

Effect of posterior cruciate ligament recession on knee joint pressure and joint space measured by an electronic pressure sensor during total knee arthroplasty

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Study protocol

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Abstract

Purpose: The purpose of this study was to evaluate the change in posterior cruciate ligament (PCL) tension by directly measuring the pressure changes in the knee joint when the ligament was released or resected during total knee arthroplasty (TKA).

Methods: We prospectively analysed 22 patients who underwent primary TKA (28 knees) between October 2019 and January 2020. The pressure changes in the medial and lateral compartment were measured with an electronic pressure sensor with PCL retention (at 0°, 45°, 90° and 120° of flexion), tibial recession and PCL resection, and changes in the knee joint space were measured.

Results: At 0°, 45°, 90° and 120° of flexion, the total pressure in the knee joint after tibial recession of the PCL was significantly higher than with PCL resection, and higher than PCL recession, but only at 120°. Recession or resection of the PCL affected knee joint extension, and the medial/lateral pressure in the knee joint decreased. Pressure in the lateral compartment showed no significant change, while pressure in the medial compartment decreased significantly during knee flexion, which also led to a change in the ratios of the medial and lateral pressures in the knee joint. After resecting the PCL, the mean flexion and extension gaps increased by 0.64 mm and 0.46 mm, respectively.

Conclusion: Tibial recession of the PCL can release the PCL while retaining some PCL function. PCL release affects both the flexion and extension gaps, and more cases will increase the flexion gap.

1. Introduction

Total knee arthroplasty is an effective method of treating end-stage knee osteoarthritis. There are two main types of knee arthroplasty: cruciate retaining (CR) prostheses and posterior stabilised (PS)/cruciate sacrificing (CS) prostheses, where the posterior cruciate ligament (PCL) is removed. Currently, both types of prostheses have a 10-year survival rate of more than 90%.[1–3] The PCL mainly functions to prevent excessive posterior movement of the tibia. The CR prosthesis has certain advantages in improving proprioception, reproducing physiological knee biomechanics, restoring femoral retroversion and protecting the bone-cement interface from shear stress.[4] However, a PCL that is too tight leads to a reduction in the flexion angle or to high stress on the posterior margin of the tibial plateau and the liftoff sign, accelerating polyethylene wear.[5] In contrast, excessive relaxation leads to an unstable flexion position and knee pain.[6] All of these issues shorten the life of the prosthesis and lower patient satisfaction.

PCL preservation and optimal knee balancing are the keys to success when using the CR prosthesis. However, part of the PCL tibial insertion may be damaged during knee arthroplasty, and PCL release or tibial insertion recession may also be required when PCL tension is present.[7] To address possible instability and poor clinical effects, some researchers changed the CR prosthesis to a CS or PS-type prosthesis after releasing the PCL;[8] however, the necessity for this change is controversial. Even if the tibial insertion of the PCL was completely removed, the PCL was still connected to the posterior joint

capsule and retained some function. To our knowledge, no direct data support residual tension in the PCL after complete release of the tibial insertion.

The purposes of this study were to: 1) investigate joint pressure when the PCL is retained, released or resected, using an electronic sensor; 2) measure the pressure change in the compartment pressure distribution when the PCL is released or resected and 3) measure the changes in the flexion and extension gaps of the knee joint when the PCL is retained or resected. Electronic pressure sensors have been used in knee arthroplasty to measure the pressure on the knee platform as a reference for internal and external balance.[9] Currently, widely used orthosensors can measure a pressure change of 1 lb (pound), and the finer sensor can measure a pressure change of 0.01 N (Newton), which can reflect small pressure changes caused by releasing the PCL.

