

Considerations in the Femoral Sagittal Plane

Design Rationale For Knee Prosthesis

Technical Bulletin K0009

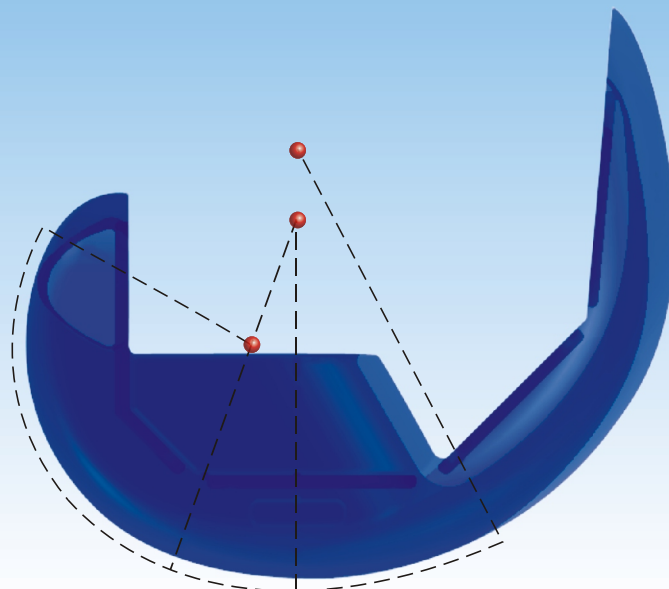


Figure 1: Femoral sagittal plane curvature

►►► The design objective of femoral sagittal curvature is to mimic anatomic knee, to provide normal knee flexion-extension. Another objective is to achieve the maximum knee flexion under normal bony cutting.

✚ Current Findings

Until today, there are still disputes regarding radiographs or Magnetic Resonance Imaging (MRI) images of the femoral geometric appearance in the sagittal plane. Hill et al. [1] analyzed MRI images of knee and found that there were two radii-extension radius and flexion radius-in the knee sagittal plane whereas Blaha et al. [2] argued that extension radius would be equal to flexion radius when the epicondylar was used as the flexion center. Hence, there are currently two main theories of femoral sagittal plane curvature in knee prosthesis design: Multi-Radius and Single-Radius (Fig. 2).

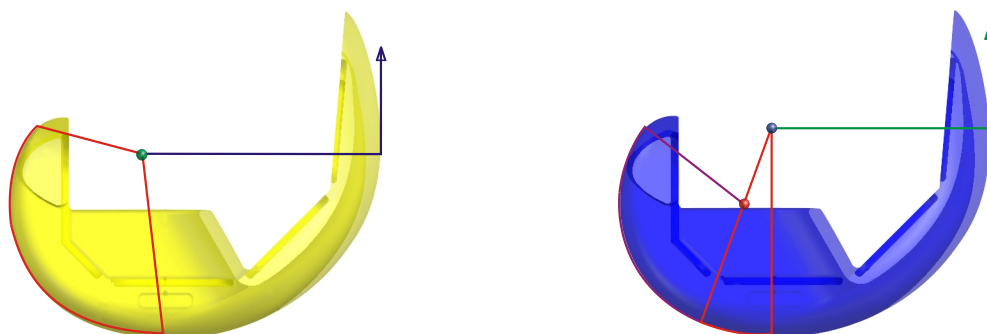


Figure 2: Single-Radius (Left) and Multi-Radius (Right) designs

Osteonics-Scorpio, which adopts Single Radius (flexion radius= extension radius), claims that since the flexion radius neither equals the extension radius during the transition from extension to flexion, nor does it share the identical flexion center with the latter, mid-flexion in stability is inevitable in Multi-Radius design. The Multi-Radius design provides good ligament stability at 0° and 90° of flexion. However, during the transition from extension to flexion, the change of flexion center and unequal radii

lead to an anisometry in collateral ligament. When the collateral ligament is anisometry, it no longer provides stable support for the knee and will cause mid-flexion instability and unstable state of the knee that often occurs at 30° to 45° of flexion. Patients underwent total knee arthroplasty are less confident and less capable of performing simple daily tasks that require mid-flexion stability, such as rising from a chair and ascending or descending stairs. In addition, Scorpio knee also claims that its SingleRadius design functions to reduce anterior knee pain since its Single-Radius design has a longer moment arm (from the center of single radius to the patella) than that of the Multi-Radius design's extension radius. A longer moment arm increases the efficacy for quadriceps muscle contraction, which reduces patellofemoral joint reaction force, further reduces the contact stress of patellar component. This is how the Single-Radius design can reduce the likelihood of anterior knee pain.

Mahoney et al. [3] reported the effect of total knee prosthesis design on the extension mechanism function. They compared two groups of patients: one consisted of 83 patients using Osteonics-Series 7000 (Multi-Radius design); the other 101 patients using Osteonics-Scorpio (Single-Radius design). Since Series 7000 and Scorpio have the identical femoral internal box that allows using the same operation instrumentations. Therefore, effects caused by different operation methods can be minimized. After 2 years postoperatively, the patient was asked to rise from a chair without using any aid and stand up solely by the strength of their knees. Then questionnaires were handed out, asking the patients if any anterior knee pain was felt when they performed the movement. The result showed that the proportion of patients in the Scorpio knee group who felt anterior knee pain is significantly lower than that in the Series 7000 group. The range of motions in these two groups do not have a significant difference in 3rd month postoperatively, however, the patients in the Scorpio knee group had a larger range of motion in 6th month postoperatively.

