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Extramedullary Tibial Bone Cutting Using Medial Cortical Line in Total Knee Arthroplasty

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Purpose: This study aims to identify the effectiveness of the medial cortical line for attaining a more accurate tibial component alignment in proximal tibial resection using an extramedullary alignment rod.
Materials and Methods: The study examined 100 cases of total knee arthroplasty performed from December 2013 to February 2014 in a retrospective manner. On a preoperative anteroposterior (AP) radiograph of the entire tibia, we identified the medial cortical line that runs parallel to the tibial anatomical axis and passes the medial tibial spine, and measured the point where the medial cortical line crosses between the medial malleolus and the lateral malleolus in the ankle joint.
Results: The preoperative AP radiograph of the tibia showed the medial cortical line passing the point 40.4%±0.8% medial to the distance from the medial malleolus to the lateral malleolus including the skin thickness in the ankle joint. When the proximal tibial resection was performed with the extramedullary tibial cutting guide aligned with the medial cortical line, the tibial component angle averaged 0.7°±0.3° varus and the alignment accuracy of the tibial component within 0°±3° varus amounted to 97.0%.
Conclusions: The use of the medial cortical line in proximal tibial resection with an extramedullary tibial cutting guide allowed for relatively accurate alignment of the tibial component.

Keywords: Knee, Arthroplasty, Tibial bone resection

Introduction

Factors known to affect the surgical outcome of total knee arthroplasty (TKA) include the appropriate patient selection, type of implant, proper soft tissue balancing, recovery of the flexion and extension gap balance, proper implant alignment, and restoration of the joint line[1,2]. Among them, implant malalignment causes improper stress to the implant due to asymmetrical load distribution, which in turn triggers implant subsidence and excessive wear of the polyethylene[3]. This is known to have negative impacts on the short-term and long-term clinical results and lead to a high chance of failure[4,5]. Therefore, it is critical for a successful TKA to properly recover the implant alignment. Several authors have reported that if the implant alignment is within ±3° of the ideal alignment on the coronal plane, it does not have much impact on the long-term postoperative outcome[6,7].

In the case of severe varus deformity or bowing deformity in the medial proximal tibia, the point at which the anatomical axis crosses the plateau varies and the middle point of the talar dome is inconsistent. To address this problem, several anatomical indicators[8-12] have been proposed such as the mechanical axis; nonetheless, it is challenging to apply these indicators uniformly due to the lack of consistency resulting from anatomical differences of the tibia or soft tissue or in the location of the ankle joint[13]. Therefore, when installing an extramedullary cutting guide for the tibia in order to achieve a more precise cutting angle, positioning the guide according to the anatomical axis which is mea-

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surable on a preoperative tibial radiograph can be more accurate than following the mechanical axis whose definition and location lack clarity.

Since the point at which the anatomical axis crosses the tibial plateau and the ankle joint are different for each patient, these locations need to be confirmed on a preoperative radiograph. Against this background, this paper aims to discuss the effectiveness of the medial cortical line in proximal tibial resection using an extramedullary cutting guide to facilitate the installment of the guide and to accomplish a more accurate tibial component alignment.

Materials and Methods

1. Materials

This study examined 100 cases (75 patients) of TKA performed between December 2013 and February 2014 in a retrospective manner. The study protocol was approved by our Institutional Review Board. The average age of the subjects was 70±6.4 years, and 10 cases were in males (8 patients) and 90 cases were in females (67 patients). Their body mass index (BMI) averaged 26.8±3.5 kg/m^2. There were 99 cases of degenerative arthritis and 1 case of osteonecrosis. On average, the preoperative range of motion in the knee joint was 124°±20.0° the preoperative knee score was 33.5±18 while the preoperative femorotibial angle was 4.5°±3.4° varus (Table 1).

