

# We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

6,900

Open access books available

186,000

International authors and editors

200M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index  
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?  
Contact [book.department@intechopen.com](mailto:book.department@intechopen.com)

Numbers displayed above are based on latest data collected.  
For more information visit [www.intechopen.com](http://www.intechopen.com)



---

# **Tourniquet Use in Total Knee Arthroplasty**

---

Kai-Lan Hsu, Chih-Wei Chang, Chyun-Yu Yang and  
Jou-Hua Wang

Additional information is available at the end of the chapter

<http://dx.doi.org/10.5772/intechopen.73644>

---

## **Abstract**

The use of an intraoperative tourniquet for total knee arthroplasty (TKA) is a common practice. Although it provides clear field and ideal cementation during surgery, issues regarding the effectiveness, drawbacks and complications are still investigated. This review was conducted to evaluate the role of tourniquet in TKA through a comprehensive literature search was done in PubMed Medicine, Embase, and other internet database. Debating issues, including the blood loss, operation time, alignment, compromised wound healing, quadriceps weakness and timing of release were furtherly examined. Based on our prior work and the general consensus that the tourniquet should be set with the lowest pressure and for the least ischemic time possible, we recommend early tourniquet release right after the closure of extensor mechanism in the TKAs without drainage.

**Keywords:** tourniquet, total knee arthroplasty, ischemic, blood loss, timing

---

## **1. Introduction**

Total knee arthroplasty (TKA) is associated with substantial postoperative blood loss for which blood transfusion might be necessary. Various strategies to hemostasis had been proposed, including the use of tourniquet during surgery. The use of tourniquet was believed to help reduce intraoperative blood loss [1–4], provide better visualization, save operative time [4, 5], and facilitate the cementing quality and other surgical procedures. However, some conflicting results were reported regarding blood loss and fixation of cemented [6–8]. Furthermore, certain drawbacks were mentioned after the use of tourniquet, including thigh pain, nerve

palsy, ischemia [9], soft tissue damage, thromboembolic complications [10], decrease muscle strength [11], and knee range of motion (ROM) [3]. In spite of the common use of tourniquet in orthopedic surgeries, the role of tourniquet in TKA remains controversial, and some surgeons suggested that tourniquet is not necessary [12, 13].

To reduce the aforementioned drawbacks, adjunctive measures such as skin protection [14], elastic cuff [15], and reducing cuff pressure [16, 17] are frequently taken while applying the tourniquet during TKAs. Recently, early deflation of tourniquet has drawn increasing attention. Since most surgeons use tourniquet to facilitate the procedure mainly, there are no need for prolonged use of tourniquet. Various timings of deflation have been proposed in the literature, such as deflating tourniquet after cementing the implants [18–20], after closure of arthrotomy [21], or immediately after wound closure [22]. However, no consensus has been achieved to date.

To clarify the role of tourniquet in TKA, a comprehensive review was therefore conducted. An extensive search as well as review of the related literature regarding the tourniquet use was performed. This review focused on:

1. Effectiveness of tourniquet use in TKA.
2. Safety and complications of tourniquet use in TKA.
3. Effect of early deflation of tourniquet.

## 2. Search of literature

Our review team completed the search of electronic databases, including the Cochrane Central Register of Controlled Trials (2010), PubMed Medline (1966 to May 2011), and Embase (1980 to May 2011). We used the following search terms and Boolean operators: (tourniquet) AND (knee OR arthroplasty OR joint replacement). We also searched the reference lists of the relevant articles for any further associated studies. The criteria for inclusion were (1) reports dealing with patients undergoing primary TKA and (2) studies about tourniquet use. After reviewing the titles and abstracts of the studies, we determined if the study was appropriate for retrieval. The retrieved literature was completely reviewed. A consensus about the content of this review article was reached throughout series of discussion.