Another product, Wright-Advance (medial pivot), also adopts Single-Radius design, but with an appeal of medial pivot rather than Single-Radius curvature. Zimmer-NexGen LPS knee features high flexion. To meet the requirements of high flexion for the knee prosthesis, curvature for the posterior-superior femur must be made small. Despite that no data on its sagittal plane curvature is found, it is very likely that Zimmer-NexGen LPS knee is of the Multi-Radius design judging from the Perspective drawing. The UKnee PS knee prosthesis of UOC was adopted a Multi-Radius design too.

✚ Design Concept

Should U2 knee system hold on to the Multi-Radius design or adopt the Single-Radius design? We found that the Single-Radius design has two major concerns as follows:

- 1. The largest knee joint reaction force occurs at approximately 5° to 10° of flexion in human walking; since the curvature radius of Single-Radius design is smaller than the Multi-Radius design at 5° to 15° of flexion, it results in a larger contact pressure, and the likelihood of future polyethylene wear is also greater.
- 2. The patellar moment arm of the Single-Radius design is longer than that of the Multi-Radius design's extension radius, but shorter than the Multi-Radius design's flexion radius. It means that the Multi-Radius design makes quadriceps more effective at larger flexion angle(Fig. 3).

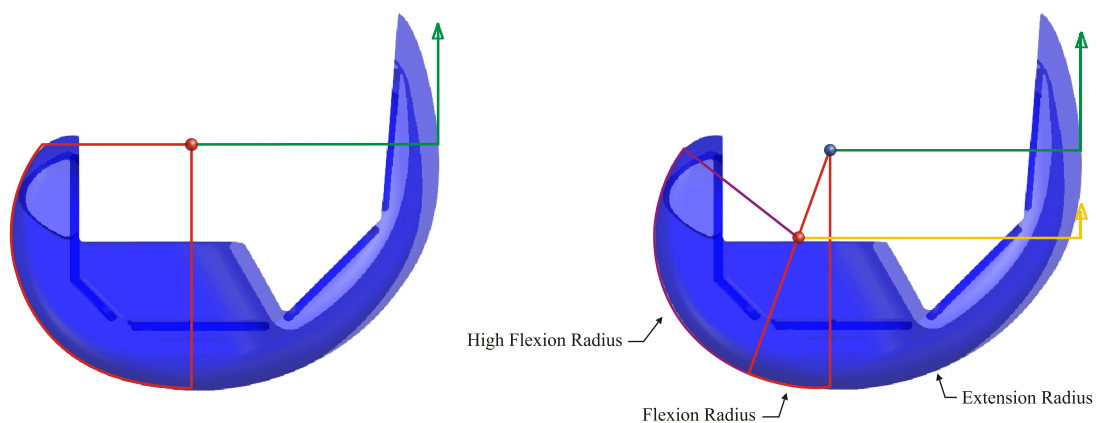


Figure 3: Patellar moment arm in Single-Radius and Multi-Radius designs

Therefore, the sagittal curvature for the U2 femoral component will still be of **Multi-Radius design**; respectively extension radius, flexion radius, and high flexion radius. The intersection angle of flexion radius and extension radius in UKnee femoral component varies in accordance with the femoral sizes, ranged from 14.5° to 41°. This intersection angle in U2 femoral component is set at approximately 20° with an aim to provide a larger contact area when knee joint sustained the largest reaction force in human walking.

Summary

▶▶▶ The U2 femoral component hold on to the Multi-Radius design while the intersection angle for flexion radius and extension radius remains at 20°, and the extension radius identical with the design for the UKnee femoral component, and with a smaller radius to match the posterior condyle for high flexion. The appearance of U2 size 1 femoral component is shown in Figure 4.

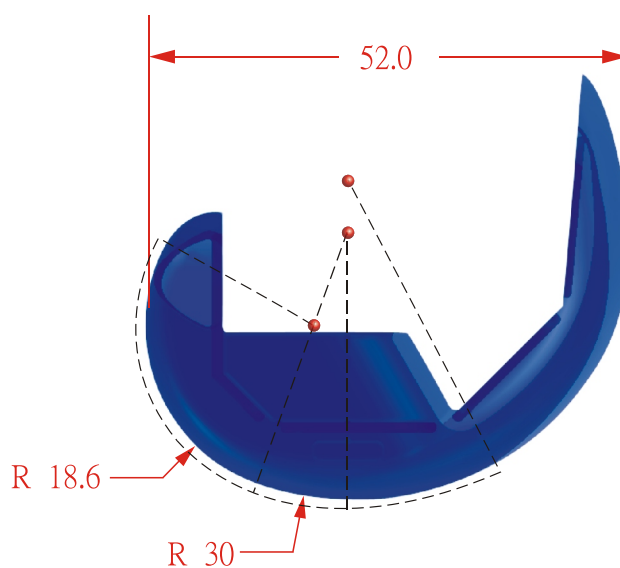


Figure 4: The geometric appearance of the sagittal plane in U2 knee, size 1 femoral component

Reference:

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2. Blaha JD, Mancinelli CA, Simons WH: Using the transepicondylar axis to define the sagittal morphology of the distal part of the femur. J Bone Joint Surg, 84A Suppl 2: 48-55, 2002.
3. Mahoney OM, McClung CD, Rosa MAD, Schmalzried TP: The effect of total knee arthroplasty design on extensor mechanism function. J Arthroplasty 17(4):416-421, 2002.



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