The Impact of Intraoperative Gap Difference Between Extension and Flexion on Perception of Joint Function After Total Knee Arthroplasty: a Comparative Retrospective Study

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Research Article

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Abstract

Background: The argument presupposes that intra-operative soft tissue balance is associated with patient-reported outcome measures after total knee arthroplasty (TKA). Our aim was to assess the association between the extension-to-flexion gap and patients' reported perception of knee joint function.

Methods: This was a retrospective study of 60 cases of primary cruciate-retaining TKAs performed for the treatment of medial-compartment knee osteoarthritis, at a mean follow-up of 2.6 (range, 2.0–5.2) years. Knee perception was evaluated by asking patients whether they considered their knee joint as "natural" (grade I) or "artificial", *with* or *without* restrictions (grades II–V). The following factors were compared between the two groups: age, sex, and the extension-to-flexion gap difference. A multiple logistic regression analysis was used to identify predictive factors of an artificial knee joint perception. A receiver operating characteristic curve analysis was used to identify cut-off values of predictive factors.

Result: Compared to a natural knee joint perception (26 knees, 43%), an artificial perception (34 knees, 57%) was associated with a smaller gap difference at the distraction force of 20 lbf ($p < .001$), 30 lbf ($p = .022$), and 40 lbf ($p = .038$), a lower EuroQol 5-Dimension score ($p = .029$), and self-reported joint health (Knee injury and Osteoarthritis Outcome Score-Joint Replacement [KOOS-JR], $p = .032$). A gap difference <1.0 mm was a predictive of an artificial perception (odds ratio, 1.63; 95% confidence interval, 1.33–4.54; $p < .001$). A cut-off gap difference of 0.99 mm at 20 lbf predicted an artificial perception with a sensitivity of 81.5% and a specificity of 87.9%. Post-operative satisfaction ($p < .001$), KOOS-JR ($p < .001$), patient's joint perception ($p = .006$), pain ($p = .015$), and EuroQol 5-Dimension ($p = .032$) differed between the two groups when the gap difference threshold was set to 1.0 mm.

Conclusion: Careful balancing of soft tissue during TKA to achieve an extension-to-flexion gap ≥ 1.0 mm can improve patients' perception of knee joint function and quality of life.

Background

An equidistant flexion and extension gap, with accurate component placement, is essential for successful total knee arthroplasty (TKA) [1, 2]. However, the optimal intra-operative soft tissue balance is generally based on surgeon-specific assessment [3]. Some studies have used measurement devices to quantify the extension and flexion gap intra-operatively under a pre-defined distraction force [4–8]. The extension-to-flexion gap difference has also been measured intra-operatively by subtracting the extension gap from the flexion gap, with and without the femoral component placement [5, 6, 8]. Measurement of the extension-to-flexion gap is important as it relates to patient-reported outcomes after TKA.

While TKA is recognized as an effective treatment for knee joint osteoarthritis (OA) worldwide, up to 20% of patients unfortunately report persistent dissatisfaction with their post-TKA outcomes [9, 10]. As the demand for TKA is expected to increase rapidly in the future [11], further improvement in patient satisfaction after TKA is considered a pertinent clinical issue necessary to address.

Patient-reported outcome measures (PROMs) are now promoted to evaluate patient satisfaction in general, including post-TKA. Among PROMs for TKA, the Forgotten Joint Score-12 and the Patient's Joint Perception questionnaire have been found to be useful as they avoid the ceiling effect that is a significant limitation of other PROMs for postoperative patient satisfaction with different prostheses or inserts [12, 13]. A few studies have investigated the correlation between extension and flexion gap measurements and patient reported perception of joint function [14]. However, this issue needs further research to improve our understanding of the relationship between soft tissue balance during TKA and postoperative knee joint function. Therefore, the purpose of our study was to assess the association between the intraoperative difference in the extension and flexion gap and PROMs after TKA, including satisfaction and perception of knee joint function.

Materials And Methods

Statement of ethics

The study was approved by the institutional review board of our university hospital, located in a city with a population > 350,000. All patients provided informed consent for the surgery and the use of their data for research.

Study design and group

This was a retrospective study of patients who underwent primary cruciate-retaining TKA, using a single-radius prosthesis, between April 2016 and March 2019 at a single institution. To control for possible confounding effects of ethnicity, only patients of Asian race were included. As well, only those who completed a minimum follow-up of 2 years after TKA were eligible. Of the 68 TKAs performed over the study period, 63 knees were included in the analysis for the treatment of medial-compartment OA. From this group, 3 patients were excluded for the following reasons: traumatic arthritis (2 knees) and previous knee surgery (1 knee). Ultimately, 52 patients (60 knees) were included, with a mean follow-up of 2.6 (range, 2.0–5.2) years (Fig. 1).

Surgical procedure and perioperative management

All cruciate-retaining TKAs (Scorpio NRG; Stryker Howmedica Osteonics, Mahwah, NJ, USA) were performed under general anesthesia and regional analgesia by the senior author, via a long straight mid-line incision and a measured resection technique, using an intramedullary guide [15, 16]. The extent of distal resection was fixed at 8 mm, regardless of the component size, with the extent of posterior resection determined to achieve the same thickness as the femoral component. External rotation was set parallel to the surgical epicondylar axis and the component size was determined using posterior referencing. An extramedullary alignment guide was used to perform proximal tibial resection perpendicular to the mechanical axis, with the targeted resection level set approximately 10 mm below the less affected area of the lateral tibial plateau and the posterior tibial slope set to 5°. We created a bone island to avoid injury to the attachment of the posterior cruciate ligament [17]. All patients underwent patellar resurfacing and all implants were fixed using bone cement (ENDURANCE; DePuy Orthopaedics, USA). On the second postoperative day, all patients were allowed to walk at full weight-bearing, initiated a program of knee exercises with a physical therapist, and were prescribed anticoagulants for two weeks to prevent deep vein thrombosis.

