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STATE-OF-THE-ART

Computer Assisted Total Knee Arthroplasty: Does it Make a Difference?

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ABSTRACT

The longevity of total knee prostheses depends mostly on the correct alignment (frontal, sagittal and axial) of the prosthetic components, soft tissue balancing and restoring the mechanical axis of the lower limb.

The use of computer-assisted navigation allows more accurate and reproducible restoration of mechanical axis and component positioning, better results in patients with extra-articular deformities and it has an important role in surgical training.

Better alignment should lead to an improved functional outcome and an increased long-term survival of the prosthesis. Several studies have proven an improved function in the short and mid-term but we still lack long-term data regarding functional outcome and longevity of the prostheses.

Keywords: computer-assisted, navigation, total knee arthroplasty

INTRODUCTION

Knee osteoarthritis represents a major health issue. The prevalence of symptomatic tibio-femoral osteoarthritis was estimated at 12.1% of the adult population in the US (1). Over half of adults in the US diagnosed with knee osteoarthritis will undergo a total knee replacement. The number of total knee arthroplasties (TKA) performed annually in the US has doubled in the last decade. It has been estimated that 4.2% of the population over fifty years of age in the US currently lives with a total knee replacement (2).

The longevity of total knee prostheses depends mostly on the correct alignment (frontal, sagittal and axial) of the prosthetic components, soft tissue balancing and restoring the mechanical axis of the lower limb.

It has been shown (3) that without proper planning (the so-called "conventional navigation") patient specific cutting blocks or computer navigation, the frontal alignment will be deviated more then ± 3° from the neutral mechanical axis in 20% to 30% of the cases. In only 75% of conventional total knee replacements (even if they were performed by experienced surgeons) is the restoration of mechanical axis ideal.

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Misalignment of a total knee replacement can lead to early loosening, accelerated polyethylene wear and instability.

The importance of frontal alignment has been questioned in another study (4), where the authors could not find any difference in the 15-year survival between the frontal well-aligned knees (within ± 3° of ideal) and outliers (more than 3° of deviation).

It is important to plan the femur size in the sagittal plane to restore the posterior offset. A pathologic tibial slope should be corrected and the planned postoperative slope depends mainly on the type of implant and constraint used (3).

Axial plane deformities are encountered frequently. It has been observed that most patients (especially women) with patello-femoral arthritis have a torsional tibial and/or femoral deformity (5). Insufficient correction of torsional deformity can lead to anterior knee pain and early loosening.

The daily life activities evaluated with The Western Ontario and McMaster Universities Arthritis Index (WOMAC) and the 12-Item Short Form Health Survey (SF-12) are significantly affected if the misalignment is more than 3° (6).

Computer Aided Orthopedic Surgery (CAOS) includes all the techniques utilized to improve visibility of the surgical field and provide better accuracy using robots or navigation systems. Surgical navigation systems are an attractive option in knee surgery improving the accuracy of the operations without the drawbacks and costs of robots.

Navigation systems are offering information in real time concerning the positioning of the surgical instruments in relation to a virtual representation of the surgical object (the anatomy operated on).

The most basic component is the navigation computer on which the system relies for coordination of received data, mathematical interpretation and display of the resultant information on a monitor. The other required components are the tracking system and the dynamic reference bases that constitute the target objects of the navigation. The target objects include the patient's local anatomic structures, the surgical instruments and the implants (7).

The surgical navigation models used in computer assisted orthopedic surgery are:

1. Preoperative image-based (CT scans);
2. Intraoperative image-based (fluoroscopy);
3. Image-free (based on anatomic landmarks registered intra-operatively);
4. Individual templating.

The image-free systems based on kinematic models to determine joints centers and on the acquisition of anatomic landmarks are the most frequent methods used to perform navigated knee surgery.

In 1991 Dr. Stephan Lavallée from Grenoble University establishes a navigation system for anterior cruciate ligamentoplasty. Prof. Dominique Saragaglia introduced the first kinematic navigation protocol to determine hip and knee rotation centers, opening the way for image-free navigation systems.

The first navigated total knee replacement was performed at Grenoble in January 1997 by Prof. Saragaglia and Dr. Picard. They utilized an image-free navigation system, which used a kinematic model to determine hip center (axial rotation of the femur using Kienzle principle), knee center (flexion-extension and axial rotation of the knee in 90° of flexion) and ankle center (flexion-extension and inversion-eversion of the foot). The system was improved by adding the acquisition of anatomic landmarks from the knee and ankle.

FIGURE 1. The navigation computer and camera of the OrthoPilot system.

