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Total Knee Arthroplasty: The Impact of Tourniquet Usage on Cement Penetration, Operation Time, and Bleeding Control

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ABSTRACT

Objective: The cementing technique employed in total knee arthroplasty (TKA) significantly influences the penetration of cement into the bone, ultimately affecting the stability of the joint. This study aimed to assess the impact of tourniquet usage on tibial cement penetration, operative time, bleeding, and functional outcomes following TKA.

Materials and Methods: A retrospective evaluation was conducted on 103 patients who had undergone TKA and had a minimum follow-up period of 2 years. The patients were categorized into three groups: Group 1 utilized a tourniquet throughout the entire surgery, Group 2 released the tourniquet immediately after prosthesis implantation, just before cement hardening, and Group 3 did not employ a tourniquet at any stage of the procedure. Tibial cement penetration was assessed via X-ray examination, following the Knee Society Scoring System criteria. Operative time, bleeding levels, and Lysholm and Oxford scores were compared among the groups. Statistical analysis was performed using SPSS version 22.0 software.

Results: In Group 1, bone penetration of cement was significantly higher than in both Group 2 and Group 3, except for zone 1 in the anterior-posterior (AP) view ($p < 0.017$). Group 3 exhibited significantly less bleeding compared to the other groups ($p < 0.017$). There was no significant difference in terms of bleeding between Group 1 and Group 2. The operation time was significantly shorter in Group 1 compared to the other groups ($p < 0.017$). The mean cement penetration depth across all groups was measured at 2.44 ± 0.27 mm. Bleeding volume and operation time did not have a significant effect on mean cement penetration ($p > 0.05$). Additionally, there were no significant differences observed between the groups in terms of the Lysholm and Oxford functional test results ($p > 0.017$).

Conclusions: The use of a tourniquet was found to increase cement penetration and reduce operation time; however, it did not have a significant impact on reducing bleeding. Based on our findings, we recommend considering a shorter tourniquet time and implementing effective bleeding control measures to mitigate potential complications associated with tourniquet usage.

Keywords: tourniquet; arthroplasty; knee; time; function; bone cement

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INTRODUCTION

Total knee arthroplasty (TKA) is an effective treatment method for end-stage knee arthritis, offering high levels of patient satisfaction, pain relief, and improved function (1-3). The long-term success of this procedure largely depends on the mechanical stability of the implants (4). However, a subset of patients may experience early implant loosening, leading to suboptimal outcomes and necessitating revision surgery (5).

The cementing technique used in TKA plays a critical role in determining the survival of the cement-bone interface, both in the short and long term, primarily by influencing cement penetration into the bone (6, 7). The tibial component, which is cemented for fixation in up to 90% of cases, is a common site for loosening in TKA. Various methods, such as lavage, suction, syringes, and pressurized cement guns, are employed alongside a tourniquet to enhance cement penetration into clean and dry bone (8).

The intraoperative use of a tourniquet enhances surgical field visibility and reduces blood loss by minimizing blood and fat within the bone (9, 10). Nevertheless, tourniquet application, leading to decreased blood flow, may result in ischemia, thereby increasing the risk of muscle damage, pain, swelling, and delayed healing (11). Surgeons adopt different approaches when it comes to tourniquet usage: some perform surgery without a tourniquet, some use it throughout the procedure, and others deploy it just before cementation. Additionally, alternative methods, including elastic tourniquets, tranexamic acid, and hypotensive epidural anesthesia, have been explored to mitigate the adverse effects associated with tourniquet use.

This study aims to assess the impact of different tourniquet usage protocols on tibial cement migration, operation duration, bleeding volume, and the functional outcomes of TKA patients.

MATERIAL and METHODs

Patients who underwent TKA surgery diagnosed with end-stage gonarthrosis between 01/01/2019 and 01/03/2020 were investigated retrospectively. Inclusion criteria included TKA surgery for primary gonarthrosis, being 18 years or older, having a minimum of two years follow-up, and accessing information like operation time, amount of bleeding and X-rays from the hospital's data processing system. Preoperative informed consent was obtained from all patients. Prior to the study, approval was obtained from the local ethics committee of our institution with the approval code 2021/71. All information about patients was obtained by retrospective file scanning. Those whose last follow-up period was insufficient were contacted by phone, and filled out functional outcome scores. Those who came for control were examined and the results were recorded. Patients with missing information in the archives, who do not have first-control x-rays and did not attend the follow-up examinations, who had traumatic injury after the operation, had extreme deformity before surgery, and those who were followed up for less than 24 months were excluded from the study. Among 132 patients who met these criteria, 21 patients with secondary osteoarthritis, 3 patients with extreme deformity (foreseeable for extra thick bone resections or wedge usage during the surgery), and 5 patients who had traumatic injury after knee arthroplasty were excluded from the study. The remaining 103 patients were included in the groups. Patients were divided to 3 groups according to the tourniquet usage. In group 1, the tourniquet was used throughout the surgery, in group 2, the tourniquet was released just after prosthesis implantation before cement hardening; and in group 3, the tourniquet was not used at all. All surgeries were performed by a single senior surgeon using the same surgical approach and prosthesis, which is discussed further below.