Soft tissue balance measurement

We used a tensor device (DynAccurate, Stryker, Japan) to continuously quantify the distraction force, with the soft tissue balance measured with the femoral trial component in place and the patella in a reduced position. Our measurement of soft tissue balance was validated in our previous study, as follows [16]. Two raters measured the extension gap three times at a distraction force of 10–50 lbf. The intraclass correlation coefficient (1,1 and 2,1, respectively) for the distraction forces used, were as follows, respectively [16]: 10 lbf, 0.90 and 0.68; 20 lbf, 0.80 and 0.70; 30 lbf, 0.80 and 0.72; 40 lbf, 0.89 and 0.70; and 50 lbf, 0.92 and 0.78. The intraoperative joint gap at full knee extension and at a 90° of knee flexion were measured three times at distraction forces ranging from 0 lbf to 40 lbf, with an accuracy level within 0.01 lbf and calculated to an accuracy of two decimal places. Based on a simple regression analysis of the association between the distraction force and the extension or the flexion gap, we calculated the gap difference by subtracting the extension gap from the flexion gap at a distraction force ranging from 5 lbf to 40 lbf [8, 16]. The coefficient of determination between the applied distraction force and the measured gap was 0.93 (standard deviation, 0.07) for extension and 0.96 (0.02) for flexion.

Measured variables

Preoperatively and at the last follow-up, we measured the range of motion using a goniometer, with a resolution of 1°, and the Knee Society Score (KSS) [18]. We evaluated the following PROMs: pain, satisfaction, and knee joint perception [12, 13, 19]. Pain was evaluated using a 100-mm visual analogue scale (VAS), with anchors at “0” mm (no pain) and “100” mm (worst pain imaginable) [19]. Satisfaction was also evaluated using a 100-mm VAS, with anchors at “0” (very satisfied) and “100” (completely dissatisfied). Joint perception after TKA was evaluated by asking individuals whether they perceived their knee joint as being “natural” or “artificial” and whether or not they perceived functional limitations, as previously described [12, 13]. Specifically, patients were asked to respond to the following question: “How do you perceive your operated knee?” Responses were graded as follows: I, like a native or natural joint; II, like an artificial joint with no restriction; III, like an artificial joint with minimal restriction; IV, like an artificial joint with major restriction; and V, like a non-functional joint [12, 13]. We used the Knee Injury and Osteoarthritis Outcome Score for Joint Replacement (KOOS-JR) as a measure of pain and function on activities of daily living. The KOOS-JR was developed to evaluate function pre- to post-TKA among patients who undergo TKA for knee OA [20]. The KOOS-JR includes 7 items and with demonstrated validity and reliability as a measure of joint health. Each item on the KOOS-JR is measured on a scale of ‘0’ (none) to ‘4’ (extreme), with higher a score indicative of poor outcome. The overall score is then converted into an interval score ranging from ‘0’ (total joint-related disability) to ‘100’ (perfect joint health) [20]. The EuroQol 5-Dimension 5-Level scale was used as a measure of patient-reported quality of life [21].

Radiological evaluations

Limb alignment was assessed pre-operatively and at the last follow-up. Whole-leg anteroposterior radiographs were obtained in weight-bearing, with patients standing with the back of their knees in contact with the vertical cassette and the central beam centered 2.5 cm below the apex of the patella and placed anterior to the apex using a film to a focus distance of 1.0 m. The settings of the radiographic beam, centered on the knee at a distance of 2.4 m, were about 90 kV for anteroposterior and lateral radiographs [22, 23]. The radiographic images were retrieved using the picture archiving and communication system (IMPAX; Agfa Healthcare, Mortsel, Belgium). We measured the hip-knee-ankle angle, formed by a line drawn from the center of the hip to the center of the knee joint and a line drawn from the center of the ankle to the center point of the knee [22]. We used the American Knee Society radiographic evaluation to measure component orientation, as follows. In the anteroposterior view, we measured the femoral component medial angle, between the articular surface and the femoral anatomical axis, and the tibial component medial angle, measured between the implant and the tibial anatomical axis. In the lateral view, we measured the femoral component flexion angle, between the line perpendicular to the distal articular surface and the axis, and the tibial posterior slope angle, between the articular surface and the axis [23].

Statistical analyses

Statistical analyses were performed using JMP 14 software (SAS Institute Inc, Cary, NC, USA), with a p-value < 0.05 considered statistically significant. The patients were classified into two groups based on self-reported perception of their knee joint as being 'natural' (graded response I) or 'artificial' (graded responses II-V) [13]. Between-group differences were evaluated using a Student's t test or Mann–Whitney U test, depending on the normality of the data distribution evaluated using the Shapiro-Wilk test, with a Fisher's exact or chi-squared test to evaluate between-group differences for dichotomous variables. A repeated measures analysis of variance (ANOVA) was used to compare soft tissue measurements for the different distraction forces used, with Fisher's protected least significance difference test used for post-hoc analysis.

A multivariate logistic regression was used to calculate the odds ratio and associated 95% confidence interval (CI) for identified risk factors for an artificial perception of the knee post-TKA, graded responses II-V [12, 13]. A multicollinearity test was performed, with the inflation factor set at < 10. Age was included as a confounding factor. To identify the cut-off value of the parameters for predicting an artificial perception of the knee post-TKA, we used the receiver-operating characteristic (ROC) curve.

