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Determinants of range of motion in cruciate retaining total knee arthroplasty: a prospective study

Nageswara Rao K., T. S. S. Harsha*

Department of Orthopaedics, Nizams Institute of Medical Sciences, Hyderabad, Telangana, India

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***Correspondence:**
Dr. T. S. S. Harsha,
E-mail: meetmeatsrisri240590@gmail.com

ABSTRACT

Background: Total knee replacement (TKR) is to provide a stable painless knee with adequate range of motion (ROM) for daily activities. The aim of the study is to evaluate various factors that influence ROM in cruciate retaining TKR postoperatively.
Methods: Fourty four patients with osteoarthritis knee treated in our institute with TKR using cruciate retaining prosthesis are included in study and analysed prospectively. Mean follow up was 6 months. Patients are analyzed for following factors–age, gender, BMI, preoperative ROM, changes in posterior femoral condylar offset, posterior tibial slope after surgery. Statistical analysis of effect of all factors on knee ROM was done. Assessment was done preoperatively and 3 and 6 months postoperatively.
Results: Gender did not affect the final ROM. Mean age of patients is 65. Age has negative correlation with ROM (p=-0.45). The mean knee range improved from 92˚ to 101˚. Factors that negatively affect ROM include, BMI (p=-0.04) and Preoperative flexion deformity (p=-0.03). Factors that positively affect ROM include, knee scores and good preoperative flexion (p=0.001). Males have good amount of flexion preoperatively and post operatively when compared to females.
Conclusions: Preoperative ROM, flexion contracture and BMI are the important factors affecting the range of motion in total knee arthroplasty. Proper counselling of patient preoperatively regarding these various factors and appropriate selection of patient is of utmost important for satisfactory functional outcome.

Keywords: Posterior femoral condylar offset, Posterior tibial slope, Range of motion

INTRODUCTION

Total knee arthroplasty (TKA) is a successful procedure used for Osteoarthritis. Though there are other procedures such as osteotomy, unicompartmental replacement, which could serve purpose but TKA remains the procedure of choice.

The goal of TKA is to provide a stable painless knee with adequate ROM for daily activities.[1] Understanding the biomechanics and how small changes influence knee function is of utmost importance.[2] A high demand to achieve deep flexion exists among our current population of patients.[2]

ROM is the most important outcome that defines the functional ability after TKA. A minimum ROM of 90° is essential to daily activities with about 67° required in swing phase, 83° in climbing stairs, 90° in descending stairs, and 93° in rising from a chair.[3] Conventional TKA designs limited ROM to near 90°.[4] Long term follow up of PFC knees have shown average ROM of 101°.[5] Many of the TKA performed before 1990 showed that upto 50% of patients could not flex their knees beyond 90˚

after the surgery.[6] Older published series report a final flexion between 100 and 115°.[7–10] High flex knee designs have been introduced with improved ROM and ability to reach higher flexion angles.[11] Results of the high flex implants are not consistent.[12-14] Recent reviews state that there is no difference in outcome between high flexion and standard implants.[15-17] However a number of studies studies were performed but no subgroup analysis was made on the factors affecting the outcome. Preoperative ROM, etiology, BMI, patient age, and knee society score are among the most important factors that affect the final outcome.[18,19] Surgical technique, implant design, changes in posterior femoral condylar offset and posterior tibial slope and postoperative rehabilitation are also said to affect the final knee ROM.[19,20] The aim of this study is to investigate these factors that affect the final ROM achieved following TKA.

METHODS

An observational study of all the knees, operated with PFC SIGMA knee prosthesis in our Institute between Aug 2015 and Jan 2016 was set up. Inclusion criteria were any primary osteoarthritis or rheumatoid arthritis of knee operated with TKA with the chosen prosthesis. Patients with complex knees with ROM less than 50°, severe varus or valgus deformity >20°, or bone defect requiring bone grafting were excluded. This was done to minimize the effect of these factors on the ROM and get a relatively homogeneous cohort. 94 patients were screened. A total number of 14 patients did not consent for study while 10 patients were excluded as they stayed at faraway places and regular follow-up was not feasible. A total number of 26 patients were excluded according to exclusion criteria. Thus, 44 patients (50 knees; 6 bilateral) met the inclusion criteria and were available for final analysis. All patients underwent TKA using standard median parapatellar approach. A uniform postoperative rehabilitation protocol was employed for every patient. Knee ROM of all patients was evaluated using a standard goniometer.[21] (Figure 4). Calculation of knee ROM, flexion deformity, and Total Knee Score(KS) and Functional Score(FS) was done by a group of trained outcome assessors who were blinded to the aim of the study. Knee ROM was assessed preoperatively and at 3 months, 6 months postoperatively.

