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Effect of Tourniquet Application on Postoperative Functional Outcome Following Total Knee Arthroplasty: A Prospective Cohort Study

Teitsma XM[1*], Tamminga R[1], Snoeker BAM[2] , Lucas C[2], Van der Hart CP[3], Feilzer QGB[3] and Moen MH[3]

[1]Medicort Sport and Orthopedic Care, Department of Physical therapy, Naarden, Netherlands
[2]Department of Clinical Epidemiology, Biostatistics and Bioinformatics, Amsterdam Medical Centre, University of Amsterdam, Amsterdam, Netherlands
[3]Department of Orthopaedics, Bergman Clinics Naarden, Naarden, Netherlands

Abstract

Background: A pneumatic tourniquet is often used during total knee arthroplasty (TKA). However, tourniquet application is often associated with an increased incidence of adverse events and soft tissue damage due to high mechanical pressure. This could potentially result in delayed recovery. The aim of the present study was to evaluate the effect of tourniquet use during TKA on the postoperative functional outcome.

Methods: In this prospective cohort study, patients were eligible for inclusion when they were scheduled for primary TKA due to osteoarthritis, age between 50 and 75 years and Dutch language proficiency. Exclusion criteria were inflammatory arthritis, severe cardiac complaints, severe pulmonary disorders, Body Mass Index (BMI) >35, severe coagulation disorders or hospitalization in the previous two months before surgery. The Knee Osteoarthritis Outcome Score (KOOS) questionnaire was obtained at baseline and eight weeks postoperative to evaluate the functional outcome. In addition, muscle strength of the upper and lower limb, range of motion (ROM) of the knee joint and Visual Analogue Scale (VAS) were assessed as secondary outcomes. Length of stay, analgesic consumption and adverse events were also recorded.

Results: In total, 96 consecutive patients undergoing TKA met the inclusion criteria. They received usual care according to the surgeon's preferences whereas 49 patients received no tourniquet (non-tourniquet group) during surgery and in 47 patients a tourniquet was standard applied (tourniquet group). There were no significant differences between both groups in terms of KOOS 1) pain (p=0.398), 2) symptoms (p=0.514), 3) daily living (p=0.904), 4) sport/recreation (p=0.635) and 5) knee-related quality of life (p=0.970) scores eight weeks after surgery. Also no significant differences were found in respect to knee ROM (p=0.982) and muscle strength (p≤0.300) during follow-up. We found however, less pain in the tourniquet group compared to the non-tourniquet group but this was only significant during the first days after surgery (p≤0.043).

Conclusion: Our results show that tourniquet application during TKA did not significantly affect the short-term functional outcome as assessed by KOOS scores, ROM of the knee joint and muscle strength of the upper and lower limb. However, there were minor differences in respect to knee related pain between both groups during the first days after surgery.

Keywords: Total knee; Arthroplasty; Osteoarthritis; Tourniquet

Introduction

During total knee arthroplasty (TKA), tourniquets are widely used to provide clear visualization of the tissue. An advantage of tourniquet use is the possible reduction in intraoperative blood loss [1,2]. However, this hypothesis still remains debatable due to contradictory findings of other studies who found no reduction in blood loss when a tourniquet was applied during surgery [3]. Another proposed advantage of tourniquet application is that it facilitates the bone-cement interface by creating a bloodless surgical field [4]. This could possibly lead to longer implant survival because of the better adherence between the bone and the implant. However, this hypothesis has not been confirmed by previous studies because no data has been published that report on survival and failure rates of knee implants with emphasize on the use of a tourniquet [5].

Tourniquet use has some potential benefits, but it may also involve certain risks. For example, sustaining nerve injury and ischemia due to the high mechanical pressure on the soft tissue of the upper limb which can result in delayed functional recovery [6-8]. Another disadvantage is the higher incidence rate of adverse events, such as deep vein thrombosis (DVT) and pulmonary embolism (PE) [2,9-11]. However, in a systematic review of Tai et al. [12] no significant differences were found in terms of incidence rates regarding DVT (p=0.120) or PE (p=0.120) between patients who received a tourniquet during surgery and patients treated without.