## 3. Intraoperative tourniquet use

### 3.1. Blood loss

Whether or not a tourniquet can reduce blood loss in total knee arthroplasty is still being debated in the literature. Although intraoperative blood loss was significantly less in the tourniquet group in the present study, there is often a substantial hidden or unmeasured blood loss in TKA. Some authors claimed that a tourniquet is effective for reducing blood loss [1, 2, 23],

but others did not agree. Numerous studies reported no significant difference in the amount of blood loss with or without tourniquet use [24, 25], and others even suggested that the use of tourniquet induces more blood loss [26, 27].

There are some parameters commonly used to evaluate the blood loss of the surgery. Directly measured items include *the intraoperative blood loss* and *the transfusion rate*. *Measurable total blood loss*, the summation of intra- and postoperative blood loss, is determined by the increasing weight of soaked gauze added the amount of postoperative drainage. *Calculated total blood loss*, which is always regarded as true total blood loss, was measured by Hb and Hct levels before and after surgery.

In the research model of meta-analysis, some authors suggested that the use of tourniquet did not affect total blood loss [3, 5, 8, 28], which was opposed by Alcelik et al. [29]. However, Alcelik et al. [29] estimated total blood loss simply based on the measurable blood loss while overlooking the hidden blood loss. Thus, the evidence available indicates that tourniquet indeed significantly reduce the intraoperative blood loss rather than the total blood loss.

### 3.2. Operation time

The application of a tourniquet in TKA was believed to afford a relative bloodless surgical field, facilitating time saving. However, the critical timing of deflation should be mentioned regarding the operation time. The pooling data showed significantly shortened surgical duration in the tourniquet group once the tourniquet was released after wound closure and compressive dressing [2, 27, 30]. In comparison, early release of the tourniquet right after cementing the prosthesis for hemostasis would prolong the operation time for troublesome oozing [5, 20, 31–34]. Thus, the studies with early release of tourniquet did not correlate with significant shortened operation time [23, 24, 26].

### 3.3. Alignment and stability

A tourniquet use is believed to improve the visualization of anatomical structures [35] due to better control of intraoperative bleeding. However, this advantage does not necessarily promise the improved implant position or surgical accuracy. Stetzelberger et al. [36] found that the mechanical leg alignment, the joint line level, and the patellar height could be accurately reconstructed with and without the tourniquet use.

On the other hand, an inflated tourniquet could alter the patellofemoral tracking [28] and may give the impression of an enhanced lateral tracking because of an increased lateral retinacular tension [37, 38]. Some authors recommend the deflation of the tourniquet prior to a lateral release to avoid unnecessary interventions. However, Matsui et al. [39] found that there is low clinical relevance even tourniquet deflation significantly improved the patellofemoral tracking and it is reliable to test intraoperative congruity a tourniquet in place.

There is a lack of data available in the literature whether the use of a tourniquet increases implant fixation in TKA. Radiostereometric analysis (RSA) has been used to investigate the influence of the tourniquet on implant fixation, but no difference was found [40, 41]. Recently,

Pfutzner et al. found that the use of a tourniquet in primary TKA increased the tibial cement mantle thickness [42], which could increase implant stability and survival [43].

### 3.4. Risk of thrombosis

The use of a tourniquet can be an important issue but still controversial regarding the formation of deep vein thrombosis (DVT) after TKA. Abdel-Salam and Eyres [44], Mori et al. [10], and Tai et al. [5] reported an increased incidence of DVT with the use of a tourniquet in TKA, but Wakankar et al. [35] and Fukuda et al. [23] both reported that the incidence of DVT was not related to the use of a tourniquet. However, these studies vary in diagnostic tool, race, and the presentation of symptoms.

The length of tourniquet time (ischemic duration) is another factor affecting the risk of thrombosis. Bin Abd Razak et al. [45] and Chung et al. [46] reported that the rate of DVT appeared to be associated with prolonged tourniquet time, probably due to a long period of venous stasis and damage to calcified vessels. Early deflation of tourniquet is also found to decrease the risk of DVT [18, 47].