Anteroposterior and lateral knee radiographs taken at sixth week after TKA procedure were examined. In the radiographic examination, the tibial plateau was divided into 4 zonees in the anterior-posterior radiograph and 2 zonees in the lateral radiograph, according to the Knee Society Scoring (CSS) System (7). Only the 1st and 4th zonees could be evaluated since the prosthesis prevented the cement appearance in the 2nd and 3rd zonees on the anterior-posterior x-ray. In order to avoid measurement error, the actual dimensions of the prosthesis were taken and compared with the radiographic dimensions and calibrated. Radiographic findings were measured independently by 2 orthopedic surgeons. Average cement penetration depth was calculated for each region in groups 1, 2 and 3.

Operative time (minutes) was defined as the time from the completion of the patient's anesthesia procedure to the closure of the wound. The amount of bleeding (ml) was determined by collecting the amount aspirated during surgery and draining on the 1st postoperative day. Lysholm and Oxford tests were performed to evaluate the functional status of all patients at the last follow-up. Comparisons were made between the groups in terms of operative time, amount of bleeding and functional scores.

Surgical technique

The implant employed in this study was a cemented cruciate-retaining design with a mobile-bearing insert. Low-viscosity polymethylmethacrylate (PMMA) bone cement was uniformly utilized for all patients. The surgical procedures were conducted under spinal anesthesia, employing a medial parapatellar approach. Tranexamic acid was not administered in any of the cases.

Following distal femoral resection, the proximal tibial cut was determined using an extramedullary instrument, referenced off the medial tibial plateau. The cut surfaces were meticulously prepared, washed, and dried. Notably, a patellar component was not utilized in this study. Pulsatile lavage and bone suction were applied. The cement was prepared by hand-mixing for one minute in a container, and it was applied as soon as it reached the dough phase and no longer adhered to the surgical glove. Cement was applied directly to the bone-contacting surfaces of both the tibial and femoral components, securely placed onto the bone surface, and any excess cement was meticulously removed. Subsequently, the knee was maintained in full extension until the cement hardened.

In addition to implant placement, bleeding control measures and negative pressure drain application were performed for all patients before the surgical closure. Group 1 involved the use of a tourniquet throughout the entire operation. In Group 2, the tourniquet was deflated immediately after implant placement but before cement hardening, and in Group 3, no tourniquet was employed during the surgical procedure.

Statistically analysis

After the data were transferred to the computer environment, they were evaluated with SPSS software (IBM version 22.0, Chicago, USA, 2013). The conformity of the data to the normal distribution was evaluated according to the Shapiro Wilk test, Skewness and Kurtosis values, and histogram. In the comparisons between groups, ANOVA and posthoc test were performed with Bonferroni for the homogeneous distribution of the groups for continuously variable data. In the absence of homogeneous distribution, Welch test and post-test were performed with Tamhane. Results with a P value below 0.017 were considered statistically significant. The efficiency of continuous variables on each other was evaluated by simple linear regression analysis, values below $p<0.05$ were considered significant.

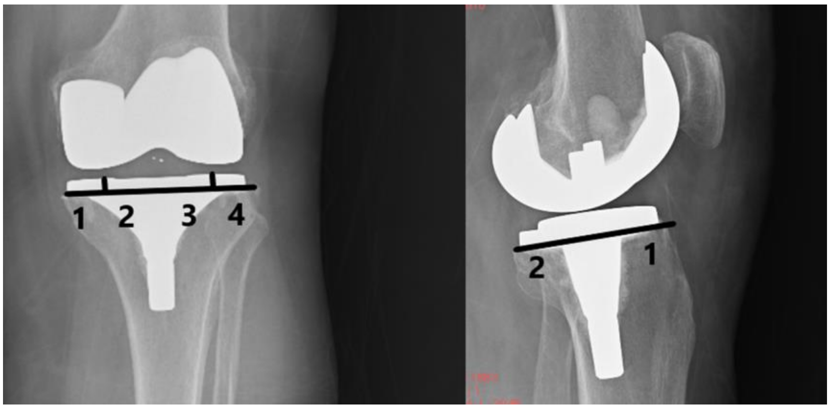

Figure 1. Anterior-posterior and lateral X-rays and zones according to Knee Society scoring system