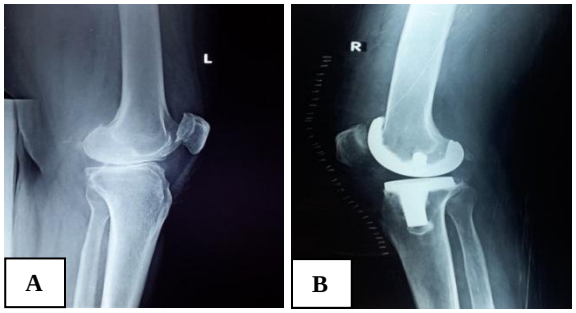

Figure 1: A=true lateral radiographs of knee joint preoperative; B= true lateral radiographs of knee joint postoperatively.

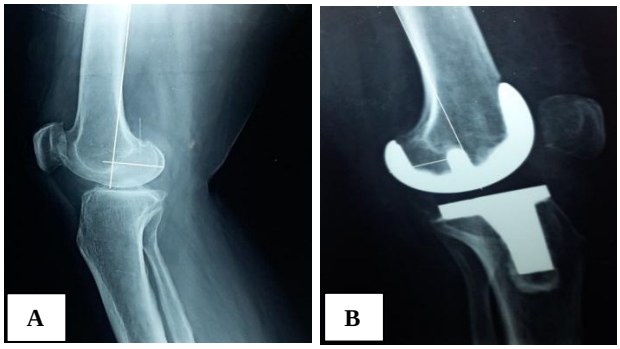

Figure 2: A=measuring posterior femoral offset preoperatively; B=measuring posterior femoral offset postoperatively.

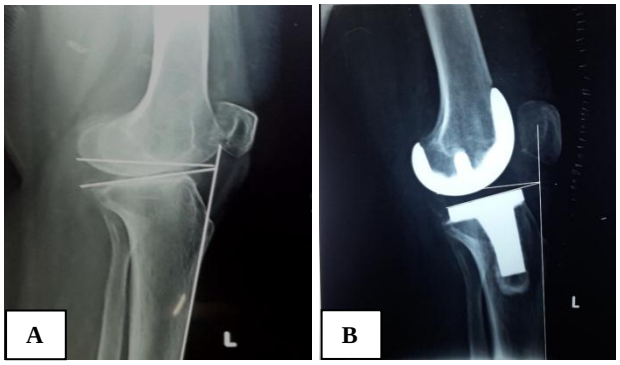

Figure 3: A=measuring posterior tibial slope preoperatively; B=measuring posterior tibial slope postoperatively.

Figure 4: Various way of calculating knee ROM with goniometer.

Lateral views of the knee with superimposition of the femoral condyles were obtained by plain radiography preoperatively and fluoroscopic radiography postoperatively (Figure 1A and 1B). The FCO was measured as the distance from the tangent of the femoral diaphysis posterior cortex to the apex of the posterior femoral condyle preoperatively and to the apex of the posterior femoral component postoperatively (Figure 2A and 2B). Pre- and post-operative PTS measurements were

performed using the anterior tibial cortex as a reference. The inclination angle between the line drawn perpendicular to the tangent of the anterior tibial cortex and the tangent to the tibial plateau was recorded as the preoperative PTS and the angle created with the tangent to the tibial cut surface or implant surface as the postoperative PTS (Figure 3A and 3B).

Subgroup analysis was performed dividing the cohort based on following factors, age, gender, body mass index, preoperative ROM, preoperative flexion deformity, preoperative Knee scores, posterior femoral condylar offset, posterior tibial slope, which were statistically correlated with the final ROM attained. Gain in ROM from base line was also assessed in various subgroups.