Although most DVTs were asymptomatic, an asymptomatic postoperative DVT is associated with an increased risk of the late development of the post-thrombotic syndrome [48, 49]. Thus, patients with an asymptomatic DVT should be monitored carefully.

### 3.5. Complication related to wound healing

Wound condition after TKA is important for the prevention of periprosthetic infection [50, 51]. Delay in wound healing is associated with deep infection, which leads to the arthroplasty failure [52].

The use of a tourniquet is associated with a higher incidence of postoperative wound problems [3, 5, 28, 44], including significant hematoma, wound oozing, skin blistering, bruising, necrosis, and superficial wound infection requiring antibiotics treatment. Circulatory stasis caused by tourniquet inflation may worsen the local soft tissue condition [5]; furthermore, reactive hyperemia and activation of fibrinolytic cascade after tourniquet release increase the tissue pressure and local inflammation [3, 53], all of which lead to tissue hypoxia and subsequently compromised wound healing.

### 3.6. Thigh pain, weakness, and postoperative recovery

For patients who undergo tourniquet-controlled TKA, thigh pain is a very common complaint during the early postoperative period. Performing TKA without a tourniquet could reduce postoperative thigh pain in several literature [1, 3, 12, 13], but the benefit declines with time and becomes insignificant different at follow-ups longer than 6 months.

Compromised knee motion after tourniquet use has also been mentioned in some literature [35, 40, 44]. The possible reasons are as follows: (1) using a tourniquet may injure the nerve and the skeletal muscle, even causing rhabdomyolysis [40, 54] and (2) increased postoperative pain would limit the patient's ability to perform postoperative training [40, 55].

Considering the acting and involving region of tourniquet, quadriceps weakness is a hallmark of TKA [56, 57], though few studies investigated this issue. Abdel-Salam and Eyres observed a quicker ability to achieve a straight leg raise maneuver in whom a tourniquet was not used [44]. Dennis et al. [11] also reported the diminished strength of quadriceps during the first 3 months after TKA using a tourniquet. However, no significant difference of knee-extension strength 48 h after surgery was reported by Harsten et al. [58].

Long-term effect of tourniquet use on the postoperative ROM is still debating. Ledin et al. [40] reported that the ROM was 11° greater in the non-tourniquet group after 2-year follow-up, but Abdel-Salam and Eyres [44] and Liu et al. [13] found no difference in knee flexion after 1-year follow-up.

#### **4. Timing of tourniquet release**

To reduce the ischemic duration and the incidence of complications aforementioned, some surgeons suggested the early release of tourniquet. The different timings of tourniquet deflation include immediately after wound closure [22], after a tight arthrotomy closure [21] and mostly after the implantation of the prostheses [18, 20, 32].

Although there were some reviewing articles related to the timing of tourniquet release in TKA, the results varied. For blood loss, Huang et al. [59] and Zan et al. [47] suggested that tourniquet release before wound closure for hemostasis would significantly increase not only total measured blood loss but also calculated blood loss. Zhang et al. [31] found that releasing tourniquet before wound closure could increase only total blood loss. However, Tie et al. [60] reported no significant difference existed in calculated blood loss nor total blood losses. To analyze the blood loss in detail, intraoperative blood loss may contribute to most of increased blood loss. Releasing tourniquet before wound closure theoretically could ensure a better view of hemostasis, and patients would have better blood conservation. Nevertheless, fibrinolytic activity rises after the release of an arterial tourniquet [61], contributing to the higher perioperative blood loss. In addition, it was impossible to find all bleeding sources, especially the oozing spots. These are the reasons why total blood loss is higher when tourniquet is released before wound closure in some reviewing article.

Several studies demonstrated that releasing tourniquet before wound closure had a decreased risk of postoperative complications such as wound complications [22], deep infection, DVT [31], and so on [47, 60, 62]. Although there is no significant difference in some meta-analysis [18, 59], it had a trend that releasing tourniquet before wound closure could decrease the incidence rate of major complication.