Due to these inconclusive findings of the potential advantages and risks, the use of a pneumatic tourniquet still mostly depends on the preferences of the orthopedic surgeon. To our knowledge, no studies have been conducted that evaluated the effect of tourniquet application on the functional outcome. We hypothesized that loss of muscle strength, decreased Range of motion (ROM) and a higher pain perception due to the use of a tourniquet can only be observed within a relatively short period after surgery. During this critical phase, optimal recovery is of high importance for further uncomplicated rehabilitation [13]. Therefore, the aim of this study was to determine the effect of tourniquet application during surgery on short-term functional recovery after primary total knee replacement.

*Corresponding author: Teitsma XM, Medicort Sport and Orthopedic Care, Department of Physical therapy, Naarden, Netherlands, Tel: 088-7080860; Fax: 035-6949413; E-mail: xteitsma@medicort.nl

Materials and Methods

In a prospective cohort design, consecutive series of patients who underwent primary unilateral TKA in the Bergman Clinic Naarden, the Netherlands were investigated. Patients scheduled for primary TKA due to osteoarthritis (OA), age between 50 and 75 years, Dutch language proficiency and signed informed consent were eligible for inclusion. Exclusion criteria were inflammatory arthritis, severe cardiac complaints, severe pulmonary disorders, Body Mass Index (BMI) >35, severe coagulation disorders or hospitalization in the previous two months before surgery.

The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement was used to report on this study. The Regional Ethics Committee VCMO in Nieuwegein, the Netherlands, registration number W13.022, approved the research protocol.

Surgical procedures and rehabilitation

All surgeries were performed between October 2013 to April 2014 by experienced (>16yrs) orthopedic surgeons CH or QF. In patients operated by CH, no pneumatic tourniquet was applied during surgery (non-tourniquet group) and patients operated by QGBF a tourniquet was standard applied (tourniquet-group). In both groups patients received usual care according to the surgeon surgical preferences. All operative procedures were comparable between both surgeons, except for tourniquet use, In the tourniquet group, a bloodless field was obtained with use of a pneumatic tourniquet at a pressure of 250 mm Hg after draping the knee, holding the leg high for one minute and applying pressure holding the knee in 90 degrees of flexion. In both groups, an anterior midline skin incision (10 to 12 cm in length) was used, followed by a medial parapatellar capsular incision. Femoral preparation was performed first, followed by tibial preparation. Both surgeons attempted to set 3° of external rotation of the femoral component in relation to the posterior aspect of the femoral condyles, perpendicular to the whiteside line and parallel to the transepicondylar axis. Rotational guides were used during all operations. None of them were prioritized. The ligaments were balanced in flexion and extension. During surgery both surgeons resected approximately 10 mm of tibial bone distally from what was considered to be the least-involved plateau in order to achieve a surface that was perpendicular to the shaft of the tibia in the coronal plane with a 7° posterior slope in the sagittal plane. All implants were cemented after pulsed lavage, drying, and pressurization of cement. Both surgeons used the NexGen LPS-Flex fixed bearing (Zimmer, Warsaw, Indiana) cemented prostheses. In the tourniquet group the extension gap first method was used and all patellae were resurfaced routinely with use of polyethylene patellar prosthesis whereas in the non-tourniquet group the patellae were selective resurfaced based on perioperative findings. Information regarding surgical interventions was registered by both orthopedic surgeons using a case record form.

Postoperatively, both groups received similar medical care. The postoperative rehabilitation started on the day of surgery with active range of motion training and quadriceps exercises according to standard protocol. All patients underwent physical therapy two times a day at their bedside and began walking with crutches or a walker under supervision on the first day after surgery. During walking, patients were allowed full weight bearing on the operated side. All patients were advised to use crutches for a minimum of six weeks. After discharge from the clinic, a standard six months rehabilitation protocol was given to the patients. Radiographic evaluations were done the day after surgery and clinical evaluations were done two and eight weeks after surgery.

