The Knee 26 (2019) 1338–1347

Contents lists available at ScienceDirect

The Knee

Does total contact of the patella with the femoral trochlea during no thumb test significantly reduce anterior knee pain?

Jitesh Manghwani [a], Shrinand V. Vaidya [a,*], Hiren Patel [b], Chintan S. Vaidya [c]

[a] Department of Orthopaedic Surgery, King Edward VII Memorial Hospital, Mumbai, India
[b] Department of Orthopaedics, BYL Nair Hospital, Mumbai, India
[c] Dr. R N Cooper Municipal General Hospital, Mumbai, India

ARTICLE INFO

Article history:
Received 23 March 2018
Received in revised form 11 August 2018
Accepted 5 September 2018

Keywords:
Anterior knee pain
Dissatisfaction
Grades of contact
No thumb test
Patellofemoral contact

ABSTRACT

Background: Complications such as anterior knee pain (AKP) and crepitus continue to be causes of dissatisfaction after total knee arthroplasty (TKA). This prospective study aimed to study the significance of total patellar contact with the femoral trochlea of the implant, with the no thumb test during trial reduction, and its effect on reducing AKP.
Methods: Between 2014 and 2016, 445 patellofemoral joints (M:F 126:319, age 45–80 years) and their contact with the trochlea of the femoral component were graded at trial reduction without lateral retinaculum release (Grades I, Ia, II, III based on existing publications). The aim was to restore all patellae to pre-operative thickness. Posterior stabilized implants with a domed patella were used in all cases. The Knee Society Score (KSS) and Visual Analogue Scale (VAS) score were noted at follow up between 12 and 24 months after surgery.
Results: AKP was significantly lower with 100% patellofemoral contact. The KSS and VAS had statistically significant *P*-values of 0.021 and 0.025 in Grade I and Ia contact, respectively. Better results were achieved where patellar thickness was restored in Grades I and Ia with *P*-values of 0.041 and 0.046 for VAS change and 0.038 and 0.044 for KSS change, respectively.
Conclusion: At follow up, superior results were obtained where there was a complete patellofemoral contact at trial reduction in Grade I and Grade Ia, and when other confounding factors such as patellar thickness and normal rotation of the femoral and tibial components were standardized. To minimize AKP it is imperative to have total patellar contact with the femoral trochlea.

1. Introduction

There is well-documented discrepancy between clinicians' and patients' ratings of total knee arthroplasty (TKA) surgical outcomes, making patient satisfaction an important area of concern [1–6]. As per the reports, dissatisfaction ranges from 11 to 20% [2,7–9]. Mannion et al. reported that 43% of patients remained completely pain free after primary TKA, with 2% of failures owing to pain [10,11]. This dissatisfaction has been attributed to multiple factors [12,13]. The most common is anterior knee pain (AKP), which may affect up to 50% of patients [1,14–16]. The etiology of AKP is multifactorial, with some factors being identified as contributory, including: patellofemoral maltracking, patellar tilt, patellofemoral overstuffing, or technique [14,17,18].

* Corresponding author. Room no # 608, Department of Orthopaedic Surgery, Multi-storey building, King Edward VII Memorial Hospital, Parel, Mumbai 400012, India.
E-mail address: drsvv1@yahoo.com drsvv1@gmail.com (S.V. Vaidya).

https://doi.org/10.1016/j.knee.2018.09.004
0968-0160/

The aim of the current study was to identify and address possible factors that will reduce AKP; it especially focused on the patellofemoral joint. The percentage of patellar prosthesis contact with the femoral trochlea at the extremes of flexion during surgery has never been explored as one of the causative mechanisms of AKP. Patellar contact with the femur is influenced by size of the femoral and tibial components, along with their rotations, alignment, surgical approach, and patellar design [19–24]; it might also lead to extensor mechanism complications [19,25–28].

Maniar et al. conducted a study that classified patellofemoral contact, with the no thumb test, into four categories from full contact to complete dislocation, and recommended release based on this classification (Table 1) [29]. The current study aimed to evaluate the clinical outcomes of these four grades of patellofemoral contact only, without any release. It aimed to confirm whether the significance of Grade I or 100% patellofemoral contact would lead to better results in terms of AKP as compared with other grades. The amount of reduction of AKP in different grades of patellofemoral contact was compared with patellar thickness. The no thumb test was considered as one of the best parameters with which to assess patellar tracking, as the pressures are highest at 120° flexion. The authors believe that there is no study that further subclassifies patellofemoral contact during the no thumb test and its correlation with outcomes.

Therefore, the aim of this prospective study was to confirm the correlation of percentage contact with the sequential reduction in AKP (i.e. the lesser the contact, the more the AKP, and vice versa).

2. Material and methods

A total of 445 primary knees with etiology of osteoarthritis and operated during 2014–2016 were included in the study. A cemented, posterior stabilized, primary press fit condylar (PFC) implant was used (SIGMA systems, DePUY Orthopedics, Inc. Warsaw, IN, USA). All patellae were resurfaced. The surgical procedure was performed by the same senior surgeon. The patients were asked to follow up at regular intervals of 3 months, with a range of 12–24.5 months and mean of 17.6 months. (Figure 1).

