Gait Parameters and Functional Outcomes After Total Knee Arthroplasty Using Persona Knee System With Cruciate Retaining and Ultracongruent Knee Inserts

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ABSTRACT

Background: Total knee arthroplasty is a well-established treatment for managing end-stage symptomatic knee osteoarthritis. Currently, different designs of prostheses are available with majority ensuring similar clinical outcomes. Altered surface geometry is introduced to strive toward gaining superior outcomes. We aimed to investigate any differences in functional outcomes between 2 different polyethylene designs namely the Persona CR (cruciate retaining) and Persona UC (ultracongruent) tibial inserts (Zimmer-Biomet, Warsaw, IN).

Methods: This prospective single blind, single-surgeon randomized controlled trial reports on 105 patients, (66 female and 39 male), who underwent simultaneous bilateral total knee arthroplasty using the Persona knee system (Zimmer-Biomet) UC inserts in one side and CR inserts in the contralateral side. By a blind assessor, at regular time intervals patients were assessed in terms of function and gait. The functional knee scoring scales used were the Western Ontario and McMaster Universities Osteoarthritis Index and Modified Knee Society Score. The gait parameters evaluated were foot pressure and step length.

Results: During the study period, no patient was lost to follow-up or underwent revision surgery for any cause. Western Ontario and McMaster Universities Osteoarthritis Index scores, Modified Knee Society Score, and knee range of motion of all 105 patients assessed preoperatively and postoperatively at 6 months, 1 year, and 2 years showed statistically better results (P < .05) for UC inserts. Gait analysis measuring foot pressures and step length, however, did not show any statistically significant differences at 2-year follow-up.

Conclusion: Ultracongruent tibial inserts show significantly better functional outcomes as compared to CR inserts during a 2-year follow-up period. However, in this study these findings were not shown to be attributed to differences in gait parameters.

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Total knee arthroplasty (TKA) is a gold standard surgical procedure for treating symptomatic end-stage osteoarthritis [1]. It not only relieves the patients from excruciating pain but also improves function including range of motion and walking ability. TKA also helps to restore the anatomical alignment of the tibiofemoral joint [2], thereby, improving biomechanics of the knee. Despite various improvements in surgical technique, implant design, and perioperative management, a significant proportion of patients after TKA continue to exhibit long-term functional deficits [3] and report difficulties with lower limb function during activities of daily living [4,5] when compared with age-matched controls [6-8]. One year after TKA, patients walk 15% slower than age-matched individuals without known knee pathology [4]. During the timed stair-climbing task, individuals after TKA had even greater functional limitations as evidenced by a 50% slower performance compared to age-matched healthy individuals [4]. These functional deficits are mainly attributed to altered kinetics of the replaced knee joint. Currently there are a number of different designs of prosthesis available for TKA. These include the cruciate retaining (CR) knee...
design where the posterior cruciate ligament (PCL) is retained, the cruciate sacrificing knee design where the PCL is sacrificed and the posterior stabilizing (PS) knee design where the PCL is substituted [9]. The philosophy of CR knee assumes that the PCL retains some function in the absence of the anterior cruciate ligament. It is suggested that the PCL has a beneficial effect on femoral rollback, range of movement, quadriceps efficiency, joint stability, and on reducing tibial shear forces [10]. The philosophy of PS knee questions the function of the PCL in isolation but acknowledges the need for posterior stabilization and uses the cam/post mechanism to replicate the physiological functions of the PCL [11]. The primary function of PCL is to limit the posterior glide and femoral rollback during knee flexion. However, in the absence of anterior cruciate ligament, PCL alone does not function optimally, and therefore, many surgeons resect the PCL as well and substitute its function by using a PS knee which has a cam-post mechanism [10].

A cam on the femur articulates with a post on the tibial insert ensuring obligatory femoral rollback. Although in theory this should improve knee flexion and reduce instability, in practice this is not always the case. Femoral rollback after a PS knee has been shown to be not too dissimilar to CR knee possibly because of lack of cam-post engagement in early-to-mid flexion arc. In addition, use of a PS design is associated with resection of a significant amount of bone and soft tissues from the femur, and there is an additional risk of increased wear at cam-post interface with risk of loosening [10] and of “cam over post” jump [12,13].

