Total knee replacement (TKR) has been one of the most successful operative procedures with a significant socio-economic impact.\(^1,2\) With the growing success of TKR, its utilization has expanded to include younger and more active patients. This population has expectations of returning to an active and productive lifestyle, which also comprises participation in recreational activities such as sports and travel after TKR.\(^3\) To date, there remains a gap in patient’s expectations and the patient-reported outcomes of TKR. Recent studies have shown lower satisfaction rates of TKR and there is an emphasis to optimize patient satisfaction and performance.\(^4\)\(^-\)\(^6\) There has been a sustained effort to refine each aspect of TKR and recent emphasis has been on developing and refining modern designs of total knee implants, attempting to mimic the natural knee motion and feel. One such new design reproducing the medial and lateral knee pivot is a dual-pivot (DP) knee. In the present study, we endeavored to compare the performance of the DP knee vis-a-vis an ultracongruent (UC) Knee design.

**Methods:** This prospective cohort study was performed in a joint replacement center of a tertiary care military hospital. We enrolled 50 patients each in the DP knee group and the UC knee group and assessed knee flexion, patient-reported outcome (new Knee Society Score [nKSS]), patient performance (Delaware Osteoarthritis Profile Score), and function (Forgotten Joint Score [FJS]) at 2 years of follow-up.

**Results:** The nKSS was similar in the two groups. In the DP group, patients had significantly better improvement in the stair climb test ($p = 0.026$). In the UC group, timed up and go test was significantly better ($p = 0.004$). The gain in knee flexion was similar in the two groups: $26.3^\circ \pm 23.3^\circ$ in the DP group and $27.5^\circ \pm 27.5^\circ$ in the UC group ($p = 0.930$). Return to activity as judged by 2-year FJS was similar in both groups ($p = 0.687$).

**Conclusions:** Our study showed that the DP knee design had similar knee function to the UC knee. The DP knee design had significantly better stair climbing ability, whereas getting up from chair was better in the UC knee design. With comparable patient-reported outcome and possible differences in patient performance in terms of day-to-day activities, any future trial should focus on comparing patient performance.

**Keywords:** Total knee arthroplasty, Dual-pivot, Ultra-congruent, Patient-performance, Patient reported outcomes
on newer implant designs, which are anatomical requiring minimum alteration of the patient's native soft-tissue envelope for their implantation and thus restoring near natural form and function of the knee.\textsuperscript{7,8} The dual-pivot (DP) knee (Empower 3D Knee; Donjoy Global, Lewisville, TX, USA) is an anatomically designed implant, the use of which has been claimed to reduce dissatisfied patients by 50\% as compared to contemporary implants.\textsuperscript{9} Usage of ultracongruent (UC) inserts in TKR has witnessed an upsurge in global practice in recent times in a quest to enhance performance and satisfaction.\textsuperscript{10,11} We have been using UC inserts for most of our primary TKR since 2015. The DP knee was introduced in our practice in 2017. The objective of our study was to compare patient-reported outcomes and performance in patients undergoing TKR using the DP knee (3D knee implant; DJO, Lewisville, TX, USA) vis-a-vis the UC design (Johnson & Johnson cruciate retaining [CR] 150 implant with curved plus insert; Johnson & Johnson, Cork, Ireland) using validated patient-reported outcome measures, performance-based outcome measures, and tools to assess the return of function at an early follow-up (24 months). We hypothesized that the patient-reported outcomes and performance following TKR using the DP knee would be better than the UC design.

**METHODS**

This is a prospective, comparative study, implemented after institutional ethics committee clearance at the Joint Replacement center of Air Force Hospital Kanpur after obtaining informed consent from January 2017 till December 2020 (IRB No. 7AFH/IEC/2016/09/12).