Of the 445 cases: 12 could not be followed up; five were ineligible for follow up owing to death due to natural causes; and seven were lost to follow up and stopped reporting at the 3-monthly intervals. Therefore, the effective sample size was 433. The age ranged from 45 to 80 years, with a mean of 64.4 ± 5.2 years. A total of 309 (71%) were females and 124 (29%) were males. Cases with neurological illnesses, known pain syndromes, and Grade IV patella were excluded. Cases with postoperative evidence of any lucencies, lysis or instability, as per the Knee Society criteria, were not considered as a part of the study [30].

The patients' body mass indexes were recorded and ranged from 19.7 to 46.5 kg/m^2 (mean 27 ± 4.6). Pre-operative varus angle ranged from 7 to 27° (mean 17 ± 3.7).

2.1. Surgical technique

All surgeries were performed by the senior author (S.V.V.) under pneumatic tourniquet. An anterior midline skin incision with mid-vastus approach and medial parapatellar arthrotomy with a similar gap balancing technique was used in all cases [31–34]. The lateral patellofemoral ligament was routinely released for better lateral patellar retraction without everting the patella. The femoral cut was first made with an intramedullary guide confirming the rotations. The valgus angle cut was always confirmed as part of pre-operative planning, as shown in Figures 2 and 3. The tibial cut was always taken with the knee in 90° flexion, confirming the rotations with 5° posterior slope in all cases (by aligning the component with the medial one-third of the tibial tubercle, confirming the posteriomedial area of tibial plateau bone, be uncovered). The gap balancing technique was employed using lamina spreaders to balance the knee in flexion. The anteroposterior femoral cutting jig was appropriately rotated so as to create a rectangular gap. The medial and lateral gaps were equaled with exact dimensions of the flexion space. The transepicondylar line in each case was used for rechecking and confirming the balance (Figures 4 and 5).

The tibial component was aligned with the lateral border of the tibia so that the Q angle was in pre-arthritic state. With the knee in extension and a spacer inserted in the created space between the tibia and femur, the patella was everted and held by standard towel clips. Patellar thickness was measured at the median raphae using Vernier calipers (Figure 5). The inferior fat pad was removed to define the patella inferior sulcus. The patella was sawed at the equator in a superior inferior fashion. Slivers of lateral facet and medial facet were removed at the equator. Three pegs were drilled, a trial was inserted, and the patellar thickness with the insert was measured again (Figure 5).

Table 1
Grading by Maniar et al. [29].

Sr No	Grade	Description
1	I	Normal tracking: patellar trial component is in full contact with the femoral component. Figure 6
2	Ia	Near normal tracking: medial facet of the patella is lifted off the medial femoral trochlea; separation of the patella medial facet from the medial femoral trochlea is <2 mm. Figure 7
3	II	Tilting of patella: patellar medial facet is lifted away from the medial femoral trochlea by >2 mm. Figure 8
4	III	Subluxed patella: medial and lateral facets of the patellar insert are not in contact with their respective parts on the trochlear groove. A portion of the laterally displaced medial facet is in contact with the lateral aspect of the femoral component. Figure 9
5	IV	Dislocated patella

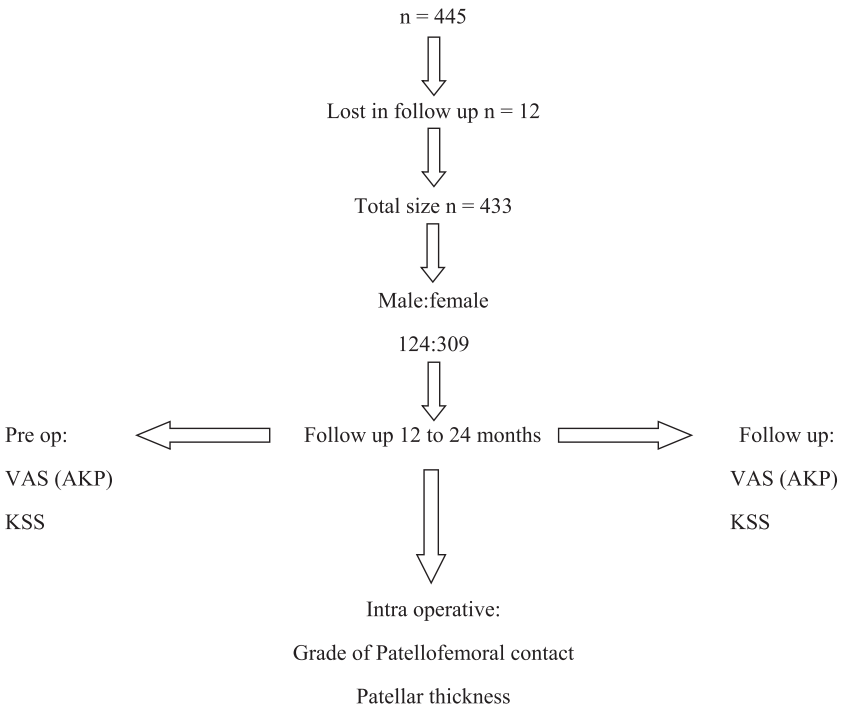

Figure 1. Patient demographics.