#### **5. Pressure**

Clinical and experimental studies supported a positive correlation between the degree of neuromuscular injury and the amount of pressure or the ischemia duration. Olivecrona et al. [16]



reported a higher cuff pressure increase risks of tourniquet-related postoperative complications. Despite various pressures being used in different studies, the general consensus is that the tourniquet should be employed at the lowest pressure and for the least ischemic time possible to avoid complications. In some published studies [17, 34, 53, 63], cuff pressures, ranging from 300 to 350 mm Hg, have been reported.

To reduce the cuff pressure, some surgeons preferred the setting of cuff pressure on the basis of the systolic blood pressure plus a margin of 100 mmHg [34], and less early postoperative pain has been reported [64]. Meanwhile, another common method, twice of the systolic pressure, has also been adopted [65]. Besides, based on the fluctuating systolic pressure, improved devices with timely automated measurement of limb occlusion pressure have been investigated to reduce the cuff pressure [16].

## 6. Authors' preference

For the past decade, the authors focused on the effects of a tourniquet in TKA. In a meta-analysis [5], we found that using tourniquet in TKA may save time without evident hemostatic benefits. Then, a prospective, randomized, controlled trial was therefore conducted to clarify the effect of tourniquets in TKA. Reduced operative time, reduced intraoperative blood loss, and prevented excessive inflammation and muscle damage were obtained in the tourniquet-controlled TKAs [1]. Further, to save unnecessary ischemic duration, an effective hemostasis via a tamponade by the closed arthrotomy without drainage was used. Not only the shortened ischemic time but also better earlier functional recovery was obtained at early postoperative follow-ups [21]. Currently, although tourniquet is routinely used in our daily practice of TKAs, timely release as well as low cuff pressure is stressed based on the awareness of the risks of thromboembolism and other aforementioned complications.

## Author details

Kai-Lan Hsu<sup>1,2</sup>, Chih-Wei Chang<sup>1,2,3\*</sup>, Chyun-Yu Yang<sup>1,3</sup> and Jou-Hua Wang<sup>1</sup>

\*Address all correspondence to: u7901064@yahoo.com.tw

1 Department of Orthopaedic Surgery, National Cheng Kung University Hospital, College of Medicine, National Cheng Kung University, Tainan, Taiwan

2 Department of Biomedical Engineering, College of Engineering, National Cheng Kung University, Tainan, Taiwan

3 Bone and Joint Center, National Cheng Kung University Hospital, College of Medicine, National Cheng Kung University, Tainan, Taiwan