Table 1. Patient Demographics

Demographic	Value
No. of cases	100 (75 patients)
Sex	
Male	10 (8 patients)
Female	90 (67 patients)
Age (yr)	70±6.4
Body mass index (kg/m^2)	26.8±3.5
Preop diagnosis	
Osteoarthritis	99 (74 patients)
Osteonecrosis	1
Preop ROM (°)	124±20
Preop HSS score	33.5±18
Preop femorotibial angle (°)	4.5±3.4 varus

Values are presented as mean±standard deviation.
Preop: preoperative, ROM: range of motion, HSS: Hospital for Special Surgery.

2. Definition of Medial Cortical Line

The tibial anatomical axis was defined in relation to the intramedullary canal. The tibial anatomical axis was drawn proximal to distal in the intramedullary canal bisecting the tibia in half by connecting the center point of the tibia 5 cm distal to the knee joint, the center point 5 cm proximal to the ankle joint, and the middle point of the outer cortex which is considered the center of the tibial intramedullary on a preoperative anteroposterior (AP) radiograph of the tibia. The ratio (b/a) of the medial distance (b) to the medial and lateral distance (a) was measured at the point where the anatomical axis passed the tibial plateau. Also, the ratio (e/d) of the distance from the medial malleolus to the anatomical axis including the skin thickness perpendicular to the axis (e) to the distance perpendicular to the anatomical axis between the medial malleolus and the lateral malleolus including the skin thickness in the ankle joint (d) was measured.

The medial cortical line was defined as a line that runs parallel to the tibial anatomical axis and crosses the medial tibial spine. At the point where the medial cortical line passes the tibial plateau, the ratio (c/a) of the medial distance (c) to the medial and lateral distance (a) was measured. In addition, the ratio (f/d) of the distance from the medial malleolus to the medial cortical line including the skin thickness perpendicular to the line (f) to the distance perpendicular to the medial cortical line between

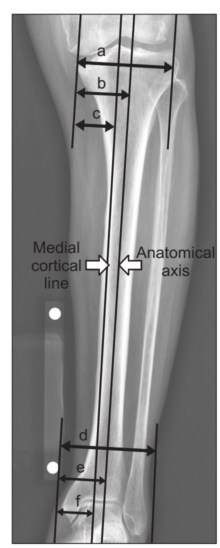

Fig. 1. Anatomical axis and medial cortical line of the tibia. The ratios of the medial distance to the anatomical axis are calculated as b/a and e/d. The ratios of the medial distance to the medial cortical line are calculated as c/a and f/d. a: medial an lateral distance of tibial plateau, b: medial distance to the anatomical axis, c: medial distance to the medial cortical line, d: skin thickness in the ankle joint, e: skin thickness to the anatomical axis in the ankle joint, f: skin thickness to the medial cortical line in the ankle joint.

the medial malleolus and the lateral malleolus including the skin thickness in the ankle joint (d) was measured (Fig. 1).

3. Installation of Extramedullary Cutting Guide

In order to properly identify and palpate the anatomical landmarks of the leg and ankle, Iovan (Iovan 2 Antimicrobial Film Incise Drapes; 3M, Maplewood, MN, USA) and Coban (Coban Self-adherent Wrap, 3M) were used to drape the leg and apply tension (Fig. 2A). The tibial cutting angle was set to run perpendicular to the medial cortical line which runs parallel to the anatomical axis on the coronal plane. With regard to the installation of the extramedullary cutting guide at the proximal site, the two long and short spikes attached to the top of the guide were fixed to the medial tibial spine of the tibial plateau. At the same time, it was made sure that the extramedullary rod was located in the anterior tibia. The side slope of the cutting guide on the sagittal plane was set to run parallel to the anterior tibia. At the distal site, the extramedullary cutting guide was fixed with a clamp device in the ankle joint at the point where the medial cortical line passes (Fig. 2B). In the joint ankle, it passed 40.4%±0.8% of the distance between the medial malleolus and lateral malleolus including the skin thickness (f/d) on average.