RESULTs

Group 1 consisted of 35 patients who utilized a tourniquet throughout the entire surgery, Group 2 consisted of 40 patients whose tourniquet was released immediately after prosthesis implantation, just before cement hardening and group 3 consisted of 28 patients no tourniquet was employed during the surgical procedure.

1. Cement Penetration

When we assessed the amounts of cement penetration into the bone among the groups, the following observations were made:

In zone 1 in the anterior-posterior (AP) view, Group 2 exhibited more penetration than Group 1. In zone 4 in the anterior-posterior (AP) view, Group 1 had more penetration than Group 2. In zone 1 in the lateral (LAT) view, Group 1 had more penetration than both Group 2 and Group 3. In zone 2 in the lateral (LAT) view, Group 1 had more penetration than Group 2 ($p < 0.017$).

When we considered the overall average across all zones, we found that Group 1 exhibited significantly greater cement penetration into the bone compared to both Group 2 and Group 3 ($p < 0.017$). The mean depth of cement penetration across all groups was measured at 2.44 ± 0.27 mm (**Table 1**).

2. Operation Time and Bleeding

We conducted a statistical evaluation of the total amount of bleeding during and after the operation until the drain was removed (measured in milliliters, ml) and the operation time (measured in minutes, min) across the groups. The results indicated the following:

Group 1 experienced significantly more bleeding compared to Group 3 ($p < 0.017$). The operation time was significantly shorter in Group 1 compared to the other groups ($p < 0.017$). Subsequently, we performed regression analysis within each group, which revealed that neither the amount of bleeding nor the operation time had any significant effect on mean cement penetration (**Table 2**).

3. Functional Scores

Lysholm and Oxford tests were performed to evaluate the functional status of all patients. Since the data did not show normal distribution, the Kruscal Wallis test was performed. No functionally significant difference was detected between the groups (**Table 3**).

Table 1. Amount of cement penetration depth (standard deviation) and statistical values between groups

	Group 1 n:35	Group 2 n:40	Group 3 n:28	Mean depth(mm)	p
Zone 1 AP (mm)	2,62(±0,16)[¥]	2,88(±0,37)[¥]	2,64(±0,56)	2.71(±0,36)	**0,000[a]**
Zone 4 AP (mm)	2,36(±0,33)[¥]	1,90(±0,33)[¥]	2,03(±0,67)	2,09(±0,44)	**0,000[a]**
Zone 1 LAT (mm)	2,90(±0,68)[¥,†]	2,38(±0,34)[¥]	2,26(±0,54)[†]	2,5(±0,52)	**0,000[a]**
Zone 2 LAT (mm)	2,62(±0,36)[¥]	2,21(±0,63)[¥]	2,50(±0,42)	2,4(±0,47)	**0,003[a]**
Mean cement penetration of zones (mm)	2,62(±0,22)[¥,†]	2,34(±0,20)[¥]	2,36(±0,32)[†]	2.44±0.27	**0,000[b]**

a: Welch test, b: One Way ANOVA test, p value <0,017.

Table 2. Comparison of the operative times and the amount of bleeding of the groups

	Group 1 n:35	Group 2 n:40	Group 3 n:28	p
Operation time (min)	84,96(±10,37)[¥,†]	88,38(±14,10)[¥]	102,57(±10,94)[†]	**0,000[a]**
Bleeding volume (ml)	278,71(±25,99)[¥]	273(±23,55)	248,54(±40,82)[¥]	**0,004[a]**

a: One Way ANOVA test; p value < 0,017

Table 3. Comparison of functional scores of the groups

	Group 1 n:35	Group 2 n:40	Group 3 n:28	p
LYSHOLM	80,26(±15,42)	81,38(±12,90)	81,14(±11,92)	**0,981[a]**
OXFORD	39,23(±6,50)	37,80(±5,12)	38,25(±4,97)	**0,251[a]**

DISCUSSION

The most significant discovery in this study is that deflating the tourniquet immediately after prosthesis implantation, just before cement hardening, results in a shorter tourniquet duration without any adverse effects on functional scores. This reduction in tourniquet duration holds crucial importance as it helps mitigate the risk of tourniquet-related ischemic complications. Importantly, our findings indicate that there is no discernible difference in functional scores and bleeding between the full-time tourniquet usage and the tourniquet deflation immediately after implantation method, despite the shorter operative time observed in Group 1.