2. Materials And Methods

The data were collected prospectively with the approval of our institutional review board. From October 2019 to January 2020, patients who underwent knee arthroplasty in our hospital were screened. Inclusion criteria were: 1) patients with osteoarthritis; 2) patients with genu varum, varus $\leq 25^\circ$ and flexion contracture $\leq 25^\circ$. Exclusion criteria were: 1) patients with rheumatoid arthritis or traumatic osteoarthritis; 2) patients who had received a joint replacement with a metal gasket owing to severe varus deformity, flexion contracture or a bone defect and 3) patients with a damaged PCL. A total of 22 cases (28 knees) were included (15 left knees and 13 right knees). Patients' average age was 66 years (range: 56–79 years), and the average angle of varus deformity was 12.2° (range: 5° – 25°). The Smith & Nephew Genesis II PS (Smith & Nephew, London, United Kingdom) implant was used for all operations.

All operations were performed by the same senior surgeon. An anterior midline incision was made, a medial parapatellar approach was performed, the deep part of the medial collateral ligament was retained and turned over the patella. First, a 9-mm osteotomy was performed with the extramedullary tibial alignment at 3° , and the tibial insertion of the PCL was retained (Fig. 1a). Then, a 9-mm osteotomy was performed with the intramedullary femoral alignment at 5° . Osteophytes were removed, and the flexion and extension gaps were adjusted. If the flexion and extension were unbalanced, the distal end of the femur was cut when the extension gap was less than the flexion gap. When the extension gap was greater than the flexion gap, more posterior condyle was cut, and a smaller prosthesis was selected.

We used a wireless electronic pressure sensor produced by Yiemed Co. Ltd., Shandong, China (Fig. 2a), with a shape in accordance with the Genesis II CR, which can measure the pressure of the medial and lateral compartments and cannot show the contact position of the femoral condyle and sensor. The electronic sensor fits gaps larger than 9 mm, and a 1-mm or 2-mm thickener can be used to adapt to different gaps.

The data for the PCL retention group, tibial recession group and resection group were measured using the method described below. The measurements constituted the pressure of the medial and lateral

compartments at 0°, 45°, 90° and 120° of flexion, and the flexion and extension gaps of the knee joint in each group.

1. Acquisition of data from the retention group: After adjusting the flexion gap balance, the metal femoral condyle CR test prosthesis and the matching tibial electronic sensor were placed, and the medial and lateral pressures provided by the sensor at 0°, 45°, 90° and 120° of flexion were measured and recorded. During the measurement, the operator held the patient's calf and thigh to overcome gravity. During flexion, the patient's foot was lifted above the operating table, and the patella was reduced. The electronic sensor recorded the pressure in real time, three stable data points were taken and the mean value was recorded.
The femoral condyle and electronic sensor were removed, and the extension gaps at 0° and 90° at 20 lbs were measured using the Smith & Nephew tools, and values were recorded.
2. Acquisition of data from the tibial recession group: After the above procedure, the tibial insertion of the PCL was released to 8–10 mm below the plateau (Fig. 1b). The pressures at 0°, 45°, 90° and 120° of flexion were measured, as above.
3. Acquisition of data from the resection group: The electronic sensor and condyle were not removed, and the tibial insertion of the PCL was completely resected (Fig. 1c and d). We measured the pressures at 0°, 45°, 90° and 120° of flexion, then removed the electronic sensor and femoral condyle and measured the gap at 0° and 90° of flexion (Fig. 2b).

a: After routine tibial osteotomy, attention was paid to protecting the tibial/femoral PCL. b: After obtaining the measurement data in the retention group, the femoral test model and tibial sensor were removed, and the tibial insertion of the PCL was completely released to 8–10 mm below the plateau. Then, the same type of femoral test model and tibial sensor were re-installed to measure the data in the tibial recession group. c: After obtaining the measurement data in the tibial recession group, the femoral PCL was resected, and we obtained the measurement data in the resection group. d: Photograph of the resected PCL.