**Patient Enrollment**

All patients with advanced bilateral knee osteoarthritis who were determined fit for surgery were offered to enroll in the study after sharing complete trial information, and those who consented were screened for participation in the study (Fig. 1). Excluded were the patients with polyarticular inflammatory joint disease, pathology of adjoining bone and joint affecting functional restoration after elective arthroplasty, and inability to follow-up at our center for a minimum of 2 years. Once identified as eligible for

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*Fig. 1. Consolidated Standards of Reporting Trials (CONSORT) diagram of the study showing enrollment, allocation, follow-up, and analysis of the patients. TKR: total knee replacement, KSS: Knee Society Score, DOPS: Delaware Osteoarthritis Profile Score, EQ-5D: EuroQol five-dimensional instrument, UC: ultracongruent, DP: dual-pivot, VAS: visual analog scale, FJS: Forgotten Joint Score.*
the study, the patients were counselled regarding the two implant options (that is, the CR knee implant and the newer design implant, DP knee with its presumed advantages) and those who consented to the use of either one was enrolled in the study. However, the operating surgeon’s decision was final on the choice of implant to be inserted as per patient profile based on patient’s sex, morphology, type, and degree of deformity. Since the DP implant had limited options for an increase in constrain or use of additional stems, the use of DP knees was favored by the surgeon in the knees having lesser deformity and better bone stock. The implant to be used was even changed intraoperatively on a few occasions where the surgeon determined a particular implant as appropriate in individual cases. Patients were analyzed in the group they were allocated to after the surgery.

Sample Size Calculation
We calculated the required sample size using Stata 12 software (StataCorp., College Station, TX, USA). Minimum clinically important difference in Knee Society Function Score (KSFS) is 10 points. For the study to have 80% power to detect a 10-point difference in KSFS between the two groups, we needed 34 patients in each group. Assuming a 10% loss to follow-up and considering the cohort study design, we enrolled 50 patients in each group to accommodate the need for adjusted statistical analysis for potential confounders.

Baseline Data Collection
After enrolment in the study, a trained team of physiotherapist and research assistant (RSY and GK) collected baseline demographic and disease data. The number of comorbidities was recorded including pre-anesthesia grading (American Society of Anesthesiologists [ASA]). The severity of knee deformity was recorded as a total deformity in the coronal and sagittal planes and graded as mild (<15°), moderate (16°–30°), and severe (>30°). The patient-reported function was recorded as new Knee Society Score (nKSS), performance using Delaware Osteoarthritis Profile (DOP), and EQ-5D VAS Score (EQ-5D).

Arthroplasty Protocol
All patients underwent preoperative workup and optimization as per the institutional protocol. Patients were started with skin preparation at home using overnight chlorhexidine wipes 3 days before surgery. On the morning of surgery, multimodal oral pain control drugs were started and continued postoperatively. All the surgical procedures were performed under single-shot, low-dose, spinal anesthesia. At induction, we used broad-spectrum antibiotics, which was continued for 24 hours, an anti-fibrinolytic was given 2 hours later, and dexamethasone was given once daily for 48 hours. All operations were performed by fellowship-trained surgeons (VK and SK) sequentially under tourniquet use, using medial parapatellar arthroscopy. The implant choice was as per the shared decision-making process between the surgeon and the patient. In the case of the UC group, we used Johnson & Johnson CR 150 implant with a curved plus insert and for the DP group, we used DJO, a three-dimensional knee implant.

In both groups, we used gap balancing principles to perform the surgery; however, in the DP group, we allowed minimal medial tightness and asymmetrical gap as compared to the UC group where we aimed for perfect mediolateral balance in both flexion and extension. The tibial baseplate was externally rotated, lining up with the medial third of the tibial tuberosity in the CR 150 knees but for DJO, we used anatomical coverage of the tibia, as the baseplate was asymmetric in design. In all cases, we used barbed bidirectional absorbable sutures for closure of arthrotomy. No drains were used. Postoperatively, all patients received an adductor canal block for pain relief. Deep vein thrombosis prophylaxis was given as per risk stratification. All patients underwent an accelerated rehabilitation protocol and depending on recovery, they were discharged in 3–4 days after the surgery. Dressing change was done on the day of discharge using silver-impregnated hydrocolloid dressing.

