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# Anterior knee pain after total knee arthroplasty: does it correlate with patellar blood flow?

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**Abstract**
*Purpose* Total knee arthroplasty (TKA) disturbs patellar blood flow, an unintended accompaniment to TKA that may be a cause of postoperative anterior knee pain. We examine whether disrupted patellar blood flow correlates with anterior knee pain following TKA.
*Methods* In 50 patients (21 men, 29 women) undergoing TKA, we compared patellar blood flow at flexions 0° to 30°, 60°, 90°, and 110° before and after medial parapatellar arthrotomy to pre- and postoperative anterior knee pain scores by means of a laser Doppler flowmeter (LDF) probe. Anterior knee pain was assessed using the pain intensity numeric rating scale (NRS) of 0–10 (0-no, 10-worst pain). Based on the NRS pain values, patients were divided into two main groups: group A ($n = 34$) with no pain or discomfort (NRS range 0–4) and group B ($n = 16$) with anterior knee pain (NRS range 5–10).
*Results* Patients of group B demonstrated a significant decrease in blood flow before arthrotomy at flexions from 0° to 90°, and 110° and from 0° to 60°, 90°, and 110° after arthrotomy. For group A, a significant decrease in blood flow was detected at flexions from 0° to 90°, and 110° before and after arthrotomy. For both groups, medial arthrotomy did not have a statistically significant influence on patellar blood flow (margin of significance $P < 0.05$). Prior to TKA, 16 of the 50 patients of group B (32%) complained of anterior knee pain (mean NRS 7.1 ± 1.7). At 2-year follow-up, pain significantly decreased (NRS 3.1 ± 2.1) and only 4 of the 16 patients (25%) complained of moderate anterior pain (average NRS 5.7 ± 0.5), while 8 of 16 (50%) patients reported discomfort (mean NRS 3.5 ± 1.8) around the patella. Patients in group A also demonstrated a significant decrease in pain intensity (from NRS 1.5 ± 1.4 preoperatively to NRS 0.4 ± 1.5 at 2-year follow-up). Statistical analysis demonstrated no statistically significant correlation between pre-arthrotomy/post-arthrotomy patellar blood flow and the presence of preoperative and postoperative anterior knee pain. Only the degree of flexion had an influence on patellar blood flow.
*Conclusion* Medial arthrotomy had no direct significant effect on patellar blood flow, and the diminished blood flow did not correlate with postoperative anterior knee pain. However, a significant correlation was revealed between patellar blood flow and the degree of flexion: in almost a quarter of patients, blood flow dropped to zero at flexions of 100° and above.
*Level of evidence* II.

**Keywords** Total knee arthroplasty · Anterior knee pain · Patellar blood flow

## Introduction

Anterior knee pain is a well-described but unexplained complication of total knee arthroplasty (TKA) [1, 5, 7, 8, 17, 30, 31]. During the last years, several etiologies, including the patellofemoral maltracking and more recently the neural model, have been presented to explain its pathogenesis [15, 17, 28, 29]. Among the surgical strategies deployed to prevent it are the midvastus, subvastus and MIS approaches [2, 3, 10, 12, 20, 36], peripatellar

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denervation [34], avoidance of overstuffing [17, 26], and routine insertion of a patellar prosthesis [6, 13, 21, 35]. None of these measures, however, can consistently prevent the occurrence of parapatellar pain. The patella functions as a hypomochlion that optimizes the force vector during knee extension [25]. Several studies have shown that TKA increases the tension on the patella and surrounding soft tissues with increased flexion [16, 24, 27]. This rise in tension can lead to the squeezing of vessels supplying the patella and thus to disruption of the patellar blood flow [11], especially during prolonged sitting. The parapatellar approach can additionally disrupt the blood supply to the patella [4, 14]. To determine whether patellar blood flow correlates with persisting anterior knee pain following TKA**,** patella's intraosseous blood flow during TKA was determined. The hypothesis was that medial arthrotomy and knee flexion during TKA implantation can disturb patellar blood flow leading to anterior knee pain. To evaluate this hypothesis, patella's intraosseous blood flow was compared at different knee joint angles before and after medial parapatellar arthrotomy to pre- and postoperative anterior knee pain values.