Deep-dished bearings have been introduced to minimize bone loss and improve knee stability without the risks of cam-post issues. One such design is the Persona ultracongruent (UC) knee system (Zimmer-Biomet, Warsaw, IN). The deep-dish design provides larger tibiofemoral contact area and reliable femoral rollback because of raised anterior and posterior lips [14]. The raised anterior lip theoretically prevents anterior subluxation of the femoral condyles during flexion [15,16], whereas the raised posterior lip provides posterior stabilization as in the PS knee but without bone sacrifice (as against the PS knee). This increased congruence and conformity of surfaces should theoretically avoid contact stress peaks providing better distribution of stress forces [17] which may further help to achieve better functional outcomes by improving gait patterns and postoperative range of motion [14]. Using these inserts the stability of the knee is guaranteed by a more conforming articulation in conjunction with correct soft tissue tension. However, no in vivo study comparing the gait and functional outcome after TKA using UC bearings with TKA using conventional bearings has been conducted so far.

Present study is aimed at assessing differences in pain, function, and gait parameters in terms of step length and weight bearing on foot, in the UC, and CR knee inserts.

Materials and Methods

A consecutive series of 105 subjects, 66 women and 39 men, who underwent simultaneous bilateral TKA using Persona knee system (Zimmer-Biomet) with a UC insert and CR insert on contralateral sides (randomly allocated), participated in this study. As per the Altman nomogram [18] (Fig. 1), using a standardized difference of 0.5 with a power of 80% and a P-value of .05 the sample size required for this study was 64. We took a standardized difference of 0.5 with a power of 95% and a P-value of .05 resulting in a required sample size of 104.

All the patients were operated by the same orthopedic surgeon. Subjects with bilateral TKA were excluded if they had any previous lower extremity surgery, spine surgery, or neurological impairments with altered sensation in the feet. Subjects were also excluded if they had arthritis in other joints of the lower extremities, were blind, or had completely ankylosed knee joints before the surgery. Subjects with cardiac involvement, flexion deformity accounting to >20° and valgus >5° were also excluded from the study. The study was approved by local ethics committee and institutional review board. All patients gave informed consent for participation in the study.

All the subjects underwent a clinical assessment at 4 stages—preoperatively, at 6 months, at 1 year, and at 2 years postoperatively. The clinician/assessor was blinded with regard to which prosthesis was implanted in each knee of the patient. Clinical assessment included Modified Knee Society Score (MKSS) [19] and WOMAC scores [20] along with a careful record of any complications encountered. Following this, gait of all subjects was analyzed using H/P Cosmos Gait Analyzer (2011, h/p/cosmos sports & medical GmBH, ISO 9001:2008). Two key outcome measures were taken into account for the gait analysis—weight distribution on forefoot, midfoot and hindfoot, and step length. Foot rotation

![Fig. 1. Altman nomogram showing prior sample size calculation.](image-url)
angle, stride length, step length, step width, percentage distribution of 3 phases of gait, cadence, velocity, and pressure analysis on the 3 zones of the foot are the elements analyzed by the gait analyzer. Many studies have used various spatial and temporal parameters along with knee flexion angles in stance and swing phase as their outcome measures after TKA[21]. However, there are no studies on the foot pressure variations following a TKA. In a normal gait cycle the right and left step lengths are equal. Similarly, the pressure distribution in each of the 3 zones (forefoot, midfoot, and hindfoot) of the foot is equal for each foot in healthy individuals. Measuring pressures in each of these zones gives a good measure of confidence the patient enjoys during different phases of gait. Since we were evaluating outcomes in subjects who had been implanted with different knee inserts on contralateral sides, we set out to find a variation, if any, in these 2 specific gait parameters (step length and pressures in different zones of the foot) of a gait cycle in an individual undergoing TKA. All the subjects practiced walking on the H/P Cosmos Gait Analyzer until they reached a self-selected comfortable speed. After 3 trials, final stance and gait readings were obtained for a preset time range of 10 seconds and 30 seconds, respectively.

