A Comparison of Accuracy between Step and Non-Step Reamers of Femoral Intramedullary Alignment System in Total Knee Arthroplasty Evaluated by Computer-Assisted Navigation

Pramook Vanasbodeekul MD*, Thanainit Chotanaphuti MD**,
Piti Rattanaprichavej MD**, Visit Wangwittayakul MD**

** Orthopaedic Surgery Unit, Chao Phraya Abhaibhubejhr Hospital, Prajeenburi, Thailand*
*** Department of Orthopaedics, Phramongkutklao Army Hospital, Bangkok, Thailand*

Limb alignment after total knee replacement has been demonstrated to be one of the most influential in determining long-term survival of the implants. Malalignment can contribute to early prosthesis failure through point loading and premature polyethelene wear. Alignment guides have been developed to improve the accuracy of femoral and tibial cuts during surgery. Recently, there are at least two groups of femoral intramedullary reamer. The first group uses step reamer (8 mm drill with 10 mm step) and another one uses non-step reamer (8 mm drill). The purpose of this cadaveric study was to analyse the accuracy of both design by compared with computer navigation system. Eight cadaveric lower extremities were used for the present study in four cadaveric bodies. The step reamer was applied on the left side and the non-step reamer was applied on the right side of the same cadaver. The distal femoral cuts, using femoral valgus angle 6°, were performed. The resection angles between the cutting surface and the mechanical axis were measured and collected by means of computer navigation system. The results show that the step reamer resulted in 0.125° $\pm$ 0.25° of varus, whereas the non-step reamer resulted in 0.5° $\pm$ 1.08° of varus compared with the calculated mechanical axis by computer-assisted navigation. These data suggest that step reamer has the accuracy more than non-step reamer when evaluated by computer-assisted navigation.

Keywords: *Intramedullary guide, Femoral alignment system, Total knee arthroplasty, Step reamer, Entry point, Computer-assisted navigation*

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Total knee arthroplasty (TKA) has been established as reliable treatment for the osteoarthritis of the knee[1-3]. As many authors[4-9] have shown, the factor with the greatest influence on TKA survival and durability is prosthetic alignment. Malalignment can contribute to early prosthesis failure through point loading and premature polyethelene wear[10]. In the Swedish Knee Arthroplasty Register a satisfactory outcome has been reported in 82% of patients after TKA with aseptic loosening and instability as the most common indications for revision TKA[11,12]. The direct impact of alignment on long-term survival of TKA has resulted in the rapid evolution of many alignment systems including intramedullary and extramedullary system[13]. Focusing on the femoral side, multiple investigations have demonstrated that both intramedullary and extramedullary alignment system are accurate. However, the intramedullary alignment is generally more favorable[14] because the thigh musculature, obesity and surgical drape usually limit the application of extramedullary alignment system.

Inaccuracies with the intramedullary femoral guide arise from both an improperly positioned distal femoral entry site and poor centering of the rod within the canal proximally. Poor centering of the rod can be reduced by uses of longer and larger rod sizes, unfortunately this maybe improper for many patients. Nowadays, we have at least 2 designs, the 8-mm non-step reamers and the step reamers. The step reamers (Fig. 1) are designed to improve centering of the rod within the canal. The first part with 8-mm diameter is proper for entering almost all femoral canals. The step part with 10-mm diameter is used for dilating and accommodating the entry point. Theoretically, the step reamers should be enhancing the accuracy of distal

Correspondence to:
Vanasbodeekul P, Orthopaedic Surgery Unit, Chao Phraya Abhaibhubejhr Hospital, Prajeenburi 25000, Thailand.
Phone: 037-216-145
E-mail: mk096@yahoo.com

femoral cut when compare with the 8-mm non-step reamers. The purpose of this cadaveric study was to compare the accuracy between step (8-mm with 10-mm step reamer) and non-step (8-mm reamer) designs by uses of computer navigation system.

Material and Method

Eight cadaveric lower extremities were used for the present study in 4 cadaveric bodies. For each lower extremity, a standard midline incision and medial parapatellar approach were performed. The femoral intramedullary alignment system was applied on the distal femur to make a distal femoral cut. The non-step reamer was used on the left side and the step reamer was applied on the right side of the same cadaver. The non-step groups used the 8 mm IM reamer to make an entering hole at 1 cm anterior to the origin of PCL and just medial to the center of trochlear groove as conventional technique (Fig. 2). The step groups used the step IM reamer (8-mm drill with 10-mm step) to make an entering hole at 1cm anterior to the origin of PCL and midline of trochlear groove as suggested in manufacturer's surgical technique (Fig. 3). In both groups, the 8-mm IM rod and distal femoral cutting block, using femoral valgus angle 6°, were inserted. Then the distal femoral cut was performed incompletely in order to make a registration later.