4. Surgical Methods

All operations were performed using minimally invasive surgery (MIS) quad-sparing instrumentation by the first author of this paper, an experienced surgeon in MIS. NexGen Legacy Posterior Stabilized Flex Fixed Bearing (LPS Flex Fixed; Zimmer, Warsaw, IN, USA) was used for all cases and a Modular tibial component (Mini-keel, Nexgen MIS Tibial Component; Zimmer) was used as the tibial component.

The resection of the proximal tibia involved the use of an extramedullary alignment guide, commonly used in conventional surgical techniques, so that it could be performed aligned to the medial cortical line. First, the cutting began at the anteromedial tibia using the cutting guide. When roughly 80% of the osteotomy was completed, excluding some of the posterolateral tibia and lateral tibia, the cutting guide was removed. Following a lateral soft tissue release performed with the knee joint extended, the remaining resection was carried out using the free hand technique.

The postoperative radiological evaluation involved the measurement of the femorotibial angle, tibial component angle, and tibial component posterior inclination on AP and lateral radiographs of the knee joint taken after the operation. In order to assess the accuracy of implant alignment, the proportions of patients with an optimal femorotibial angle (6°±3° valgus) and tibial component angle (0°±3° varus) were evaluated.

Results

On the preoperative tibial AP radiograph, the tibial anatomical axis crossed 53%±4% of the distance between the medial and lat-

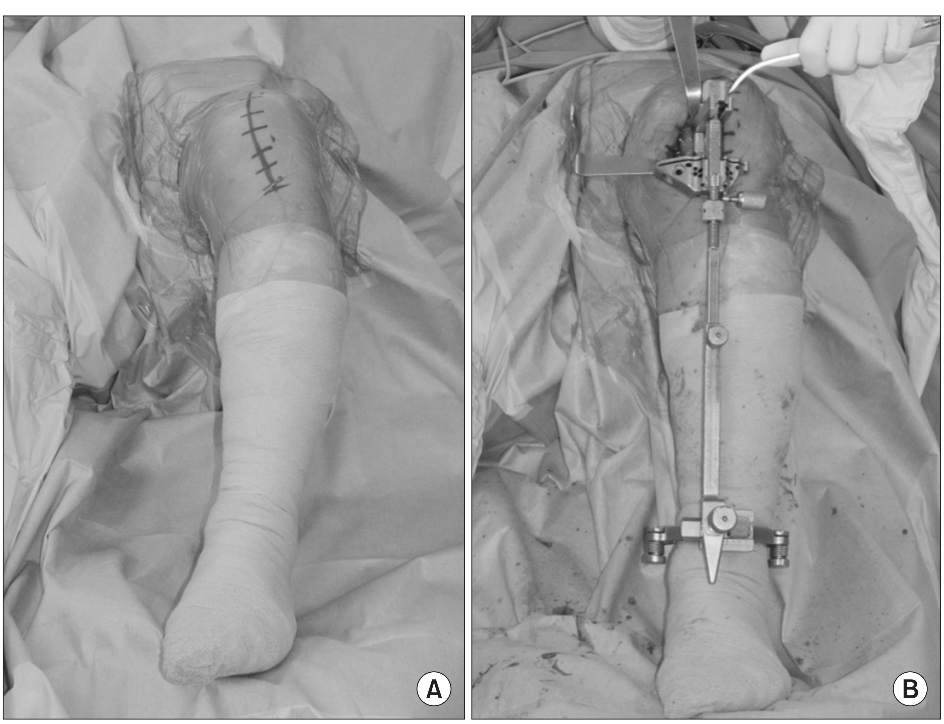

Fig. 2. (A) Preoperative draping using Coban and Ioban. (B) Positioning of an extramedullary guide for tibial cutting. The extramedullary rod was fixed from the medial tibial spine proximally to the ankle joint distally regardless of the presence of tibial bowing and shape.