Results

The mean WOMAC score of 105 patients preoperatively was 76.1 for right side (standard deviation [SD] = 6.66) and 76.2 for left side (SD = 7.32). This score improved at 6 months in both CR and UC but was better for UC inserts (CR = 55.7, SD = 8.01, UC = 47.7, SD = 8.17). These scores continued to improve over 2 years with more improvement in UC inserts (CR = 19.5, SD = 3.35, UC = 15.6, SD = 2.54). The WOMAC score mean difference between CR and UC implants was found to be statistically significant at 6 months, 1 year, and 2 years postoperatively (paired t test [6 months, MD = 6.324, SD = 3.426, \( P < .001 \); at 1 year, MD = 6.886, SD = 3.027, \( P < .001 \); and at 2 years, MD = 6.895, SD = 3.038, \( P < .001 \); Table 2).

The mean forefoot pressure score of 105 patients preoperatively was 13.47 for right side (SD = 5.83) and 13.44 for left side (SD = 6.13). This score improved at 6 months in both CR and UC (CR = 17.85, SD = 5.53, UC = 17.82, SD = 4.97) and showed no further improvement over 2 years (CR = 18.07, SD = 3.36, UC = 18.61, SD = 3.09). The forefoot pressure score mean difference between CR and UC implants was found to be statistically nonsignificant at 6 months, 1 year, and 2 years postoperatively, with the help of a paired test (6 months, MD = 0.03, SD = 0.73, \( P = .963 \); at 1 year, MD = 0.60, SD = 0.46, \( P = .195 \); and at 2 years, MD = −0.55, SD = 0.45, \( P = .221 \); Table 3).

The mean midfoot pressure score of 105 patients preoperatively was 12.93 for right side (SD = 4.00) and 13.81 for left side (SD = 3.71). This score improved very slightly at 6 months in both CR and UC (CR = 13.59, SD = 3.52, UC = 13.85, SD = 3.39) and showed no further change over 2 years (CR = 12.10, SD = 1.72, UC = 11.99, SD = 1.61). The midfoot pressure score mean difference between CR and UC implants was found to be statistically nonsignificant at 6 months, 1 year, and 2 years postoperatively, with the help of a paired test (6 months, MD = −0.26, SD = 0.48, \( P = .582 \); at 1 year, MD = 0.18, SD = 0.26, \( P = .486 \); and at 2 years, MD = 0.11, SD = 0.23, \( P = .631 \); Table 4).

The mean hindfoot pressure score of 105 patients preoperatively was 17.27 for right side (SD = 4.76) and 15.58 for left side (SD = 4.68). This score improved very slightly at 6 months in both CR and UC (CR = 17.85, SD = 5.53, UC = 17.82, SD = 4.97) and showed no further change over 2 years (CR = 18.01, SD = 3.53, UC = 18.61, SD = 3.18). The hindfoot pressure score mean difference between CR and UC implants was found to be statistically nonsignificant at 6 months, 1 year, and 2 years postoperatively, with the help of a paired test (6 months, MD = −0.03, SD = 0.73, \( P = .963 \); at 1 year, MD = −0.55, SD = 0.45, \( P = .221 \); and at 2 years, MD = −0.60, SD = 0.46, \( P = .195 \); Table 5).

The mean step length of 105 patients preoperatively was 7.04 for right side (SD = 1.72) and 7.90 for left side (SD = 1.77). This score improved further change over 2 years (CR = 7.04, SD = 1.72, UC = 7.90, SD = 1.77). The step length score mean difference between CR and UC implants was found to be statistically nonsignificant at 6 months, 1 year, and 2 years postoperatively, with the help of a paired test (6 months, MD = −1.30, SD = 0.60, \( P = .195 \); Table 5).

<table>
<thead>
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<th>Table 2</th>
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<tr>
<td><strong>Modified Knee Society Score</strong></td>
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<tr>
<td><strong>Comparison Between CR and UC</strong></td>
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<tr>
<td>At 6 mo</td>
</tr>
<tr>
<td>At 1 y</td>
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<tr>
<td>At 2 y</td>
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CR, Persona cruciate retaining; UC, Persona ultracongruent; SD, standard deviation.

