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Review Article

Imageless Computer Navigation in Total Knee Arthroplasty—The Pitfalls
無影像計算機導航系统在全膝關節置換術的困難和風險

Chiu Kwok-Hing*, Cheung Kin-Wing, Chung Kwong-Yin

Department of Orthopaedics & Traumatology, Prince of Wales Hospital, The Chinese University of Hong Kong, Shatin, Hong Kong

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A B S T R A C T

Correct implant positioning and mechanical alignment are crucial for long-term survival of the total knee prosthesis. Imageless navigation can improve the femoral and tibial component position in the sagittal and coronal planes, as well as the overall lower limb mechanical axis. However, there are pitfalls related to the imageless computer navigation systems in total knee arthroplasty. We need to know these pitfalls and weight against the benefits of this new technology.

中 文 摘 要

正確假體位置和正確機械列線為全膝關節置換長期生存的關鍵。無影像導航可改善股骨假體和脛骨假體組在前面和側面的位置，以及更準確的整體機械軸線。然而，無影像計算機導航系统在全膝關節置換也有存在困難和風險。我們需要知道這些困難和風險才去衡量這種新技術的好處。

Optimal positioning and alignment of the prosthetic components is crucial for the best long-term results in total knee arthroplasty. Mechanical alignment greater than 3° in the frontal plane is associated with component loosening.[1,2] Computer navigation decreases the risk of mechanical malalignment at critical thresholds of more than 3°.[3–6] Conventional instrumentation may be difficult in patients with bony deformity and retained hardware (Figure 1).[7]

The development of computer navigation in total knee arthroplasty has been rapid in the last decade. The more popular imageless computer navigation system does not require preoperative or intraoperative imaging. The imageless system provides equal good results in frontal and sagittal planes but less irradiation and less expensive comparing with the image-based systems.[8] It either uses passive reflective trackers or active infrared trackers for signal transmission. The line-of-sight issue may be a problem in the overcrowded operating theatre. Although more and more total knee arthroplasties are being done with the aid of computer navigation, the history is still relatively short. There are pitfalls that we need to consider before its clinical use.

The surgeons who are going to start with imageless computer navigation in total knee arthroplasty must be familiar with the conventional method. The computer may break down during the course of the operation either because of hardware or software problems. If this happens, the surgeons will need to proceed the operation with the conventional instrumentation.

The set-up of imageless computer navigation is expensive. If the improvement in the postoperative alignment can prolong the survivorship and therefore reduce the revision rate of total knee arthroplasty, it may be worthwhile to develop this technology in terms of economic consideration. However, we cannot assume that imageless computer navigation can improve the results in an inexperienced or occasional total knee arthroplasty surgeon. Yau et al[9] had proved that the accuracy of postoperative overall limb alignment, femoral component alignment, and tibial component alignment were not improved by imageless computer navigation in low volume total knee arthroplasty practice. Moreover, we may need a large volume of cases to have a significant saving to compensate for the cost of imageless computer navigation. Slover et al[10] in 2008 performed a study to examine the impact of hospital volume of total knee arthroplasty on the cost-effectiveness of imageless computer navigation. It was found that imageless computer navigation became less cost-effective as the annual hospital volume decreased. Hospitals with annual volume of 250, 150, and 25 computer-navigated total knee arthroplasties would require a reduction of the annual revision rate of 2%, 2.5%, and 13%, respectively to cover the cost of the computer navigation.

Using imageless computer navigation will increase the surgery time in total knee arthroplasty. The extra time is mostly spent in the

* Corresponding author. *E-mail:* khchiu@ort.cuhk.edu.hk.