## References

- [1] Tai TW, Chang CW, Lai KA, Lin CJ, Yang CY. Effects of tourniquet use on blood loss and soft-tissue damage in total knee arthroplasty: A randomized controlled trial. *The Journal of Bone and Joint Surgery American Volume*. 2012;**94**(24):2209-2215
- [2] Vandebussche E, Duranthon LD, Couturier M, Pidhorz L, Augereau B. The effect of tourniquet use in total knee arthroplasty. *International Orthopaedics*. 2002;**26**(5):306-309
- [3] Zhang W, Liu A, Hu D, Tan Y, Al-Aidaros M, Pan Z. Effects of the timing of tourniquet release in cemented total knee arthroplasty: A systematic review and meta-analysis of randomized controlled trials. *Journal of Orthopaedic Surgery and Research*. 2014;**9**:125
- [4] Yi S, Tan J, Chen C, Chen H, Huang W. The use of pneumatic tourniquet in total knee arthroplasty: A meta-analysis. *Archives of Orthopaedic and Trauma Surgery*. 2014;**134**(10):1469-1476
- [5] Tai TW, Lin CJ, Jou IM, Chang CW, Lai KA, Yang CY. Tourniquet use in total knee arthroplasty: A meta-analysis. *Knee Surgery, Sports Traumatology, Arthroscopy: Official Journal of the ESSKA*. 2011;**19**(7):1121-1130
- [6] Yin D, Delisle J, Banica A, Senay A, Ranger P, Laflamme GY, et al. Tourniquet and closed-suction drains in total knee arthroplasty. No beneficial effects on bleeding management and knee function at a higher cost. *Orthopaedics & Traumatology, Surgery & Research: OTSR*. 2017;**103**(4):583-589
- [7] Ejaz A, Laursen AC, Jakobsen T, Rasmussen S, Nielsen PT, Laursen MB. Absence of a tourniquet does not affect fixation of cemented TKA: A randomized RSA study of 70 patients. *The Journal of Arthroplasty*. 2015;**30**(12):2128-2132
- [8] Smith TO, Hing CB. Is a tourniquet beneficial in total knee replacement surgery? A meta-analysis and systematic review. *The Knee*. 2010;**17**(2):141-147
- [9] Ejaz A, Laursen AC, Kappel A, Jakobsen T, Nielsen PT, Rasmussen S. Tourniquet induced ischemia and changes in metabolism during TKA: A randomized study using microdialysis. *BMC Musculoskeletal Disorders*. 2015;**16**:326
- [10] Mori N, Kimura S, Onodera T, Iwasaki N, Nakagawa I, Masuda T. Use of a pneumatic tourniquet in total knee arthroplasty increases the risk of distal deep vein thrombosis: A prospective, randomized study. *The Knee*. 2016;**23**(5):887-889
- [11] Dennis DA, Kittelson AJ, Yang CC, Miner TM, Kim RH, Stevens-Lapsley JE. Does tourniquet use in TKA affect recovery of lower extremity strength and function? A randomized trial. *Clinical Orthopaedics and Related Research*. 2016;**474**(1):69-77
- [12] Ejaz A, Laursen AC, Kappel A, Laursen MB, Jakobsen T, Rasmussen S, et al. Faster recovery without the use of a tourniquet in total knee arthroplasty. *Acta Orthopaedica*. 2014;**85**(4):422-426



- [13] Liu D, Graham D, Gillies K, Gillies RM. Effects of tourniquet use on quadriceps function and pain in total knee arthroplasty. *Knee Surgery & Related Research*. 2014;**26**(4):207-213
- [14] Olivecrona C, Tidermark J, Hamberg P, Ponzer S, Cederfjall C. Skin protection underneath the pneumatic tourniquet during total knee arthroplasty: A randomized controlled trial of 92 patients. *Acta Orthopaedica*. 2006;**77**(3):519-523
- [15] Lee OS, Lee MC, Han HS. Efficacy and safety of a new elastic tourniquet cuff in total knee arthroplasty: A prospective randomized controlled study. *Biomedical Engineering Online*. 2017;**16**(1):102
- [16] Olivecrona C, Ponzer S, Hamberg P, Blomfeldt R. Lower tourniquet cuff pressure reduces postoperative wound complications after total knee arthroplasty: A randomized controlled study of 164 patients. *The Journal of Bone and Joint Surgery American Volume*. 2012;**94**(24):2216-2221
- [17] Olivecrona C, Blomfeldt R, Ponzer S, Stanford BR, Nilsson BY. Tourniquet cuff pressure and nerve injury in knee arthroplasty in a bloodless field: A neurophysiological study. *Acta Orthopaedica*. 2013;**84**(2):159-164
- [18] Zan P, Mol MO, Yao JJ, Fan L, Yang D, Liu K, et al. Release of the tourniquet immediately after the implantation of the components reduces the incidence of deep vein thrombosis after primary total knee arthroplasty. *Bone & Joint Research*. 2017;**6**(9):535-541
- [19] Steffin B, Green-Riviere E, Giori NJ. Timing of tourniquet release in total knee arthroplasty when using a postoperative blood salvage drain. *The Journal of Arthroplasty*. 2009;**24**(4):539-542
- [20] Kvederas G, Porvaneckas N, Andrijauskas A, Svensen CH, Ivaskevicius J, Mazunaitis J, et al. A randomized double-blind clinical trial of tourniquet application strategies for total knee arthroplasty. *Knee Surgery, Sports Traumatology, Arthroscopy: Official Journal of the ESSKA*. 2013;**21**(12):2790-2799
- [21] Chang CW, Lan SM, Tai TW, Lai KA, Yang CY. An effective method to reduce ischemia time during total knee arthroplasty. *Journal of the Formosan Medical Association*. 2012;**111**(1):19-23
- [22] Heller S, Chen A, Restrepo C, Albert E, Hozack WJ. Tourniquet release prior to dressing application reduces blistering following total knee arthroplasty. *The Journal of Arthroplasty*. 2015;**30**(7):1207-1210
- [23] Fukuda A, Hasegawa M, Kato K, Shi D, Sudo A, Uchida A. Effect of tourniquet application on deep vein thrombosis after total knee arthroplasty. *Archives of Orthopaedic and Trauma Surgery*. 2007;**127**(8):671-675
- [24] Aglietti P, Baldini A, Vena LM, Abbate R, Fedi S, Falciani M. Effect of tourniquet use on activation of coagulation in total knee replacement. *Clinical Orthopaedics and Related Research*. 2000;**371**:169-177
- [25] Katsumata S, Nagashima M, Kato K, Tachihara A, Wauke K, Saito S, et al. Changes in coagulation-fibrinolysis marker and neutrophil elastase following the use of tourniquet