Follow-up
We recorded all the perioperative complications and adverse events in a register maintained by the study nurse (PS). Sutures were removed at 2 weeks. Patients were subsequently assessed at 3, 6, and 12 months for postoperative progression and complications. At 2 years of follow-up, nKSS, DOP, Forgotten Joint Score (FJS-12), and EQ-5D were recorded.

Statistical Analysis
Statistical analyses were performed with Stata version 12 (StataCorp.). The distributions of patient demographics and baseline disease data including severity of deformity, bone quality as assessed preoperatively, comorbidities (functional comorbidity index), hemoglobin level, and anesthetic risk assessment (ASA grade) were compared between study groups to identify any difference that might confound outcome comparisons. The potential confounder was identified and its effect was regressed from the out-
The incidences of complications were compared between the groups using the univariable Fisher’s exact test and the effect was quantified by the relative risk and its 95% confidence interval. The outcome of interest being patient-reported functional scores at the 2-year follow-up, it was planned to calculate the improvement in scores as compared to the baseline scores to make the estimates more reliable by removing the effect of baseline differences in the group. All outcome scores being continuous numerical variables, we calculated mean, mode, and median including standard deviation in the two groups and applied a parametric t-test to look for any significant difference ($p < 0.05$). We further performed a regression analysis to remove the effect of any baseline confounder to confirm the effect of implant choice on outcomes of interest. All estimates of group effect will thus be provided with their 95% confidence intervals.

**RESULTS**

Fifty patients each were enrolled in both DP and CR groups. The average age of patients was close to 63 years in both groups with the majority being women in the CR group and men in the DP group. The gender difference was significant between the groups, while the rest of the demographics, including comorbidities, were similar between the DP and CR groups (Table 1). In both groups, most patients were in the ASA grade II in pre-anesthetic evaluation. Average deformity (coronal and sagittal together) was $18.26^\circ \pm 10.76^\circ$ in the DP group and $27.38^\circ \pm 17.89^\circ$ in the CR group; the difference was statistically significant ($p < 0.001$). Regarding the severity of deformity in the DP group, 28 (56%) had mild, 13 (26%) had moderate, and 9 (18%) had severe deformity, whereas in the CR group, 15 (30%) had mild, 16 (32%) had moderate, and 19 (38%) had severe deformity, and the difference between the two groups was significant ($p = 0.002$). The baseline mean knee flexion was close to 90° in both groups (Table 2). The Delaware index was used to assess performance in each dimension (i.e., timed up and go [TUG] test, stair climb test [SCT], self-paced walk [SPW] test, chair to stand test, and leg holding test). SCT, SPW test, and leg holding test were significantly better in the DP group at the preoperative evaluation. There was no significant difference between the groups in nKSS (objective, satisfaction, expectation, and activity scores). EQ-5D on the visual analog scale was also similar between the groups.

At the 2-year follow-up, all patients were contacted telephonically and called for follow-up. But 6 patients in the CR group and 4 patients in the DP group could not come for final evaluation as they had relocated to a distant place and were not able to travel for the follow-up. The dropouts were excluded from the analysis as they could not be evaluated for their performance. The mean improvement in knee flexion was similar in the DP group and CR group, and the difference was not statistically

### Table 1. Demographic Profile in the Dual-Pivot Knee Group and Ultracongruent Group Including Comorbidities

| Variable                  | DP TKR (n = 46) | CR TKR (n = 44) | p-value |
|---------------------------|-----------------|-----------------|---------|
| Age (yr)                  | 62.47 ± 6.94    | 62.47 ± 7.48    | 0.77    |
| Sex (male : female)       | 22 : 24         | 31 : 13         | 0.02    |
| BMI (kg/m²)               | 27.76 ± 4.03    | 27.80 ± 4.88    | 0.76    |
| Functional comorbidity index | 1.00 ± 0.81   | 0.81 ± 0.69     | 0.33    |
| ASA grade (I : II : III)  | 2 : 42 : 2      | 4 : 39 : 1      | 0.56    |
| Hemoglobin G (%)          | 13.51 ± 0.44 (11.2–17.4) | 12.80 ± 1.44 (11–16.6) | 0.007   |
| Deformity in coronal and sagittal plane | 18.26 ± 10.76 | 27.38 ± 10.76 | 0.001   |
| Severity of deformity     |                 |                 | 0.02    |
| Mild                      | 26              | 13              |        |
| Moderate                  | 12              | 15              |        |
| Severe                    | 8               | 16              |        |