After obtaining all measurement data, the wireless electronic sensor was used again to measure and adjust the medial and lateral pressure difference during flexion to less than 30 N. The Smith & Nephew Genesis II PS (Smith & Nephew) and its PS-type gasket were used in the operation.

a: Photograph of the wireless electronic pressure sensor produced by Yiemed Co. Ltd., Shandong, China.
b: Photograph of the gap measurement module in the Smith & Nephew Genesis II PS (Smith & Nephew, London, United Kingdom).

Statistical analysis was performed using SPSS software (IBM SPSS Statistics for Windows, Version 22.0; IBM Corp., Armonk, NY, USA). The Kolmogorov–Smirnov test was used to verify the normal distribution of the data, and the results showed that the data were non-normally distributed. A nonparametric paired test of the total pressure, medial compartment pressure and lateral compartment pressure was conducted using the Wilcoxon signed-rank test. Using the Wilcoxon signed-rank test, we calculated the

compartmental load ratio (CLR), which represented the relative load transferred through the medial compartment as follows: $CLR = \frac{F_m}{F_l}$ (Fm medial pressure, Fl lateral pressure). $P < 0.05$ was considered statistically significant. Changes in the flexion gap in the knee joint after complete resection of the PCL were also measured and calculated.

3. Results

In the 28 knees undergoing TKA, the changes in total pressure in the PCL retention group, tibial recession group and resection group are shown in Fig. 3. The total pressure in all three groups decreased with increased flexion angle. At 0° of flexion, the pressure in the retention group was the highest, at an average of 81.9 N, which decreased rapidly at 45° of flexion, with an average of 37.1 N. Although the pressure continued to decrease with increased flexion angle, there was no significant difference at 90° and 120° of flexion. There was also no significant difference in the average pressure at 0°, 45° and 90° between the retention group and the tibial recession group. After complete resection of the PCL, at 0°, 45°, 90° and 120° of flexion, the total pressure was significantly lower than in the other two groups, indicating that pressures with tibial recession of the PCL differed from those with PCL resection, and that the PCL maintained partial articular cavity pressure.

The total pressure in the knee joint decreased obviously from 45° to 0°, varying obviously with flexion.

The pressure in the medial compartment in the three groups is shown in Fig. 4, and the trend was similar to that for total pressure. Compared with the PCL retention group, the pressure in the resection group decreased significantly, and compared with the PCL retention group, the pressure in the tibial recession group decreased significantly at 45° and 120°. There was also a significant difference in the pressure at 90° and 120° between the tibial PCL recession group and the resection group.

The pressure changes in the lateral compartment in the three groups are shown in Fig. 5. When the knee joint was in 0° of flexion, the pressure in the resection group was significantly lower than in the retention group and the recession group, indicating that PCL resection can reduce the lateral pressure or increase the lateral space. At 45° of flexion, the lateral pressure in the retention group was significantly higher than in the recession group by an average of 3.1 N.

We measured the results for total pressure in the retention group minus the recession group, and for the retention group minus the resection group. The results were tested using the paired t-test and showed that the retention group minus the resection group had a greater difference ($P < 0.05$). Interestingly, there were no statistical differences when we compared the medial pressure difference at 0° ($P = 0.173$) and 45° ($P = 0.360$), and no statistical differences when we compared the lateral pressure difference at 0° ($P = 0.173$) and 45° ($P = 0.360$).

The ratio of medial compartment pressure in the knee joint in each group was statistically analysed (Fig. 6). The results showed that there was no significant difference between the three groups at 0°; however, at 90° and 120° of knee flexion, there was a significant difference between the three groups. At

45° of flexion, there was no significant difference between the tibial retention group and the resection group, while there was a significant difference in the other group comparisons.

Tables 1–3 show that the pressure in the lateral compartment exceeded the medial compartment pressure when the knee was flexed to 45°. With further release and resection of the PCL, the difference in pressure between the medial and lateral sides of the PCL increased gradually.

The percentage pressure in the medial compartment was calculated as follows: $\% = \text{medial pressure} / (\text{medial pressure} + \text{lateral pressure}) * 100\%$.