## Materials and methods

Patella intraosseous blood flow was measured in 50 patients (21 men, 29 women; mean age 73.1 ± 8.6 years) undergoing primary TKA surgery. The diagnosis of anterior knee pain syndrome was based on the pain intensity numeric rating scale (NRS). One day before surgery and at 2-year follow-up, patients were asked to rate the intensity of their anterior knee pain on a scale of 0–10, 0 meaning no pain and 10 the worst pain possible. The questionnaire was standardized to the patient and also investigated about pain at rest or after simple everyday activities such as stair climbing, rising from a chair, etc. Based on the NRS pain values, patients were divided into two groups: group A ($n = 34$) including patients with no pain or discomfort (NRS range 0–4) and group B ($n = 16$) with patients suffering from anterior knee pain (NRS range 5–10). All surgeries were performed without patella resurfacing by one experienced knee surgeon. No lateral release was performed, and patellar fat pad was always preserved. For all patients, a Balansys TKA (Mathys, Bettlach, Switzerland) was implanted. Institutional review board approval was obtained for all procedures.

A standard medial parapatellar approach without a tourniquet was used in all patients. After subcutaneous dissection, a 3.5-mm diameter hole was drilled in the central spongious part of the patella. A laser Doppler flowmeter (LDF) probe (Moor Instruments, Axminster, UK) was placed in the hole and used in combination with a conventional laser Doppler flowmeter (DRT4; Moor Instruments, Axminster, UK) [19]. The energy source was 20 mW (emitting laser light with a 780 nm wavelength); the distance between the emitting and receiving fibers was 2.5 mm (one emitting, 3 collecting). Measurements were taken at full extension and at 30°, 60°, 90°, and 110° of flexion prior to and after medial arthrotomy without removing the LDF probe between measurements. All data were continuously recorded in real-time mode and stored for analysis on a DRT4 laser Doppler monitor using Windows based software (Moor Instruments, Axminster, UK). Blood flow was measured in flux units related to the mean red blood cell flow as calibrated against a standard reference of polystyrene microspheres provided by the manufacturer (Moor Instruments, Axminster, UK). The signal amplitudes were compared to the simultaneously recorded (electrocardiogram) heart rate. The measured amplitude depended on the probe's specific position, but the relative changes identified any maneuvers that altered perfusion [18, 33].

### Statistical analysis

Statistical analysis was performed with the Student's *t* test and Spearman correlation coefficient using SAS vs. 9.2 (SAS Institute Inc., Cary, North Carolina). Blood flow amplitudes were compared in each individual at 0°, 30°, 60°, 90°, and 110° of flexion before and after performing the medial parapatellar arthrotomy. The alpha level of significance for all tests was set at $P < 0.05$ based on the power calculation undertaken prior to study commencement. The Spearman correlation coefficients were used for the calculation of the patella blood flow with the intensity of pre- or postoperative anterior knee pain.

## Results

Patients' demographics and pain scores are shown in Table 1. No complications related to LDF monitoring were encountered. A large variability in flow changes was noted between patients. Mean blood flow at full extension was 43 ± 23.6 units. At 90° of flexion, all patients exhibited a reduction in blood flow to an average 65% of blood flow at full extension. More specifically, for patients in group A, a significant decrease in blood flow was detected at 90° and 110° of flexion before arthrotomy ($P$ values: $\ll$0.05, and $\ll$0.05, respectively) and at 60°, 90°, and 110° of flexion after arthrotomy ($P$ values: 0.016, $\ll$0.05 and $\ll$0.05, respectively), while no impact on blood flow was present at 30° of flexion before and after arthrotomy and at 60° of flexion before arthrotomy ($P$ values: 0.5, 0.4, 0.06,

**Table 1** Patients' demographics and pain scores before surgery and at 2-year follow-up

| Groups | Mean age | Males | Females | Right knees | Left knees | Mean pain before surgery | Mean pain at 2-year follow-up |
|---|---|---|---|---|---|---|---|
| Group A: discomfort ($n = 34$) | 74.1 ± 6.8 | 14 | 20 | 19 | 15 | 1.4 ± 1.5 | 0.3 ± 1.5 |
| Group B: anterior knee pain ($n = 16$) | 70.8 ± 6.5 | 7 | 9 | 6 | 10 | 7.0 ± 1.7 | 3.1 ± 2.1 |