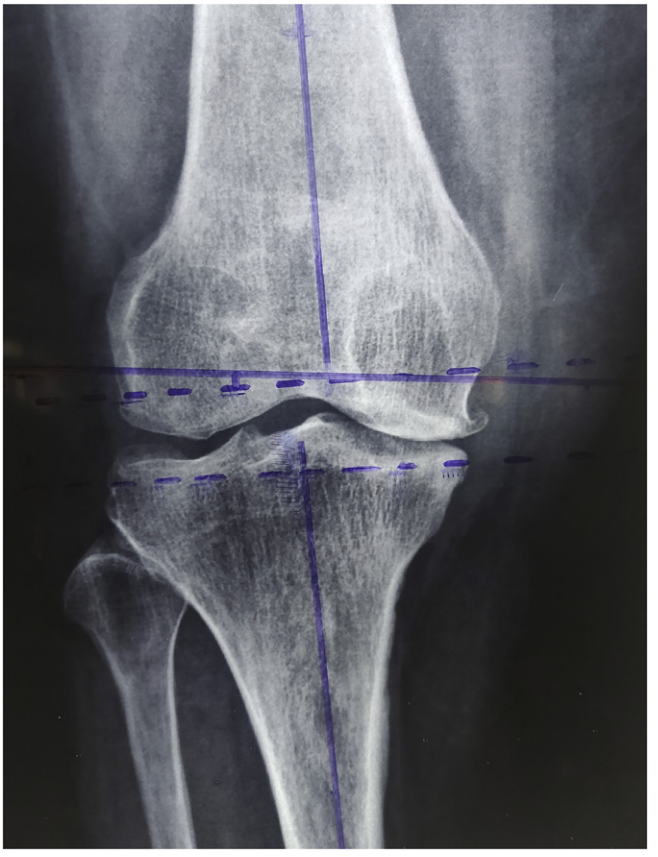

Figure 2. Pre-operative planning in anterior–posterior radiographs.

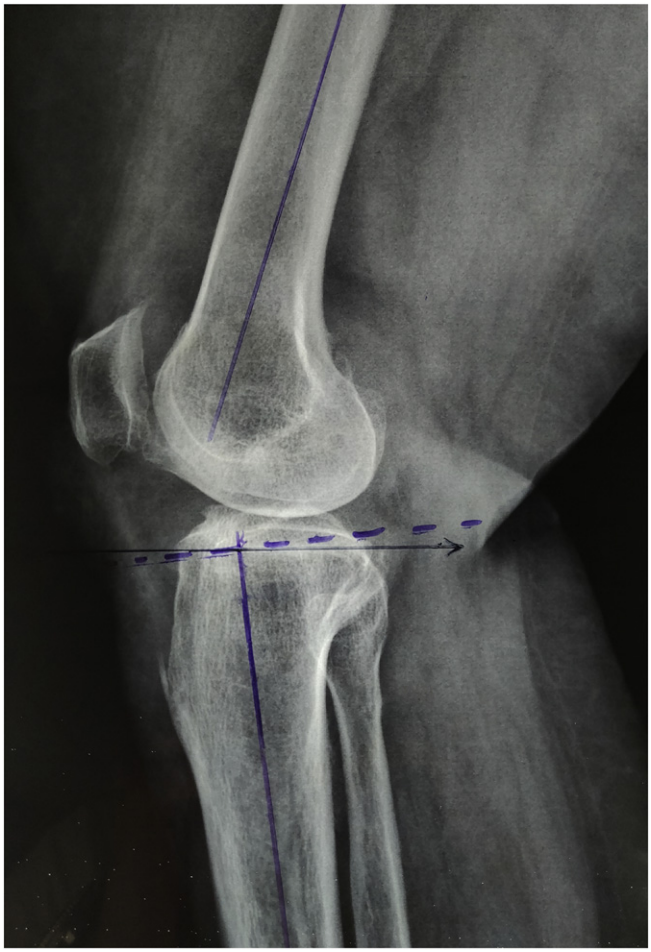

Figure 3. Pre-operative planning in lateral radiographs.

Patellofemoral tracking was confirmed and re-evaluated using the no thumb test. Two independent observers confirmed the grading as per Maniar et al. (Table 1) (Figures 6–9) [29]. Grading was based on patella insert contact with the femoral condyles. The amount of patellofemoral contact between the resurfaced patellar and the femoral component trochlea was judged to be around 120° flexion by the no thumb test. Tracking was assessed at maximum possible flexion by flexing the knee as much as possible; the end point of it was contact between the heel and buttocks in all patients.

A limitation of this study was the possible effect of the inflated tourniquet on patellar tracking, as all the tracking was assessed with the tourniquet inflated. The patients had identical postoperative pain control and rehabilitation protocols. No lateral

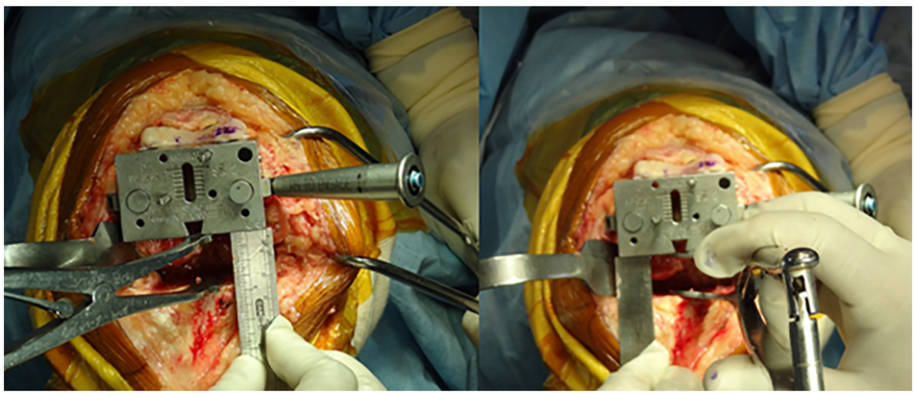

Figure 4. Gap balancing technique, confirming medial and lateral spaces stretched equally using lamina spreader.