Aseptic loosening ranks among the most common causes for revision in cemented total knee arthroplasty (TKA) (12). It is imperative to underscore the significance of employing an appropriate and effective bone cementing technique during surgery as a pivotal surgical factor to mitigate the risk of this complication (13).

The polymerization process of cement can be delineated into four distinct phases: Mixing, waiting, working, and setting time. The period from the mixing phase to the culmination of the setting time, during which the cement solidifies, spans approximately 10-15 minutes (14). Recent studies advocate for the release of the tourniquet before wound closure, as this approach appears to diminish the risk of complications (15). Notably, significantly lower wound complication rate was observed in the early tourniquet release group compared to the late tourniquet release group in the literature (16).

In our study, we introduced a third group alongside the two groups employing tourniquets and non-tourniquet usage during the operation. This third group aimed to address the challenge by shortening tourniquet usage, deflating it immediately after prosthesis implantation before cement hardening.

Cement penetration of 2 to 5 mm decreases the likelihood of loosening by increasing the interface strength (12, 17, 18). Walker et al. suggested that the ideal cement penetration depth is 3-4 mm(17). However, penetration more than 5 mm may increase the risk of bone necrosis(19, 20). Cement penetration can be improved with pulse lavage, bone suction and pressurized cement gun usage(12). Various cementing techniques are used in TKA (21). Applying cement to both the tibial surface and the component seems more advantageous than applying it to a single surface. Both techniques produce a sufficient penetration of at least 2 mm; therefore, the clinical relevance must be investigated further (12). Refsum et al. recommended a comprehensive approach that includes pulsatile lavage irrigation of the bone, drilling multiple holes, thorough bone drying before cementing and implant insertion, and applying cement both to the implant and directly onto the bone (22). The retrospective study of Hedge et al. concluded that dryer surfaces provided by a tourniquet during cementation may improve penetration and reduce radiolucentline progression, resulting in superior initial fixation strength and potentially reducing the long-term risk of aseptic loosening (23). In a study of Vertullo et al., the tourniquet inflation during the cementation group did not have greater tibial cement penetration compared to a non-tourniquet group (24). Juliusson et al., injected cement into holes drilled into the femoral head before and after osteotomy of the femoral neck to determine the influence of circulating blood on cement penetration. The penetration of cement has been shown to increase by an average of 100 percent in the absence of proper circulation (25). In a study conducted by Dincel et al., the mean cement penetration in the entire study population was measured at 2.34 ± 0.24 mm (26). Furthermore, failure was found to be associated with a higher number of zones exhibiting cement penetration of less than 2 mm (27). Hoffman et al. reported an average cement penetration depth of 2.7 mm in their study (28). Sun et al. found an increase in the thickness of tibial bone cement penetration mainly located in zone 3 on the anteroposterior (AP) view with the application of a tourniquet (29). Radiographic analysis of Rathod et al. revealed no differences in cement penetration around the tibial component in any zone (30). Silverman et al. recommended to use of dough phase cement in their AP fluoroscopic image-based study. It statistically significantly penetrated deeper than the liquid phase in zones 1, 2 and 3 (31). In our study, we applied cement in the dough phase to both the bone-contacting surfaces of the tibial and femoral components as well as the bony surfaces. The mean cement penetration depth was 2.44±0.27 mm, consistent with the literature. It was found that the cement penetration was statistically significantly higher in the group using tourniquet throughout the entire operation period compared to the other groups. There was no significant difference between groups 2 and 3. In all zones except zone 1 AP, penetration of this group was higher than the others.

While there are a few studies demonstrating potential benefits of tourniquet usage in terms of medium to long-term implant stability and function, the majority of research reports no significant advantage (11). For instance, Güler et al., in their study comparing groups with and without tourniquet application, found that the tourniquet-applied group had a significantly higher WOMAC (Western Ontario and McMaster Universities Osteoarthritis Index) score and lower KSS (Knee Society Score) (32). Conversely, Dragosloveanu et al. found no discernible difference in knee function between groups with and without a tourniquet (33). Similarly, Smith et al. conducted a comparison of short tourniquet (ST) time vs. long tourniquet (LT) time and found no significant advantages of ST use in primary TKA concerning opioid consumption, patient-reported pain, and KSS scores (34).