Fig. 1 The step IM reamer

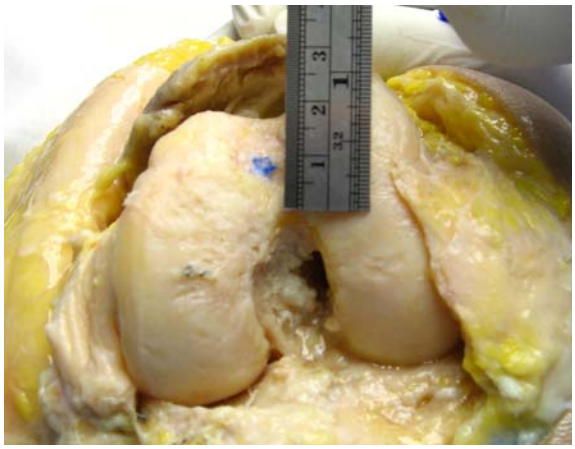

Fig. 2 The entry point of 8-mm non-step reamer

The reference arrays were attached firmly, Y-geometry at the femur and T-geometry at the tibia, by used of Schanz screws and bone fixators. Registration of the lower extremity was then carried out by first determining the center of the femoral head. Then a pointing device was applied to register bony landmarks of the distal femur, proximal tibia and ankle. This allowed the mechanical axis of the femur to be defined. The distal femoral cut was done completely. The resection angle between the cutting surface and the mechanical axis was calculated by used of computer navigation system (DePuy, BrainLAB Knee essential) (Fig. 4 and Fig. 5). The comparison of accuracy was made using a descriptive statistics.

Results

The resection angles between the cutting surface and the mechanical axis was recorded for the step and non-step reamer. The symbol "+" means varus resection angle and the symbol "-" means valgus resection angle. The step group on averaged resulted in 0.17° $\pm$ 0.29° and the non-step group resulted in 1.0° $\pm$ 0.5° compared with the calculated mechanical axis by computer-assisted navigation (Table 1).

Discussion

Axial alignment of the limb with restoration of the mechanical axis is one of many factors that determine the result of total knee arthroplasty. Many studies shown that a mechanical axis within a range of $\pm$ 3° varus/valgus is associated with better outcome[15-19]. A misaligned primary TKA may result in an earlier than expected revision. The use of intramedullary alignment has greatly improved the coronal plane alignment of femoral components and helped to increase the long-term survival of TKA. The accuracy of inserting an IM rod in the isthmus of the medullary canal is an important factor for re-establish the anatomical axis[20]. Nuno-Siebrecht showed that minor deviations in the insertion point of IM guides can result in malalignment of several degrees[21]. This

Table 1. Comparision of the resection angle from step and non-step reamer. ("+" = varus, "-" = valgus)

Cadavers/Reamers	1	2	3	4	Mean ± SD	95% CI
Step	0°	+ 0.5°	0°	0°	0.125° ± 0.25°	- 0.273°-0.523°
Non-step	+ 1°	+ 0.5°	+ 1.5°	- 1°	0.5° ± 1.08°	- 1.219°-2.219°

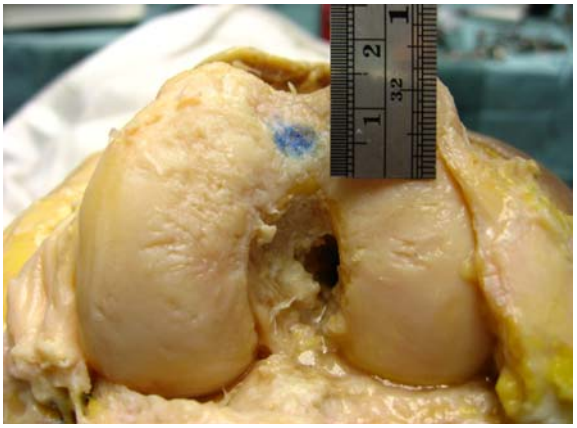

Fig. 3 The entry point of step reamer

Fig. 4 Measuring of resection angles by computer-assisted navigation

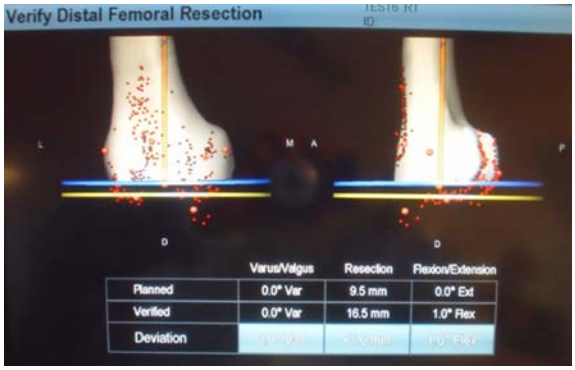

Fig. 5 Depuy, BrainLAB knee essential

error can be minimized by careful attention to the entry point of the IM instrumentation or by increasing the IM rod diameter and length.