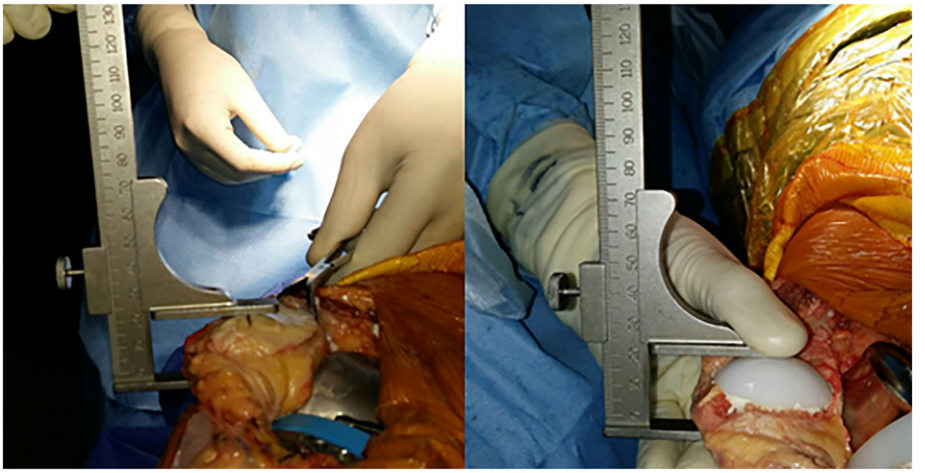

Figure 5. Measurement of patellar thickness: pre-cut and post-implantation.

retinaculum release was performed to improve the quantity of contact, as performed by Maniar et al. [29] This patellofemoral contact grading can be determined intraoperatively with the no thumb test, not pre-operatively.

The criteria for defining AKP after TKA were pain on standing up and/or activities such as stair climbing [35,36]. At follow up the patients were asked whether they had any pain around the patella during activities such as sitting, standing up from a chair, climbing up and down stairs, or walking. The patients were asked to locate the pain, and only the ones classically locating pain anteriorly over the knee were considered as having AKP.

Pre-operative and postoperative Visual Analogue Scale (VAS) and Knee Society Score (KSS) scores were recorded by the operating surgeon, with regular follow ups at 3-monthly intervals. The outcomes of VAS change and new KSS of various grades of contact were compared by the Kruskal–Wallis test. Comparison between patella thickness maintained (PTM) or not maintained (PTNM) of each grade was performed by Mann–Whitney tests.

3. Results

3.1. Grading

The sample (n = 433) was divided as per the grading of patellar tracking (Table 2): PTM and PTNM.

Change in VAS and KSS scores rather than pre-operative and postoperative scores was chosen, as some patients reported with a lower score and some with higher. There was a wide variation in the scores; hence, it was felt that the change in scores from pre-operative status held more value than just the comparison between the pre- and post operative scores. It is important to note

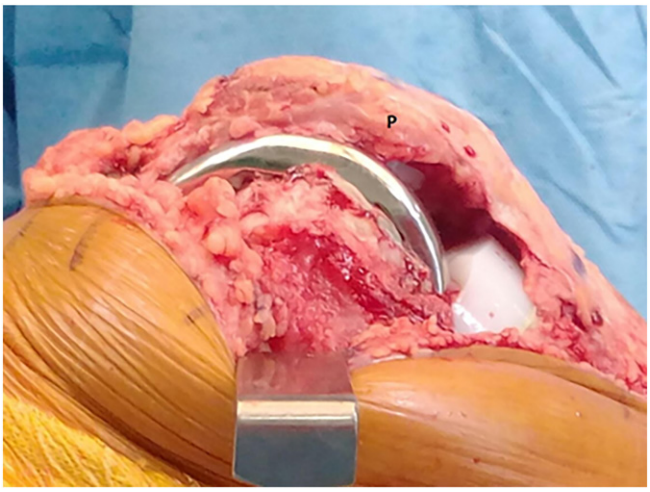

Figure 6. Grade I tracking: normal tracking. The medial facet is touching the medial femoral trochlea. The lateral facet is touching the lateral femoral trochlea. Patellar insert in full contact with the femoral component.

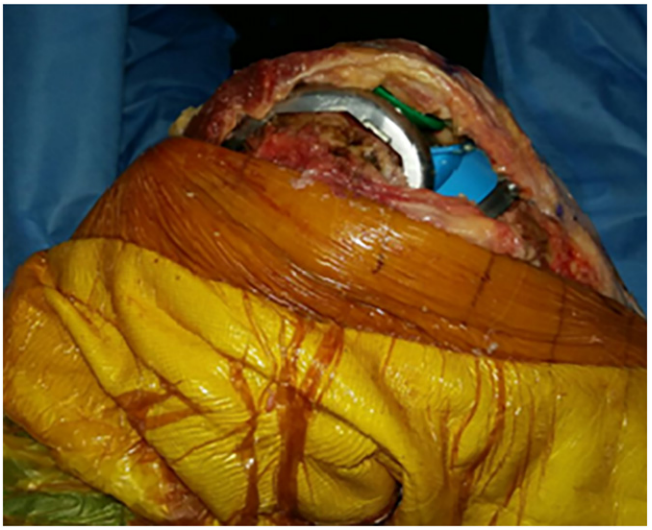

Figure 7. Grade Ia tracking: near-normal tracking. Same as in Grade I, except that the medial facet of the patella is lifted off the medial femoral trochlea; the separation of the patellar medial facet from the medial femoral trochlea is less than 2 mm.

that the high number of PTNM patients was due to only patients being included with exact thickness maintained in the PTM group as before the patellar cut rather than considering any alteration in thickness in the PTM group.