FIGURE 2. Determining hip rotation center during a total knee arthroplasty.

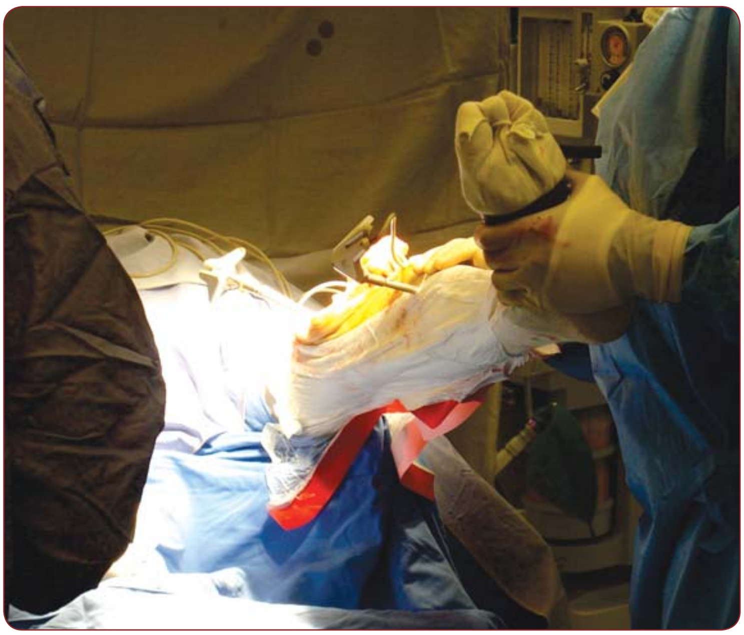

FIGURE 3. Determining hip rotation center during a total knee arthroplasty.

The computer assisted orthopedic surgery is not error-free. The trackers must be well fixed to the bone, any mobilization leading to errors in the acquisition of data. All the osteotomies must be checked as the saw blade can deviate because of sclerotic bone. The acquisition of anatomic landmarks by palpation is surgeon-dependent and not very reproducible.

The use of a navigation system for total knee replacements enjoys an increasing popularity. There are significant differences in the adoption level between regions and countries. In 2008 11.1% of total knee replacements in Australia were realized using a navigation system compared to 2% in the UK (data from the national arthroplasty registers) (8).

Comparison between conventional and navigated total knee replacement

There are a lot of studies comparing the results of conventional versus navigated total knee replacement.

Several studies (9, 10) found an improvement in the functional outcome (evaluated by the Oxford Knee Score, Knee Society Score, WOMAC) in the navigated compared to conventional total knee replacement.

Other studies (11, 12) did not find a significant difference regarding the functional results between the two groups (navigated and conventional TKA):

Most studies (10, 12-15) found a significant improvement in the navigated group, with fewer outliers in several alignment parameters (restoration of mechanical axis, coronal and sagittal alignment). Other studies only found an improvement in coronal alignment of the femoral component (11) or coronal tibial alignment (16). The improvement in accuracy given by computer navigation can be minimized by positioning errors during implantation of the final prosthesis, particularly in the tibia (17).

No significant improvement in the alignment parameters was found in other studies (18,19).

Bauwens et al (20) in a meta-analysis of 33 studies comparing navigated with conventional TKA (including 11 randomized controlled trials) did not find a significant benefit in terms of alignment in the navigated TKA when compared with conventional techniques. Mason et al (21) also in 2007, published a meta-analysis of alignment outcomes in navigated TKA citing 29 studies (including 9 randomized controlled trials), included in the meta-analysis of Bauwens et al. Mason et al reached the conclusion that a significant improvement in component orientation and restoration of the mechanical axis was obtained with navigation in comparison with the conventional technique. In their paper, Mason et al noted that they believe the differences in conclusions are due to analytic error in Bauwens et al study. Other meta-analysis (22) of the English literature published in 2011 and including 23 studies concluded that imageless navigation improves component orientation and postoperative limb alignment. Two recent meta-analyses (23,24) reached the same conclusion: computer assisted navigation improves the restoration of mechanical leg axis and component orientation. The only exception, in one of the meta-analysis (24), is the tibial sagittal alignment, where the authors could not prove any improvement with the use of navigation.

It is worth noting the lack of correlation between navigation and radiographic measurements which may question whether plain radiograph are useful to determine the accuracy of navigation achieved alignment in TKA (25).

Regarding the rotation of the components some studies (11,14) found no differences between navigated and conventional TKA, while other study (26) proved a significant improvement in the rotation of components with a significant reduction of outliers.