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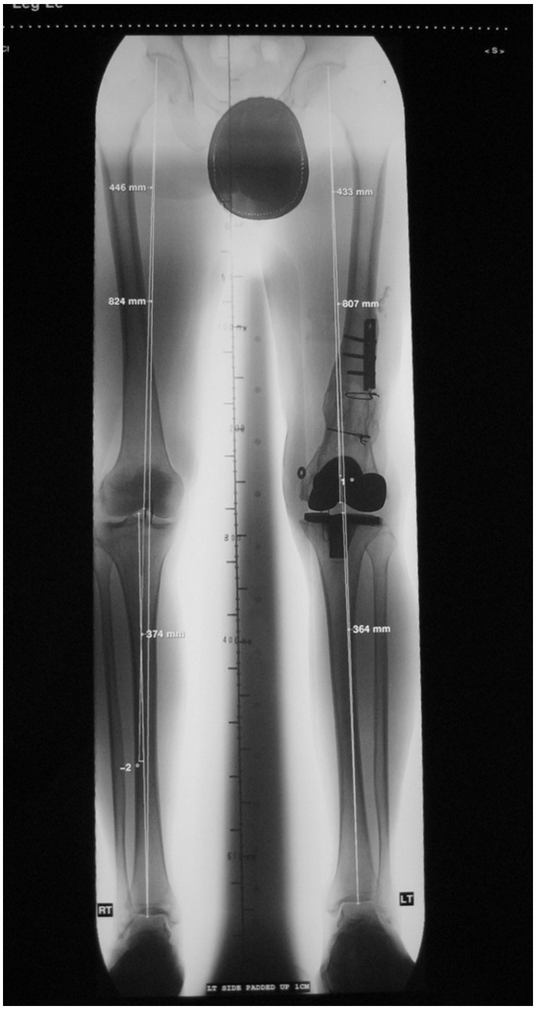

Figure 1. Left total knee arthroplasty using imageless computer navigation technique in a patient with previous fracture of the left femur.

landmarks registration. Although the extra time spent will decrease with learning, the average time increased was 13 minutes in our study.[6] Bauwens et al[4] in a meta-analysis of 33 studies showed an average increase of 17 minutes in the duration of surgery in the computer-navigated group. This extra time spent may be significant in a busy operating theatre.

Although imageless computer navigation can improve the overall lower limb mechanical axis, significant deviation can still occur. Small inaccuracies in different areas can add up together to give a significant error. These inaccuracies can be because of dirty or defective reflectors (Figure 2) and camera, loosening of tracker clamps and pins especially in osteoporotic bone, intraobserver errors in landmarks registration,[11] micromovement of the cutting guide during sawing, bending of saw blade,[12] and errors related to components implantation,[13] rounding up of 0.5° by the computer and general acceptance of 1° error by the surgeon.

The tracker pin site can cause significant complications. Fracture through a tracker pin site, although rare, is a serious complication requiring additional surgery and may result in significant morbidity.[14–17] The fracture rate had been reported to be around 1%.[15] Pin track infection is a more common complication and had been reported to be 3%–4%.[18]

The optimal rotational alignment of the femoral and tibial components in total knee arthroplasty is still a matter of debate.[5]

Figure 2. Defective reflector.

Landmarks that can be used for the femur during imageless computer-navigated total knee arthroplasty include the epicondylar axis, the anteroposterior axis (Whiteside's line), the posterior condylar axis, and the symmetry of flexion gap.[19] For the tibia, landmarks that can be used include axes between the medial 1/3 of tibial tubercle to posterior cruciate ligament attachment, between the medial border of tibial tubercle to posterior cruciate ligament attachment, between the projection of anterior crest to posterior cruciate ligament attachment and between the most medial and most lateral points of the tibial plateau.[20] Whether imageless computer navigation can improve the rotational alignment of the prosthetic components is still controversial. Matziolis et al[5] found that the rotational alignment of the femoral and tibial components was not improved through imageless computer navigation by using the epicondylar axis as a landmark for the femur and the tuberosity for the tibia. Siston et al,[19] in a cadaveric study, compared imageless computer navigation using the epicodylar axis with manual techniques using either the epicodylar axis, the posterior condylar axis, or the anteroposterior axis. There was high variability in the femoral component rotation for all techniques. Imageless computer navigation had no more accurate than the manual techniques in femoral rotation. The same group of authors, in another cadaveric study, found that imageless computer navigation using the various anatomical landmarks was not more reliable