during total knee arthroplasty and the influence of neutrophil elastase on thromboembolism. *Acta Anaesthesiologica Scandinavica*. 2005;**49**(4):510-516

- [26] Tetro AM, Rudan JF. The effects of a pneumatic tourniquet on blood loss in total knee arthroplasty. *Canadian Journal of Surgery*. 2001;**44**(1):33-38
- [27] Li B, Wen Y, Wu H, Qian Q, Lin X, Zhao H. The effect of tourniquet use on hidden blood loss in total knee arthroplasty. *International Orthopaedics*. 2009;**33**(5):1263-1268
- [28] Jiang FZ, Zhong HM, Hong YC, Zhao GF. Use of a tourniquet in total knee arthroplasty: A systematic review and meta-analysis of randomized controlled trials. *Journal of Orthopaedic Science: Official Journal of the Japanese Orthopaedic Association*. 2015;**20**(1):110-123
- [29] Alcelik I, Pollock RD, Sukeik M, Bettany-Saltikov J, Armstrong PM, Fismer PA. Comparison of outcomes with and without a tourniquet in total knee arthroplasty: A systematic review and meta-analysis of randomized controlled trials. *The Journal of Arthroplasty*. 2012;**27**(3):331-340
- [30] Nishiguchi M, Takamura N, Abe Y, Kono M, Shindo H, Aoyagi K. Pilot study on the use of tourniquet: A risk factor for pulmonary thromboembolism after total knee arthroplasty? *Thrombosis Research*. 2005;**115**(4):271-276
- [31] Zhang P, Liang Y, He J, Fang Y, Chen P, Wang J. Timing of tourniquet release in total knee arthroplasty: A meta-analysis. *Medicine*. 2017;**96**(17):e6786
- [32] Christodoulou AG, Ploumis AL, Terzidis IP, Chantzidis P, Metsovitis SR, Nikiforos DG. The role of timing of tourniquet release and cementing on perioperative blood loss in total knee replacement. *The Knee*. 2004;**11**(4):313-317
- [33] Hersekli MA, Akpınar S, Ozkoc G, Ozalay M, Uysal M, Cesur N, et al. The timing of tourniquet release and its influence on blood loss after total knee arthroplasty. *International Orthopaedics*. 2004;**28**(3):138-141
- [34] Ishii Y, Matsuda Y. Effect of the timing of tourniquet release on perioperative blood loss associated with cementless total knee arthroplasty: A prospective randomized study. *The Journal of Arthroplasty*. 2005;**20**(8):977-983
- [35] Wakankar HM, Nicholl JE, Koka R, D'Arcy JC. The tourniquet in total knee arthroplasty. A prospective, randomised study. *The Journal of Bone and Joint Surgery British Volume*. 1999;**81**(1):30-33
- [36] Stetzelberger V, Obertacke U, Jawhar A. Tourniquet application during TKA did not affect the accuracy of implant positioning: A randomized clinical trial. *Knee Surgery, Sports Traumatology, Arthroscopy: Official Journal of the ESSKA*. 2017
- [37] Husted H, Toftgaard Jensen T. Influence of the pneumatic tourniquet on patella tracking in total knee arthroplasty: A prospective randomized study in 100 patients. *The Journal of Arthroplasty*. 2005;**20**(6):694-697
- [38] Komatsu T, Ishibashi Y, Otsuka H, Nagao A, Toh S. The effect of surgical approaches and tourniquet application on patellofemoral tracking in total knee arthroplasty. *The Journal of Arthroplasty*. 2003;**18**(3):308-312

