Original research

Does the anatomic design of total knee prosthesis allow for a better component fit than its nonanatomic predecessor? A matched cohort Study

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ABSTRACT

Background: Total knee arthroplasty (TKA) is considered the most efficient treatment of end-stage osteoarthritis. There is an ongoing debate about proper implant designs and articulation types. One of the considered causes of unsatisfactory outcome and patients’ dissatisfaction is femoral or tibial component overhanging, which can lead to chronic knee pain and restricted motion. The aim of this study is to compare radiological outcomes of TKA using an anatomic PERSONA Posterior-Stabilized (PS) knee design with its nonanatomic predecessor, the NexGen LPS.

Methods: A group of 39 patients who received the PERSONA PS system and 33 patients who received the NexGen LPS was included. PERSONA patients were matched to NexGen patients using a 0.1 propensity score threshold with priority given to exact matches. Anteroposterior, lateral, and long-leg radiographs were taken preoperatively and at 6 weeks postoperatively to perform radiological and statistical analysis.

Results: The PERSONA subgroup had statistically higher posterior condylar offset. There is no statistically significant difference in posterior condylar offset ratio. There were less cases of femoral notching, femoral overhang, and placing tibial baseplate in the medial overhang in the PERSONA PS subgroup than in the NexGen subgroup (each statistically significant). Occurrence of tibial underhang was not statistically significant.

Conclusion: Radiological assessment in short-term follow-up showed excellent results for PERSONA knee design with better fit to native femur and tibia. In comparison to its predecessor, it also spares more bone tissue. As the aforementioned parameters are risk factors of lesser clinical outcomes, the PERSONA design gives high hopes for improvement of TKA satisfaction rate.

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Introduction

Total knee arthroplasty (TKA) is considered the standard of care for symptomatic end-stage knee osteoarthritis [1,2]. The frequency of TKA is growing worldwide [3,4], and it is estimated that the number of patients electing for TKA will continue to rise [5]. Despite most patients being pleased with their outcomes after TKA, approximately 20% remain unsatisfied [6]. Satisfaction after TKA is correlated with achieving painless functional range of motion [7].
Arthroplasty surgeons have been unable to achieve the same success rate with knee replacements as they have with hip replacements despite varied implant designs, surgical techniques, and changes in implant alignment [8-10]. Both patient-related and technique-related factors affect the outcome of TKA [11,12]. A combination of the aforementioned factors, one of which is imperfect implant fit, may contribute to the dissatisfaction with the outcome in 20% of patients undergoing TKA. Femoral and tibial component overhang can result in pain and worse biomechanical outcomes [13]. In the study by Mahoney and Kinsey, it was estimated that nearly 30% of chronic pain cases after TKA were linked with component overhang [14].

Reproducing a patient’s native joint mechanics is critical to the success of TKA. An implant that is designed to restore the patient’s anatomy may assist in this. It may allow for a better fit of the components and, thus, limit the risk of implant loosening. In addition, it helps sustain a native joint line and avoid implant misalignment which is crucial for restoring the primary knee biomechanics [15,16].

In recent years, surgeons have had high hopes associated with development of the anatomical design of total knee implants. One of the most recent implants available in the market is PERSONA (Zimmer Biomet, Warsaw, IN). The tibial baseplate is asymmetric and, compared to its predecessor, has more size options on the femoral side. Given the aforementioned differences, this implant is proved to have a lower risk of femoral and tibial component overhang [17,18].

Each femoral component size has both a standard and narrow option, which is 2 mm narrower in the mediolateral dimension. This helps to avoid mediolateral overhang and soft-tissue impingement. The femoral component, with asymmetric posterior condyles, was designed to fit the native anatomy of the tibial plateau. Other differences with this new design as compared to its predecessor include an enhanced locking mechanism of the polyethylene insert into the tibial baseplate and less bone removal from the box in a posterior-stabilized implant than in other commonly used systems [19].