In a meta-analysis, the group in which a tourniquet was not used during TKA exhibited the lowest visual analog scale (VAS) scores, the greatest improvement in motion at 3 days, and the highest KSS scores (35). Another meta-analysis reached the conclusion that abstaining from tourniquet usage during the TKA procedure, or employing it solely during the implant cementation phase, resulted in a swifter functional recovery compared to continuous tourniquet usage (36). Additionally, Cinka et al. argued that limiting the duration of tourniquet usage during TKA led to less postoperative pain and better early postoperative functional outcomes, although this difference became less pronounced in the long term (37).

In our study, Group 2 implemented a unique approach. We initiated tourniquet usage at the start of the surgery to reduce bleeding and shorten the operation duration, deflating it immediately after prosthesis implantation but before cement hardening to minimize the tourniquet duration. The aim of this approach was to secure implantation on clean bone surfaces while keeping the tourniquet duration brief. When the tourniquet was released before the cement fully hardened, blood flow was restored at the cement-tibia contact area. We also explored whether this practice influenced the functional outcomes of TKA by comparing the groups. The evaluation of functional status involved Lysholm and Oxford tests, revealing no functionally significant differences between the groups.

Du et al suggested that tourniquet application in TKA increases hidden blood loss, and that tourniquet duration and pressure should be reduced in patients with high risk of thrombosis (38). While Albayrak et al. did not find a statistically significant difference in total blood loss between tourniquet applied and non-applied groups, postoperative occult blood loss was found to be higher in the tourniquet applied group(39). Tie et al report that primary TKA with tourniquet release after cementing the prosthesis is similar to tourniquet release after wound closure and pressure dressing regarding perioperative blood loss, operative time, and incidence of DVT. Early tourniquet release reduced the incidence of wound complications (16). Zhang et al determined that tourniquet release before wound closure for hemostasis might reduce the rate of complications, but it could not limit overall blood loss. The current evidence is insufficient to indicate that tourniquet release before wound closure is superior to its release after wound closure in cemented TKA (40).

On the contrary Grigoras et al. speculated tourniquet use is associated with lower blood loss and similar postoperative pain, range of motion, quadriceps lag, length of stay, and thromboembolic risk (41). Similar to these results Migliorini et al found that shorter duration of surgery, lower intra-operative blood lost, lower drops in haemoglobin and fewer transfusion units are associated with longer tourniquet usage for knee arthroplasty (42). In our study, we found that operation times in groups 1 and 2 were statistically significantly lower than in group 3. Less bleeding occurred in group 3 without a tourniquet (table 2). There was no statistically significant difference in the amount of bleeding between groups 1 and 2. We conclude that this is due to bleeding control during the entire operation. We recommend that the tourniquet be deflated before cement hardening just after prosthesis implantation, because the amount of bleeding is not more than group 1, there is no functionally significant difference between groups and it has the advantage of shortening the tourniquet period.

Tourniquets have some complications as skin blistering, wound hematoma, muscle injury, rhabdomyolysis, nerve palsy, postoperative stiffness, deep vein thrombosis (DVT), pulmonary embolism, lower functional scores due to quadriceps weakness after surgery as well as residual pain in the thigh(7, 43). To mitigate the risk of these complications, it is advantageous to minimize the duration of tourniquet usage. This was the primary objective behind deflating the tourniquet immediately after prosthesis implantation in patients belonging to Group 2. It is worth noting that there are no other studies in the existing literature that specifically address the practice of releasing the tourniquet immediately after the total knee prosthesis implantation, just before the cement fully hardens.

One of the limitations of our study is that we did not compare complications between the groups. It's worth noting that there remains an absence of consensus in the existing literature regarding tourniquet application in total knee arthroplasty (TKA). Additionally, the follow-up period for the patients in our study was limited to 2 years. Therefore, conducting future research with a larger patient cohort and an extended follow-up duration would provide valuable insights into longer-term prosthesis survival and functional outcomes.

CONCLUSION

In summary, our findings indicate that the use of a tourniquet in total knee arthroplasty (TKA) enhances cement penetration across multiple zones and offers the benefit of reduced operation time. Nonetheless, it is important to note that tourniquet usage does not result in a reduction in bleeding. Therefore, we recommend the implementation of effective bleeding control measures in TKA procedures.

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