Using the Smith & Nephew Genesis II tool, the gap changes under a certain opening force were measured using a 1-mm scale. After PCL resection, the flexion and extension gap in the knee joint increased significantly ($P = 0.025$). Of the 28 cases, 11 cases showed an increase of ≤ 1 mm in both flexion and extension gap, 12 cases showed increased gaps and five patients had a different increase in flexion and extension gaps after PCL resection, showing an increase in the flexion gap with no increase in the extension gap.

4. Discussion

The PCL can prevent excessive backward movement of the tibia and promote normal anatomical femoral rollback. When the knee is flexed $> 90^\circ$, the PCL is stretched, and backward rolling of the femur is helpful to increase the torque in the quadriceps femoris, which improves the flexion angle of the knee joint[10]. An important step in using a CR-type prosthesis in total knee arthroplasty is to balance and protect the PCL. An excessively tight PCL leads to excessive backward rolling of the femur, which limits joint flexion. Excessive tightness can also increase contact stress and lead to polyethylene wear, liftoff at the leading edge of the tibia plateau, spinout of the flexible plateau and even posterior medial dislocation of the femur.[11] Additionally, PCL release may lead to knee instability and post-operative pain.[12]

Recession of the PCL at its tibial insertion is a common treatment for a tense PCL, and even tibial osteotomy partially or completely damages the tibial insertion of the PCL. Whether PCL resection enables using a PS prosthesis remains unclear. It is generally believed that the PCL is still connected to the posterior edge of the tibia through the posterior joint capsule, to maintain tension after tibial recession. Our study simulated tibial recession and PCL resection, and the data showed that after tibial resection of the PCL, the total pressure in the knee joint decreased, which may have affected PCL function. However, the knee joint pressure in the recession group was higher than that in the resection group, indicating that the PCL still had partial tension at all angles of flexion and extension. This finding also suggested that the PCL still functioned, which may indicate that the CR prosthesis can be used.[13] Therefore, even if recession of the tibial insertion occurs because of osteotomy or using a Hoffman hook in knee arthroplasty, the PCL may still function, and a CR prosthesis could be used.[14, 15] Ritter et al.[16] examined 3018 CR patients, and showed that there was a mild difference in long-term all-cause aseptic survival between the PCL retention group (96.4% at 15 years) combined with the PCL recession group (96.6% at 15 years) compared with the PCL resection group (95.0% at 15 years).

In this study, the pressure in the knee joint in the retention group was the highest in extension (0°), and the medial pressure was greater than the lateral pressure. The pressure in the knee joint, especially the pressure in the medial compartment, decreased significantly during knee flexion, especially from 0° to 45°, and decreased gradually after 90° flexion. The lateral pressure decreased gradually and remained stable between 45° and 120°, and the lateral pressure was slightly higher than the medial pressure during flexion, which was consistent with previous reports.[17] In this study, at 90° and 120°, with release and transection of the PCL, the medial pressure and its percentage decreased significantly, while the change in lateral pressure was not significant and resulted in a higher percentage. A study by Iwaki et al.[18] showed that in patients who underwent knee joint replacement with a CR prosthesis, the percentage of medial compartment pressure increased slightly with an increase in joint flexion angle. This increase was consistent with normal knee joint anatomy reconstructed with a CR prosthesis, in which the lateral compartment rolls backwards with the medial compartment in the rotation axis. Schnaser et al. used a sensor to measure the pressure in the lateral compartment in 60 cases receiving the PS prosthesis, and showed that with an increase in the flexion angle of the knee joint, the percentage of medial compartment pressure decreased gradually.[19] The pressure distribution in our results was similar to the transition from a CR- to a PS-type prosthesis. Our data also suggest that the PCL has a greater effect on the change in medial pressure than on lateral pressure. After PCL resection, the medial pressure decreased significantly from 0° to 120°, and the lateral pressure decreased significantly only at 0°. The average variation value was also smaller than for the medial pressure, which is consistent with the PCL maintaining the medial flexion gap and balancing valgus deformity; thus, PCL transection may increase the medial gap.[20]