Focusing on the effect of the position of the entry point. In coronal plane, Kapandji demonstrated the entry point as being in the center of the femoral notch[22]. However, Moreland noted that the anatomical axis intersects the distal femoral articular surface medial to the notch[23]. Reed and Gollish demonstrated that the entry point is as individual as the patients, with an average location 6.6 mm medial to the center of the notch. Lateral or medial insertion more than this location can produce valgus or varus malalignment respectively[24]. Yongsak Wangroongsub recommend the proper entry point at the distal femur should be 1.5 ± 2.01 mm medial and 12 ± 2.72 mm superior to the top of the femoral intercondylar notch[25]. Harding recommend using a femoral valgus angle of 5° with a hole anterior to the intercondylar notch and 7° with an anteromedial hole[26]. In sagital plane, Mihalko found that entry point deviation of just 5 mm anteriorly or posteriorly to the standard starting point (10 mm anterior to the origin of PCL) may result in a significant change in alignment of the femoral mechanical axis and a significant amount of flexion or extension when compared with computer-defined calculation and CT scan data[13].

Focusing on the effect of IM rod diameter and length. Bertin calculated potential proximal canal error using radiographic measurements and a mathematical calculation of rod deviation within canal[20]. With an 8-mm-diameter, 4-inch rod, the maximum error was 8.65°, whereas with a 10-mm x 12-inch rod this could be reduced to only 0.76°. This showed that poor centering of the rod can be reduced by uses of longer and larger rod sizes, unfortunately this maybe improper for many patients. In Bertin's series, the 10-mm rod would fit only 40% of measured subjects, whereas the 8-mm rod would be accommodated by 91%[20]. This means that the authors cannot use the 10-

mm rod practically even though it has more accuracy. Step reamers are designed to solve this problem, but there are few evidences to support this advantages. So, the authors designed the present study to compare the accuracy between step and non-step reamers by uses of computer-assisted navigation for evaluation.

The results of the present study show that using step reamer gives a better resection of distal femoral cut compared with non-step reamer. These mean that the step reamer is more accuracy than non-step reamer. However, mean $\pm$ SD and 95% CI of both groups were within a range of $\pm$ 3° varus/valgus compare with mechanical axis. Therefore, the authors can use either step or non-step intramedullary femoral alignment but with careful attention to the entry point of the reamer.

The limitations of the present study is that there are small numbers of population. So, the authors can uses only descriptive statistics to analyze the results.

Potential conflicts of interest

None.

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การเปรียบเทียบความแม่นยำระหว่าง step กับ non-step reamer ของ femoral intramedullary alignment system ในการผ่าตัดเปลี่ยนข้อเข่าเทียมโดยประเมินด้วยเครื่องช่วยผ่าตัดระบบนำวิถีด้วยคอมพิวเตอร์

ประมุข วนัสบดีกุล, ธไนนิธย์ โชตนภูติ, ปิติ รัตนปรีชาเวช, วิสิทธิ์ วังวิทยากุล

ในการผ่าตัดเปลี่ยนข้อเข่าเทียม (total knee arthroplasty, TKA) เราพบว่าแนวของกระดูกขาภายหลังผ่าตัดเปลี่ยนข้อเข่าเทียม มีความสำคัญอย่างมากต่ออายุการใช้งานของข้อเข่าเทียม การที่ขาผิดแนวทำให้เกิด early prosthesis failure จากแรงที่มากระทำมากเกินไปจน polyethylene สึกกร่อนเร็วกว่าปรกติ เครื่องมือในการผ่าตัดจึงต้องพัฒนาเพื่อให้การตัดกระดูก tibia และกระดูก femur มีความแม่นยำมากขึ้นในปัจจุบันมี femoral intramedullary alignment system อย่างน้อยสองแบบ แบบแรกใช้ step reamer (หัวเจาะขนาด 8 มม. และมีส่วนขยายขึ้นมาอีกเป็น 10 มม.) กลุ่มที่สองใช้ non-step reamer (หัวเจาะขนาด 8 มม.) วัตถุประสงค์ของการศึกษานี้คือต้องการวิเคราะห์ความแม่นยำของเครื่องมือทั้งสองแบบ โดยเปรียบเทียบกับเครื่องช่วยผ่าตัดระบบนำวิถีด้วยคอมพิวเตอร์ (computer-assisted navigation)

การศึกษานี้ใช้เข่าแปดข้างจากร่างของผู้บริจาคสี่ร่าง กลุ่ม step reamer จะใช้กับเข่าข้างขวา และกลุ่ม non-step reamer จะใช้กับเข่าข้างซ้ายทำการตัด distal femoral โดยตั้ง femoral valgus angle 6^{o} จากนั้นวัด resection angles คือมุมระหว่างรอยตัดกับ mechanical axis โดยใช้เครื่องช่วยผ่าตัดระบบนำวิถีด้วยคอมพิวเตอร์ ผลการวิจัยพบว่ากลุ่ม step reamer มี resection angle เท่ากับ $0.125^{o} \pm 0.25^{o}$ ขณะที่กลุ่ม non-step reamer ได้ resection angle เท่ากับ $0.5^{o} \pm 1.08^{o}$ จากข้อมูลแสดงให้เห็นว่ากลุ่ม step reamer มีความแม่นยำมากกว่ากลุ่ม non-step reamer