Results

For all 52 patients, there was a significant improvement from baseline to the final follow-up, as follows: KSS ($p = .019$); functional score ($p = .013$); KOOS-JR ($p = .012$); and EQ-5D-5L ($p = .018$). The soft tissue measurement at 20 lbf was statistically different from the flexion gap measured at 10 lbf ($p = .011$) and the extension gap measured at 30 lbf ($p = .017$) (Fig. 2). Post-TKA, a natural perception was reported in 26 knees (43%) and an artificial perception in 34 (57%). Compared to the natural knee joint perception group, patients with an artificial knee joint perception had a smaller gap extension-to-flexion difference at the distraction force of 20 lbf ($p < .001$), 30 lbf ($p = .022$), and 40 lbf ($p = .038$), a lower EuroQol 5-Dimension scale score ($p = .029$), and KOOS-JR ($p = .032$) (Tables 2 and 3). A gap difference < 1.0 mm was predictive of an artificial knee joint perception (odds ratio, 1.63; 95% confidence interval, 1.33–4.54; $p < .001$; Table 4). The diagnostic performance of the gap difference at a distraction force of 20 lbf was evaluated from the ROC curve. The cut-off gap value of < 0.99 mm had a sensitivity of 81.5% and a specificity of 87.9% (Fig. 3). Postoperative satisfaction ($p < .001$), KOOS-JR ($p < .001$), patient's joint perception ($p = .006$), pain ($p = .015$), and EuroQol 5-Dimension scale score ($p = .032$) were different between the 'natural' and 'artificial' groups when the threshold gap of 1.0 mm was used (Table 5).

Discussion

The most important finding of our study was that an artificial knee joint perception (57% of patients overall) was associated with a smaller extension-to-flexion gap difference at a distraction force of 20 lbf ($p < .001$) to 40 lbf ($p = .038$), a lower EuroQol 5-Dimension scale score ($p = .029$), and KOOS-JR ($p = .032$), compared to patients reporting a natural knee joint perception group (Tables 2, 3). Moreover, a gap difference of < 1.0 mm at the distraction force of 20 lbf was predictive of an artificial knee joint perception (Table 4), in agreement with the cut-off value of < 0.99 mm identified in the ROC analysis (Fig. 3). This finding indicates the careful consideration that clinicians must place in measuring the extension-to-flexion gap during TKA to improve postoperative patient satisfaction and health-related quality of life.

In their study on posterior-stabilized TKA, Nagai et al. reported no significant differences between the extension and flexion gap at a distraction force of 20 lbf, 40 lbf, and 60 lbf, with a positive correlation between soft tissue measurement and the applied distraction force ($p < .01$) [24]. Our findings are in agreement with those of Nagai et al., with little difference between the extension and flexion gap at distraction forces of 5–40 lbf (Table 2). Our focus was on assessing the association between the measured intra-operative extension-to-flexion gap difference and PROMs after TKA, including satisfaction and joint perception. We identified differences in post-operative satisfaction ($p < .001$), KOOS-JR ($p < .001$), patient's joint perception ($p = .006$), pain ($p = .015$), and EuroQol 5-Dimension scale score ($p = .032$) between patients with an extension-to-flexion gap < 1.0 mm compared to a gap ≥ 1.0 mm at a distraction force of 20 lbf (Table 5).

The limitations of our study should be acknowledged in the interpretation of results for practice. First, this was a retrospective study with a relatively small sample which included only patients of Asian ethnicity; therefore, our findings might not be applicable to other populations. Also, all surgeries were performed by a single surgeon, using only one type of cruciate-retaining prosthesis with a single-radius used [15, 16]. Therefore, our results cannot be generalized to other implant types (Table 1). We do note that the primary indication for TKA is medial-compartment OA, with a greater prevalence of TKA in women than men [5, 7]. In fact, only 16.7% of our study group were men. Second, we did not assess the intra-operative soft tissue balance at the mid-flexion position which would be important to determine the presence/absence of mid-flexion knee joint instability [7]. This would be important as previous studies have reported normal kinematics throughout the range of knee joint motion for cruciate-retaining TKA [25].

Despite these limitations, our study does highlight that the extension-to-flexion gap difference measured under a distraction force of 20 lbf could affect functional disability 2 to 5.2 years after TKA. Although it has been suggested that post-TKA satisfaction is generally determined by an individual's personality and/or medical expectation, our findings to show that an intra-operative extension-to-flexion gap difference < 1.0 mm is associated with a self-reported artificial perception of knee joint function after TKA (Fig. 3). Therefore, this result should be precisely evaluated during TKA to improve patient satisfaction [6]. Our use of patient-reported knee joint perception is novel and was sensitive to an extension-to-flexion gap < 1.0 mm or ≥ 1.0 mm. Therefore, the measured gap and knee joint perception could be helpful in setting expectations for patients and surgeons, which would have a beneficial impact on PROMs.

Conclusions

Careful balancing of soft tissue during TKA to achieve an extension-to-flexion gap ≥ 1.0 mm can improve patients' perception of knee joint function and quality of life after TKA. The measured gap difference provides a feasible strategy to understand the relationship between the soft tissue balance and postoperative outcomes. This could also suggest a means to manage surgeons' and patients' expectations after TKA.

List Of Abbreviations

CI, confidence interval

KOOS-JR, Knee Injury and Osteoarthritis Outcome Score for Joint Replacement

OR, odds ratio

PROM, patient-reported outcome measures

ROC, receiver-operating characteristic

TKA, total knee arthroplasty

VAS, visual analogue scale

Declarations

Ethics approval and consent to participate

This study was performed in accordance with the principles of the Declaration of Helsinki (1964) and its subsequent amendments and was approved by the institutional review board of Osaka Medical College hospital (approval number-2288). Informed consent was obtained from all individual participants included in the study.