3.2. AKP

The change in VAS score in various grades of tracking is shown in Table 3. After applying the Kruskal–Wallis test, the VAS change was statistically significant with a *P*-value of 0.021 (Table 3). This means that AKP (VAS score) was significantly lower in patients with Grade I tracking as compared with other grades.

After applying the Kruskal–Wallis test, the change in KSS score in a Grade I tracking patella was statistically significant with a *P*-value of 0.021 (Table 2). This means that the function and range was better in patients with a Grade I tracking patella as compared with other grades.

The change in VAS with respect to patellar thickness in various grades of tracking is shown in Table 4. The reduction in AKP, as seen in the Table 4, was statistically significant in cases with Grade I and Grade Ia tracking with maintained patellar thickness, as compared with the ones in which patellar thickness was not maintained in the same grade of tracking. The *P*-values were 0.041 and 0.046, respectively, after applying the Mann–Whitney test (Table 4). However, no such statistical significance was seen in Grade II and III tracking patellae.

The change in KSS with respect to patellar thickness in various grades of tracking is shown in Table 5. The change in KSS was statistically significant in cases with Grade I and Grade Ia tracking with maintained patellar thickness, as compared with the ones

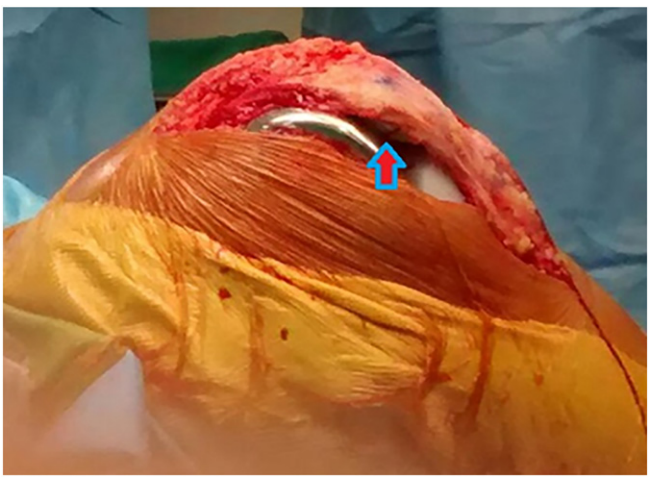

Figure 8. Grade II tracking: tilting of patella. Similar to Grade Ia, except that the patellar medial facet is lifted away from the medial femoral trochlea by more than 2 mm.

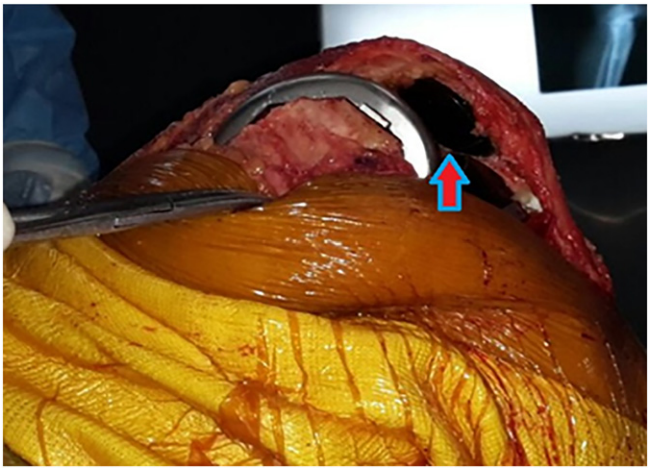

Figure 9. Grade III tracking: subluxation of patella. The medial and lateral facets of the patellar insert are not in contact with their respective parts on the trochlear groove. A portion of the laterally displaced medial facet is in contact with the lateral aspect of the femoral component,

in which patellar thickness was not maintained in the same grade of tracking (Table 5). The *P*-values were 0.038 and 0.044, respectively, on application of the Mann–Whitney test (Table 5). However, no such statistical significance was seen in Grade II and III tracking patellae.

No significant association was found between AKP and sex, body mass index, and pre-operative varus angle. No association was found between AKP and clunk with AKP in various grades.

4. Discussion

AKP remains a major cause of dissatisfaction after TKA surgery [2]. Residual AKP may have multiple causes, as discussed. AKP is primarily associated with loaded activities such as getting up from a chair and climbing stairs (including high flexion activities) [35,36]. Undoubtedly, one of the prerequisites for a good outcome is to have excellent patellar tracking. This study attempted to specifically correlate the significance of amount of patellar contact with the femoral trochlea (Grade I–IV tracking) with presence of AKP. It is believed that this study is the first of its kind, where accurate patellar resurfacing was judged by totality of its contact with the femoral prosthesis trochlea after confirming with no thumb test at trial reduction. The contact areas between the patella and femur vary at different degrees of knee flexion [37,38]. With the increase in the amount of knee flexion, the patellofemoral contact forces proportionately increase [39–41]. Hence, the current assessment was performed at 120° flexion or maximum achievable thickness at trial reduction. The totality of contact of the patellar component with the trochlea of the femoral component has been classified by Maniar et al. into different grades as per the amount of contact, as discussed [29].