In the study by Dai et al., authors concluded that the anatomical design of the tibial baseplate increases tibial coverage and can restore the shape of tibia more accurately than standard knee designs [20].

The aim of this study was to assess radiological outcomes of TKA using the PERSONA PS at 6 weeks postoperatively and compare them with a matched cohort of patients who underwent TKA with its predecessor, the NexGen LPS (Zimmer Biomet, Warsaw, IN) system.

**Material and methods**

This study was conducted according to The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement, and an appropriate checklist was presented to the Editors [21]. Informed consent was obtained from all subjects involved in the study.

Patients included in the study were older than 50 years, had osteoarthritis, were undergoing primary TKA with a PS-implant without patellar resurfacing, and had at least 15 degree of extension or intraoperative diagnosis of PCL intact at time of surgery or absent flexion contracture preoperatively.

Thirty-nine patients who underwent PERSONA TKA and thirty-four patients who underwent no gender-specific NexGen LPS TKA met inclusion criteria. All surgeries in both groups were performed between September 2019 and January 2020. For both PERSONA PS and NexGen LPS cohorts, a propensity score based on gathered demographic data of patients (age at surgery, sex, and body mass index) was generated. PERSONA patients were matched to NexGen patients using a 0.1 propensity score threshold with priority given to exact matches (Table 1).

All patients qualified for the TKA have a standard anteroposterior, lateral weight-bearing and long-leg view radiographic examination performed preoperatively at the admission day to the hospital for evaluation of the intraarticular grade of osteoarthritis and assessment of the lower limb alignment. Long-leg view radiograms were performed with 30 cm distance between participant’s feet and patella of both limbs directed forward and with 5-7 degrees of tube inclination [22].

All surgeries were performed at a level III academic hospital by two senior authors (A.S., B.M.M.), who are fellowship-trained surgeons: A.S. performed 19 TKA using PERSONA PS and 17 using NexGen LPS, and B.M.M. performed 20 TKA using PERSONA PS and 16 using NexGen LPS. All surgeries were performed using a standard midline incision and medial parapatellar arthroscopy with a tourniquet (average time of 80 minutes) and postoperative drainage for at least 12 hours in all cases. Cruciate sacrificing implants were used because of the preoperative presence of fixed deficit of 15 degrees of extension or intraoperative diagnosis of PCL insufficiency. Tibial cut was performed first using extramedullary alignment jigs perpendicular to the long axis of the tibia, matching the patient’s native slope, unless native slope was less than 3° or greater than 7°. The femur was prepared using an intramedullary alignment tool with a valgus angle between 5° and 7° and external rotation of 3°. Femoral bone cuts were made in the sequence as recommended by the surgical protocol of the PERSONA PS knee system and the NexGen LPS system. After removal of posterior and peripheral osteophytes, soft-tissue balance was assessed using the tibial insert trial. Flexion and extension gaps were balanced. No patella resurfacing was performed. All components were implanted with the use of cement. All liners implanted were PS. The postoperative protocol included chemical and mechanical thrombophrophylaxis unless specifically contraindicated. All patients received one dose of parenteral antibiotics at the induction of anesthesia and two further doses postoperatively.

Preoperative as well as 6-week postoperative anteroposterior, lateral and long-leg radiographs were used to assess the radiological parameters.

Analysis of the radiographic images was performed using the INFINITT PACS system (INFINITT Healthcare, Seoul, South Korea). The parameters evaluated in the preoperative radiographs included mechanical axis of the limb, angle of valgus/varus deformity of the distal femur (lateral distal femur angle) and proximal tibia (medial proximal tibial angle), posterior condylar offset (PCO), posterior condylar offset ratio (PCOR), and posterior tibial slope. Postoperative radiological analysis consisted of mechanical axis of the limb, coronal and sagittal alignment and position of the knee.
components (lateral distal femur angle, medial proximal tibial angle), PCO and PCOR, number of implants with tibial overhang or underhang of less or more than 2 mm, potential femoral overhanging or notching, and efficacy of preoperative posterior tibial slope restoration. All radiographs were measured three times by two independent researchers, and mean values of their results were noted. To avoid potential risk of bias, all data concerning participants were blinded. Mean intraobserver and interobserver differences in measurements of femoral and tibial components were calculated for all cases. Intraobserver and interobserver reliability was determined by calculating the intraclass correlation coefficient with a confidence interval of 95%.