Values are presented as mean ± standard deviation (SD), number, or mean ± SD (range). DP: dual-pivot, TKR: total knee replacement, CR: cruciate retaining, BMI: body mass index, ASA: American Society of Anesthesiologist (grading of anesthesia risks).
significant \( (p = 0.930) \) (Table 3). Regarding the regression analysis in comparison of the change from the baseline in different parameters of the DOP score, significant differences were found in the TUG test and SCT only (the difference remained significant even after regressing for baseline differences in sex and severity of deformity between the groups (Table 4). The mean reduction in the TUG \( (p = 0.004) \) test was greater in the CR group than in the DP group, whereas the mean reduction in the SCT test \( (p = 0.026) \) was greater in the DP group than in the CR group. On the change in different components of the nKSS, there was no significant difference between the two groups at the 24-month follow-up for objective, satisfaction, expectation, and activity scales. With respect to the change in EQ-5D and FJS scores, the difference between the two groups was not significant statistically at the 24 months of follow-up (Table 3).

In the DP group, 1 patient had hypotension on day 1 postoperatively, 2 patients had stiff knee, and 1 had superficial cautery burn, while in the CR group, 1 patient had eczema and 2 had stiffness of the knee. Statistically, there was no significant difference in complications between the two groups. None of the patients in either group had a prosthetic joint infection, instability, cardiopulmonary complications, or periprosthetic fracture.

**DISCUSSION**

The advent of TKR was a significant step in the management of knee osteoarthritis. Within two decades of its use, it established itself as an extremely successful surgical procedure with high patient satisfaction (80%–100%).\(^{16}\) Unlike THR wherein more than 95% of patients achieve satisfaction from the procedure, most studies showed a dissatisfaction rate of 20% after TKR.\(^ {17}\) One reason cited for its less than optimum results is the complex bony and ligamentous anatomy of the knee, making it difficult for any prosthetic design to mimic its kinematics.\(^ {18}\) There have been continued efforts to modify the design of the knee in terms of the femoral component and articular insert to optimize the kinematics.

Two knee implant designs, which till recently were the only popular designs, posterior stabilized knee (PS Knee) and CR Knee, have been questioned in their ability to restore the pre-arthritic level of activity of the patient and hence considered inadequate in maximizing patient satisfaction. As an attempt to improve the outcomes and take advantage of the two designs (PS and CR), the UC Knee has been popularized. Since its introduction in our country in the last decade, we have been using the same design in most of our primary TKR.

| Table 2. Baseline Disease, Function, Performance, and Quality of Life Scores in the Dual-Pivot Knee Group and Ultracongruent Group |
| Parameter | DP TKR (n = 46) | CR TKR (n = 44) | p-value* |
| --- | --- | --- | --- |
| Knee flexion \(^ {\circ})\) | 94.13 ± 17.2 | 86.70 ± 20.8 | 0.09 |
| Delaware index | | | |
| Timed up and go test (sec) | 33.89 ± 14.6 | 45.77 ± 19.5 | 0.001 |
| Stair climb test (sec) | 62.52 ± 22.7 | 68.26 ± 18.7 | 0.35 |
| Self-paced walk test (m/sec) | 0.10 ± 0.90 | 0.18 ± 0.30 | 0.57 |
| Chair to stand test (n) | 3.97 ± 2.00 | 3.32 ± 2.00 | 0.09 |
| Leg holding test (sec) | 18.24 ± 6.40 | 15.43 ± 11.0 | 0.00 |
| New KSS | | | |
| Objective (max 100) | 47.8 ± 10.7 | 47.8 ± 11.9 | 0.85 |
| Satisfaction (max 40) | 10.1 ± 2.5 | 10.4 ± 4.7 | 0.98 |
| Expectation (max 15) | 10.5 ± 2.5 | 9.7 ± 2.5 | 0.12 |
| Activity (max 100) | 18.2 ± 5.7 | 18.5 ± 6.3 | 0.69 |
| EQ-5D (VAS, max 100) | 43.8 ± 7.2 | 43.5 ± 7.7 | 0.36 |

Values are presented as mean ± standard deviation.