\* P value < .05, statistically significant.

<table>
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<th>Table 3</th>
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<tr>
<td><strong>Forefoot Pressure Score</strong></td>
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<tr>
<td><strong>Comparison Between CR and UC</strong></td>
</tr>
<tr>
<td>At 6 mo</td>
</tr>
<tr>
<td>At 1 y</td>
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<td>At 2 y</td>
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</table>

CR, Persona cruciate retaining; UC, Persona ultracongruent; SD, standard deviation.

\* P value < .05, statistically significant.
months postoperatively (6 months, MD = 1.10, SD = 1.40, P = .430; at 1 year, MD = 0.70, SD = 0.97, P = .484; and at 2 years, MD = 0.57, SD = 0.97, P = .557; Table 6).

The mean range of motion of UC knees (n = 105) was 119 (SD = 5.09). The mean for CR knees (n = 105) was 115 (SD = 4.96). A significant statistical difference in range of motion between UC and CR knee inserts (MD = 4.57, SD = 4.18, P = .000) was noted.

Discussion

This is a clinical study to compare advantages of using ultracongruent inserts with CR inserts when used with the Persona TKA system (Zimmer-Biomet). Functional outcomes and range of motion are significantly better in the UC knees as compared to the CR knees. However, this study fails to show any difference in chosen gait parameters of step length and foot pressure, which improved slightly but did not differ significantly between CR and UC implants. The current designs for TKA revolve around the idea of sacrificing or substituting the PCL. The PS design offers easier correction of deformity without concern for obtaining appropriate tension on the PCL, a more conforming polyethylene surface that results in decreased polyethylene wear, and more reliable rollback of the femur on the tibia in flexion [10]. Proponents of the PS design note the more widespread clinical usefulness in that it can be used in knees without a PCL [11] as well as the potential benefit of avoiding late posterior instability from PCL rupture, which has been reported in osteoarthritic patients [22]. Joglekar et al undertook a study to demonstrate differences in key gait characteristics and functional stability between PS and CR prosthesis in the absence of PCL. They had set out with the idea that excessive stresses of stair ascent and descent will unmask the subtle differences in stability between CR and UC prosthesis in the absence of PCL. They demonstrated differences in key gait characteristics and functional outcomes between CR and UC implants, and try to assess the patients' ease in doing so, post TKA. Walking distance and stair climbing were the specific areas which improved in the improved WOMAC and MKSS scores [19,20].

We chose MKSS and WOMAC score as our primary outcome measures and 2 key gait parameters—pressure on foot and step length, as the secondary outcome measures. These scores take into account clinical components including patient expectation and satisfaction levels after TKA. They also take into account varied levels of activities, be it basic, advanced, or recreational activities and try to assess the patients' ease in doing so, post TKA. Walking distance and stair climbing were the specific areas which improved after TKA as seen in the WOMAC and MKSS scoring in the UC group (P = .000 and P < .001) as compared to the CR group. All these were well reflected in the improved WOMAC and MKSS scores [19,20].

This study has several strengths and some limitations. The primary strength is that the analysis is based on validated and reliable WOMAC and MKSSs and H/P Cosmos Gait Analyzer. Comparison of the benefits of 2 different inserts in the same patient has the advantage that "patient-dependent" prognostic factors are eliminated. This trial design ensures that the statistical comparisons are within patients (paired) and not between patients as is more typical. The minimum follow-up of 2 years and none lost to follow-up are other key strengths.

There were few limitations as well. Radiographic evaluations were not accounted for while doing this study. Many patients had

Table 5

Hindfoot Pressure Score and Score Comparison Between CR and UC at 6 Months, 1 Year, and 2 Years.