This study examined the finer aspects of patellofemoral contact, not just the no thumb test. No thumb test is the point where the patella does not need to be stabilized by the pressuring thumb on its anterior surface during trial reduction. The patella in full contact with the femoral trochlea helps the quadriceps mechanism to work efficiently without causing any pain that may be due to malalignment in any plane. The patella acts as an efficient pulley without any deviation, which is possible only with complete contact. It has never been thought that lateral retinaculum release would improve patellofemoral contact or achieve Grade I contact every time. It has been presumed that any overenthusiastic release, to fine-tune no thumb test, may cause immediate post operative pain at the outer lateral margin of the retinaculum [42,43]. The current results showed that Grade I tracking achieved the best results, with maximum reduction in AKP as per the VAS change and KSS (Table 2). This agrees with the findings by Maniar et al. [29] However, as opposed to Maniar et al., the current study did not perform any lateral retinaculum release to convert all Grade II, III, IV to Grade I tracking because the sole aim was to see whether a better result is related to superiority of

Table 2
Division of sample size.

Grade I	n = 119	PTM	n = 60
		PTNM	n = 59
Grade Ia	n = 118	PTM	n = 58
		PTNM	n = 60
Grade II	n = 105	PTM	n = 55
		PTNM	n = 50
Grade III	n = 91	PTM	n = 46
		PTNM	n = 55

PTM, patellar thickness maintained; PTNM, patellar thickness not maintained.

Table 3
Visual Analogue Scale change in different grades of patellar tracking.

	AKP (VAS change)	KSS change
Grade I	66.17%	127.26
Grade Ia	64.54%	119.22
Grade II	53.46%	110.14
Grade III	50.09%	106.84
	$P = 0.021$*	$P = 0.025$*

AKP, anterior knee pain; KSS, Knee Society Score; VAS, Visual Analogue Scale.

contact when other confounding factors are the same. Although there was apprehension about pain at the release site, retinaculum release is recommended as an afterthought, as superiority of all Grade I patella undoubtedly led to better results as opposed to other grades as a control. Hence, achieving total facet contact as an ideal end point for smooth patellar tracking together with thickness restoration is recommend. Every patella must have total contact for good results, ignoring the disadvantage of pain at the release site, which subsides over a period of time; the advantages outweigh this disadvantage. This is in total agreement with the study by Maniar et al. [29]

This study went a step beyond: to find the significance of patellar thickness at each grade. The patients in each group were divided into PTM and PTNM groups. The PTM included only the patients who had exactly the same patellar thickness (in mm) after instrumentation as before the cut. Despite efforts to restore pre-operative thickness, the thickness may not be possible to maintain after trial owing to: thicker cement, uneven cut, or leaving the lateral facet unsawn. As seen in Table 4, significant *P*-values were found for KSS and VAS score differences in Grades I and Ia. This suggests that a Grade I tracking patella with retained patellar thickness is definitely better compared with altered thickness, on the basis of AKP and KSS with statistical significance. However, no such significance was found in Grades II and III, which implies that if the contact is less than the retaining thickness it would not influence the AKP.

Bengs and Scott designed a study to evaluate the intraoperative effect of patellar thickness on patellar tracking during TKA [44]. They reported that with every 2-mm increase in patellar thickness there was a decrease in passive knee flexion by 3°. One prospective study of 50 TKAs using condylar prostheses and a standardized technique for patellar resurfacing was performed to evaluate the accuracy of resurfacing by Rand [18]. He also reported decreased incidence of AKP in cases with patellar thicknesses the same as the pre-operative levels.

A similar implant was used in all cases (PFC). The confounders were removed by using a similar implant in terms of patellar design, femoral condyle design and bearing surface. It is believed that this may be reproducible in any other system, at least in terms of percentage of patellofemoral area of contact.

There were no complications such as clunk or crepitus in the current cohort. These causes of AKP were removed by meticulous technique employed by the authors, which included steps such as recreation of thickness, removal of suprapatellar synovial folds, and sawing of lateral facets to prevent incidence of these complications. Thus, these meticulous steps helped in avoiding complications in all cases.

The current authors tried to highlight one of the major causes of AKP that may lead to dissatisfaction. The initial apprehension about what was felt about over release, irrespective of steady patella on no thumb test, was totally unfounded. The results in Tables 2-4 clearly confirm this, and would therefore be recommended in principle to achieve excellent patellofemoral articulation contact in all the cases. It is proposed that this classification be used for ideal tracking of patella [29].

The authors are in total agreement with Maniar et al.: to release every case, so as to improve the patellofemoral contact as much as possible, by graded lateral retinaculum release with the aim of achieving 100% contact (Grade I). Although the release area over the retinaculum is painful postoperatively, the pain quickly diminishes completely and there is no AKP in the long-term, with 100% patellar articulation. Maniar et al. recommended an outside–in technique for release; however, the current authors do not have any experience with this [29].