DP: dual-pivot, TKR: total knee replacement, CR: cruciate retaining, KSS: Knee Society Score, EQ-5D: EuroQoL five-dimensional instrument, VAS: visual analog scale.

*Using t-test.
In the recent past, we introduced the medial pivot knee design in our practice and had encouraging results comparable to those of the PS knee design as published by the authors in the past. The medial pivot knee had a smaller final range of movement as compared to the PS knee but had better performance in some parameters of the DOP score like walking speed and climbing stairs. The medial pivot knee has a deep congruent medial compartment, almost mimicking a ball in socket geometry, thus providing stability on the medial side while allowing increased lateral gliding and rollback.\(^{16,19-21}\) It tries to mimic the natural screw home movement of the knee. This philosophy introduced in the early 90s encompassed the ball and socket ultra-congruent medial compartment between the single radius femoral component and the asymmetrical tibia conforming controlled congruent motion medially through the complete range of flexion while allowing easy translation in the lateral compartment, mimicking more natural kinematics of the prosthetic knee. The lateral pivot or rather the DP knee popularized by DJO surgical is an alternate philosophy introduced with an analogy to provide stabilizing properties of anterior cruciate substitution.

| Parameter | Delta KSFS | Delta VAS | Delta TUG test | Delta CTST | Delta SCT | Delta SPWT | Delta THLT |
|-----------|------------|-----------|----------------|------------|-----------|------------|------------|
| Deformity | 0.06 (0.54) | 0.12 (0.31) | 0.04 (0.73) | 0.03 (0.12) | −0.18 (0.20) | 0.01 (0.39) | 0.13 (0.22) |
| Sex       | 7.49 (0.04) | 0.91 (0.80) | 2.99 (0.43) | 1.61 (0.02) | 6.02 (0.18) | 0.15 (0.69) | 1.75 (0.61) |
| Implant   | −1.50 (0.69) | 4.58 (0.23) | −11.73 (0.04) | 1.20 (0.09) | 10.55 (0.02) | 0.69 (0.08) | 1.74 (0.62) |

KSFS: Knee Society Function Score, VAS: visual analog scale, TUG: timed up and go, CTST: chair to stand test, SCT: stair climb test, SPWT: self-paced walk test, THLT: time horizontal leg test.

### Table 3. Difference as Compared to Baseline in the 2-Year Outcome Function, Performance, and Quality of life Scores between the Dual-Pivot Knee Group and Ultracongruent Group

| Parameter | DP TKR (n = 46) | CR TKR (n = 46) | p-value* | Adjusted for sex and deformity |
|-----------|----------------|----------------|----------|-------------------------------|
| Knee flexion (°) | 26.3 ± 23.3 | 27.5 ± 27.5 | 0.930 | 0.283 |
| Delaware index | | | | |
| Timed up and go test (sec) | −20.0 ± 15.3 | −30.1 ± 18.5 | 0.007 | 0.004 |
| Stair climb test (sec) | −51.1 ± 18.2 | −42.2 ± 23.3 | 0.013 | 0.026 |
| Self-paced walk test (n/sec) | 0.3 ± 1.0 | 0.9 ± 2.3 | 0.665 | 0.089 |
| Chair to stand test (n) | 5.9 ± 3.1 | 6.2 ± 3.4 | 0.152 | 0.092 |
| Leg holding test (sec) | 6.2 ± 13.5 | 10.3 ± 17.1 | 0.153 | 0.625 |
| New KSS | | | | |
| Objective (max 100) | 41.9 ± 14.1 | 43.0 ± 13.6 | 0.320 | 0.662 |
| Satisfaction (max 40) | 25.8 ± 5.4 | 26.3 ± 7.4 | 0.430 | 0.482 |
| Expectation (max 15) | 4.0 ± 2.6 | 2.9 ± 4.0 | 0.486 | 0.471 |
| Function (max 100) | 47.9 ± 18.9 | 44.3 ± 12.6 | 0.254 | 0.691 |
| EQ-5D (VAS, max 100) | 33.7 ± 18.2 | 44.4 ± 15.0 | 0.148 | 0.239 |
| FJS at 24 months (max 100) | 71.9 ± 14.8 | 72.1 ± 16.4 | 0.945 | 0.687 |