Statistical methods

Paired t test was used for statistical testing of the difference in mean values in comparing preoperative to postoperative improvement, and a significant difference was found with a risk less than 5%, i.e., $p<0.05$ (2 tailed). Unpaired t test was used for subgroup analysis with significant $p<0.05$. For analysis of the correlation of the two variants, Pearson correlation coefficient was calculated. For analysis of multiple variants, ANOVA test was used.

RESULTS

The mean age was 65 years (42-83) at the time of the surgery. 5 patients between 41–50 yrs, 18 between 51–60 yrs, 20 between 61–70 yrs, 6 between 71–80 yrs, one above 80 yrs (Figure 5A). A total of 40 were females and 10 were men (Figure 5B). The surgery was performed on 23 right knees and 27 left knees, including 6 patients in whom bilateral surgery was performed. Average BMI of the patients was 30.6 (range= 27–36). Highest BMI is 36 and lowest is 27. Mean BMI in males is 29.2 in females it is 30.The implant used was cruciate retaining PFC SIGMA knee design. All surgeries were performed through a medial parapatellar approach. All components were cemented. Patella was not replaced in any patient. Tourniquet was used in every case. Preoperative diagnosis was osteoarthritis (OA) in 49 subjects (98%), rheumatoid arthritis (RA) in 1 subject (2%). Preoperatively the mean ROM was 92.4 (range 60 to 120°). This improved postoperatively to 101° (range 90 - 130). A total of 32 out of 44 patients (76.6%) patients retained their ability to sit cross legged at final follow up. The KS improved from 36.9 (with highest score of 69 and least score of 0) to 79.2 (with highest score of 90 and least score of 61) (Figure 6A). The FS improved from 49.2 (with highest score of 70 and lowest score of 5) to 80.9 (with highest score of 100 and lowest score of 60) (Figure 6A). Statistical analysis of ROM, knee score, and function score showed significant improvement postoperatively ($p<0.001$). The average preoperative FCO is 3.38 cm (4 cm-2.5 cm). The average post-operative FCO was 3.43 cm (4.5 cm-3 cm). The average preoperative PTS was 15.4˚ (22˚-2.5˚).The average postoperative PTS was 12.8˚ (18˚-8˚).

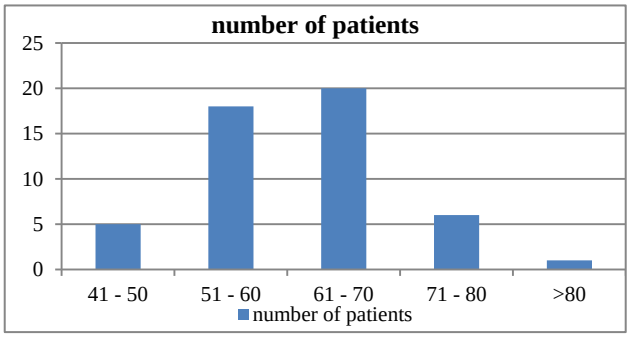

Figure 5: A=Distribution of patients according to age.

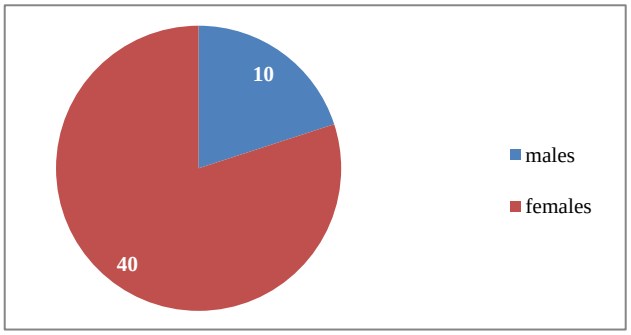

Figure 5: B=Gender distribution.

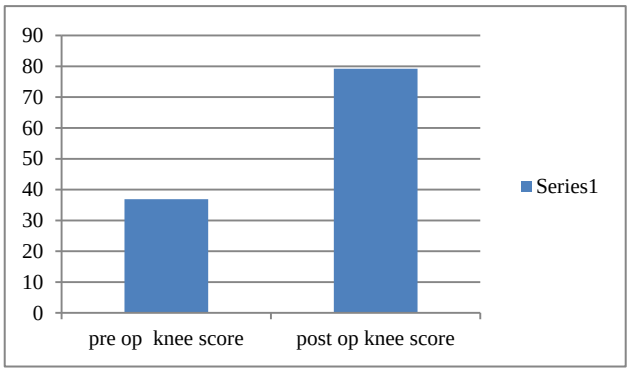

Figure 6: A=Comparison between preoperative and postoperative knee scores.