Measurements

PCO was defined as the maximum thickness of the posterior femoral condyles, measured on the true lateral view as the distance between the radius corresponding to the margin of the posterior cortex and its tangent parallel to the condyles posteriorly [23].

PCOR was defined as the ratio between PCO and the distance between the radius corresponding to the anterior femoral cortex and its tangent parallel to the posterior condyles [24] (Fig. 1).

In order to assess potential notching or overhang of the femoral component, a line was drawn through the anterior margin of the femoral anterior cortex on the true lateral view knee radiograph, and its relation to the posterior border of the femoral component was analyzed (Fig. 2).

In order to assess the potential overhang or underhang of the tibial component, a line was drawn perpendicular to the tibial line at the border of the tibial plateau on the anterior-posterior and lateral radiographs, and its relation to the borders of the tibial baseplate was analyzed (Fig. 3).

Statistical analysis

A statistical analysis of the results was performed. All comparisons were made between continuous variables in independent groups.

Thereafter both t-student and U Mann-Whitney tests were used, according to the normality of distribution tested with the use of Shapiro-Wilk test.

Significance level was set at P value below .05. All statistical analyses were conducted using SAS software, Version 9.4, for Windows (SAS Institute Inc., Cary, NC).

Statement of Human and Animal rights

It is hereby declared that this study was conducted in accordance with the ethical and clinical standards of the Institutional Bioethics Committee.

Results

A total of 39 patients from the PERSONA PS cohort (100%) and 33 patients from the NexGen (97%) matched control cohort completed the assessment at 6 weeks postoperatively. One patient from the NexGen cohort was excluded from the assessment as he did not arrive for the follow-up visit.

Interobserver reliability was high with an ICC of >0.9 for all measurements.

On the preoperative radiographs, the assessment of mechanical axis revealed that 31 knees had varus deformity, 3 had valgus deformity, and 5 were neutral; in the postoperative radiographs, 38 knees were neutral while one limb was left with residual varus.

Femoral notching of less than 2 mm occurred in one patient who underwent PERSONA TKA and greater than 2 mm in three patients in the NexGen LPS cohort. The difference was not statistically significant. The PCO was found to be increased after the surgery; the mean difference between preoperative and postoperative values was compared between the NexGen and PERSONA groups. The result was statistically significant and favored the PERSONA group. The PCOR was found to be decreased after the surgery; the mean difference between preoperative and postoperative values was not statistically significant between the analyzed groups (Table 2).

Femoral notching of less than 2 mm occurred in one patient who underwent PERSONA TKA and greater than 2 mm in three patients in the NexGen LPS cohort. The difference was not statistically significant ($P = .3266$). Femoral overhang was observed in a single PERSONA PS and four NexGen LPS femoral implants. The difference was statistically significant ($P = .0398$).

The tibial baseplate was overhanging more than 2 mm in one PERSONA PS tibial implant and four NexGen tibial implants ($P = .0398$). In the NexGen group, two cases of tibial underhang of more than 2 mm both on the medial and lateral sides were observed, while in the PERSONA group, there was only one on the medial side ($P = .425$) (Table 3).

Discussion

Despite the ongoing development of newer knee joint implants that better fit the native bone morphology, the proportion of patients unsatisfied with their TKA remains constant. There are several known risk factors of dissatisfaction including patient-
related, surgical technique-related, and implant-related issues [7,25].

The aim of this study was to assess the radiological outcome of TKA with the use of PERSONA PS knee design after the first 6 postoperative weeks and compare it with a matched cohort of patients who underwent TKA with the use of PERSONA’s predecessor, NexGen LPS system.