Values are presented as mean ± standard deviation. DP: dual-pivot, TKR: total knee replacement, CR: cruciate retaining, KSS: Knee Society Score, EQ-5D: EuroQoL five-dimensional instrument, VAS: visual analog scale, FJS: Forgotten Joint Score.

In the recent past, we introduced the medial pivot knee design in our practice and had encouraging results comparable to those of the PS knee design as published by the authors in the past. The medial pivot knee had a smaller final range of movement as compared to the PS knee but had better performance in some parameters of the DOP score like walking speed and climbing stairs. The medial pivot knee has a deep congruent medial compartment, almost mimicking a ball in socket geometry, thus providing stability on the medial side while allowing increased lateral gliding and rollback.\(^{16,19-21}\) It tries to mimic the natural screw home movement of the knee. This philosophy introduced in the early 90s encompassed the ball and socket ultra-congruent medial compartment between the single radius femoral component and the asymmetrical tibia conforming controlled congruent motion medially through the complete range of flexion while allowing easy translation in the lateral compartment, mimicking more natural kinematics of the prosthetic knee. The lateral pivot or rather the DP knee popularized by DJO surgical is an alternate philosophy introduced with an analogy to provide stabilizing properties of anterior cruciate substitution.
during early flexion/extension, while behaving as a medial pivot in deeper flexions of the knee to overcome the mechanical issues of intrinsic stability, weakness, endurance, and feel of the unnatural knee during various phases of gait to enhance function and patient satisfaction.\(^\text{9,13,14,22}\)

The initial lateral pivot is accomplished by sphericity of the lateral compartment, which imparts more conformity to enhance anterior stability in the early range of flexion, while its anteroposterior laxity helps posterior translation of the femur on the lateral surface simultaneously with optimal translation on a sagittal anatomically curved articulation of the medial condyle in deeper flexion (Fig. 2).

In our study, we compared patient satisfaction and performance of the DP knee to the UC knee in terms of nKSS, FJS, and DOP at 2 years of follow-up. We found that there was no significant difference in patient-reported function and satisfaction between the UC and DP group patients. Looking at performance, the UC group had a significantly better ability to get up from the chair and walk, whereas the DP group had a significantly better ability to climb stairs. The rest of the performance indicators were similar in the two groups. Barring some differences in the performance, the patient-reported satisfaction, function and objective improvement in knee range of movement, alignment, and stability were similar in both DP and UC groups. Not many of the published retrospective comparative studies to date have compared the DP design to any other design. Sandberg et al.\(^\text{14}\) equated the DP with CR knees and observed marginally better walking ability with less pain. Meneghini et al.\(^\text{23}\) found better functional scores in their retrospective review. Mikashima\(^\text{13}\) in their small cohort of 10 cases compared with CR design found better flexion in the DP group. None of these findings have been supported in our prospective controlled trial (Table 5). We found no significant difference in function and satisfaction.

There are some limitations of our study. First, we could not randomize the allocation as the DP knee was a relatively new introduction in our practice; we had to allocate patients as per the surgeon’s and patient’s preference, which is likely to confound the outcome. However, we recorded all the possible disease and patient parameters, which were likely to be the predictors of outcome, and