Consent for publication

All authors agree to publish in this journal.

Availability of data and materials

The datasets used and/or analysed in this study are available from the corresponding author on reasonable request.

Competing interests

TO and YO were asked to provide the measurement equipment for Stryker Japan. The other authors have no conflicts of interest to declare.

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Authors' contributions

TO, YO, HW, and SO designed the study. TO and YO collected the data. TO completed the initial draft. YO performed the statistical analysis. YO and MN ensured the accuracy of the data and analysis.

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References

1. Sharkey PF, Hozack WJ, Rothman RH, Shastri S, Jacoby SM. Why are total knee arthroplasties failing today? Clin Orthop Relat Res 2002:404:7–13. https://doi.org/10.1097/00003086-200211000-00003.
2. Atwood SA, Currier JH, Mayor MB, Collier JP, Van Citters DW, Kennedy FE. Clinical wear measurement on low contact stress rotating platform knee bearings. J Arthroplasty 2008;23:431–40. https://doi: 10.1016/j.arth.2007.06.005.
3. Gustke KA, Golladay GJ, Roche MW, Elson LC, Anderson CR. A new method for defining balance: promising short-term clinical outcomes of sensor-guided TKA. J Arthroplasty 2014;29:955–60. https://doi.org/10.1016/j.arth.2013.10.020.

4. Tsubosaka M, Muratsu H, Takayama K, Miya H, Kuroda R, Matsumoto T. Comparison of intraoperative soft tissue balance between cruciate-retaining and posterior-stabilized total knee arthroplasty performed by a newly developed medial preserving gap technique. J Arthroplasty 2018;33:729–34. https://doi.org/10.1016/j.arth.2017.09.070.
5. Okamoto Y, Nakajima M, Jotoku T, Otsuki S, Neo M. Capsular release around the intercondylar notch increases the extension gap in posterior-stabilized rotating-platform total knee arthroplasty. Knee 2016;23:730–5. https://doi.org/10.1016/j.knee.2015.11.022.
6. Hayashi S, Murakami Y, Inoue H, Nobutou H, Nishida K, Mochizuki Y. Gap measurement in posterior-stabilized total knee arthroplasty with or without a trial femoral component. Arch Orthop Trauma Surg 2014;134:861–5. https://doi.org/10.1007/s00402-014-1955-2.
7. Minoda Y, Nakagawa S, Sugama R, Ikawa T, Noguchi T, Hirakawa M. Joint gap in mid-flexion is not a predictor of postoperative flexion angle after total knee arthroplasty. J Arthroplasty. 2018;33:735-9. https://doi.org/10.1016/j.arth.2017.10.030
8. Hananouchi T, Yamamoto K, Ando W, Fudo K, Ohzono K. The intraoperative gap difference (flexion gap minus extension gap) is altered by insertion of the trial femoral component. Knee. 2012;19:601-5. https://doi.org/10.1016/j.knee.2011.08.001
9. Heck DA, Robinson RL, Partridge CM, Lubitz RM, Freund DA. Patient outcomes after knee replacement. Clin Orthop Relat Res 1998:93–110. https://doi.org/10.1097/00003086-199811000-00015.
10. Bourne RB, Chesworth BM, Davis AM, Mahomed NN, Charron KDJ. Patient satisfaction after total knee arthroplasty: Who is satisfied and who is not? Clin Orthop Relat Res 2010;468:57–63. https://doi.org/10.1007/s11999-009-1119-9.
11. Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. J Bone Joint Surg Am 2007;89:780–5. https://doi.org/10.2106/JBJS.F.00222.
12. Collins M, Lavigne M, Girard J, Vendittoli PA. Joint perception after hip or knee replacement surgery. Orthop Traumatol Surg Res 2012;98:275-80. http://dx.doi.org/10.1016%2Fj.otsr.2011.08.021
13. Eichler D, Beaulieu Y, Barry J, Massé V, Vendittoli PA. Perception of a natural joint after total knee arthroplasty. J Arthroplasty. 2020;35:358-63. https://doi.org/10.1016/j.arth.2019.09.036
14. Fujimoto E, Sasashige Y, Tomita T, Sasaki H, Touten Y, Fujiwara Y, et al. Intra-operative gaps affect outcome and postoperative kinematics in vivo following cruciate-retaining total knee arthroplasty. Int Orthop 2016;40:41–9. https://doi.org/10.1007/s00264-015-2847-y
15. Okamoto Y, Otsuki S, Jotoku T, Nakajima M, Neo M. Clinical usefulness of hindfoot assessment for total knee arthroplasty: persistent post-operative hindfoot pain and alignment in pre-existing severe knee deformity. Knee Surg Sports Traumatol Arthrosc. 2017;25:2632-39. https://doi.org/10.1007/s00167-016-4122-1
16. Wakama H, Okamoto Y, Otsuki S, Nakagawa K, Okuno N, Neo M. Preoperative factors associated with extension gap in cruciate-retaining total knee arthroplasty: A retrospective study on continuous