Outcome measurements

Primary outcomes: a) KOOS: The functional outcome was assessed by using the Knee injury and Osteoarthritis Outcome Score (KOOS) questionnaire, which consists of five different subscales: 1) Pain; 2) Symptoms; 3) Function in daily living; 4) Function in sport and recreation and 5) Knee-related quality of life [14]. The score for each subscale was calculated whereas zero indicates severe knee problems and 100 no knee problems.

Secondary outcomes: a) Range of Motion (ROM): The ROM was measured with use of a standard validated 30 cm clinical goniometer in supine position, as described by Lenssen et al. The proximal arm was aligned with the femur using the greater trochanter as reference and the distal arm was aligned with the tibia using the lateral malleolus as reference [15-17].

b) Bilateral isometric strength and VAS: Bilateral isometric strength of the lower limb was measured using hand-held dynamometry (HHD), which has been previously validated in patients with OA of the knee joint [18]. Strength measurements of the upper limb muscles were performed with the patient seated in an upright position whereas the knee joint was positioned in 90° flexion [19]. Lower limb muscle strength was measured with the patient in supine position whereas the knee was maintained in full extension [20]. Patients were allowed to perform three trials whereas the strongest trial was noted. The unaffected side was tested first followed by the affected side. The 100 mm Visual Analogue Scale (VAS) was used for measuring current, minimal and maximal pain [21]. All measurements were performed at the day of surgery and after eight weeks. In addition, ROM and VAS were measured after one, two and three days postoperatively.

c) Length of stay, analgesics and adverse events: Length of stay was determined from the day of admission until discharge. The attending nurses noted analgesics during the clinical phase whereas the doses and time interval of each medication was recorded. Patients first received paracetomol ($\leq$4000 mg p/day) and diclofenac ($\leq$150 mg p/day) as primary pain management. If not satisfactory, they received tramadol ($\leq$150 mg p/day) and/or morphine ($\leq$30 mg p/day). Adverse events were determined by the orthopedic surgeons during the two or eight week follow up and were reported in the patient's health record.

d) Sample size: The required sample size was estimated from a mean difference of 12 in the KOOS score between both treatments groups with a standard deviation (SD) of 20, which is considered relevant based on previous findings [14]. The power (beta) was set at 0.8 and the significance level (alpha) was set at 0.05 (two-sided). Based on sample size analysis, a total of 44 patients in each group (88 patients in the serie) were minimally needed for this study to find possible statistical significant differences.

e) Statistical analysis: Demographic characteristics and postoperative parameters were extracted for analysis. Mean and SD are reported for continuous variables and median (interquartile range, IQR) for non-normally distributed variables. The Kolmogorov-Smirnov test, Q-Q plot and histogram were used for testing normality of the variances. Differences between groups were analyzed using the independent t test for parametric continuous variables, and the Mann-Whitney U test for non-parametric continuous variables. The Pearson χ^2 test was used for dichotomous variables. Significance level was set at $p<0.05$ and analyses were performed using SPSS 20.0 (IBM Inc., Chicago, Illinois).

Results

From October 2013 to April 2014 a total of 150 consecutive patients received primary TKA of which 99 patients met the inclusion criteria. Three patients were excluded from analysis after inclusion: one patient received a different prosthesis, one patient in the tourniquet group received no tourniquet, and one patient was lost to follow up (wound infection). In total, 96 patients were included for analysis (Figure 1). For three of the 96 included patients, data was missing for VAS and ROM scores during one follow-up measurement. As data was missing completely at random, we decided to perform complete case analysis without using multiple imptutation.