![Fig. 2. DJO three-dimensional knee with a femoral component insert and a tibial component.](image)

| Table 5. Literature Review |
|---------------------------|
| **Study** | **Type of study** | **DP/other design** | **Follow-up (yr)** | **Function score** | **Remark** |
| Mikashima et al. (2010)\(^\text{13}\) | Retrospective | 10/10 (CR) | 1 | KSS | DP design exhibited greater flexion (by 10°), femoral anteroposterior translation, and tibial internal rotation |
| Meneghini et al. (2017)\(^\text{23}\) | Retrospective review | 16/43 (OKK) | 1 | nKSS, UCLA | Dual-Pivot knee had higher functional outcome scores along with higher overall patient satisfaction. |
| Banks and Meneghini (2018)\(^\text{9}\) | Retrospective review | 126/126 (NC) | 1 | UCLA | Dual-Pivot knees had better “knee feel,” higher postoperative activity levels, and better satisfaction. |
| Sandberg et al. (2019)\(^\text{14}\) | Retrospective study | 183/183 (CR) | 1 | KSS, UCLA | Dual-Pivot knees reported to have less walking pain and potential benefit of lateral-pivot motion in early flexion activities. |
| This study (2021) | Prospective series | 46/44 (CR) | 1 | nKSS, DOPS, FJS-12 | No difference |

DP: dual-pivot, CR: cruciate retaining, KSS: Knee Society Score, OKK: other kinematic knee, nKSS: new Knee Society Score (objective and subjective), UCLA: University of California, Los Angeles, NC: nonconforming knee, DOPS: Delaware Osteoarthritis Profile Score, FJS: Forgotten Joint Score.
identified potential confounders, thus enabling us to carry out adjusted statistical analysis to validate our results. Second, the use of a newer implant (DP knee) with limited usage in the past might have affected the surgical outcomes in the group.

To optimize familiarity of the operating team to the DP knee, the study was started only after the surgical team had performed 200 cases. And as brought out in the technique, the basic step followed was gap balancing technique. The notable strength of our study was that it was a prospective controlled cohort study with a priori sample size calculation allowing statistical adjustments if required of potential confounders. The strong design of the study makes it the only level I study published to date comparing the DP knee with any other knee designs. It is the only study that has used a performance indicator (DOP) to look for any advantages of the DP knee. The outcome assessment was meticulously blinded using trained physiotherapists. With the inclusion of only patients who underwent bilateral TKR, we could ensure comparable outcome assessment as there was no need to control for contralateral knee disease, which would have been necessary and difficult in cases of unilateral TKR. Our study had more than 90% follow-up and with a liberal inclusion criterion, it has very good external validity.

To conclude, the DP knee provided excellent outcomes in terms of patient-reported function, which was similar to those achieved with the UC knee design at the 24 months of follow-up. Regarding performance, there were differences in stair climbing ability and ability to stand up from chair between the two designs, but it was not significant enough to be able to establish an advantage of one design over the other. With the extreme paucity of studies, it would be prudent to design a randomized study with the primary outcome being patient performance, using objective outcome assessment tools including scales to assess high-performance activities.

**CONFLICT OF INTEREST**

No potential conflict of interest relevant to this article was reported.

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**REFERENCES**

1. Ackerman IN, Bohensky MA, Zomer E, et al. The projected burden of primary total knee and hip replacement for osteoarthritis in Australia to the year 2030. BMC Musculoskelet Disord. 2019;20(1):90.
2. Ellisa HB, Howard KJ, Khaleela M. Influence of socioeconomic status on outcome of joint replacement surgery. Curr Orthop Pract. 2010;21(2):132-7.
3. Nilsdotter AK, Toksvig-Larsen S, Roos EM. Knee arthroplasty: are patients’ expectations fulfilled? A prospective study of pain and function in 102 patients with 5-year follow-up. Acta Orthop. 2009;80(1):55-61.
4. Bryan S, Goldsmith LJ, Davis JC, et al. Revisiting patient satisfaction following total knee arthroplasty: a longitudinal observational study. BMC Musculoskelet Disord. 2018;19(1):423.
5. Dunbar MJ, Richardson G, Robertsson O. I can’t get no satisfaction after my total knee replacement: rhymes and reasons. Bone Joint J. 2013;95(11 Suppl A):148-52.
6. Bourne RB, Chesworth BM, Davis AM, Mahomed NN, Charron KD. Patient satisfaction after total knee arthroplasty: who is satisfied and who is not? Clin Orthop Relat Res. 2010;468(1):57-63.
7. Banks SA, Hodge WA. Implant design affects knee arthroplasty kinematics during stair-stepping. Clin Orthop Relat Res. 2004;(426):187-93.
8. Causero A, Di Benedetto P, Beltrame A, Gisonni R, Cainero V, Pagano M. Design evolution in total knee replacement: which is the future? Acta Biomed. 2014;85 Suppl 2:5-19.
9. Banks SA, Meneghini RM. Achieving more natural motion, stability, and function with a dual-pivot ACL-substituting total knee arthroplasty design. Tech Orthop. 2018;33(1):48-51.
10. Lutzner J, Beyer F, Lutzner C, Riedel R, Tille E. Ultracongruent insert design is a safe alternative to posterior cruciate-substituting total knee arthroplasty: 5-year results of a randomized controlled trial. Knee Surg Sports Traumatol Arthrosoc. 2022;30:3000-6.