respectively). Patients in group B demonstrated a significant decrease in blood flow at 90° and 110° of flexion before and after arthrotomy (*P* values: ≪0.05, ≪0.05 and 0.002, ≪0.05, respectively), while no significant difference was observed at 30° and 60° of flexion before or after arthrotomy (*P* values: 0.77, 0.282 and 0.65, 0.308, respectively) (Table 2, Fig. 1). A pulse-synchronous signal was detected in 39 of the 50 patients at full extension. The number of patients with a pulse-synchronous signal gradually decreased as the flexion angle increased, dropping to 30 at 60° and to only 9 at 90° degrees of knee flexion (Fig. 2). In 14 patients, no blood flow was detected at 90° degrees of flexion. The medial arthrotomy did not have a statistically significant influence on patellar blood flow (Table 3). Nineteen patients exhibited an average 14% (range 1–54%) increase in patellar blood perfusion at knee flexions of 90° and 110° after medial arthrotomy. Prior to TKA, 16 patients of group B (100%) complained of anterior knee pain (NRS 7.1 ± 1.7). At 2-year follow-up, 4 of the 16 patients (25%) complained of moderate anterior pain (NRS 5.7 ± 0.5), while 8 of 16 (50%) patients reported discomfort (NRS 3.5 ± 1.8) around the patella. Overall, patients of group B demonstrated a significant decrease on NRS ($P < 0.0001$). In group A, prior to TKA, 34 (100%) patients reported no pain or mild discomfort (NRS 1.5 ± 1.4). At 2-year follow-up, patients of group A also exhibited a significant decrease on NRS (average: 0.4 ± 1.5). However, two patients who had not complained of knee pain prior to TKA described anterior knee pain (NRS 5.5 ± 0.5) after TKA (Fig. 3). No correlation was found between intraoperative findings on patellar blood flow and the intensity of pre- or postoperative anterior knee pain. For the whole study group, Spearman correlation coefficients were 0.12 and 0.05, before and at 2 years after surgery, respectively. Stratified by the presence of pain, they were 0.12 and 0.28 in the pain-free group and 0.19 and 0.24 in the painful group, respectively.

## Discussion

The most important finding of the present study was that knee positioning during TKA can significantly disturb patellar blood flow at flexions from 0° to 90°, and 110° before and after arthrotomy. Medial arthrotomy displayed no statistically significant influence on patellar blood flow. No significant correlation could be established between patellar blood flow changes and the presence of pre- or postoperative anterior knee pain.

Patellofemoral complications account for up to 50% of all post-TKA complications [30]. Loosening, maltracking, stress fractures, osteonecrosis of the patella, and anterior knee pain are some of the problems described in the literature [6, 21, 25]. A possible mechanism investigating such complications is the disturbance of local blood flow. Vascular blood supply to the patella is mainly provided through an anastomotic ring consisting of the anterior tibial recurrent artery and five genicular arteries [24, 27]. The patellar ligament and quadriceps tendon have been shown to supply additional blood [16].

**Table 2** Mean blood flow at different degrees of flexion and *P* values of the two study groups

| Flexion | Before arthrotomy | | | | | After arthrotomy | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0° | 30° | 60° | 90° | 110° | 0° | 30° | 60° | 90° | 110° |
| Group A | | | | | | | | | | |
| Mean flow | 42.4 ± 23.6 | 38.2 ± 20.4 | 34.9 ± 19.2 | 11.2 ± 11.2 | 5.5 ± 6.2 | 40.6 ± 22.5 | 35.9 ± 18.8 | 33.1 ± 18.5 | 11.3 ± 11.8 | 7.0 ± 9.4 |
| *P* values | | NS | NS | <0.05 | <0.05 | | NS | <0.05 | <0.05 | <0.05 |
| Group B | | | | | | | | | | |
| Mean flow | 43.1 ± 29.6 | 38.8 ± 22.6 | 33.5 ± 19.4 | 15.5 ± 13.1 | 5.0 ± 7.1 | 40.5 ± 29.6 | 35.9 ± 23.6 | 30.3 ± 15.6 | 16.2 ± 15.8 | 8.0 ± 7.5 |
| *P values* | | NS | NS | <0.05 | <0.05 | | NS | NS | <0.05 | <0.05 |