There were no significant differences in demographics at baseline between both groups in terms of sex, age, weight, length, smoking, operated side, or onset of symptoms (Table 1). Patellae were routinely resurfaced in the tourniquet group and selective resurfaced in the non-tourniquet group resulting in significant differences (p<0.0001) between both treatment groups. The operation time was significantly shorter (p<0.001) in the tourniquet group (mean (SD), 63 (5) minutes) compared to the non-tourniquet group (mean (SD), 82 (10) minutes). In the tourniquet group, the mean (SD) duration of tourniquet application was 65 (11) minutes.

KOOS

Both groups improved in all KOOS scores, from baseline until eight weeks postoperative (Table 2). At baseline, the KOOS scores were not significant different (p>0.205) between both treatment groups.

When evaluating KOOS scores during the eight weeks follow-up, the tourniquet group scored higher on the questionnaire. However, these differences were not significant (p>0.398).

Range of motion, pain and isometric strength

Postoperative knee ROM increased daily in both groups, however no significant differences were found between both groups during the follow-up measurements (Table 3). For the assessment of pain, no significant differences were found at baseline (Figure 2a, 2b and 2c). In the tourniquet group, we found postoperatively significant lower $VAS_{MINIMUM}$ scores at day one (p=0.023), lower $VAS_{MAXIMUM}$ scores at day two (p=0.009) and three (p=0.003), and lower $VAS_{CURRENT}$ scores at day one (p=0.036) and three (p=0.430). However, during the eight-week follow follow-up there were no significant differences found in all VAS scores.

Isometric strength of the lower limb was measured of the involved and the uninvolved side whereas a negative value indicates a strength deficit of the involved side (Table 4). No significant differences were found between both groups during the preoperative measurement (p>0.156) and eight weeks follow-up measurement (p>0.300).

Length of stay and analgesic consumption

The average length of stay after surgery was significantly shorter in the tourniquet group (mean (SD), 4.1 (0.4) days) compared to the non-tourniquet group (mean (SD), 4.5 (0.9) days) (p=0.007).

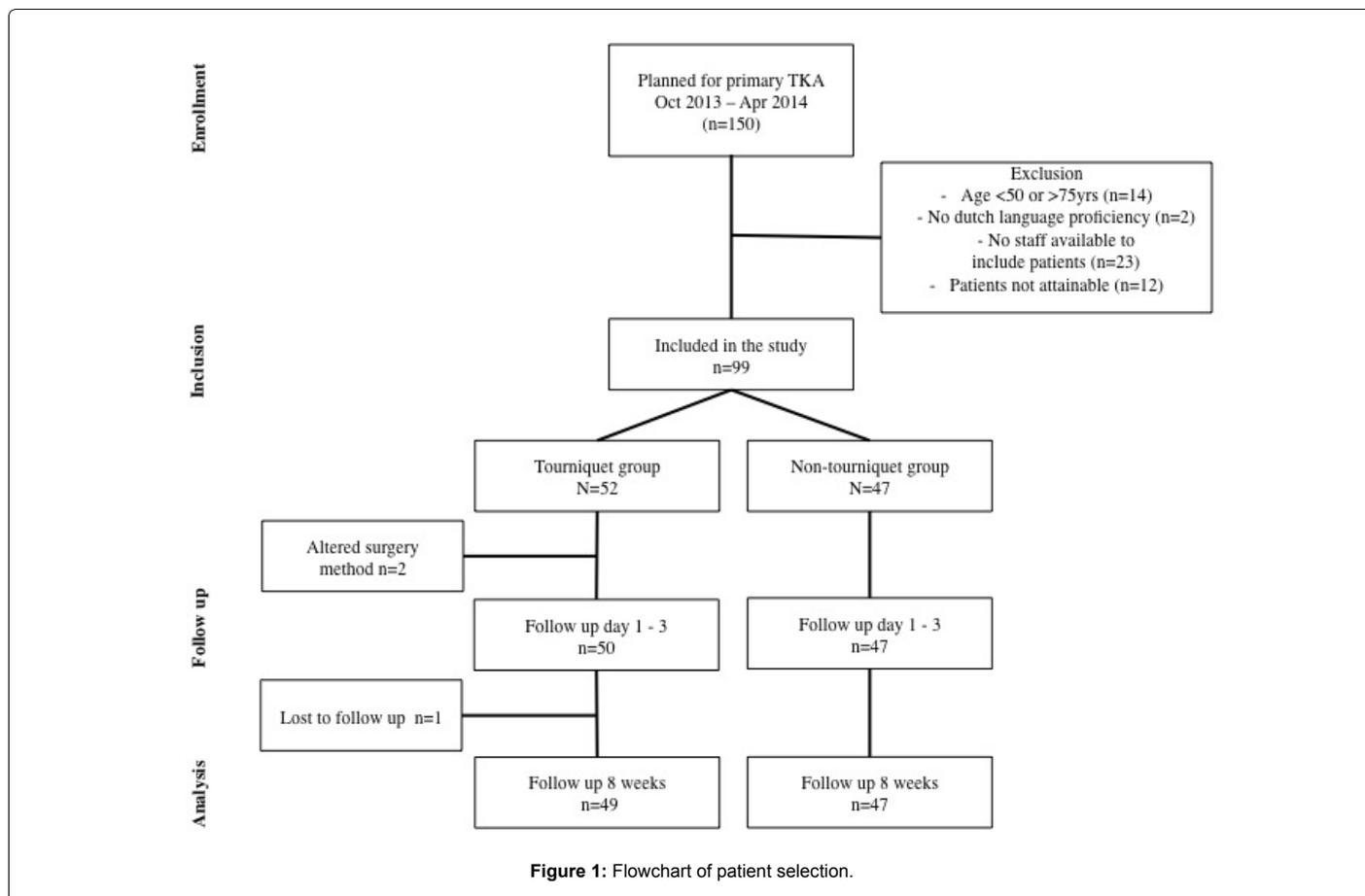Paracetemol and diclofenac was used as primary pain medication