determination of distraction force. J Orthop Sci 2020:8–12. https://doi.org/10.1016/j.jos.2019.12.004.
17. Onishi Y, Hino K, Watanabe S, Watamori K, Kutsuna T, Miura H. The influence of tibial resection on the PCL in PCL-retaining total knee arthroplasty: A clinical and cadaveric study. J Orthop Sci 2016;21:798–803. https://doi.org/10.1016/j.jos.2016.07.008.
18. Insall JN, Dorr LD, Scott RD, Scott WN. Rationale of the Knee Society clinical rating system. Clin Orthop Relat Res. 1989;248:13-4
19. Mahomed N, Gandhi R, Daltroy L, Katz JN. The self-administered patient satisfaction scale for primary hip and knee arthroplasty. Arthritis. 2011;2011:591253. https://doi.org/10.1155/2011/591253
20. Lyman S, Lee YY, Franklin PD, Li W, Cross MB, Padgett DE. Validation of the KOOS, JR: A Short-form Knee Arthroplasty Outcomes Survey. Clin Orthop Relat Res. 2016;474:1461-71. https://doi.org/10.1007/s11999-016-4719-1
21. Siljander MP, McQuivey KS, Fahs AM, Galasso LA, Serdahely KJ, Karadsheh MS. Current trends in patient-reported outcome measures in total joint arthroplasty: a study of 4 major orthopaedic journals. J Arthroplasty. 2018;33:3416-21. https://doi.org/10.1016/j.arth.2018.06.034
22. Moreland JR, Bassett LW, Hanker GJ. Radiographic analysis of the axial alignment of the lower extremity. J Bone Joint Surg Am 1987;69:745-9.
23. Okamoto Y, Otsuki S, Nakajima M, Jotoku T, Wakama H, Neo M. Sagittal alignment of the femoral component and patient height are associated with persisting flexion contracture after primary total knee arthroplasty. J Arthroplasty. 2019;34:1476-82. https://doi.org/10.1016/j.arth.2019.02.051
24. Nagai K, Muratsu H, Takeoka Y, Tsubosaka M, Kuroda R, Matsumoto T. The influence of joint distraction force on the soft-tissue balance using modified gap-balancing technique in posterior-stabilized total knee arthroplasty. J Arthroplasty 2017;32:2995–9. https://doi.org/10.1016/j.arth.2017.04.058.
25. Komistek RD, Mahfouz MR, Bertin KC, Rosenberg A, Kennedy W. In Vivo determination of total knee arthroplasty kinematics. a multicenter analysis of an asymmetrical posterior cruciate retaining total knee arthroplasty. J Arthroplasty 2008;23:41–50. https://doi.org/10.1016/j.arth.2007.01.016.

Tables

Table 1 Comparison of baseline characteristics between the ‘natural’ and ‘artificial’ knee joint perception groups

	Total n = 60	Natural perception n = 26	Artificial perception n = 34	*P* Value
Age, years	74.1 ± 7.1	74.1 ± 7.1	74.1 ± 7.3	.884
Male, n (%)	10 (16.7)	4 (15.4)	6 (17.6)	.816
Body mass index, kg/m^2	24.9 ± 3.0	24.4 ± 3.3	25.3 ± 3.2	.745
Follow-up duration, years	2.6 ± 1.3	2.5 ± 1.0	2.7 ± 1.1	.873
Kellgren-Lawrence classification, n				
Garde II: III: IV	2 :18: 40	1: 9: 16	1: 16: 17	.625
Charlson Comorbidity Index, n (%)				.998
0	21 (35.0)	9 (34.6)	12 (35.3)	
1 – 2	32 (53.3)	14 (53.8)	18 (52.9)	
3+	7 (11.7)	3 (11.5)	4 (11.8)	
Knee extension angle, degrees	-10.5 ± 8.3	-10.1 ± 7.6	-10.8 ± 8.5	.846
Knee flexion angle, degrees	116.4 ± 15.2	117.1 ± 15.3	115.9 ± 15.1	.772
Knee score, points	50.8 ± 13.2	51.2 ± 12.3	50.5 ± 13.6	.537
Functional score, points	48.6 ± 21.9	49.2 ± 21.3	48.1 ± 20.5	.473
Hip knee ankle angle, degrees	9.8 varus ± 4.2	9.7 varus ± 4.1	9.9 varus ± 4.5	.671

Data are expressed as the mean ± standard deviation or count (%) as appropriate for the data type.

A *P*-value < .05 is indicative of a significant between-group difference.

Table 2 Between-group comparisons of intraoperative soft tissue balance measures

	Distraction force, lbf	Natural perception	Artificial perception	*P* Value
Extension gap, mm	5	7.45 ± 0.91	7.49 ± 0.92	.875
	10	8.25 ± 1.03	8.21 ± 1.04	.474
	20	9.63 ± 1.51	9.70 ± 1.46	.376
	30	11.22 ± 2.02	11.23 ± 2.03	.762
	40	12.64 ± 2.48	12.70 ± 2.52	.881
Flexion gap, mm	5	7.90 ± 1.41	7.94 ± 1.43	.173
	10	8.73 ± 1.71	8.72 ± 1.74	.536
	20	11.22 ± 2.19 *	10.46 ± 2.22	**.041**
	30	12.10 ± 2.79	11.53 ± 2.81	.372
	40	13.83 ± 3.41	13.56 ± 3.43	.793
Gap difference, mm	5	0.45 ± 1.01	0.45 ± 1.04	.556
	10	0.48 ± 1.11	0.51 ± 1.12	.648
	20	1.59 ± 1.32 *	0.76 ± 1.35	**<.001**
	30	0.88 ± 1.59 *	0.30 ± 1.64 *	**.022**
	40	1.19 ± 2.01	0.86 ± 1.97 *	**.038**

Data are expressed as the mean ± standard deviation.

*, statistical difference relative to the lesser distraction force ($P < .05$).

$P < .05$ in boldface indicates a significant between-group difference.