11. Song EK, Lim HA, Joo SD, Kim SK, Lee KB, Seon JK. Total knee arthroplasty using ultra-congruent inserts can provide similar stability and function compared with cruciate-retaining total knee arthroplasty. Knee Surg Sports Traumatol Arthrosoc. 2017;25(11):3530-5.

12. Lizaur-Utrilla A, Gonzalez-Parreno S, Martinez-Mendez D, Miralles-Munoz FA, Lopez-Prats FA. Minimal clinically important differences and substantial clinical benefits for Knee Society Scores. Knee Surg Sports Traumatol Arthrosoc. 2020;28(5):1473-8.

13. Mikashima Y, Tomatsu T, Horikoshi M, et al. In vivo deepflexion kinematics in patients with posterior-cruciate retaining and anterior-cruciate substituting total knee arthroplasty. Clin Biomech (Bristol, Avon). 2010;25(1):83-7.

14. Sandberg R, Deckard ER, Ziemia-Davis M, Banks SA, Meneghini RM. Dual-pivot bearings improve ambulation and promote increased activity levels in total knee arthroplasty: a match-controlled retrospective study. Knee. 2019;26(6):1243-9.

15. Kulshrestha V, Kumar S. DVT prophylaxis after TKA: routine anticoagulation vs risk screening approach: a randomized study. J Arthroplasty. 2013;28(10):1868-73.

16. Kahlenberg CA, Nwachukwu BU, McLawhorn AS, Cross MB, Cornell CN, Padgett DE. Patient satisfaction after total knee replacement: a systematic review. HSS J. 2018;14(2):192-201.

17. Klem NR, Kent P, Smith A, et al. Satisfaction after total knee replacement for osteoarthritis is usually high, but what are we measuring? A systematic review. Osteoarthr Cartil Open. 2020;2(1):100032.

18. Verhaar J. Patient satisfaction after total knee replacement: still a challenge. Acta Orthop. 2020;91(3):241-2.

19. Kulshrestha V, Sood M, Kanade S, Kumar S, Datta B, Mittal G. Early outcomes of medial pivot total knee arthroplasty compared to posterior-stabilized design: a randomized controlled trial. Clin Orthop Surg. 2020;12(2):178-86.

20. Atzori F, Salama W, Sabatini L, Mousa S, Khalefa A. Medial pivot knee in primary total knee arthroplasty. Ann Transl Med. 2016;4(1):6.

21. Bordini B, Ancarani C, Fitch DA. Long-term survivorship of a medial-pivot total knee system compared with other cemented designs in an arthroplasty registry. J Orthop Surg Res. 2016;11:44.

22. Hossain F, Patel S, Rhee SJ, Haddad FS. Knee arthroplasty with a medially conforming ball-and-socket tibiofemoral articulation provides better function. Clin Orthop Relat Res. 2011;469(1):55-63.

23. Meneghini RM, Deckard ER, Ishmael MK, Ziemia-Davis M. A dual-pivot pattern simulating native knee kinematics optimizes functional outcomes after total knee arthroplasty. J Arthroplasty. 2017;32(10):3009-15.