During CR knee arthroplasty, if the flexion gap is smaller than the extension gap, there are usually three ways to balance the gap: 1) select a smaller femoral condyle prosthesis, which can increase the osteotomy of the posterior femoral condyle by 2 mm; 2) increase the posterior tilt of the tibial osteotomy or 3) release or even resect the PCL to increase the flexion gap. According to our results, the total pressure in the knee joint at 120° of flexion decreased significantly after PCL release and recession, and the quantitative analysis showed that the PCL release with the recession method relaxed the PCL during > 90° of flexion. However, there was no significant difference between the retention and recession groups when the flexion gap was > 90°, indicating that PCL recession does not increase the flexion gap, and the average gap increase was < 1 mm. In one study, the flexion gap after in vitro cadaveric resection of the PCL increased by 5.29 mm.[21] Matthews et al.[22] measured the gap changes after implanting a CR prosthesis followed by PCL resection, and the results showed that the extension space increased by 0.33–0.67 mm, and the flexion gap increased by 0.53–0.66 mm. Previous studies had similar results.[23, 24] The reason for the large differences is that some studies used only the knee joint, without the surrounding muscles. Other researchers applied excessive separation force, which does not fully simulate the patient undergoing total knee arthroplasty. Therefore, the effect of releasing the PCL is limited when the flexion gap is less than the extension gap. Increasing the posterior inclination of the tibial osteotomy itself may damage part of the tibial insertion of the PCL, so we do not commonly use this method during

CR knee arthroplasty. Instead, we often increase the flexion gap by increasing the posterior condylar osteotomy, and PCL release is performed only when the PCL is tense.

This study had some limitations. First, the sensor is designed for the CR prosthesis (not PS) even though this used after PCL removal. In addition to having no post, the Genesis II CR is flatter than the PS at the posterior edge to avoid blocking the rolling movement of the femoral condyle. Therefore, the data after PCL transection in this study cannot fully account for the pressure changes in the PS knee joint. Second, although the electronic sensor was sensitive to pressure, the weight of the knee joint and the inverting force of the operator likely affected the accuracy of the data. We attempted to balance the gravity of the knee joint to avoid potential bias; however, the position of the prosthesis also has a great impact on the intra-articular pressure. The femoral condyle prosthesis is easier to place and fix, while the tibial sensor is not fixed, and a different contact point between the sensor and the femur can lead to different pressures. Therefore, we marked the position of the sensor on the tibial plateau to maintain consistency for each position. Additionally, we measured the stable data three times and used the average value to obtain accurate results. Finally, the number of cases in this study was relatively small because of the prospective data collection, and our increased number of procedures increased the length of routine PS arthroplasty.

5. Conclusion

Tibial recession of the PCL can release the PCL while retaining some PCL function. PCL release affects both the flexion and extension gaps, and more cases will increase the flexion gap.

List Of Abbreviations

PCL, posterior cruciate ligament

TKA, total knee arthroplasty

PS: posterior stabilised

CS: cruciate sacrificing

CR: cruciate retaining

CLR: compartmental load ratio

Declarations

Ethics approval and consent to participate

The article "Effect of posterior cruciate ligament recession on knee joint pressure and joint space measured by an electronic pressure sensor during total knee arthroplasty" is approved by our ethics

committee. Please refer to the supplementary material

Consent for publication

We have signed a consent form with each volunteer before taking the TKA surgery.

Availability of data and materials

The datasets during and/or analysed during the current study available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests

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This study is not funded.

Authors' contributions

Ran Zhao: data collection and management, data analysis, manuscript writing;

Yanqing Liu: project development, manuscript editing;

Hua Tian: data management, project development;

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Tables

Due to technical limitations the Tables are available as a download in the Supplementary Files.