Table 2. Postoperative Data

Demographic	Value
Operation time (min)	76.2±10.7
Total blood loss (mL)	694.6±276.4
Skin incision (cm)	8.6±0.8
Radiological data (°)	
Femorotibial angle (valgus)	5.5±1.6
Femorotibial angle in 6°±3° valgus	97
Tibial component angle in 0°±3° varus	97
Tibial component posterior inclination	2.5±1.4

Values are presented as mean±standard deviation or percentage.

eral sites (b/a) in the tibial plateau on average. In the ankle joint, it crossed 50%±4% of the distance between the medial malleolus and the lateral malleolus including the skin thickness (e/d) on average.

The medial cortical line passed the average point of 42%±4% of the distance between the medial and lateral sites (c/a) in the tibial plateau. In the joint ankle, it passed 40.4%±0.8% of the distance between the medial malleolus and the lateral malleolus including the skin thickness (f/d) on average.

No intraoperative complications occurred and the operation time averaged 76.2±10.7 minutes (range, 60 to 110 minutes). The length of the skin incision was 8.6±0.8 cm (range, 7.2 to 10 cm) and the postoperative blood loss was measured as 694.6±276.4 mL (range, 180 to 1,540 mL) on average.

When tibial cutting was performed with the extramedullary cutting guide aligned to the medial cortical line, the femorotibial angle was 5.5°±1.6° valgus, the tibial component angle was 0.7°±1.4° varus, and the tibial component posterior inclination was 2.5°±1.4° on average. In 97% of the cases, the femorotibial angle was 6°±3° valgus and the tibial component angle was 0°±3° varus (Table 2).

Discussion

In this study, the use of medial cortical line in proximal tibial resection with an extramedullary tibial cutting guide allowed for relatively accurate alignment of the tibial prosthesis.

The use of an extramedullary cutting guide is based on the mechanical axis and anatomical axis for proximal tibial resection. The tibial anatomical axis and tibial mechanical axis are known to be identical. For installation, the guide should be aligned to one of the axes to achieve an accurate implant alignment. The tibial mechanical axis does not pass the center of the ankle joint but does pass the center of the ankle bone located 3 mm medial to the center of the ankle joint[12]. Schneider et al.[12] reported that they were able to achieve good tibial alignment when they positioned an extramedullary rod at the center of the ankle bone. Currently, most operations are performed with the extramedullary cutting guide installed at the center of the ankle bone. Typically, the mechanical axis is known to cross the tibial plateau at the center of the medial and lateral tibial spine. However, this site varies for individuals. Furthermore, in the case of a severe varus deformity or bowing deformity in the medial proximal tibia, it is difficult to accurately identify the point the mechanical axis crosses in the tibial plateau since the anatomical axis and mechanical axis are not identical. A number of anatomical indicators have been introduced to locate the mechanical axis during an operation, including the tibialis anterior tendon, the extensor hallucis longus tendon, the first or second metatarsal bone, the dorsal pedis artery, and the tibial crest[9-15]. However, it generates a huge difference depending on the patient's BMI and gender. In addition, it cannot be used in the case of severe tibial bowing and post-traumatic tibial deformity.

Therefore, aligning the extramedullary cutting guide to the tibial mechanical axis can produce misalignments due to difficulties in locating the mechanical axis during surgery. In contrast, the tibial anatomical axis can be identified with ease on preoperative radiographs. This allows for prediction of the point where the anatomical axis crosses in the tibial plateau and ankle joint. Moreover, in the case of severe bowing, the mechanical axis and anatomical axis are often not identical[16]; therefore, it is more desirable to install the cutting guide based on the anatomical axis to perform a cut perpendicular to the tibial longitudinal axis. Furthermore, one of the reasons navigation- or robot-guided surgery is considered to facilitate more accurate osteotomy is that the anatomical landmark is positioned in the tibial plateau and ankle joint[3]. In the same manner, when using an extramedullary cutting guide, placing an anatomical landmark in the plateau of the tibia where the anatomical axis passes and in the ankle joint is believed to result in a more precise resection since the process is not affected by the anatomical difference of the tibia or the location of the ankle joint[17].