In the study by Benazzo et al., it was stated that the PERSONA knee design not only provides excellent clinical and functional outcome but also helps achieve excellent radiological outcome and its reproducibility [26]. However, their results were not compared to any other knee design [26]. In our study, the PERSONA cohort was compared to its predecessor, and a significant improvement in implant fit on both tibial and femoral sides was demonstrated radiographically.

Previous studies have evaluated differences between cruciate retaining PERSONA and NexGen implants, but this is the first to evaluate the difference between these two posterior stabilized implants [27-29]. There is still a lack of studies, especially randomized-controlled studies comparing the outcome of PERSONA PS design to that of NexGen LPS.

The paramount finding of this study was that the use of PERSONA knee system allowed to increase the PCO and to decrease the incidence of both tibial and femoral overhang in comparison to the matched cohort treated with the NexGen system.

The evaluation of PCO showed a mean increase in this parameter in both groups with higher values for the PERSONA cohort. It is believed that a decrease in this value of 2 mm might decrease the

![Figure 2](image2.png)

**Figure 2.** Femoral notching (left) and femoral overhang (right) measurement.

![Figure 3](image3.png)

**Figure 3.** Tibial underhang measurement.

| Radiographic parameter | PERSONA, N = 39 | NexGen, N = 33 | P value |
|------------------------|-----------------|----------------|---------|
| PTS between 3° - 7° (% of knees) | 97.4 | 97.0 | >.05 |
| Mean difference between preoperative and postoperative PCO | 5.89 (SD = 6.3) | 1.31 (SD = 9.23) | .206 |
| Mean difference between preoperative and postoperative PCOR | 0.0323 (SD = 0.2) | 0.0112 (SD = 0.240) | .6882 |

PTS, posterior tibial slope.

Bold values are statistically significant, with P-value <.05.
postoperative flexion by 12.2° [22]. Maintaining higher values of PCO not only improves the postoperative flexion but also allows for less bone resection, which might be crucial in case of possible future revision surgery. With the use of PCL sacrificing design, it also allows to achieve greater stability in mid- and full-flexion [30,31].

Femoral notching was detected only in one case in the PERSONA cohort, and it was less than 2 mm. Femoral notching of more than 2-3 mm has been shown to be a risk factor of periprosthetic fractures of the femur. The availability of a vast array of sizes of PERSONA sizes improves its femoral fit [20,32]. A crucial aspect of the proper baseplate orientation is to cover the tibial plateau as closely as the native bone area as possible. With the asymmetric PERSONA tibial baseplate, the tibial plateau coverage is maximized, especially in the postero-lateral area, which minimizes medial overhang. This asymmetric design also allows for proper external rotation of the baseplate to enhance patellar tracking and limit anterior knee pain related to maltracking [33,34]. In vivo studies showed that the PERSONA knee design has the lowest risk of overhanging and is inclined to underhang on the medial aspect of the tibia as compared to other popular primary tibial baseplates [17]. However, there is a lack of studies examining the potential negative effects of the tibial component under-hanging. In the study by Liu et al., authors reported higher tibial bone resorption [35].

One potential limitation of the study is the fact that this is a retrospective matched-cohort study, not a randomized-controlled one. What is more, no gender-specific NexGen knee design was used, as this would potentially resolve the femoral overhang issue. Other limitations may be that the study was conducted in a single institution, and there is no comparison of clinical results with other hospitals or surgeons and also that not many patients were enrolled in the study. However, despite the small number of participants, several outcomes were found to be significant.

Conclusions

Radiological assessment in the short-term follow-up showed excellent results of PERSONA anatomical knee design with better fit to native femur and tibia. In comparison to its predecessor, it also allows to spare more bone. As the aforementioned parameters are risk factors of lesser clinical outcomes, the PERSONA knee design gives hopes for improvement in TKA satisfaction rate. Future studies should further explore if this new implant design can improve clinical outcomes after TKA.

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