Table 4
Visual Analogue Scale change in different grades of patellar tracking with respect to patellar thickness.

AKP (VAS change in %)			
Grade I	PTM	69.47	$P = 0.041$*
	PTNM	62.87	
Grade Ia	PTM	67.37	$P = 0.046$*
	PTNM	61.7	
Grade II	PTM	54.63	$P = 0.29$
	PTNM	52.3	
Grade III	PTM	51.4	$P = 0.37$
	PTNM	47.79	

AKP, anterior knee pain; PTM, patellar thickness maintained; PTNM, patellar thickness not maintained; VAS, Visual Analogue Scale.

* Significant *P*-value ($P<0.005$)

Table 5
Knee Society Score change in different grades of patellar tracking with respect to patellar thickness.

Knee Society Score change			
Grade I	PTM	132	$P = 0.038^*$
	PTNM	122.36	
Grade Ia	PTM	122.88	$P = 0.044^*$
	PTNM	112.56	
Grade II	PTM	114.08	$P = 0.137$
	PTNM	106.2	
Grade III	PTM	108.76	$P = 0.148$
	PTNM	103.76	

PTM, patellar thickness maintained; PTNM, patellar thickness not maintained.

It is possible that the results of TKA with patellar resurfacing will deteriorate over time. Also, severity of AKP and clinical scores will change with time. Therefore, this study needs to be conducted with a larger sample size and over a longer duration of follow up.

5. Conclusions

There was a statistically significant correlation between patellofemoral contact at trial reduction and no thumb test. The mean relief in AKP was one of the foremost causes of dissatisfaction.

The authors recommend not just accepting the no thumb test at trial reduction, but aiming for 100% contact for Grade I even if it requires lateral retinaculum release.

Conflict of interest

There are no conflicts of interest to declare,

Acknowledgements

We thank Dr. Rajesh Maniar for helping in structuring this paper. There are no sources of funding to declare.

References

[1] Arthur CH, Wood AM, Keenan AC, Clayton RAE, Walmsley P, Brenkel I. Ten-year results of the press fit condylar sigma total knee replacement. Bone Joint J 2013;95-B(2):177.
[2] 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.
[3] Breugem SJ, Haverkamp D. Anterior knee pain after a total knee arthroplasty: what can cause this pain? World J Orthop 2014;5(3):163.
[4] Breugem SJ, Sierevelt IN, Schafroth MU, Blankevoort L, Schaap GR, Dijk N. Less anterior knee pain with a mobile-bearing prosthesis compared with a fixed-bearing prosthesis. Clin Orthop Relat Res 2008;466(8):1959.
[5] Janse AJ, Gemke RJ, Uiterwaal CS, Tweel I, Kimpen JL, Sinnema G. Quality of life: patients and doctors don't always agree: a meta-analysis. J Clin Epidemiol 2004;57:653–61. https://doi.org/10.1016/j.jclinepi.2003.11.013.
[6] Mantyselka P, Kumpusalo E, Ahonen R, Takala J. Patients' versus general practitioners' assessments of pain intensity in primary care patients with non-cancer pain. Br J Gen Pract 2001;51:995–7.
[7] Clement ND, Burnett R. Patient satisfaction after total knee arthroplasty is affected by their general physical well-being. Knee Surg Sports Traumatol Arthrosc 2013;21(11):2638.
[8] DePuy Synthes. Attune knee system. 2012. https://www.depuysynthes.com/hcp/ knee/products/qs/ATTUNE-Knee-System [accessed June 19, 2015].
[9] Digennaro V, Zambianchi F, Marcovigi A, Mugnai R, Fiacchi F, Catani F. Design and kinematics in total knee arthroplasty. Int Orthop 2014;38(2):227.
[10] Mannion AF, Kampfen S, Munzinger U. The role of patient expectations in predicting outcome after total knee arthroplasty. Arthritis Res Ther 2009;11:R139.
[11] Seil R, Pape D. Causes of failure and etiology of painful primary total knee arthroplasty. Knee Surg Sports Traumatol Arthrosc 2011;19:1418–32.
[12] Ewald FC. The knee society total knee arthroplasty roentgenographic evaluation and scoring system. Clin Orthop Relat Res 1989(248):9.
[13] Indelli PF, Marcucci M, Pipino G, Charlton S, Carulli C, Innocenti M. The effects of femoral component design on the patello-femoral joint in a PS total knee arthroplasty. Arch Orthop Trauma Surg 2014;134(1):59.
[14] Insall JN, Dorr LD, Scott RD, Scott WN. Rationale of the Knee Society clinical rating system. Clin Orthop Relat Res 1989(248):13.
[15] Jacobs CA, Christensen CP. Factors influencing patient satisfaction two to five years after primary total knee arthroplasty. J Arthroplasty 2014;29(6):1189.
[16] Jacobs CA, Christensen CP, Karthikeyan T. Patient and intraoperative factors influencing satisfaction two to five years after primary total knee arthroplasty. J Arthroplasty 2014;29(8):1576.
[17] Barrack RL, Matzkin E, Ingraham R, Engh G, Rorabeck C. Revision knee arthroplasty with patella replacement versus bony shell. Clin Orthop Relat Res 1998;356:139–43.
[18] Rand JA. The patellofemoral joint in total knee arthroplasty. J Bone Joint Surg Am 1994;76(4):612–20.
[19] Berger RA, Crossett LS, Jacobs JJ, Rubash HE. Malrotation causing patellofemoral complications after total knee arthroplasty. Clin Orthop Relat Res 1998;356:144–53.
[20] Bindelglass DF, Cohen JL, Dorr LD. Patellar tilt and subluxation in total knee arthroplasty. Relationship to pain, fixation, and design Clin Orthop Relat Res 1993(286):103–109.
[21] Briard JL, Hungerford DS. Patellofemoral instability in total knee arthroplasty. J Arthroplasty 1989;4(Suppl):S87–97.
[22] McPherson EJ. Patellar tracking in primary total knee arthroplasty. AAOS Instr Course Lect 2006;55:439–48.
[23] Engh GA, Parks NL, Ammeen DJ. Influence of surgical approach on lateral retinacular releases in total knee arthroplasty. Clin Orthop Relat Res 1996;331:56–63.
[24] Matsueda M, Gustilo RB. Subvastus and medial parapatellar approaches in total knee arthroplasty. Clin Orthop Relat Res 2000;371:161–8.