Figure 1: Flowchart of patient selection.

	Non-tourniquet group (N=47)	Tourniquet group (N=49)	P value
Gender (male:female)	23:24	16:33	0.104
Age (yr)	65 ± 6	63 ± 6	0.103
Length (cm)	175 ± 8	172 ± 8	0.136
Weight (kg)	83 ± 13	84 ± 11	0.772
Smoking (yes:no)	4:43	2:47	0.370
Operated side (left:right)	21:26	21:28	0.857
Onset of symptoms (yr)	9 ± 8	7 ± 6	0.238
Anesthetics (spinal:general)	20:27	16:33	0.317
Operation time (min)*	82 ± 10	63 ± 5	0.000
Duration of tourniquet inflation (min)	-	65 ± 11	-
Patellar resurfacing (yes:no)	34:13	49:0	0.000
Kellgren & Lawrence score (0:1:2:3:4)			
MC femur[1]	0:0:3:5:39	0:2:7:6:34	-
LC femur[2]	3:0:19:16:9	3:20:10:8:8	-
MC tibia[1]	0:0:5:3:39	0:2:8:9:30	-
LC tibia[2]	3:1:17:18:8	4:23:8:5:9	-
Patella	1:5:7:6:28	0:0:15:30:4	-
Dropangle knee joint (°)			
Preoperative	113 (13)	109 (8)	0.056
Postoperative	118 (6)	109 (6)	0.000

Values are given as mean ± standard deviations unless otherwise indicated; 1: medial condyle; 2: lateral condyle

Table 1: Patient characteristics and demographics.

