral components are similar in basic design, but the angles and lengths of the patellofemoral shield and their cross-sections differ, particularly the distal and posterior cuts of the inner contour in relation to the femoral axis. These differences are associated with gender, kinematics (e.g. anterior translation), and guidance of the patella...
on the femoral component. Different implants use different bone-cutting devices. The proficiency of surgeons in different surgical tools and techniques affects treatment outcomes. A standardised cutting device can shorten the surgeon’s learning curve for different systems, and reduce costs in developing instruments.

In revision surgery, segmental bony defects of the distal femur and proximal tibia as well as soft-tissue alterations (particularly those affecting the extensor apparatus) necessitate good surgical skills. Standardisation of cutting devices may simplify preoperative planning and reduce bone loss by minimising bone re-resections. We compared the inner contour of the femoral component of 10 TKR designs for possible exchange in use.

**MATERIALS AND METHODS**

The femoral component of 10 cemented, cruciate-retaining TKR designs (e.motion, Genesis, Genia, Innex, LCS, Multigen Plus, NexGen, PFC, Scorpio, Vanguard) were included. At the time of this study, the Genia and the Multigen Plus (cobalt-chromium or ceramic) were being used in our hospital.

The femoral components were mounted and scanned from a distance of about 50 mm using a 3-dimensional (3D) laser scanner. The reflected laser light on the surface was detected by a camera near the laser. Scatter-plots of 2 scans were partly superimposed and wrapped by a polygon surface. Irregularities and defects were eliminated, and edges were sharpened and plain surfaces smoothened. The surface grid was generated, and the 3D non-uniform rational B-spline surfaces were made (Fig. 1).

The 3D model was redrawn to a 2-dimensional (2D) contour in the lateral view (Fig. 2). \( \alpha \) was the angle between the distal cut and the horizontal plane. The other angles were related to the distal cut: \( \beta \) was the angle between the distal and oblique anterior cuts; \( \gamma \) was the angle between the distal and anterior cuts; \( \delta \) was the angle between the distal and oblique posterior cuts, and \( \varepsilon \) was the angle between the distal and posterior cuts (Fig. 2).

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**Figure 1** (a) Scatter-plot and (b) non-uniform rational B-spline model of a femoral component.

**Figure 2** Cross-sections of a femoral component showing different cuts and angles of the inner contour.
The cross-sections of inner contours were compared by superimposition and aligning at the distal and anterior cuts (Fig. 3). The patellar notch and outer contour were not analysed.

RESULTS

For the cross-section of inner contour of each femoral component, angles between the distal cut and the posterior, anterior, and oblique cuts were compared (Table). The maximum deviation was 5 mm in the posterior and posterior oblique cuts and 10 mm in the anterior oblique cut (Fig. 3). Based on similarity of the inner contour, LCS and Innex were classified as group I, e.motion, Genesis, Scorpio, Vanguard, and Multigen Plus as group II, and Genia, NexGen, and PFC as group III.

For group I, the distal cut was not perpendicular to the transverse plane, with a mean deviation of 7.2° (Fig. 4). The 2 designs in group I could not align distally with the anterior cut of all other designs. The posterior and oblique cuts differed in shape (maximum being 20.0° at the posterior oblique cut), so that exchange of the 2 designs (or to any other

![Figure 3](image1.png)  
Figure 3  (a) Superimposition of 10 femoral component designs aligning at the distal and anterior cuts. (b) The maximum deviation was 5 mm in the posterior and posterior oblique cuts and 10 mm in the anterior oblique cut.

![Figure 4](image2.png)  
Figure 4  Superimposition of (a) LCS and Innex (group I), (b) e.motion, Genesis, Scorpio, Vanguard, and Multigen Plus (group II), and (c) Genia, NexGen, and PFC (group III).
designs) was not feasible without additional bone resection and/or augmentation with bone cement.

For group II, the distal and anterior cuts were similar (Fig. 4). The 4 designs were comparable in their distal, anterior, and posterior cuts, and exchange in use was feasible with minimal bone resection. The highest difference was between Genesis and Vanguard with 13.3º at the anterior oblique cut. The angle between the posterior and the posterior oblique cuts was larger (resulting in a gap of 2 mm) in the Multigen Plus than in the 4 other designs. The angle between the distal and posterior cuts was therefore larger (the highest being 5.5º between Multigen Plus and e.motion); the other cuts were comparable. Exchange in use was feasible, but associated with an additional posterior cut.

For group III, deviations at the posterior cuts and the 2 oblique cuts were large (Fig. 4). Anterior alignment of the 3 designs was not feasible; the maximum angle difference was 7.3º between Genia and PFC. Exchange in use may result in a thicker bone cement layer or increased bone resection at all cuts. An increased posterior distance was noted in the NexGen design, but this could be due to variation in size.

**DISCUSSION**

Standardisation of the taper geometry of total hip arthroplasty stems (e.g. 12/14) facilitates preoperative planning of revision surgery. Acetabular cup reamers of different manufacturers are compatible owing to similar implant-fixation principles, but the femoral stem and rasp geometries (e.g. straight and anatomic designs) of TKR differ among manufacturers.

As the number of revision TKR increases, standardisation of cutting devices and inner contours of components facilitates exchange in use among different designs, and shortens the learning curve of the surgeons and reduces costs and intra-operative problems.

In our study, the outer contours of various femoral components were not analysed. The bearing surfaces are complex curves with exact transitions of curves. The curves (single curves or multi curves) define the bearing behaviour to the polyethylene (rolling, gliding at a defined flexion angle) and are design-specific. A more precise device such as a 3D coordinate-measuring machine is necessary for analysis.

On the contrary, the inner contour is only partly influenced by overall design features (e.g. optimal patellar tracking and joint kinematics). 30 to 50% of periprosthetic femoral fractures are associated with anterior notching. An increased angle between the distal and anterior oblique cuts enables deeper retropatellar guidance combined with reduced patellar contact pressure.

The biomechanical stresses within the implant components, cement layers, and adjacent bone areas can be calculated using finite element analysis. The stress behaviour of different inner contours of femoral components can therefore be compared. Further studies are needed to determine whether standardisation of the inner contours

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<td><strong>Angles between the distal cut and the posterior, anterior and oblique cuts of the 10 femoral component designs</strong></td>
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*α* denotes the angle between the distal cut and the horizontal plane, *β* the angle between the distal and oblique anterior cut, *γ* the angle between the distal and anterior cut, *δ* the angle between the distal and oblique posterior cut, and *ε* the angle between the distal and posterior cut.

*α denotes the angle between the distal cut and the horizontal plane, β the angle between the distal and oblique anterior cut, γ the angle between the distal and anterior cut, δ the angle between the distal and oblique posterior cut, and ε the angle between the distal and posterior cut.*
with preservation of their outer contours have an adverse effect on mechanical stability of the implant. Comparisons should also be made for components with a standard peg and patellar notch design.

One limitation of our study was that only one size of each design was analysed. The results (distances, angles) cannot be readily applied to other implant sizes. Moreover, only the femoral component design was compared. In addition, the accuracy of the laser scanner was limited, and scatter-plotting of the inner contour could create distortion. Nonetheless, the best-matched sizes of different TKR designs were selected.

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