Table 3 Between-group comparisons of post-operative outcomes at the last follow-up

		Natural perception	Artificial perception	*P* Value
Knee extension angle, degrees		-5.2 ± 3.2	-6.8 ± 3.8	.583
Knee flexion angle, degrees		125.8 ± 8.8	124.3 ± 7.1	.782
Knee score, points		87.0 ± 11.8	86.1 ± 10.3	.764
Functional score, points		79.1 ± 17.6	65.4 ± 13.1	**.021**
VAS-knee pain, mm		15.3 ± 17.2	16.7 ± 9.6	.684
VAS-satisfaction, mm		25.1 ± 9.3	35.6 ± 11.2	**.017**
KOOS-JR, points		77.8 ± 7.8	70.1 ± 8.5	**.032**
Stiffness	After first wakening in the morning	0.9 ± 0.8	1.6 ± 1.0	**.026**
Pain	Twisting/pivoting on your knee	0.2 ± 0.7	0.3 ± 0.8	.524
	Straightening knee fully	0.4 ± 0.7	0.6 ± 0.6	.312
	Going up or down stairs	1.0 ± 0.6	1.0 ± 0.7	.813
	Standing upright	0.4 ± 0.7	0.6 ± 0.8	.473
Function, daily living	Rising from sitting	0.7 ± 0.9	1.8 ± 1.1	**<.001**
	Bending to floor/pick up an object	0.9 ± 0.8	1.6 ± 0.7	**.013**
EQ-5D-5L, points		0.72 ± 0.13	0.59 ± 0.11	**.029**
Hip knee ankle angle, degrees		0.4 ± 1.1	0.7 ± 0.9	.748
Femoral component medial angle, degrees		96.7 ± 1.2	97.3 ± 1.1	.826
Femoral component flexion angle, degrees		4.3 ± 1.3	5.6 ± 1.8	.091
Tibial component medial angle, degrees		89.3 ± 1.2	88.8 ± 1.3	.126
Posterior tibia slope, degrees		83.7 ± 2.1	85.1 ± 1.9	.637

Data are expressed as mean ± standard deviation or a count (%), as appropriate for the data type.

P < .05 in boldface indicates a significant between-group difference.

EQ-5D-5L, EuroQol 5-Dimension 5-Level scale; KOOS-JR, Knee Injury and Osteoarthritis Outcome Score for Joint Replacement; VAS, visual analog scale.

[a] Composite measure of pain and function, scored on a scale ranging from 0 to 100, with a higher value representing improved function and decreased pain.

[b] Pain after total knee arthroplasty was evaluated using a 100-mm VAS, with anchors at “0” mm (best) and “100” mm (worst). Satisfaction with the total knee arthroplasty was evaluated using a 100-mm VAS from “0” mm (complete satisfaction) to “100” mm (complete dissatisfaction).

Table 4 Predictive risk factors for an artificial knee joint perception post-TKA

	Univariate analysis	Multivariate analysis		
	P Value	Odds ratio	95% CI	*P* Value
Age	.354			
Male	.569			
Gap difference at 20 lbf, mm				
≥1.0	Reference			
<1.0	**.012** [a]	1.63	1.33 – 4.54	**< .001** [b]

Statistically significant *P*-values are in boldface.

CI, confidence interval; TKA, total knee arthroplasty

[a] $P < .2$, statistically significant.

[b] $P < .05$, statistically significant.

Table 5 Comparison of demographic and outcome variables for a gap difference ≥1.0 mm or <1.0 mm

	Gap difference at 20 lbf, mm		
	≥1.0 n = 27	<1.0 n = 33	*P* Value
Age, years	74.5 ± 7.2	73.8 ± 7.3	.756
Male, n (%)	4 (14.8)	6 (18.2)	.728
Body mass index, kg/m^2	24.5 ± 3.2	25.2 ± 3.4	.662
Knee extension angle, degrees	-5.6 ± 3.1	-6.5 ± 3.5	.348
Knee flexion angle, degrees	125.3 ± 7.4	124.7 ± 6.4	.656
Patient's joint perception, n (%)			**.006**
Natural perception	18 (66.7)	8 (24.2)	
Artificial joint with no restriction	3 (11.1)	9 (27.3)	
Artificial joint with minimal restriction	5 (18.5)	8 (24.2)	
Artificial joint with major restriction	1 (3.7)	8 (24.2)	
Non-functional joint	0 (0.0)	0 (0.0)	
VAS-knee pain [a], mm	14.8 ± 5.6	17.2 ± 5.7	**.015**
VAS-satisfaction [a], mm	13.2 ± 7.4	45.7 ± 8.6	**< .001**
KOOS-JR, points	83.8 ± 6.4	65.0 ± 7.2	**< .001**
EQ-5D-5L, points	0.81 ± 0.08	0.52 ± 0.11	**.032**

Data are expressed as mean ± standard deviation or as a count (%), as appropriate for the data type.

P < .05 in boldface indicates a significant between-group difference.

EQ-5D-5L, EuroQol 5-Dimension 5-Level scale; KOOS-JR, Knee Injury and Osteoarthritis Outcome Score for Joint Replacement; VAS, Visual Analog Scale.

[a] Pain after total knee arthroplasty was evaluated using a 100-mm VAS, with anchors at "0" mm (best) and "100" mm (worst). Satisfaction with the total knee arthroplasty was evaluated using a 100-mm VAS from "0" mm (complete satisfaction) to "100" mm (complete dissatisfaction).