*NS nonsignificant*

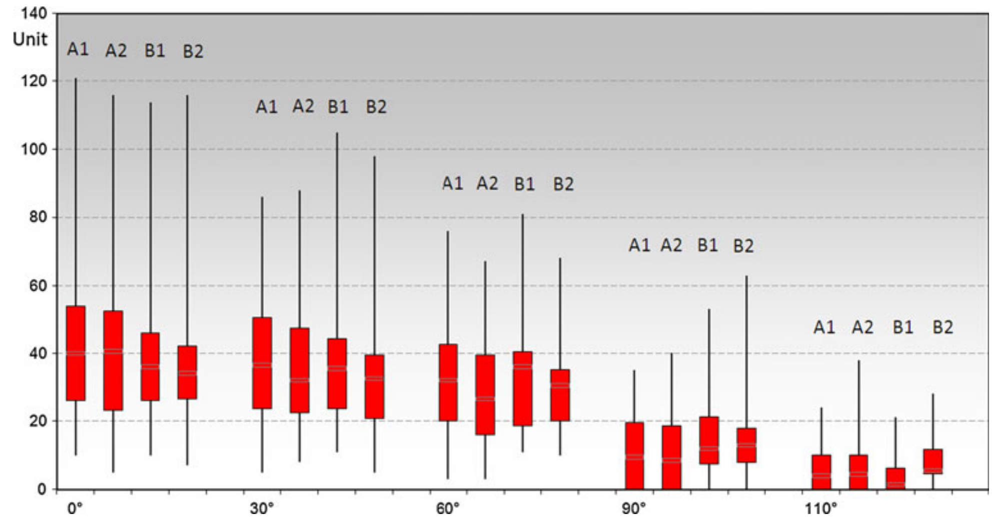


**Fig. 1** Patella blood flow (units) for different degrees of flexion of the two study groups before and after arthrotomy. *A1, B1* groups A and B before arthrotomy, *A2, B2* groups A and B after arthrotomy

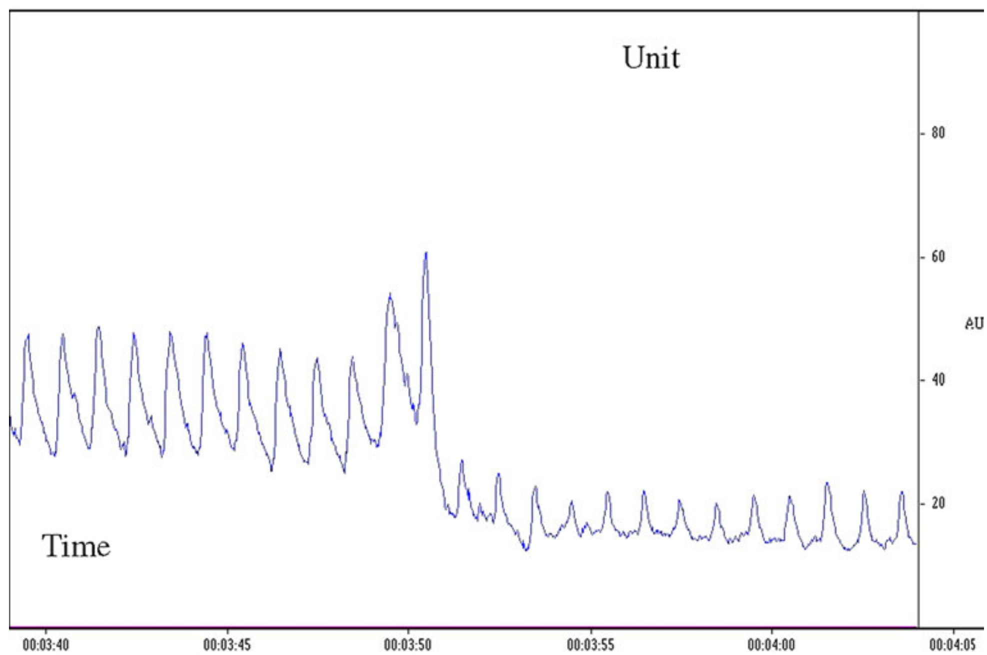


**Fig. 2** Flowcharts (blood flow/time) showing the significant decrease in blood flow at the transition from 60° extension to 90° of flexion