Figures

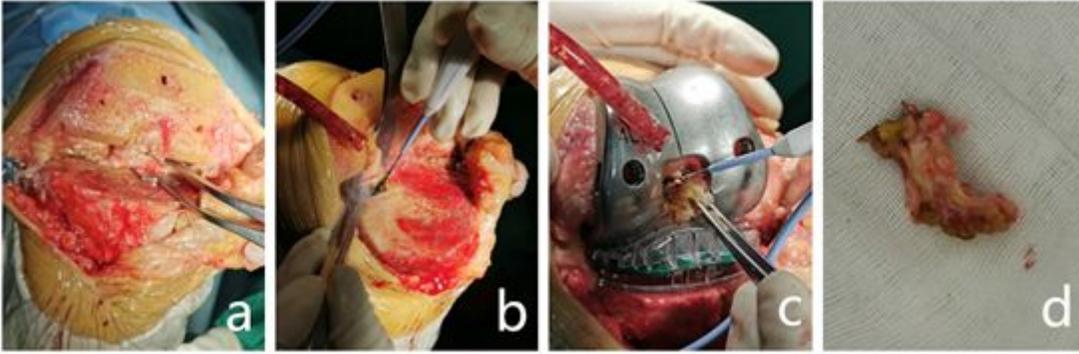


Figure 1

A 72-year-old female patient underwent left total knee arthroplasty for osteoarthritis of the knee