[25] Barrack RL, Bertot AJ, Wolfe MW, Waldman DA, Milicic M, Myers L. Patellar resurfacing in total knee arthroplasty-a prospective, randomized, double-blind study with five to seven years of follow-up. J Bone Joint Surg 2001;83A:1376–81.
[26] Boyd Jr AD, Ewald FC, Thomas WH, Poss R, Sledge CB. Long-term complications after total knee arthroplasty with or without resurfacing of the patella. J Bone Joint Surg 1993;75A:674–81.
[27] Dalury DF, Dennis DA. Extensor mechanism problems following total knee replacement. J Knee Surg 2003;16:118–22.
[28] Ritter MA, Pierce MJ, Zhou H, Meding JB, Faris PM, Keating EM. Patellar complications (total knee arthroplasty). Effect of lateral release and thickness. Clin Orthop Relat Res 1999;367:149–157.
[29] Maniar RN, Singhi T, Rathi SS, Baviskar JV, Nayak RM. Surgical technique: lateral retinaculum release in knee arthroplasty using a stepwise, outside-in technique. Clin Orthop Relat Res 2012;470(10):2854–63.
[30] Ranawat AS, Meftah M, Rodriguez-Elizalde S, Ranawat CS. The incidence of anterior knee pain and crepitation after total knee replacement: a matched pair analysis between rotating platform and fixed bearing posterior stabilized designs. ASTM INT 2011;8(10):1.
[31] Noble PC, Conditt MA, Cook KF, Mathis KB. The John Insall Award: patient expectations affect satisfaction with total knee arthroplasty. Clin Orthop Relat Res 2006; 452:35.
[32] Parvataneni HK, Ranawat AS, Ranawat CS. The use of local periarticular injections in the management of postoperative pain after total hip and knee replacement: a multimodal approach. Instr Course Lect 2007;56:125.
[33] Parvizi J, Nunley RM, Berend KR, Lombardi Jr AV, Ruh EL, Clohisy JC, et al. High level of residual symptoms in young patients after total knee arthroplasty. Clin Orthop Relat Res 2014;472(1):133.
[34] Patil SS, Branovacki G, Martin MR, Pulido PA, Levy YD, Colwell CW. 14-year median follow-up using the press-fit condylar sigma design for total knee arthroplasty. J Arthroplasty 2013;28(8):1286.
[35] Baldini A, Anderson JA, Zampetti P, Pavlov H, Sculco TP. A new patellofemoral scoring system for total knee arthroplasty. Clin Orthop Relat Res 2006;452:150–4.
[36] Meftah M, Jhurani A, Bhat JA, Ranawat AS, Ranawat CS. The effect of patellar replacement technique on patellofemoral complications and anterior knee pain. J Arthroplasty 2012;27(6):1075–80.
[37] Aglietti P, Buzzi R. Posteriorly stabilised total-condylar knee replacement: three to eight years' follow-up of 85 knees. J Bone Joint Surg 1988;70B:211–6.
[38] Goodfellow J, Hungerford DS, Zindel M. Patello-femoral joint mechanics and pathology. 1. Functional anatomy of the patello-femoral joint. J Bone Joint Surg 1976; 58B:287–90.
[39] Hungerford DS, Barry M. Biomechanics of the patellofemoral joint. Clin Orthop Relat Res 1979;144:9–15.
[40] Huberti HH, Hayes WC. Patellofemoral contact pressures. The influence of q-angle and tendofemoral contact. J Bone Joint Surg 1984;66A:715–24.
[41] Matthews LS, Sonstegard DA, Kenke JA. Load bearing characteristics of the patello-femoral joint. Acta Orthop Scand 1977;48:511–6.
[42] Lakstein D, Naser M, Adar E, Atoun E, Edelman A, Hendel D. Partial lateral patellar facetectomy as an alternative to lateral release in Total Knee Arthroplasty (TKA). J Arthroplasty 2014;29:2146–9.
[43] Molyneux S, Brenkel I. Predictors and outcomes of lateral release in total knee arthroplasty: a cohort study of 1859 knees. Knee 2012;19:688–91.
[44] Bengs BC, Scott RD. The effect of patellar thickness on intraoperative knee flexion and patellar tracking in total knee arthroplasty. J Arthroplasty 2006;21(5): 650–5.