Performing a TKA disturbs blood flow to the patella and parapatellar tissues [4, 11, 14, 24]. The effect of different surgical techniques on local blood flow has been clearly demonstrated by several authors on animal models [18, 33]. Recent studies have analyzed the impact of different surgical approaches on human patellar blood flow [11, 22, 32]. Hughes et al. [14] reported a 40% decrease in patellar blood flow after medial arthrotomy, Nicholls et al. [33] a 53% decline. The latter authors measured blood flow alterations while performing a lateral arthrotomy and concluded there is no statistical difference between the two approaches as regards patella blood supply. Hempfing et al. [11] calculated blood flow of the patella at different knee angles (100° flexion and full extension) and at different stages of the medial parapatellar approach: after arthrotomy, during Hoffa's fat pad excision, eversion, and osteotomy of the retropatellar surface. The authors reported that flexion of the knee joint resulted in markedly reduced patellar perfusion whereas the standard medial parapatellar approach had no effect on patellar blood flow.

In the present study, a serious reduction in blood flow was found amounting to an average of 65% (range 36–100%) at 90° of flexion. For patients with anterior knee pain, flexion from 0° to 90° and 110° before and after arthrotomy resulted in a significant decrease in the measured perfusion ($P < 0.0001$). For patients without anterior knee pain, a significant decrease was observed even at flexions from 0° to 60°. Although this was documented for flexion from 0° to 60° after arthrotomy ($P = 0.02$), statistical analysis for the same flexion angle before

**Table 3** Mean blood flow at different degrees of flexion and *P* values before and after arthrotomy *NS* nonsignificant

| Flexion | 0° before arthrotomy | 0° after arthrotomy | 30° before arthrotomy | 30° after arthrotomy | 60° before arthrotomy | 60° after arthrotomy | 90° before arthrotomy | 90° after arthrotomy | 110° before arthrotomy | 110° after arthrotomy |
|---|---|---|---|---|---|---|---|---|---|---|
| Group A | | | | | | | | | | |
| Mean flow | 42.4 ± 23.6 | 40.6 ± 22.5 | 38.2 ± 20.4 | 35.9 ± 18.8 | 34.9 ± 19.2 | 33.1 ± 18.5 | 11.2 ± 11.2 | 11.3 ± 11.8 | 5.5 ± 6.2 | 7.0 ± 9.4 |
| *P* values | NS | | NS | | NS | | NS | | NS | |
| Group B | | | | | | | | | | |
| Mean flow | 43.1 ± 29.6 | 40.5 ± 29.6 | 38.8 ± 22.6 | 35.9 ± 23.6 | 33.5 ± 19.4 | 30.3 ± 15.6 | 15.5 ± 13.1 | 16.2 ± 15.8 | 5.0 ± 7.1 | 8.0 ± 7.5 |
| *P* values | NS | | NS | | NS | | NS | | NS | |

arthrotomy demonstrated a borderline significance ($P = 0.06$). One reason for this difference between the two patient groups could be the limited number of patients with anterior knee pain included in this study (16/50). Another reason explaining the nonsignificant changes in perfusion for flexion from 0° to 60° in the anterior knee pain group could be the hypervascularization of the painful patella, as described by Sanchis-Alfonso [29].

Pulse-synchronous signals were detected at a rate inversely proportional to the increase in knee flexion. While a pulse-synchronous signal was detected in 39 patients at full extension, this number gradually decreased with increasing flexion angles resulting in a pulsatille but nonsynchronous signal for angles ≥90° flexion. One reason for the loss of synchronization could be the positioning of the probe to the patella. Although the probe was positioned at the center of the bone, patella has limited thickness and therefore the probe is close to the cortical bone. LDF provides only a localized measure of vascular perfusion [23]. Hence, the measurements taken in this study are site-specific and might not be extrapolated to the whole patella. Another explanation for the large variability might be anatomical variations and osteoarthritic changes. Since loss of synchronization was more obvious in the group of patients with anterior knee pain, the influence of patellar degeneration on the loss of pulse-synchronous signal at high degrees of flexion must also be considered. No statistically significant effect of medial arthrotomy on patellar blood flow could be established. These results are in accordance with those of Hempfing et al. reporting that medial parapatellar approach has no effect on patellar blood flow [11]. Furthermore, 19 patients (38%) experienced an average 14% (range 1–54%) increase in patellar blood perfusion at knee flexions of 90° and 110° after medial arthrotomy.