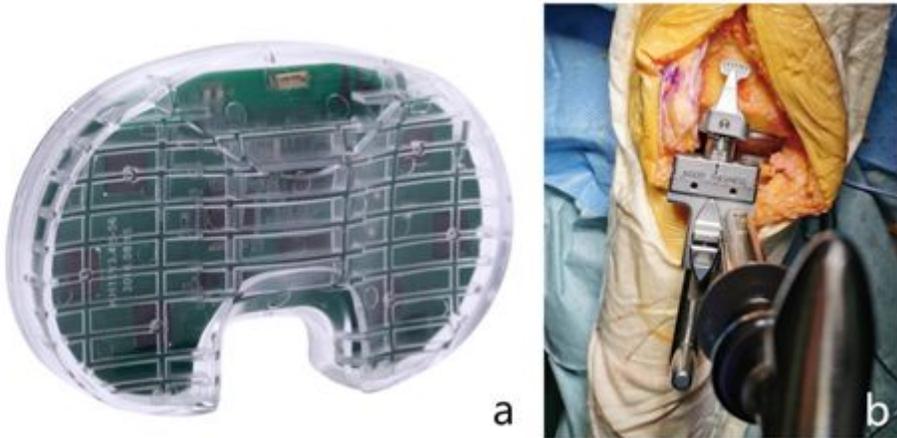


Figure 2

The electronic sensor and gap measurement module

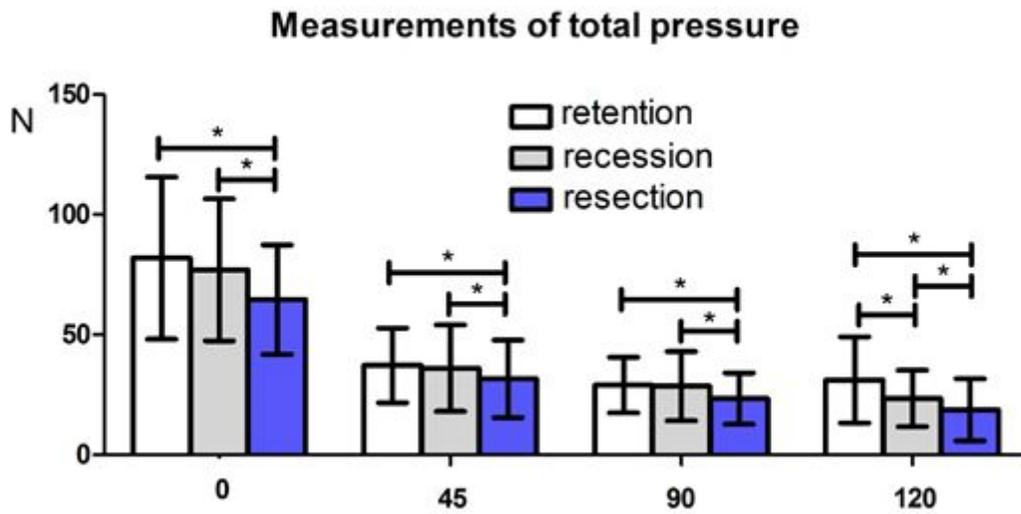


Figure 3

Comparison of the total pressure at 0°, 45°, 90° and 120° of flexion in the retention group, recession group and resection group

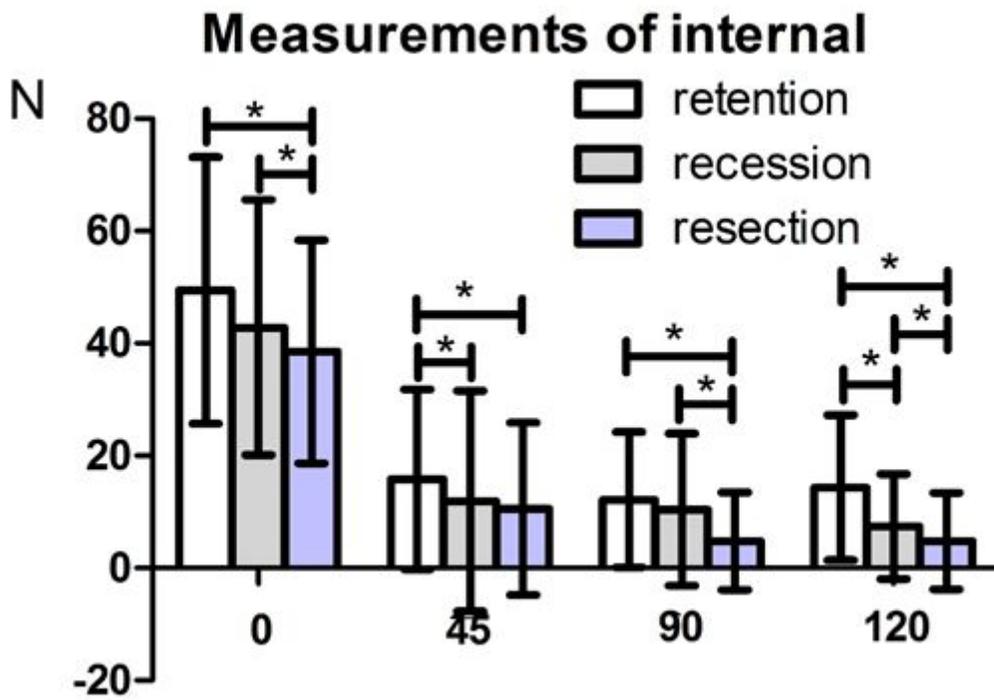


Figure 4

The pressure in the resection group decreased significantly compared with the PCL retention group