		Non-tourniquet group	Tourniquet group	P-value
Pre-ok	**Symptoms**	57 ± 21	54 ± 20	0.516
	Pain	50 ± 19	51 ± 19	0.741
	ADL	60 ± 17	57 ± 18	0.430
	Sports	26 ± 17	23 ± 20	0.205
	QoL	29 ± 18	32 ± 20	0.305
Week 8*	**Symptoms**	64 ± 14	66 ± 14	0.398
	Pain	68 ± 17	70 ± 18	0.514
	ADL	76 ± 15	76 ± 14	0.904
	Sports	35 ± 21	37 ± 23	0.635
	QoL	51 ± 20	51 ± 16	0.970

* Postoperatively

Table 2: Knee Osteoarthritis Outcome Score (KOOS) questionnaire.

and when not satisfactory patients received in addition tramadol and/or morphine. The non-tourniquet group used significant more tramadol (mean (SD) 88 (61) vs. 56 (42) mg; p=0.006) on day one and more paracetemol (mean (SD), 2915 (1265) vs. 1816 (99) mg; p=<.0001) and diclofenac (mean (SD), 93 (59) vs. 57 (38) mg; p=0.001) on day three. Morphine consumption was similar between both groups during the first three days postoperative (p>0.307).

Discussion

Although the tourniquet and non-tourniquet group improved greatly from baseline until eight weeks postoperative in terms of KOOS scores, our data show that performing TKA with or without a tourniquet did not significantly affect the short-term functional outcome. However, patients that received a tourniquet during TKA initially reported less pain the first days after surgery. We found no significant differences between both groups in regard to loss of muscle strength of the upper and lower limb muscles and ROM of the knee joint.
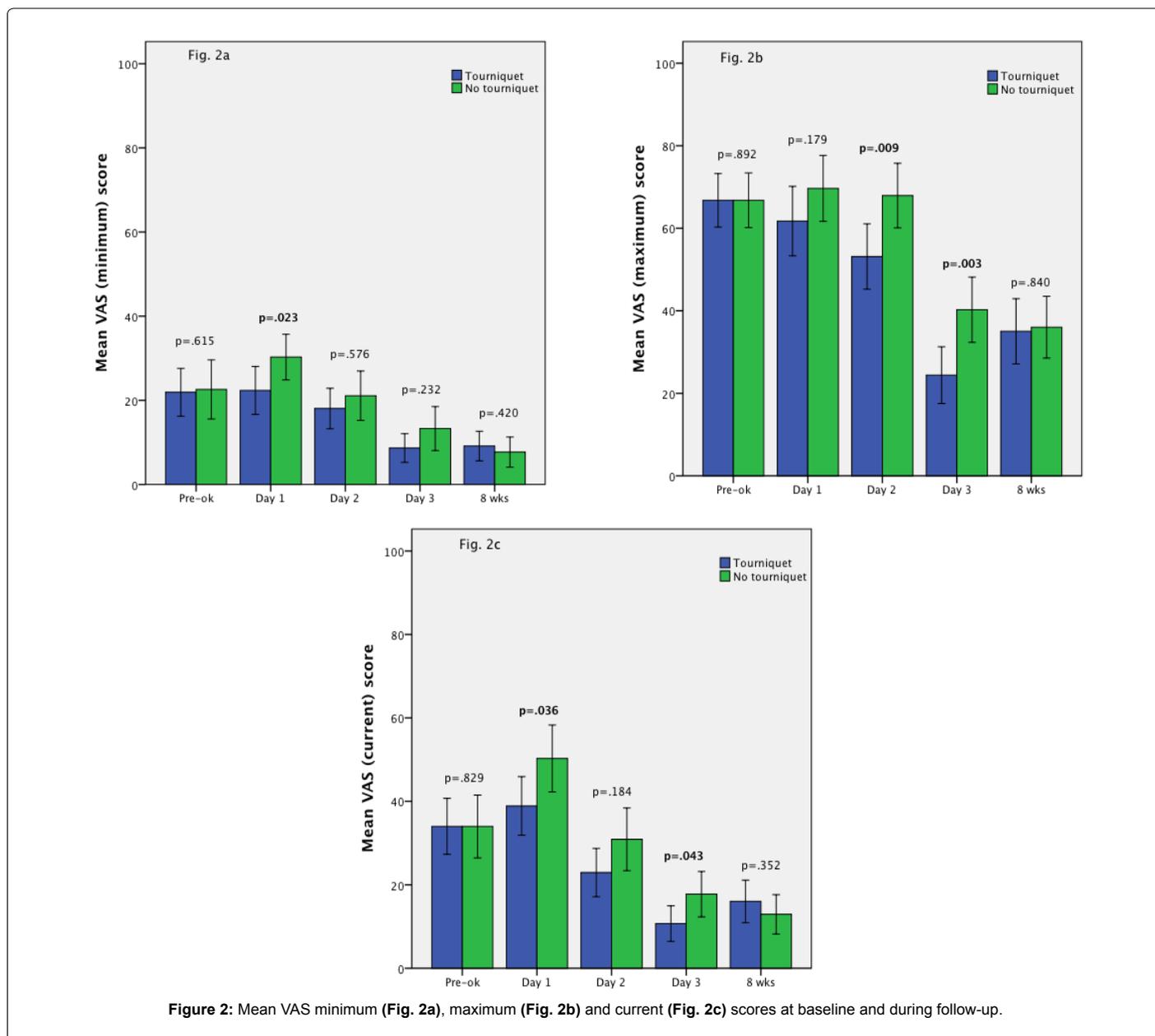
In the current literature, only one study to our knowledge previously reported KOOS scores in respect to tourniquet use [23-25]. They found higher scores in the non-tourniquet group during the eight-week follow-up. However, no significant differences were found during the six and twelve month follow-up. A possible explanation for these different findings compared to our results is assumedly the different patient populations. Our study was performed in a specialized orthopedic clinic and thus consequently a relatively homogenous group has been included. This can result in different findings compared to studies including patients who were admitted in a general hospital.