An incorrect restoration of the joint line affects the ligamentous balance and normal knee kinematics. A recent study (27) concludes that a knee navigation system can support a proper restoration of the joint line. Also there was a significant linear correlation between joint line changes and Oxford scores (increasing joint line changes resulting in poorer outcome scores).

Extra-articular deformities may complicate a TKA using the conventional instrumentation. Computer navigation is a good alternative and it allows a higher degree of accuracy compared to traditional techniques (28).

The operative time may increase (on average between 7.5 minutes and 30 minutes) using a computer-assisted technique for TKA compared to the conventional method. However, the operative time of navigated TKA decreases significantly on the learning curve, as the surgeon accumulates experience with the new method (18,23).

According to a study (29) there is a significant reduction in blood loss following navigated TKA compared to the conventional method. Other study (30) found no significant difference in peri-operative blood loss and an increase in tourniquet time using navigation compared to standard instrumentation.

Complications related to navigation are very rare and consist in pin-track induced fractures (31), superficial infection around the pin sites and osteomyelitis of the proximal tibia (most likely due to thermal necrosis following tracker pin placement) (32).

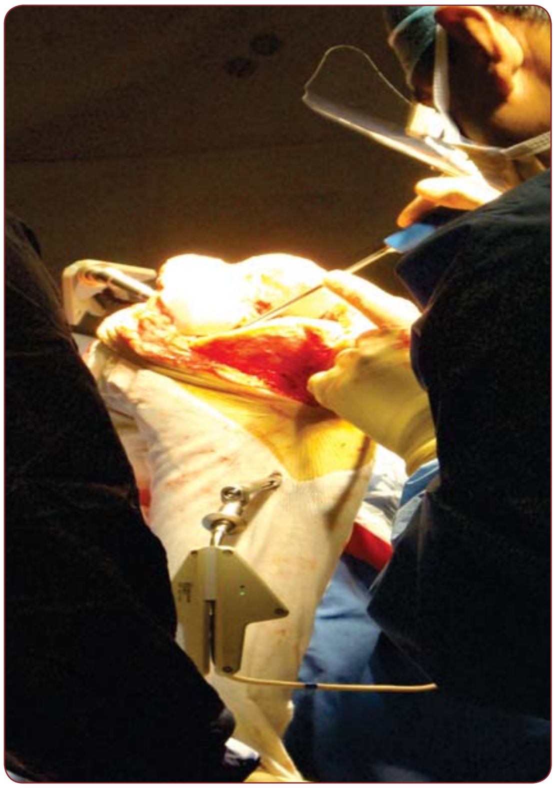

FIGURE 4. Acquisition of anatomic landmarks during a navigated total knee replacement.

FIGURE 5. Acquisition of anatomic landmarks during a navigated total knee replacement.

Computer navigated total knee arthroplasty may play an important training role. Providing real-time feedback it allows trainee surgeons to better place components and to improve visual/spatial awareness (33). Computer navigation permits residents and surgeons new to navigation to achieve similar results in terms of alignment compared to experienced consultants (34). ❑

CONCLUSIONS

It is generally accepted that the use of computer-assisted navigation allows more accurate and reproducible restoration of mechanical axis and component positioning when compared with conventional technique.

Other advantages of navigation in TKA include: improved restoration of the joint line, a reduction in peri-operative blood loss, better results in patients with extra-articular deformities and it has an important role in surgical training. Disadvantages include a longer operative time and increased cost. Complications associated with navigation technique are rare and mostly related to pin tracks.

Better alignment should lead to an improved functional outcome and an increased long-term survival of the prosthesis. As noted before, several studies have proven an improved function in the short and mid-term, while others found no significant differences. We still lack long-term data regarding functional outcome and longevity of the prostheses.

In Romania the TKA has been, in most of the cases, performed using the conventional instrumentation. We don't have enough recorded computer-assisted TKA to make a comparison of results. According to the Romanian Arthroplasty Register the number of revision TKA performed during the 2003-2010 period is too small to calculate a statistically relevant survival rate. However, most (51.8%) of the early revisions (1-7 years) were caused by aseptic loosening of the femoral and/or tibial components, polyethylene wear, instability, malimplantation (35). We consider that the implementation of computer-assisted techniques in TKA on a larger scale would be beneficial because the increase precision of implantation using a navigation system should avoid some of these early revisions. The added cost of navigation (equipment, longer operative time) should be offset by the avoidance of some expensive early revisions.

In the future, longer-term follow-up studies, better imaging for evaluating alignment and improved functional outcome evaluation scales should enable us to clearly define the role of navigation in TKA. ❑

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