Journal of Clinical Orthopaedics and Trauma 10 (2019) 87–90

Contents lists available at ScienceDirect

Journal of Clinical Orthopaedics and Trauma

journal homepage: www.elsevier.com/locate/jcot

Original article

Accuracy of medial-side cutting guide compared to anterior cutting guide in distal femoral osteotomy of total knee arthroplasty

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ARTICLE INFO

Article history:
Received 24 June 2017
Received in revised form 19 August 2017
Accepted 24 August 2017
Available online 26 August 2017

Keywords:
Total knee replacement
Minimally invasive surgery
Cutting error
Cutting guide

ABSTRACT

Introduction: Minimally invasive surgery (MIS) in total knee arthroplasty has the benefits of less postoperative pain and a faster recovery time. An MIS instrument was designed to help surgeons perform this procedure under reduced visualization conditions. A medial cutting guide of the distal femur is used to cut the distal femoral bone without patella subluxation. This study aimed to compare the accuracy of the distal femoral bone cut between the medial and standard anterior cutting guides.
Materials and methods: Two orthopedic surgeons, who specialize in total knee arthroplasty and are familiar with both of these cutting guides, performed the procedures. Forty-eight synthetic saw bones were used, and five-degree valgus medial and anterior cutting guides were randomly assigned to the surgeons. After the osteotomies were performed, the synthetic saw bones were investigated via plain radiographs. Two independent radiologists measured the medial distal femoral angle (MDFA) and the posterior distal femoral angle (PDFA).
Results: The MDFA in the medial cutting group was statistically significantly different from that of the anterior cutting group ($94.18^\circ \pm 1.47^\circ$ vs. $94.98^\circ \pm 1.14^\circ$, $P = 0.041$). However, the PDFA was not different between the two groups. Likewise, the number of outliers was not different between the groups when a $\pm 2^\circ$ error was defined as an outlier ($P = 0.609$ for MDFA and $P = 0.359$ for PDFA). Moreover, a high degree of reliability was found in both MDFA and PDFA measurements (intraclass correlation coefficients = 0.813 and 0.824, respectively).
Conclusions: In this experimental study, the MIS medial cutting guide was less accurate than the standard cutting guide in the distal femoral cut.

1. Introduction

Total knee arthroplasty (TKA) is a well-known operation that can reduce pain and improve the functions of daily activity in patients. The number of TKA operations is increasing every year. By 2030, there will be 3.48 million procedures per year in the United States.[1] Short-term outcomes such as range of motion, postoperative pain, and longevity of the implant are important. Moreover, the proper coronal alignment after TKA is correlated with the longevity of TKA.[2,3]

Minimally invasive surgery (MIS) is increasingly popular because of the reduction of postoperative pain, faster recovery, reduction in the length of hospital stay, and cosmetic reasons.[4–6] However, most surgeons are concerned with the misalignment of TKA components due to the limited exposure associated with the procedure.[7,8] Another factor that is not well recognized, which could lead to the malposition of components, is a special cutting guide made for MIS. A medial cutting guide (Zimmer Biomet, Warsaw, Indiana, USA) is fixed to the medial condyle of the femur, and the surgeon needs to cut the distal lateral condyle from the medial side of the knee (Fig. 1). The distance between the cutting guide and the bone that is longer than the standard anterior cut could lead to a bone cutting error, especially in the coronal plane. Computer-assisted surgery has improved the accuracy of placing the cutting guide on the bony surface, but cutting error is still persistent.[9,10] This could be affected by the bone cutting technique as well as the cutting guide.

We conducted an experimental study to compare the accuracy of the medial cutting guide to the standard anterior cutting guide by simulating bone cutting with synthetic bones.

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http://dx.doi.org/10.1016/j.jcot.2017.08.020
0976-5662/© 2017

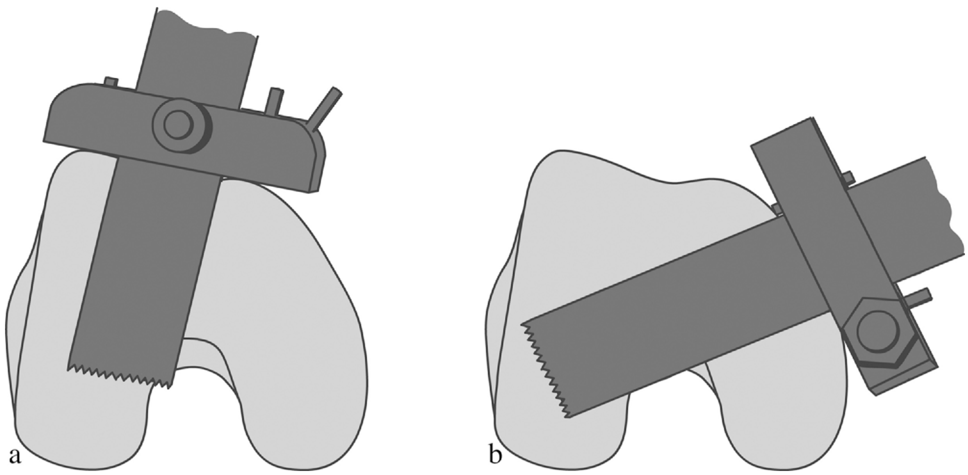

Fig. 1. Anterior cutting guide (a) and medial cutting guide (b).