We defined the tibial anatomical axis as a line connecting the point 5 cm distal to the knee joint, the point 5 cm proximal to the ankle joint, and the middle point of the outer cortex which is considered the center of the tibial intramedullary on an AP radiograph of the tibia. We believed that a cut performed perpendicular to this line would help recover proper alignment. However, since the points where the tibial anatomical axis passes the tibial plateau and ankle joint vary from patient to patient, an extramedullary cutting guide should be installed at these points after locating them on a preoperative radiograph.

In this study, the tibial anatomical axis crossed the average point of 53%±4% of the distance between the medial and lateral sites (b/a) in the tibial plateau on the preoperative AP radiograph. This point was located at the center or slightly lateral to the center of the distance between the medial and lateral sites in the plateau. In the case of severe varus deformity or bowing deformity in the medial proximal tibia, the anatomical axis was more likely to pass lateral to the center. In this case, it may be challenging to locate the extramedullary cutting guide in the tibial plateau exactly. In addition, even after locating it, it may be difficult to install it in the anterior tibia exactly if there is an interruption of the patellar tendon or patella due to an insufficient joint incision. In the ankle joint, the anatomical axis crossed the average point of 50%±4% of the distance between the medial malleolus and the lateral malleolus including the skin thickness (e/d). This demonstrates that the anatomical axis crosses a more lateral point than does the mechanical axis, which is known to be 3–5 mm medial to the ankle joint.

The medial cortical line, a line that runs parallel to the anatomical axis and crosses the medial tibial spine, passed the average point of 42%±4% of the distance between the medial and lateral sites (c/a) in the tibial plateau. Since this point is more medial to the point where the anatomical axis passes, it is less interrupted by the patella or patellar tendon, thereby facilitating easy installation of the cutting guide in the anterior tibia. The medial tibial spine, the proximal fixation point for the cutting guide, is the part where the concave medial tibial plateau is translated, which is easily identifiable in the anatomical context. In the case of severe varus deformity or bowing deformity in the medial proximal tibia, the medial cortical line could be more easily applied. Since the extramedullary rod and pegs were moved to the medial side, there were no concerns of rotational alignment such as posterolateral cutting of the tibia.

In addition, since it is where an incision is made to the anterior cruciate ligament, a peg does not slide to the medial side, allowing for easy fixation. In the joint ankle, the medial cortical line passed the average point of 40.4%±0.8% of the distance between the medial malleolus and the lateral malleolus including the skin thickness (f/d) in a relatively consistent manner. It was relatively easy to fix the extramedullary alignment rod at this point. Using this technique, we were able to achieve a femorotibial angle of 5.5°±1.6° valgus, a tibial component angle of 0.7°±1.4° varus, and a tibial component posterior inclination of 2.5°±1.4° on average.

In previous papers, knees with more than 3 degrees of deviation from the normal alignment on the coronal plane accounted for 10.2% when using navigation and 28.2% when using the conventional technique[3]. In this study, 97% showed 6°±3° valgus for the femorotibial angle whereas 97% had 0°±3° varus for the tibial component angle, which are considered satisfactory compared to the previous reports.

There are some limitations of this study. This was a retrospective study and there were no comparative group. However, our results demonstrated several advantages of the use of the medial cortical line for proximal tibial resection. The method allows for easy location and fixation of an extramedullary cutting guide, as the guide is installed based on the medial cortical line that runs parallel to the anatomical axis rather than the mechanical axis. It means we can easily fix the extramedullary rod from the medial tibial spine proximally to the ankle joint distally regardless of tibial bowing and shape.

Also, the installation of the guide at the proximal site takes place in the medial tibial spine. In addition, the medial cortical line crosses at a relatively consistent point, 40% of the distance from the medial malleolus to the lateral malleolus including the skin thickness, facilitating easy placement of the cutting guide at the relevant area. Moreover, this technique resulted in relatively satisfactory results with regard to postoperative component alignment.