- [39] Matsui Y, Shintani K, Okajima Y, Matsuura M, Nakagawa S. The effect of tourniquets on patellofemoral joint congruity during total knee arthroplasty. *Journal of Orthopaedic Science: Official Journal of the Japanese Orthopaedic Association*. 2016;**21**(5):630-634
- [40] Ledin H, Aspenberg P, Good L. Tourniquet use in total knee replacement does not improve fixation, but appears to reduce final range of motion. *Acta Orthopaedica*. 2012; **83**(5):499-503
- [41] Molt M, Harsten A, Toksvig-Larsen S. The effect of tourniquet use on fixation quality in cemented total knee arthroplasty a prospective randomized clinical controlled RSA trial. *The Knee*. 2014;**21**(2):396-401
- [42] Pfitzner T, von Roth P, Voerkelius N, Mayr H, Perka C, Hube R. Influence of the tourniquet on tibial cement mantle thickness in primary total knee arthroplasty. *Knee Surgery, Sports Traumatology, Arthroscopy: Official Journal of the ESSKA*. 2016;**24**(1):96-101
- [43] Peters CL, Craig MA, Mohr RA, Bachus KN. Tibial component fixation with cement: Full-versus surface-cementation techniques. *Clinical Orthopaedics and Related Research*. 2003;**409**:158-168
- [44] Abdel-Salam A, Eyres KS. Effects of tourniquet during total knee arthroplasty. A prospective randomised study. *The Journal of Bone and Joint Surgery British Volume*. 1995;**77**(2):250-253
- [45] Bin Abd Razak HR, Binte Abd Razak NF, Tan HA. Prevalence of venous thromboembolic events is low in Asians after Total knee arthroplasty without chemoprophylaxis. *The Journal of Arthroplasty*. 2017;**32**(3):974-979
- [46] Chung LH, Chen WM, Chen CF, Chen TH, Deep LCL. Vein thrombosis after total knee arthroplasty in asian patients without prophylactic anticoagulation. *Orthopedics*. 2011; **34**(1):15
- [47] Zan PF, Yang Y, Fu D, Yu X, Li GD. Releasing of tourniquet before wound closure or not in total knee arthroplasty: A meta-analysis of randomized controlled trials. *The Journal of Arthroplasty*. 2015;**30**(1):31-37
- [48] Wille-Jorgensen P, Jorgensen LN, Crawford M. Asymptomatic postoperative deep vein thrombosis and the development of postthrombotic syndrome. A systematic review and meta-analysis. *Thrombosis and Haemostasis*. 2005;**93**(2):236-241
- [49] Siragusa S, Beltrametti C, Barone M, Piovella F. Clinical course and incidence of post-thrombophlebitic syndrome after profound asymptomatic deep vein thrombosis. Results of a transverse epidemiologic study. *Minerva Cardioangiologica*. 1997;**45**(3):57-66
- [50] Garbedian S, Sternheim A, Backstein D. Wound healing problems in total knee arthroplasty. *Orthopedics*. 2011;**34**(9):e516-e518
- [51] Vince K, Chivas D, Droll KP. Wound complications after total knee arthroplasty. *The Journal of Arthroplasty*. 2007;**22**(4, Suppl 1):39-44
- [52] Galat DD, McGovern SC, Larson DR, Harrington JR, Hanssen AD, Clarke HD. Surgical treatment of early wound complications following primary total knee arthroplasty. *The Journal of Bone and Joint Surgery American Volume*. 2009;**91**(1):48-54