2. Materials and methods

We conducted experimental studies to compare the accuracy between a medial cutting guide and an anterior cutting guide using synthetic bones (Foam cortical shell #1130-37; Sawbones; Vashon Island, Washington, USA). Synthetic bones were used because we wanted to control confounding factors leading to malalignment such as the geometry of the femoral canal, bone alignment, bone quality, and surgical exposure. Twenty-four synthetic femoral bones were used with an anterior cutting guide and another 24 identical synthetic femoral bones with a medial cutting guide. Both guides were normally used with the NexGen total knee arthroplasty system (Zimmer Bioment, Warsaw, Indiana, USA). The width and thickness of the cutting slot of both guides were 58 mm and 2 mm, respectively. The saw blade (1.27 mm thick, 19 mm wide, and 90 mm long, Synvasive Technology, California, USA) and the electrical saw (Zimmer universal power system, Zimmer surgical, Geneva, Switzerland) were identical in both groups.

Two orthopedic surgeons, who specialize in total knee arthroplasty and are familiar with both types of cutting guides, performed the procedures. A five-degree distal femoral osteotomy guide was used for comparison in this study. In accordance with the surgical manual, both cutting guides were fixed to the bone with 2 headless pins and 1 headed pin. In the case of the anterior cutting guide, 2 headless pins were fixed through the two standard “0” pin holes and 1 headed pin was fixed through an oblique pin hole. In contrast, no oblique holes were involved with the medial cutting guide, so 2 headless pins were fixed through the endmost standard “0” pin holes, and 1headed pin was fixed in the middle of the row. Each surgeon performed 12 distal femoral osteotomies with a medial cutting guide and another 12 with an anterior cutting guide. The medial or the anterior cutting guide was selected based on a computer-generated randomized sequence for each synthetic femoral bone.

After the osteotomies were finished, all of the synthetic bones were sent for plain radiographic studies. The position of the synthetic bones and the radiography technique were controlled in order to reproduce the same exposure, magnification, and rotation for all of the synthetic bones. Using the PACS (Synapse version 2.1.2, Fuji, USA), two radiologists, who specialize in musculoskeletal radiology, measured the angle between the anatomical axis of the femur and the distal femoral osteotomy in both the coronal and sagittal planes independently. The medial distal femoral angle (MDFA) and the posterior distal femoral angle (PDFA) were measured to represent the coronal alignment and the sagittal alignment, respectively. The line connecting the two centers of the femoral width was used as the axis of the femur (Fig. 2). The radiologists were not involved in the bone-cutting procedure and were blinded from the randomized sequence. Each angle was measured two times; the average of each angle measurement was used for analysis. The outliers were defined as $\pm 2^{\circ}$ deviations from 95° for MDFA and 90° for PDFA.[11]

The comparison between the 2 groups was performed using the unpaired Student *t*-test for continuous variables and the Fisher's

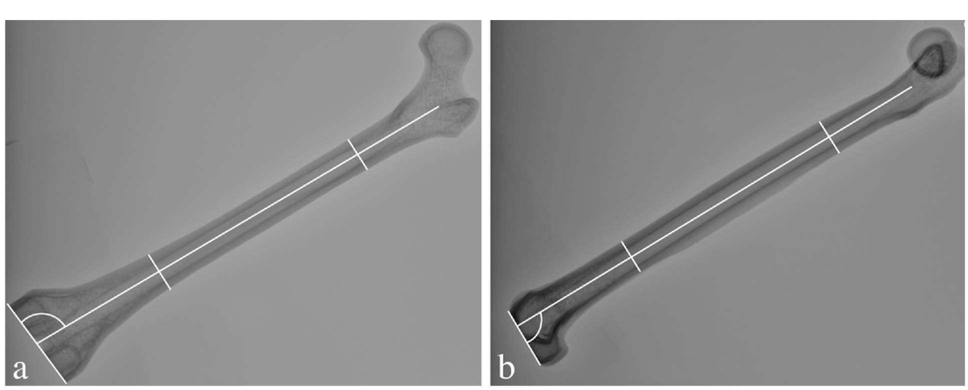

Fig. 2. Plain radiographs of synthetic bone demonstrating the medial distal femoral angle (MDFA) in the anteroposterior view (a) and the posterior distal femoral angle (PDFA) in the lateral view (b).

Table 1
Comparison of MDFA and PDFA from each cutting guide (Mean ± Standard deviation).