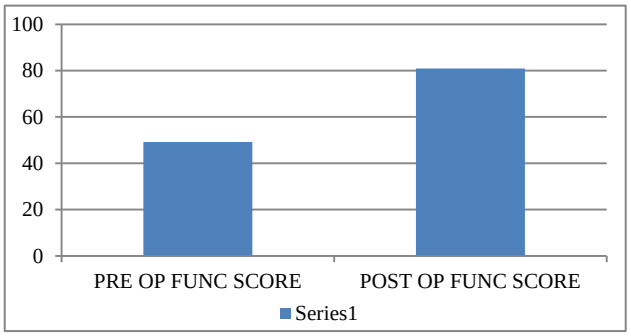

Figure 6: B=Comparison between preoperative and postoperative functional scores.

Table 1: Correlation between preoperative ROM and BMI.

		BMI
Pre op ROM	Pearson correlation	-0.300*
	Sig. (2-tailed)	0.034
	N	50

Table 2: Correlation between postoperative ROM & BMI.

		BMI
Post op ROM	Pearson correlation	-0.270*
	Sig. (2-tailed)	0.041
	N	50

Table 3: Correlation between preoperative ROM and postoperative ROM.

		Postop ROM
pre op ROM	Pearson correlation	0.506**
	Sig. (2-tailed)	0.001
	N	50

Table 4: Correlation between preoperative FFD and postoperative ROM.

		Postop ROM
Pre op FFD	Pearson correlation	-0.305*
	Sig. (2-tailed)	0.031
	N	50

Subgroup analysis

Preoperatively, significant difference in ROM was noted between the two genders, with males having good range of motion preoperatively which is significant statistically (average of 104 degrees in male patients and average of 89.5 degrees in female patients; p=0.004). The average ROM at 6 months after surgery was 107° in males and 100° in females. Even though males are doing better compared to females post operatively with average range of flexion of 107˚ (females- 100˚) it is not statistically significant (p=0.49). Even though females showed a larger gain in ROM at 6 months (females= 10.5˚, in males=3˚) after surgery this was not statistically significant. No correlation between age and postoperative ROM of the knee was found. Significant difference in gain in ROM was found in younger age groups at 3 months but this was not observed at 6 month.

BMI has a weak negative correlation with ROM at 6 months after surgery (r =-0.271, p=0.04). However, there was a strong negative correlation between BMI and preoperative ROM (r=-0.400, p=0.03). This shows that obese patients have poor range of motions and do not do better postoperatively. BMI is negatively correlated with both preoperative and postoperative knee scores. Preoperative scores are negatively correlated with BMI which is significant statistically with p=0.014 (r=-0.346). Postoperative final score is negatively correlated with BMI, very strongly significant with p=0.001 (r= -0.442).

The preoperative TKS and FS were found to have influence on both pre and postoperative ROM. There was weak negative correlation between TKS and FS on gain in ROM after 6 months, but this is not significant statistically. Both TKS and FS correlate positively with postoperative ROM. Preoperative total scores are more in men compared to females, significant with p=0.04 (men–102.8 females–82.7), though postoperative functional scores are more in males than females it is not statistically significant.

The preoperative ROM has strongly positive correlation with ROM at 6 months (r=0.501, p≤0.0001) after surgery. When considering the gain in ROM, preoperative ROM had moderately negative correlation at 6 months (r=-0.71, p≤0.0001). The preoperative flexion deformity had an opposite effect. It had a negative correlation with final flexion angle(r=-0.305, p=0.03).

The average preoperative FCO is 3.38cm (4cm - 2.5cm). The average postoperative FCO was 3.43cm (4.5cm - 3cm). The average preoperative PTS was 15.4˚ (22˚-2.5˚). The average postoperative PTS was 12.8˚(18˚- 8˚). In our study there is no statistical significant correlation between FCO and final flexion and we found there is a correlation between PTS and final flexion but it is not statistically significant with p=0.75.