- [53] Clarke MT, Longstaff L, Edwards D, Rushton N. Tourniquet-induced wound hypoxia after total knee replacement. *The Journal of Bone and Joint Surgery British Volume*. 2001; **83**(1):40-44
- [54] Appell HJ, Gloser S, Duarte JA, Zellner A, Soares JM. Skeletal muscle damage during tourniquet-induced ischaemia. The initial step towards atrophy after orthopaedic surgery? *European Journal of Applied Physiology and Occupational Physiology*. 1993; **67**(4):342-347
- [55] Kumar N, Yadav C, Singh S, Kumar A, Vaithlingam A, Yadav S. Evaluation of pain in bilateral total knee replacement with and without tourniquet; a prospective randomized control trial. *Journal of Clinical Orthopaedics and Trauma*. 2015; **6**(2):85-88
- [56] Mizner RL, Petterson SC, Snyder-Mackler L. Quadriceps strength and the time course of functional recovery after total knee arthroplasty. *The Journal of Orthopaedic and Sports Physical Therapy*. 2005; **35**(7):424-436
- [57] Stevens-Lapsley JE, Balter JE, Kohrt WM, Eckhoff DG. Quadriceps and hamstrings muscle dysfunction after total knee arthroplasty. *Clinical Orthopaedics and Related Research*. 2010; **468**(9):2460-2468
- [58] Harsten A, Bandholm T, Kehlet H, Toksvig-Larsen S. Tourniquet versus no tourniquet on knee-extension strength early after fast-track total knee arthroplasty; a randomized controlled trial. *The Knee*. 2015; **22**(2):126-130
- [59] Huang Z, Ma J, Zhu Y, Pei F, Yang J, Zhou Z, et al. Timing of tourniquet release in total knee arthroplasty. *Orthopedics*. 2015; **38**(7):445-451
- [60] Tie K, Hu D, Qi Y, Wang H, Chen L. Effects of tourniquet release on total knee arthroplasty. *Orthopedics*. 2016; **39**(4):e642-e650
- [61] Harvey EJ, Leclerc J, Brooks CE, Burke DL. Effect of tourniquet use on blood loss and incidence of deep vein thrombosis in total knee arthroplasty. *The Journal of Arthroplasty*. 1997; **12**(3):291-296
- [62] Barwell J, Anderson G, Hassan A, Rawlings I. The effects of early tourniquet release during total knee arthroplasty: A prospective randomized double-blind study. *The Journal of Bone and Joint Surgery British Volume*. 1997; **79**(2):265-268
- [63] Noordin S, McEwen JA, Kragh JF Jr, Eisen A, Masri BA. Surgical tourniquets in orthopaedics. *The Journal of Bone and Joint Surgery American Volume*. 2009; **91**(12):2958-2967
- [64] Worland RL, Arredondo J, Angles F, Lopez-Jimenez F, Jessup DE. Thigh pain following tourniquet application in simultaneous bilateral total knee replacement arthroplasty. *The Journal of Arthroplasty*. 1997; **12**(8):848-852
- [65] Liu HY, Guo JY, Zhang ZB, Li KY, Wang WD. Development of adaptive pneumatic tourniquet systems based on minimal inflation pressure for upper limb surgeries. *Biomedical Engineering Online*. 2013; **12**:92