	Anterior cutting guide (n = 24)	Medial cutting guide (n = 24)	*P* value
MDFA	94.98° ± 1.14°	94.18° ± 1.47°	0.041*
PDFA	88.13° ± 1.93°	88.66° ± 1.03°	0.240

exact test for categorical variables. The intraclass correlation coefficients (ICC) were calculated to determine inter-observer reliability. The analyses were performed with R version 3.1.0 software (R Foundation for statistical computing, Vienna, Austria), and the statistical significance was set at $P < 0.05$.

3. Results

The MDFA in the medial cutting group was statistically significantly different from that of the anterior cutting group (94.18° ± 1.47° vs. 94.98° ± 1.14°, $P = 0.041$). On the other hand, the PDFA was not different between the two groups (Table 1). Similarly, the number of outliers were not different between the groups (P = 0.609 for MDFA and P = 0.359 for PDFA) (Table 2). Furthermore, a high degree of reliability was found in both MDFA and PDFA measurements (intraclass correlation coefficient = 0.813 and 0.824, respectively).

4. Discussion

The longevity of the prosthesis after total knee arthroplasty depends on the postoperative lower-limb mechanical axis. Most literature recommends the axis should be within 3° from the neutral alignment.[2,12,13] Intraoperative cutting error still occurs even when using precise instrumentation.[13–15] Computer-assisted surgery has improved the accuracy of placing the cutting guide on the bony surface, but cutting errors continue to persist.[9,10] This could be affected by both the bone cutting technique and the cutting guide design.

Minimally invasive surgery (MIS) has the benefits of the reduction of postoperative pain, faster recovery, shorter hospital stays, and better cosmetic outcome.[4–6] The quadriceps muscle is the key muscle in an extensor mechanism. The medial cutting guide was developed to cut the distal femur from the medial side, eliminating the need to evert the patella and requiring less quadriceps retraction. The surgical technique and/or instrumentation that injures the muscle less will result in a better functional outcome.[16,17] Nevertheless, no definitive conclusion regarding the true benefit of the medial cutting guide in terms of functional outcome can be drawn from this study.

Nakahara et al. evaluated the initial distal femoral cut performed with an anterior cutting guide using a navigation system and found that 10 of 20 knees (43%) were cut in valgus.[18] They explained that a valgus distal cut might be due to the hard medial bone deflecting the saw blade and, thus, reducing the amount of bone cutting on the medial side. In the anterior cutting guide group of our study, the mean of MDFA (94.98° ± 1.14°) was close to that of the neutral alignment. This could have resulted from using synthetic bones, which are made of a softer material than the human bone, so there was less saw blade deflection.

Table 2
Comparison of outliers from each cutting guide.

	Anterior cutting guide (n = 24)	Medial cutting guide (n = 24)	*P* value
MDFA	4.17%	12.5%	0.609
PDFA	41.67%	25%	0.359

However, in the medial cutting guide group, the synthetic bones were cut in valgus. This could be explained by the fact that when cutting the lateral condyle from the medial side, the cutting teeth of the saw blade are far away from the cutting guide. This leads to less stability and an increased chance for a toggle and error.

On the other hand, we did not find a significant difference between the two cutting guides in the sagittal alignment. This finding may have been underestimated due to the limitations of the plain radiograph to assess the sagittal alignment of each condyle separately. Comparing the error in the coronal alignment in the medial cutting guide group, we may have found a difference in the sagittal alignment if we had used computer tomography for the evaluation. The sagittal alignment error changes the anteroposterior sizing of the femoral component. Nakahara et al. found that an extension or flexion error of at least 3° can either increase or decrease the size of the femoral component, respectively.[19]

In order to improve the accuracy of bone cutting, we recommend using a thicker saw blade and a thinner slot guide. Otani et al. reported that using a 1.4 mm thick saw blade reduced the mean cutting error to 488 μm compared to 802 μm with a 1.2 mm thick saw blade at the cutting depth of 5 cm[14] Furthermore, increasing the number of fixation pins to the guide will add stability and reduce cutting error.

To our knowledge, this is the first study comparing the different designs of the distal femoral cutting guide. Although an experimental study, it provided us with a controlled situation that could answer this question. However, its major limitation involves generalizability. In a real-life situation, surgical exposure and bone hardness can potentially affect bone cutting.

5. Conclusions

In this experimental study, the MIS medial cutting guide was less accurate than the standard cutting guide in the distal femoral cut. The cutting guide error may be higher than what the authors found in this study when cutting a sclerotic bone with a minimally invasive surgical exposure. When using an MIS medial cutting guide, the surgeon should employ more fixation pins and pay close attention when cutting the lateral femoral condyle in order to minimize cutting errors.

Funding

There was no funding source for this study.

Ethical approval

This article does not contain any studies involving human participants or animals performed by any of the authors.

Conflict of interest

None.

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