DISCUSSION

TKA can provide excellent pain relief and ROM in osteoarthritis. Progress in the knee implant design and the surgical techniques in TKR achieved successful results in reducing the pain and providing a stable joint; however, enhancing the postoperative range of motion is yet challengeable. The postoperative ROM is one of the major criteria of the patient's satisfaction of the arthroplasty, where the patient needs an acceptable flexion for daily activities.

Studies have compared various preoperative and postoperative parameters between high flexion and standard implant. Factors affecting ROM in a high flexion implant may be different than standard implant. We studied the DEPUY PFC sigma knee implant with respect to factors affecting the final ROM and also the functional satisfaction of the patients.

As expected, the present study revealed that all the preoperative measures of the ROM, including age, gender, body weight, severity of the disease, flexion and extension lag has significantly influence on postoperative ROM. Moreover, the mean preoperative tibiofemoral varus/valgus angle, which was calculated from radiophotographs of the knee, decreased remarkably after the arthroplasty. Besides, the clinical evaluation of the

patients, assessed by the KSS score significantly improved compared to the preoperative values. This study followed the patients up for 6 months, which makes it a limitation for the study since long-term results might be different at least for some of the studied variables.

On the other hand, the most effective clinical outcomes of the knee joint arthroplasty present themselves almost 6 months after the surgery, which makes this study valid enough to assess the factors influencing postoperative ROM.[17]

Factors affecting the final ROM are discussed below

Gender: Females (40) outnumbered males (10) as was seen in almost all studies. A study conducted by Lizaur et al showed that preoperative range of motion is greater in men than in women (p=0.038), but the final postoperative flexion was not significantly associated with gender (p=0.41).[22] Farahini et al concluded that gender showed to have no significant relationship with the postoperative flexion, which was similar with most of the previous reports however, there was a few articles discussing it as a factor related to the final range of motion outcome.[23] Harvey et al reported in his study that sex had no correlation in affecting the final knee ROM postoperatively in conventional total knee arthroplasty.[24] Other studies also showed no relation between sex and ROM. Sancheti et al gender has no influence on both preoperative and postoperative ROM. In our study we found males have more preoperative range of motion (104˚) compared to females which is significant (p=0.004), at 6 months post-surgery, we found final ROM to be slightly more in males however this was not statistically significant.[25]

Age: The mean age of the patient at the time of surgery in our study is 65 yrs. In a study conducted by Sancheti et al 2013 the mean age is 68.2 and there is no correlation between the age and ROM.[25] Schurman et al found that gain in ROM was better in younger patients at 3 months postsurgery.[26] Franklin et al reported older age groups to have a poorer outcome when compared to younger ones.[27] Farahini et al reported univariate analysis showing good correlation (r=0.102, p=0.04) with postoperative flexion angle however multivariate analysis showed no significant correlation.[23] In contrast, Anouchi et al reported no correlation between age and postoperative knee ROM.[28] In our study too using pearson correlation we found no relation between age and preoperative range of motion (p=0.74) and inverse relation between age and postoperative range of movement which is not statistically significant (p=0.45) at 6 month interval.

Body mass index: Obesity has an adverse effect on postoperative knee ROM due to soft tissue impingement between the femur and the tibia, which restricts flexion of the knee.[27] Studies show that patients who were obese had higher chances of a poor ROM. Study by Sancheti et al shows that people with lesser BMI gained significant flexion from baseline after the first 3 months till 1 year post surgery, although the patient with higher BMI did had decreased ROM, the final flexion angle did not correlate with BMI, agreeing with Kotani et al.[25,29] The study conducted by Lizaur et al 1997 concluded that there was a significant correlation between the preoperative flexion, the relative weight(r=0.24,p=0.028) and the BMI (r=0.24, p=0.030). There was also a significant relationship between preoperative flexion contracture, the relative weight (r=0.21, p=0.050) and the BMI (r=0.22, p=0.042).[22] Using logistic regression analysis they found that the BMI (r =-0.30, p=-0.030) had a significant effect on the final range of flexion. A study by Farahini et al concluded that there was no relationship between BMI and postoperative flexion.[23]

In our study, using pearson correlation we found that there is significant negative correlation between increase in BMI and preoperative and postoperative flexion which is statistically significant with p values (p=0.03; p=0.04) respectively (Table 1,Table 2).