Measurements of lateral

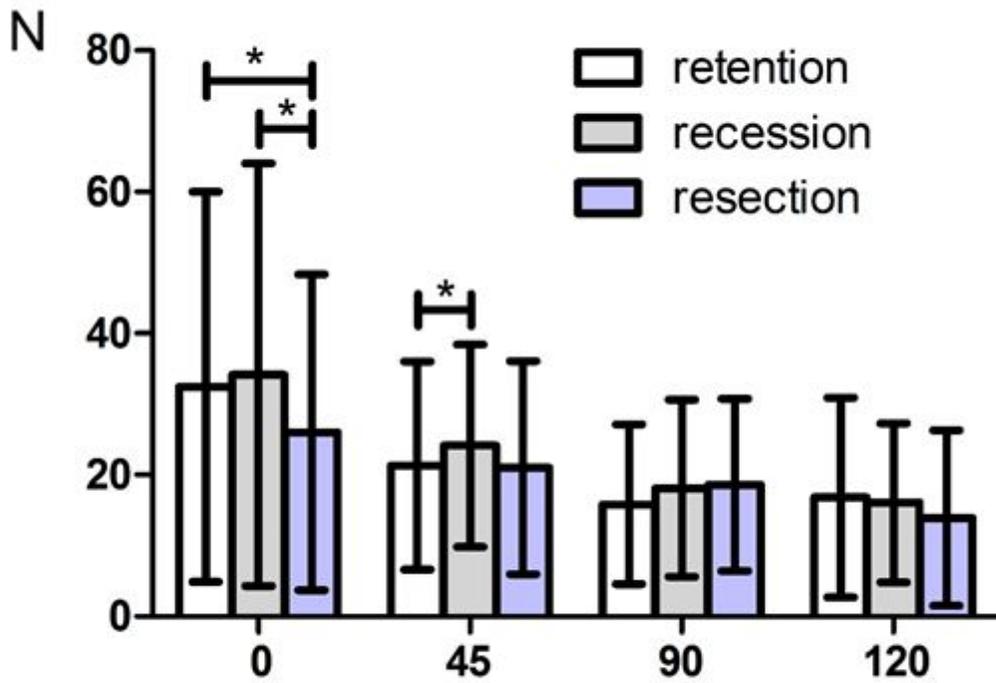


Figure 5

The pressure in the resection group was significantly lower than in the retention group and the recession group at 0°. There were no differences in lateral pressure in the three groups when the degree of knee flexion increased.

Percentage of pressure in medial compartment

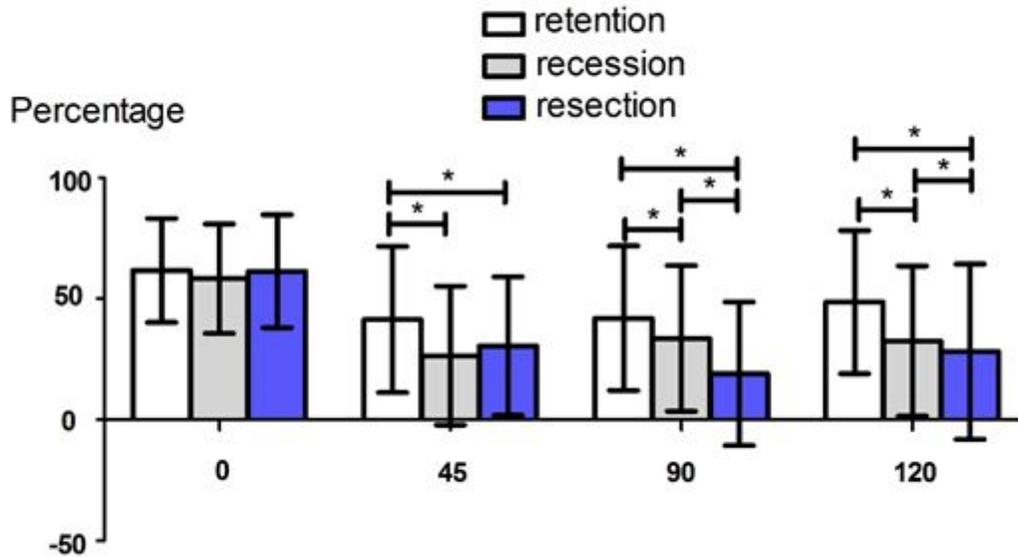


Figure 6

Comparison of the pressure percentage in the medial compartment at 0°, 45°, 90° and 120° of flexion in the three groups

Supplementary Files

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