In the present study, initial recovery of ROM postoperatively was achieved similarly in both groups, which is in accordance with previous findings. However, there are contradictory findings of other studies that report better knee ROM in patients treated without a tourniquet [25-28]. Ejaz et al. reported a better knee ROM in the non-tourniquet group at day two (mean (SD), 48° (9.5) vs. 36° (7.9); p<0.001) and after 8 weeks (mean (SD), 100° (7.2) vs. 93° (8.2); p=0.002). They found however no difference between both groups in terms of knee ROM during the 6- and 12 months follow-up. Li et al. also reported a significant better ROM in the non-tourniquet group at day one and three postoperative (p.<0001 and 0.020, respectively). A possible explanation for the contradictory findings is the differences in postoperative rehabilitation courses. All patients in the present study were treated by the same physical therapists during the clinical phase and received a standard six months rehabilitation protocol after hospital discharge to minimize treatment differences. Because all patients were treated according to the same protocol, it reduces the possibility of treatment bias, which could explain the discrepancy between our results and previous findings.

Postoperative pain scores decreased daily in the present study whereas less pain was found in the tourniquet group during the clinical phase. Therefore less analgesic consumption was used for pain management during the first days after surgery. However, there are several studies reporting different findings [2,25,27,29]. These studies found less postoperative pain initially after surgery in patients treated without a tourniquet. Pain scores can be evaluated in a variety of ways whereas each method has its strengths and limitations and thus could result in different findings. We would like to emphasize that pain scores are highly subjective and vary between relatively small time intervals. Therefore it is important to report on variables that could potentially lead to bias (e.g. analgesic consumption, time of measurement). Especially during the first postoperative days, variables such as physical activity and analgesic consumption could affect pain scores. In the present study, we evaluated $VAS_{MINIMUM}$, $VAS_{MAXIMUM}$ and $VAS_{CURRENT}$ scores in order to measure the dynamic character of pain perception more adequately.

This is the first study that evaluates the relationship between tourniquet use and the possible influences on muscle strength. TKA with tourniquet application is often associated with soft tissue damage [29] of the thigh muscles, which could affect muscle strength and could therefore postpone functional recovery. We found no significant differences between both groups at baseline (p>0.156) and follow-up (p=0.300) during the evaluation of muscle strength of the thigh and lower limb muscles. Our data indicates that tourniquet use in TKA is not related to a significantly decreased loss of muscle strength compared to no tourniquet application during surgery.