Brick et al. and Gelfer et al. contend that disturbance of patellar blood supply is associated with the development of anterior knee pain [5, 9]. The reason for this disturbance is probably the stretching of the patellar blood vessels during flexion [11]. The results of this study show that for people without anterior knee pain or with mild discomfort, flexion from 0° to 60°, 90° and 110°, before and after arthrotomy, significantly disturbs patellar blood flow.

The presence of an anterior knee pain syndrome was documented based on the NRS in 16 of 50 patients 1 day before surgery and at 2-year follow-up. Preoperatively, 16 patients of group B complained of anterior knee pain, 9 of whom reported severe or intolerable pain (VAS ≥ 7). Postoperatively, only four patients of the pain group (NRS: 4–6) and two patients of group A complained of anterior knee pain. Nevertheless, the significant pain relief in both study groups is due to the implantation of the prosthesis. As demonstrated by the Spearman correlation coefficients, no

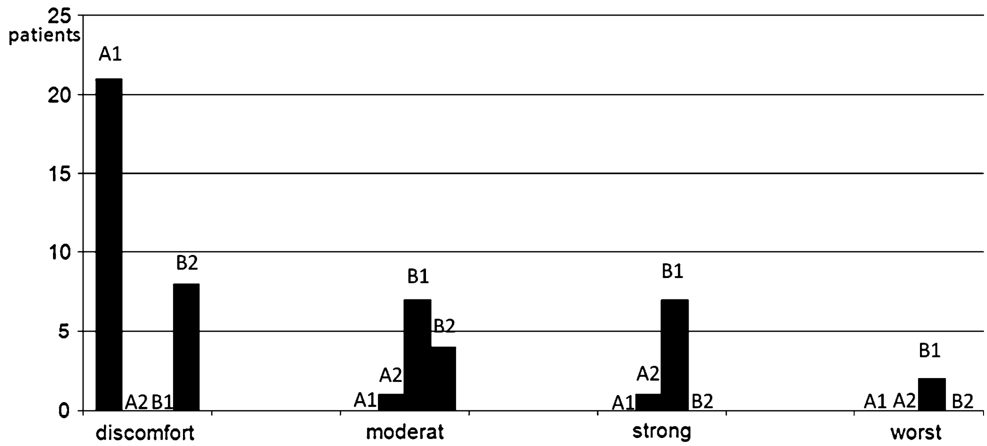


**Fig. 3** Anterior knee pain intensity numeric rating scale scores for patients of the two study groups 1 day before surgery and at 2-year follow-up. *Group A* no pain—discomfort (0–4), *Group B* anterior knee pain (5–10). *A1, B1* groups A and B before arthrotomy, *A2, B2* groups A and B after arthrotomy

statistical correlation could be shown between the intra-operative patellar blood flow and the presence of anterior knee pain.

To the best of our knowledge, this is the first study to correlate disturbances of the patella's blood supply with the development of anterior knee pain. Despite the efforts to ensure the reliability of this study, it does have certain limitations. Although the population is significantly larger from other published studies using the LDF probe, the group of patients with anterior knee pain prior to TKA (group B: 16 patients) is relatively small to draw final conclusions. NRS is not the most appropriate pain score for measuring pain intensity as it only performs a subjective evaluation. Additionally, in this study, only one measurement per flexion angle before and after arthrotomy was taken. LDF can only measure relative flow, the probe was placed at the center of the patella to demonstrate flow changes at the exact site of flexion-induced tension on the vessels, and the measurements were taken at the beginning of the operation, before tourniquet inflation. Moreover, although TKA size-design may increase soft tissue tension and consequently decrease patellar blood flow leading to the development of anterior knee pain, no measurements on blood flow were taken after the implantation of the TKA.

The results of this study clearly demonstrate that high degrees of flexion (from 0 to 90° and 0 to 110°), before and after arthrotomy, can endanger patellar blood supply. It is therefore crucial to avoid positioning the knee in high flexion while performing a TKA. High knee flexion should only be performed when necessary and only for a limited period of time to avoid patellar ischemia.

## Conclusion

In conclusion, the present results show that medial arthrotomy has no direct significant effect on patellar blood flow and that diminished blood flow does not correlate with postoperative anterior knee pain. They also demonstrate a significant correlation between patellar blood flow and the degree of flexion: in almost a quarter of patients, blood flow dropped to zero at flexions of 100° and above.

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