Conclusions

The use of medial cortical line in proximal tibial resection with an extramedullary tibial cutting guide allowed for relatively accurate alignment of the tibial prosthesis.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

References

1. Ritter MA, Faris PM, Keating EM, Meding JB. Postoperative alignment of total knee replacement. Its effect on survival. Clin Orthop Relat Res. 1994;(299):153-6.
2. Matsuda S, Miura H, Nagamine R, Urabe K, Hirata G, Iwamoto Y. Effect of femoral and tibial component position on patellar tracking following total knee arthroplasty: 10-year follow-up of Miller-Galante I knees. Am J Knee Surg. 2001;

14:152-6.
3. Liau JJ, Cheng CK, Huang CH, Lo WH. The effect of malalignment on stresses in polyethylene component of total knee prostheses: a finite element analysis. Clin Biomech (Bristol, Avon). 2002;17:140-6.
4. D'Lima DD, Chen PC, Colwell CW Jr. Polyethylene contact stresses, articular congruity, and knee alignment. Clin Orthop Relat Res. 2001;(392):232-8.
5. Werner FW, Ayers DC, Maletsky LP, Rullkoetter PJ. The effect of valgus/varus malalignment on load distribution in total knee replacements. J Biomech. 2005;38:349-55.
6. Jeffery RS, Morris RW, Denham RA. Coronal alignment after total knee replacement. J Bone Joint Surg Br. 1991;73:709-14.
7. Hernandez-Vaquero D, Suarez-Vazquez A, Iglesias-Fernandez S. Can computer assistance improve the clinical and functional scores in total knee arthroplasty? Clin Orthop Relat Res. 2011;469:3436-42.
8. Fang DM, Ritter MA, Davis KE. Coronal alignment in total knee arthroplasty: just how important is it? J Arthroplasty. 2009;24(6 Suppl):39-43.
9. Tsukeoka T, Lee TH, Tsuneizumi Y, Suzuki M. The tibial crest as a practical useful landmark in total knee arthroplasty. Knee. 2014;21:283-9.
10. Akagi M, Asada S, Mori S, Matsushita T, Hashimoto K, Hamanishi C. Estimation of frontal alignment error of the extramedullary tibial guide on the bi-malleolar technique: a simulation study with magnetic resonance imaging. Knee. 2012;19:836-42.
11. Rajadhyaksha AD, Mehta H, Zelicof SB. Use of tibialis anterior tendon as distal landmark for extramedullary tibial alignment in total knee arthroplasty: an anatomical study. Am J Orthop (Belle Mead NJ). 2009;38:E68-70.
12. Schneider M, Heisel C, Aldinger PR, Breusch SJ. Use of palpable tendons for extramedullary tibial alignment in total knee arthroplasty. J Arthroplasty. 2007;22:219-26.
13. Tew M, Waugh W. Tibiofemoral alignment and the results of knee replacement. J Bone Joint Surg Br. 1985;67:551-6.
14. Sugimura N, Ikeuchi M, Izumi M, Aso K, Ushida T, Tani T. The dorsal pedis artery as a new distal landmark for extramedullary tibial alignment in total knee arthroplasty. Knee Surg Sports Traumatol Arthrosc. 2014;22:2618-22.
15. Fukagawa S, Matsuda S, Mitsuyasu H, Miura H, Okazaki K, Tashiro Y, Iwamoto Y. Anterior border of the tibia as a landmark for extramedullary alignment guide in total knee arthroplasty for varus knees. J Orthop Res. 2011;29:919-24.
16. Maestro A, Harwin SF, Sandoval MG, Vaquero DH, Murcia A. Influence of intramedullary versus extramedullary alignment guides on final total knee arthroplasty component position: a radiographic analysis. J Arthroplasty. 1998;13:552-8.
17. Teter KE, Bregman D, Colwell CW Jr. Accuracy of intramedullary versus extramedullary tibial alignment cutting systems in total knee arthroplasty. Clin Orthop Relat Res. 1995;(321):106-10.