Figures

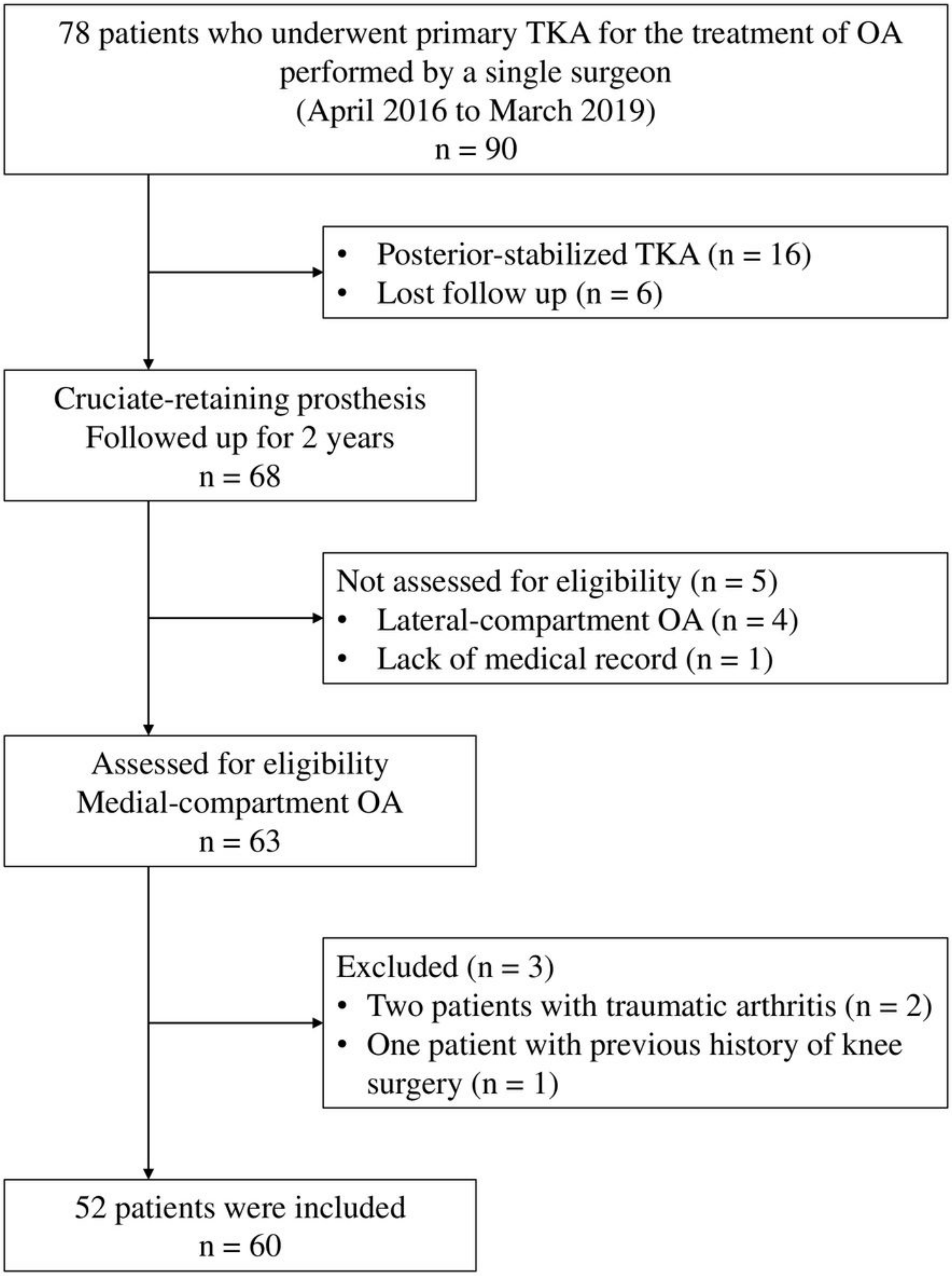

Figure 1

Flowchart of patient inclusion and exclusion criteria. OA, osteoarthritis; TKA, total knee arthroplasty.