In the present study we found a significant shorter operation time in the tourniquet group compared to the non-tourniquet group (mean (SD) 63 (5) vs. 82 (10) minutes; p<0.001). This was also found in the systematic review of Tai et al. [12], who also investigated the effect of

Figure 2: Mean VAS minimum **(Fig. 2a)**, maximum **(Fig. 2b)** and current **(Fig. 2c)** scores at baseline and during follow-up.

	Non-tourniquet	Tourniquet	P-value
Pre-ok	121 ± 13	120 ± 13	0.590
Day 1*	62 ± 19	67 ± 17	0.210
Day 2*	72 ± 16	68 ± 17	0.342
Day 3*	77 ± 15	77 ± 16	0.631
Week 8*	108 ± 15	108 ± 13	0.982
* Postoperatively			

Table 3: Range of motion (°).

timing of releasing the tourniquet on operation time. They reported that early release of the tourniquet, with direct deflation after cementing, did not significantly shorten the operation time (p=0.660), however while late release, with inflation after wound closure and compressive dressing of the tourniquet, resulted in a significant shorter operation time compared to the non-tourniquet group (p<0.001). In our study, the orthopedic surgeon used late release of the pneumatic tourniquet, which therefore led to comparable results. Shorter operation could reduce the risk for developing complications during and after surgery.

The potential increased risk for adverse when using a tourniquet during TKA has been the main contraindication for applying it during surgery. There were no cases in the present study of patients with DVT. There was only one patient in the non-tourniquet group who developed bacterial wound infection. We believe that the low incidence rate of these adverse events is likely the result of low tourniquet pressures used within the tourniquet group. In this study, a pressure of 250 mm Hg was used which is in accordance with previous recommendations [30]. Smith et al. [31] reported in their systematic review that higher tourniquet inflation pressures were related to an increased incidence of adverse events. When using a tourniquet, cuff pressure should be

		Non-tourniquet group	Tourniquet group	P-value
Pre-ok	Knee extension	-11 ± 20	-17 ± 20	0.156
	Knee flexion	-6 ± 26	-9 ± 27	0.758
	Plantar flexion	-4 ± 24	-4 ± 23	0.676
	Dorsal flexion	-9 ± 18	-9 ± 18	0.369
Week 8*	Knee extension	-31 ± 22	-28 ± 19	0.498
	Knee flexion	-29 ± 24	-27 ± 22	0.618
	Plantar flexion	-4 ± 9	-7 ± 13	0.560
	Dorsal flexion	-7 ± 16	-9 ± 17	0.300

* Postoperatively
** A negative value indicates a deficit of the involved side

Table 4: Isometric strength evaluation (HHD).

minimized to reduce tourniquet-related complications.

This prospective cohort contains several deficiencies, which we will discuss. Certain limitations are based on the non-randomized study design. This could potentially lead to information bias during the measurements of both groups. We would also like to emphasize that although both orthopedic surgeons used comparable operative procedures, except for tourniquet use, bias could occur in the operation time. Differences still remain between both surgeons in terms of quickness in performing surgical procedures what could cause distorted results. Another limitation of this study was the difference between both surgeons in patellar resurfacing which could affect the operation time and the outcome beside tourniquet use. However, previous meta-analyses performed by He et al. [32] showed that knee related pain was not statistical different between patients with resurfaced or non-resurfaced patellae.

Conclusion

In conclusion, the findings of the present study show that tourniquet application did not significantly affect the short-term functional outcome which was assessed by the KOOS questionnaire, knee ROM and muscle strength. We did find significant differences between the tourniquet and non-tourniquet group in respect to knee related pain during the first days after surgery. However, eight weeks after surgery both treatment groups showed similar pain scores whereas no significant difference could be found anymore. Further studies with longer follow up measurements are recommended to assess the clinical outcome of tourniquet application during TKA more extensively.

Acknowledgement

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