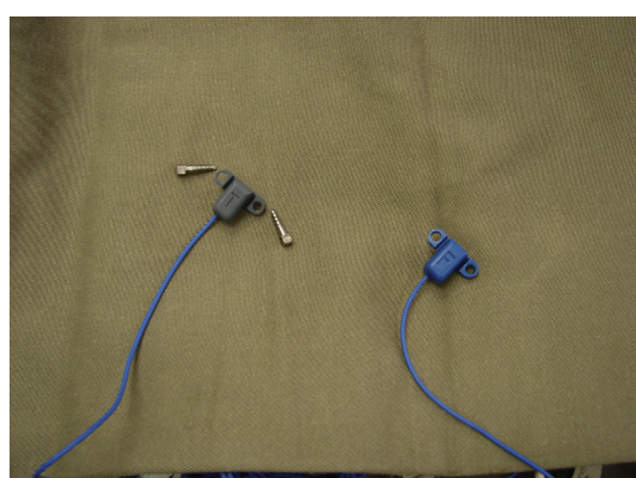

Figure 3. The small trackers used in the electromagnetic pulses system.

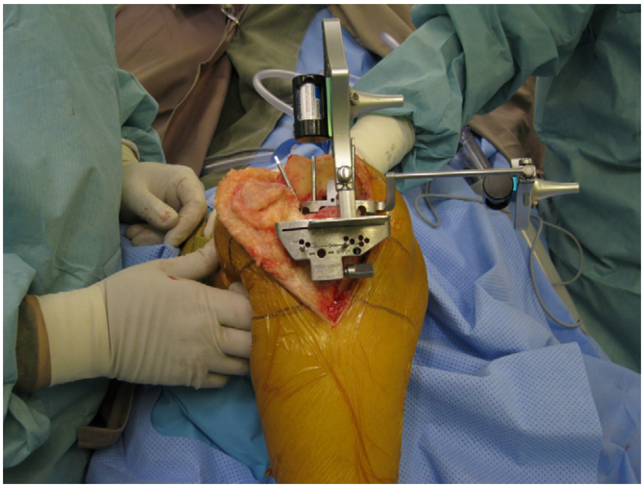

Figure 4. The articular surface mounted trackers used in the OrthoMap Articular Surface Mounted Knee Navigation System.

than the traditional instrumentation in establishing the rotational alignment of the tibial component.[20] However, computed tomography (CT)-based navigation may give a better result than conventional method in the rotational alignment of the components. Mizu-uchi et al[21] compared the CT-based computer navigation system with the conventional method in the component alignment in the three planes. The ideal angles of all alignments in the navigated group were obtained at significantly higher rates than in the conventional group. For the femoral rotation in the CT-based group, 89.3% was within 3° of the ideal angle comparing with 66.7% in the conventional group. For the tibial component in the CT-based group, 78.6% was within 3° of the ideal angle comparing with 46.2% in the conventional group.

Although imageless computer navigation decreases the risk of mechanical malalignment at critical thresholds of more than 3°, there are pitfalls that we need to consider before its clinical use. The new systems using electromagnetic pulses may give a better reception of signals without line-of-sight issue.[22] It may be good to be used in overcrowded operating theatre but there may be electromagnetic interference in the operating theatre affecting its accuracy.[23] Studies have shown that the infrared navigation system gave more accuracy as comparing with the electromagnetic system.[23,24] The small trackers in the electromagnetic system (Figure 3) and the articular surface mounted trackers (Figure 4) in the OrthoMap Articular Surface Mounted Knee Navigation System (Stryker, NewJ, USA) may decrease the complications related to the trackers.

We must familiarize with the conventional method before going into computer-aided surgery. Sikorski and Blythe[18] concluded that the computer navigation has potential pitfalls and it is not fail-safe. Surgeons must be aware of the assumptions, the default options, and settings built into the system. They need to be very wary about software upgrades and the fact that it looks good does not mean it will work.

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