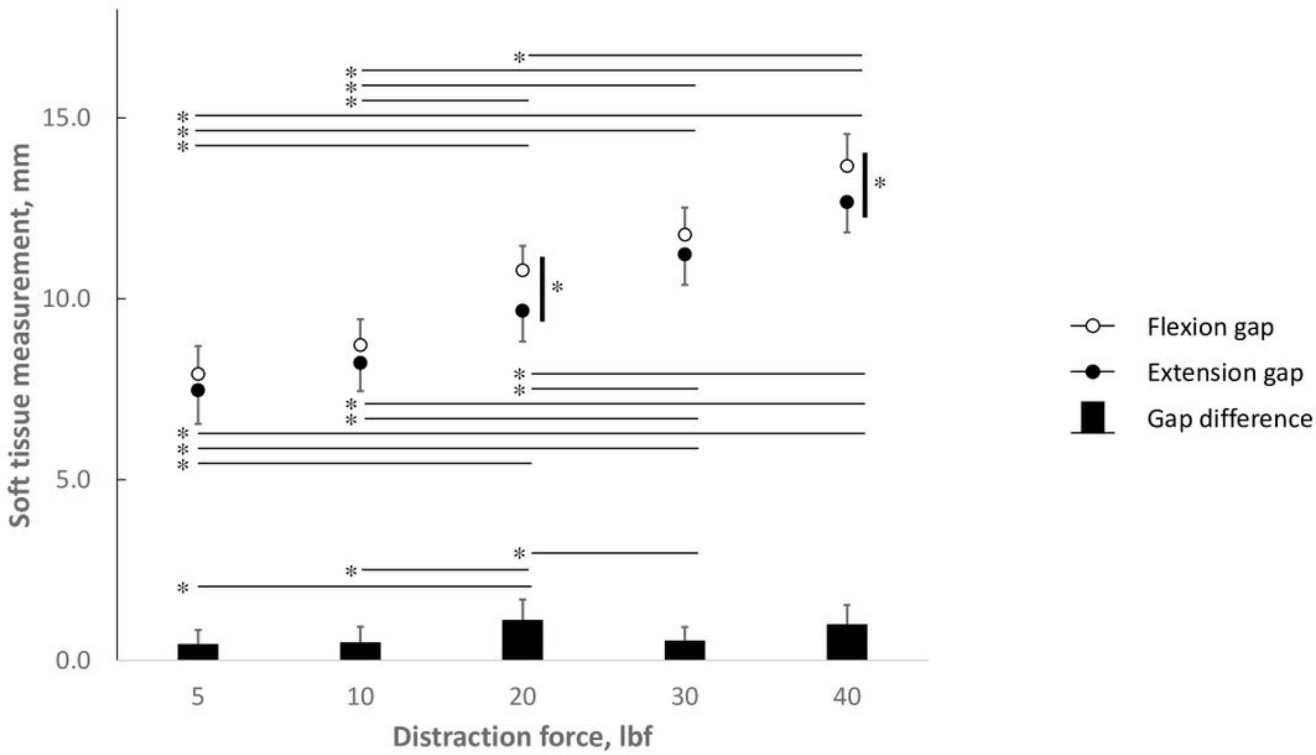

Figure 2

Of the 52 patients who met the inclusion criteria, a statistically significant difference was seen between the mean flexion (open) and extension gap (solid), expressed by the standard deviation as error bar, with the distraction force of 20 lbf ($p = .021$) and 40 lbf ($p = .034$). There is no difference in the measured values with the distraction force of 5 lbf ($p = .764$), 10 lbf ($p = .673$), and 30 lbf ($p = .764$). The bar graph shows the larger gap difference for the 20 lbf distraction force compared to the 5 lbf ($p < .001$), 10 lbf ($p = .014$), and 30 lbf ($p = .019$) force. *$P < .05$; statistically significant.

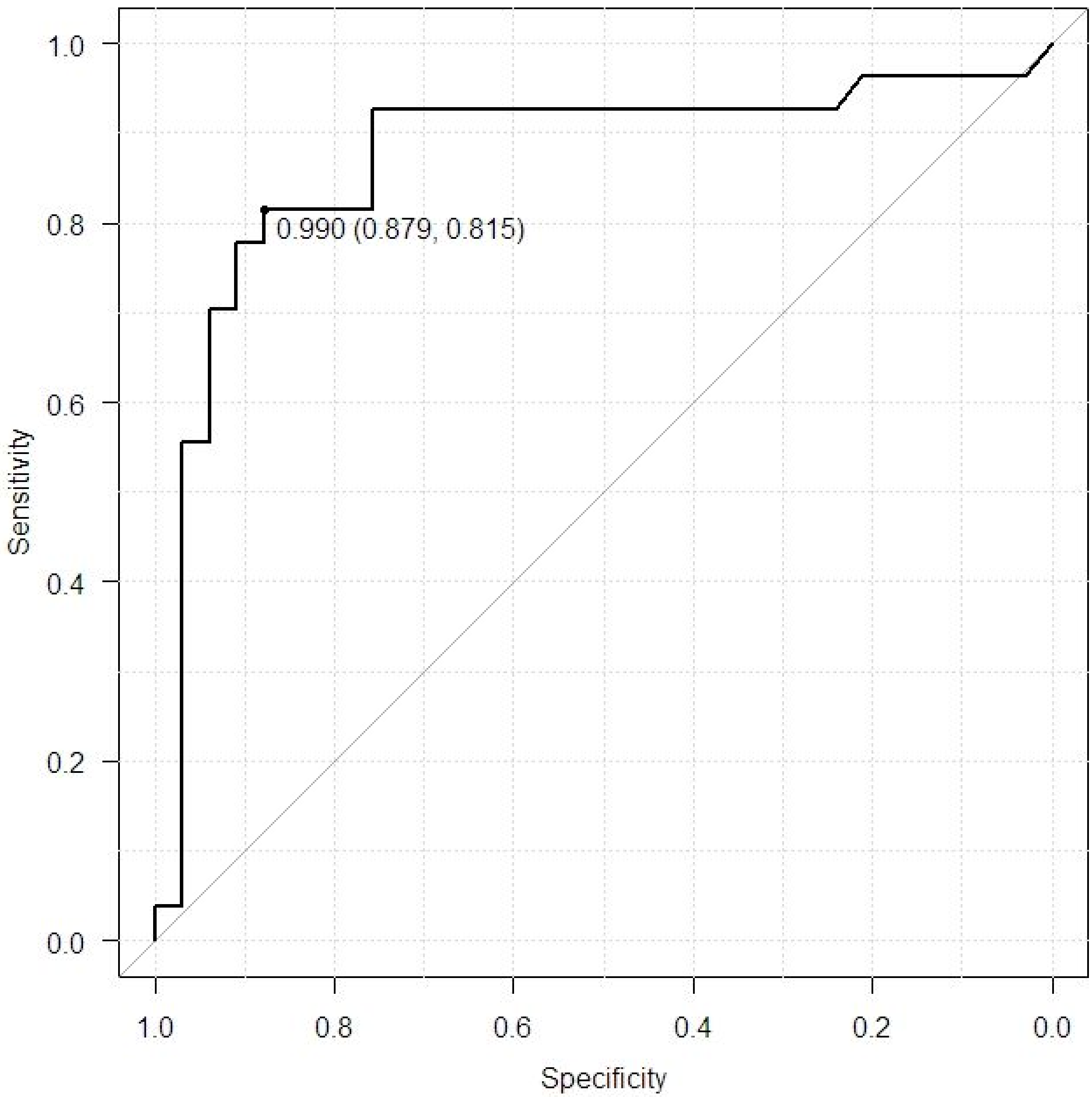

Figure 3

The receiver-operating characteristic (ROC) curve used to identify the cut-off value gap difference under a distraction force of 20 lbf to predict patients' perception of knee joint function at a mean of 2.5 years postoperatively. The area under the ROC curve at the cut-off of 1.0 mm was 0.872 (95% confidence interval, 0.767–0.977).