Type of disesase: Studies have reported that patients suffering from rheumatoid arthritis had poor preoperative ROM compared to osteoarthritis. Harvey et al described the type of disease as the most important factor in predicting ROM after total knee replacement.[24] Ritter and Stringer evaluated 145 consecutive TKAs and found that the knee flexion range increased by 2° in RA patients, a nonstatistically significant difference.[30] In a study by Sancheti et al, there was significant difference in preoperative ROM between the OA and RA groups with RA group having lesser preoperative ROM.[25] Postoperatively, the RA group showed a significantly greater increase in ROM in agreement with most published studies. The final flexion angle was greater in OA group and this was significant at the end of 1 year when compared with RA group. Thus, although patients with RA had better gain in ROM, the final ROM was better in OA group. In our study Out of 50 knees 49 knees were osteoarthritis, one patient had rheumatoid arthritis, which was operated at early age of 42 yrs and showed better functional outcome.

Preoperative range of motion: Increased preoperative ROM has proved by several studies that there is a greater postoperative flexion arc achieved by the patient. Kurosaka et al and Harvey et al.[24,31] reported that preoperative ROM of the knee joint was the most important factor with patients with good preoperative ROM showing better final outcome. A study by Sancheti et al demonstrated moderately positive correlation between preoperative flexion and postoperative flexion at 3 months and 6 months, but reduced to a weak positive correlation by the end of 1 year.[25] In our study it was concluded that knees with good preoperative flexion have better postoperative flexion which is statistically proven by pearson correlation and very significant with p value 0.001 (Table 3).

Preoperative flexion deformity: A positive correlation between preoperative and postoperative ROM is well established.[31,32] In a study by Sancheti et al, preoperative ROM had positive correlation with postoperative ROM indicating more final ROM in patients with more peroperative ROM.[25] However, preoperative ROM had negative correlation with gain in ROM indicating patients with more preoperative ROM did not gain much range (Preoperative ROM α postoperative ROM/gain in ROM). Kawamura and Bourne concluded that preoperative flexion deformity did not correlate with final ROM.[33] Sancheti et al proved that patients with greater flexion deformity had significant but weak negative correlation with final ROM and a positive correlation with gain in ROM.[25] Thus, more the preoperative flexion deformity less was the final ROM and more was the gain in ROM with $p<0.0001$ at all-time intervals (Preoperative flexion deformity directly proportional to gain in ROM and inversely proportional to final ROM). This correlation of preoperative ROM and flexion deformity with postoperative ROM and gain in ROM is not reported in literature. In our study it was concluded that preoperative flexion deformity is negatively correlated with final range of flexion which is significant with p value 0.031 (Table 4).

Scores: Anouchi et al found that most important factor to predict the ROM was the preoperative knee society scores.[28] Sancheti et al proved that, patients with good preoperative knee society score were shown to have more final range of flexion however the ones with lower TKS and FS showed higher gain in ROM from the preoperative value.[25] This was similar to findings of other studies and concluded that both preoperative and postoperative scores positively correlate with better postoperative ROM.

In our study we concluded that both preoperative and postoperative scores positively correlate with better postoperative ROM. Comparatively males have better knee scores compared to females.

Posterior femoral condylar offset and posterior tibial slope

Hanratty et al, Kim et al concluded that there is no significant correlation between FCO and final flexion.[34,35] In our study also there is no statistically significant correlation between FCO and final flexion.

Kim et al had found no correlation between PTS and knee flexion whereas Kim et al in a study of 45 knees about 1yr follow up proved there is a significant relation between PTS and postoperative knee flexion.[36,37] In our study we found there is a correlation between these two factors but it is not statistically significant with p value 0.75.

No comparison group in our study relatively short follow-up is the main limitations of the study. Intraoperative factors like ligament balancing, flexion extension gap after bony cuts among others were not considered. However, since this is a series from single institution following a standard technique, other factors can be considered to be comparable.

CONCLUSION

To conclude factors that positively affected ROM at the end of 6 months were preoperative ROM, total knee score, and functional Score whereas BMI, preoperative flexion deformity has a negative influence on final flexion at the end of 6 months. Age and gender of the patients, posterior tibial slope, posterior femoral condylar offset did not affect the final outcome.

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Ethical approval: The study was approved by the institutional ethics committee

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