<table>
<thead>
<tr>
<th>Comparison Between CR and UC</th>
<th>CR Mean ± SD</th>
<th>UC Mean ± SD</th>
<th>Comparison Mean Difference (CR-UC) ± SD</th>
<th>t Value</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>At 6 mo</td>
<td>17.85 ± 5.53</td>
<td>17.82 ± 4.97</td>
<td>0.03 ± 0.73</td>
<td>0.046</td>
<td>.963a</td>
</tr>
<tr>
<td>At 1 y</td>
<td>18.07 ± 3.36</td>
<td>18.61 ± 3.09</td>
<td>−0.55 ± 0.45</td>
<td>−1.228</td>
<td>.221a</td>
</tr>
<tr>
<td>At 2 y</td>
<td>18.01 ± 3.53</td>
<td>18.61 ± 3.18</td>
<td>−0.60 ± 0.46</td>
<td>−1.300</td>
<td>.195a</td>
</tr>
</tbody>
</table>

CR, Persona cruciate retaining; UC, Persona ultracongruent; SD, standard deviation.

a P value < .05, statistically significant.

Table 4

Midfoot Pressure Score and Score Comparison Between CR and UC at 6 Months, 1 Year, and 2 Years.

<table>
<thead>
<tr>
<th>Comparison Between CR and UC</th>
<th>CR Mean ± SD</th>
<th>UC Mean ± SD</th>
<th>Comparison Mean Difference (CR-UC) ± SD</th>
<th>t Value</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>At 6 mo</td>
<td>13.59 ± 3.52</td>
<td>13.85 ± 3.39</td>
<td>−0.26 ± 0.48</td>
<td>−0.551</td>
<td>.582a</td>
</tr>
<tr>
<td>At 1 y</td>
<td>12.13 ± 1.99</td>
<td>11.95 ± 1.73</td>
<td>0.18 ± 0.26</td>
<td>0.698</td>
<td>.486a</td>
</tr>
<tr>
<td>At 2 y</td>
<td>12.10 ± 1.72</td>
<td>11.99 ± 1.61</td>
<td>0.11 ± 0.23</td>
<td>0.482</td>
<td>.631a</td>
</tr>
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CR, Persona cruciate retaining; UC, Persona ultracongruent; SD, standard deviation.

a P value < .05, statistically significant.
no experience of walking on a treadmill, so it was difficult for them to adjust to walk on the moving surface. This hesitation and inexperience with treadmill could have resulted in variation in gait parameters of patients, who otherwise walked better on a level surface. Though every subject walked at their own comfortable speed but still unfamiliarity is an important issue and can be a factor which altered pressure on foot and step length. We tried to minimize the variation by allowing each participant to practice the exercise for analysis for gait parameters. Gait analysis recorded only 2 measurable parameters: foot pressure and step length. Other spatiotemporal parameters and dynamic parameters such as knee flexion angle, knee flexion moment, pelvic tilt, knee power absorption and so forth could not be taken into account due to their unavailability on H/P Cosmos Gait Analyzer and serve as a gap in the study. Our gait analysis did not involve any stair activities which involves stability assessment in mid flexion range (70°–90°). Further studies can be carried out to compare CR and UC implants for the stair activities and other weight bearing activities such as squatting or getting up from lower heights.

### Conclusion

This study confirms that ultracongruent bearings provide superior functional outcomes as compared to CR inserts. While no obvious differences were noted in the gait parameters that we perior functional outcomes as compared to CR inserts. While no obvious differences were noted in the gait parameters that we perior functional outcomes as compared to CR inserts. While no obvious differences were noted in the gait parameters that we perior functional outcomes as compared to CR inserts. While no obvious differences were noted in the gait parameters that we perior functional outcomes as compared to CR inserts. While no obvious differences were noted in the gait parameters that we perior functional outcomes as compared to CR inserts. While no obvious differences were noted in the gait parameters that we perior functional outcomes as compared to CR inserts. While no obvious differences were noted in the gait parameters that we perior functional outcomes as compared to CR inserts. While no obvious differences were noted in the gait parameters that we perior functional outcomes as compared to CR inserts. While no obvious differences were noted in the gait parameters that we perior functional outcomes as compared to CR inserts. While no obvious differences were noted in the gait parameters that we perior functional outcomes as compared to CR inserts. While no obvious differences were noted in the gait parameters that we perior functional outcomes as compared to CR inserts.

### References
