Implementation of a CT-based navigation system in two-stage reimplantation for infected total knee arthroplasty

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Femorotibial alignment is an important factor affecting patient outcome after total knee arthroplasty (TKA). It was the aim of this study to report our first results using a CT-based navigation system in two-stage revision surgery for infected TKA.

Two patients with chronic deep infection after primary TKA underwent two-stage revision arthroplasty with temporary articulating cement spacers followed by prosthesis re-implantation using a CT-based navigation system. Postoperative radiographs showed accurate alignment of the femoral and tibial components.

CT-based navigation systems offer the opportunity for preoperative planning and accurate intra-operative navigation of cutting blocks. They can be considered of value for primary TKA but even more so for two-stage revision arthroplasty.

INTRODUCTION

Total knee arthroplasty (TKA) has been established as a reliable treatment for pain relief and restoration of joint function in arthritic knees (18). Despite promising results and continuous improvement in surgical technique, some complications in TKA remain challenging. One of the most devastating complications is deep infection with an overall incidence of 1 to 2% (7). Two-stage revision with antibiotic-impregnated cement spacers, intravenous antibiotherapy and delayed reimplantation is considered to be the treatment of choice for deep infection in TKA. In previous studies, infection was found to be eradicated in 90 to 96% of cases based on this concept (2, 3). The currently used protocols for the treatment of infected TKAs are modifications of the two-stage exchange arthroplasty described by Insall *et al* (8).

Correct axial and rotational alignment of the prosthesis at the time of reimplantation is one of the most demanding parts of the operation, because identification of anatomical landmarks is difficult or impossible, due to loss of bone stock. In several studies, rotational alignment was shown to be crucial for patellofemoral mechanics and balancing of flexion and extension gaps, and a significant correlation was found between patient outcome and prosthesis alignment (1). The best way to determine rotation in revision TKA is to identify the medial and lateral epicondyles and to establish the epicondylar axis (4). Another reason for malalignment in revision TKA is incorrect positioning of the intramedullary femoral alignment guide. Teter *et al* (19) analysed radiographs of 201 primary TKAs performed with an intramedullary femoral alignment guide ; they found unsatisfactory alignment in 8.5% of cases.

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The application of computer science to aid in the performance in orthopaedic surgery holds real promise especially for TKA. Navigation systems address the link between image information, accessible anatomy and action of surgical instruments by combining imaging and position sensing technique. Clinical application of navigation in primary TKA systems started in 1998 (17). Overall, these systems can be subdivided into image-based (e.g. CT data) and imageless systems based on kinematic–surface point acquisition of anatomical landmarks.

So far, these new techniques have been evaluated only in a few clinical studies (9, 11). Mielke *et al* (11) reported the radiological results of a prospective evaluation of conventional versus navigation-based (n = 60) implantation of TKA with an imageless navigation system. The navigated group showed superior results compared with the conventional implantation group. Similar results have been reported in other studies, with an optimal femoro-tibial angle (+/- 3° varus/valgus) achieved postoperatively in a larger number of cases in the navigation-based implantation group (11, 17).

Based on these results, the use of navigation systems might be of even greater value in revision arthroplasty. However, no studies are available as yet in the literature investigating the use of navigation systems in revision TKA.

We started using a CT-based navigation system (Vector Vision Knee® - BrainLAB, Munich, Germany) for primary TKA in 2001. Within the first 3 months, 41 patients underwent primary TKA using this system. Following our positive experience with this new system in primary TKA, we decided to evaluate its value in revision arthroplasty.

The aim of this presentation is to report our first experience with a CT-based navigation system in two-stage revision surgery for infected TKA.

CLINICAL PRESENTATION

Case 1 : A 73-year old man was treated with a temporary cement spacer, due to early infection of a primary TKA with *Pseudomonas aeroginosa*. He received oral antibiotics (Ciprofloxacin) for 3 months postoperatively, until blood parameters of inflammation were within normal limits. Sixteen weeks after implantation of the cement-spacer blocks, re-implantation of a prosthesis was performed. At the date of surgery, the knee showed no signs of inflammation, range of motion was reduced to 0-0-40 (ext/flex), and radiographs showed the articulating cement spacer in its original position (fig 1).

Fig. 1. — Case 1, the preoperative radiographs showed the femoral and tibial cement spacers in their original position.

Case 2 : A 64-year-old woman underwent removal of a primary TKA with extensive debridement in May 2001 (7 months after implantation). Because of cardiac complications, re-implantation of the prosthesis was delayed until November 2001. By that time, the cement blocks were loose and broken (fig 2).

Pre-operatively, CT-scans were performed according to the standard protocol (CT-based navigation of primary TKA, Vector Vision Knee® - BrainLAB, Munich, Germany). Scans covered the femoral head, knee and ankle. The software automatically separated between soft-tissue and bone /cement.

The Navigation software (BrainLAB, Vector Vision Knee®, version 1.0 (case 1) and 1.1 (case 2) allowed for preoperative planning on 3D-images or original CT scans. Using this software, precise orientation of the prosthetic components with minimum bone loss and optimal prosthesis alignment to

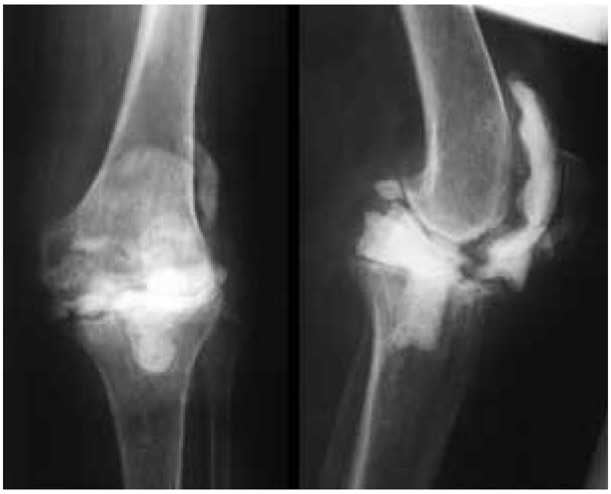

Fig. 2. — Case 2, the preoperative radiographs showed erosions of the lateral condyle and anterior cortex and broken cement spacers (tibial and femoral).

the mechanical limb axis and epicondylar axis was possible (fig 3). Preoperative planning took 35 and 30 minutes respectively for case 1 and 2. This was about 15 minutes longer than for standard planning of a primary TKA. Re-implantations were performed using a standard surgical technique according to the protocol for primary TKA.

In case 1, an additional osteotomy of the tibial tuberosity was necessary prior to prosthesis implantation, due to severe knee contracture. In this case, the articulating cement spacers were found to be in their original position and fixed to the bone. In case 2, the femoral and tibial spacer blocks were broken and loose (fig 2).

Instead of intramedullary reaming, a reference frame was attached to the distal femur and the proximal tibia with bicortical pins. For surface

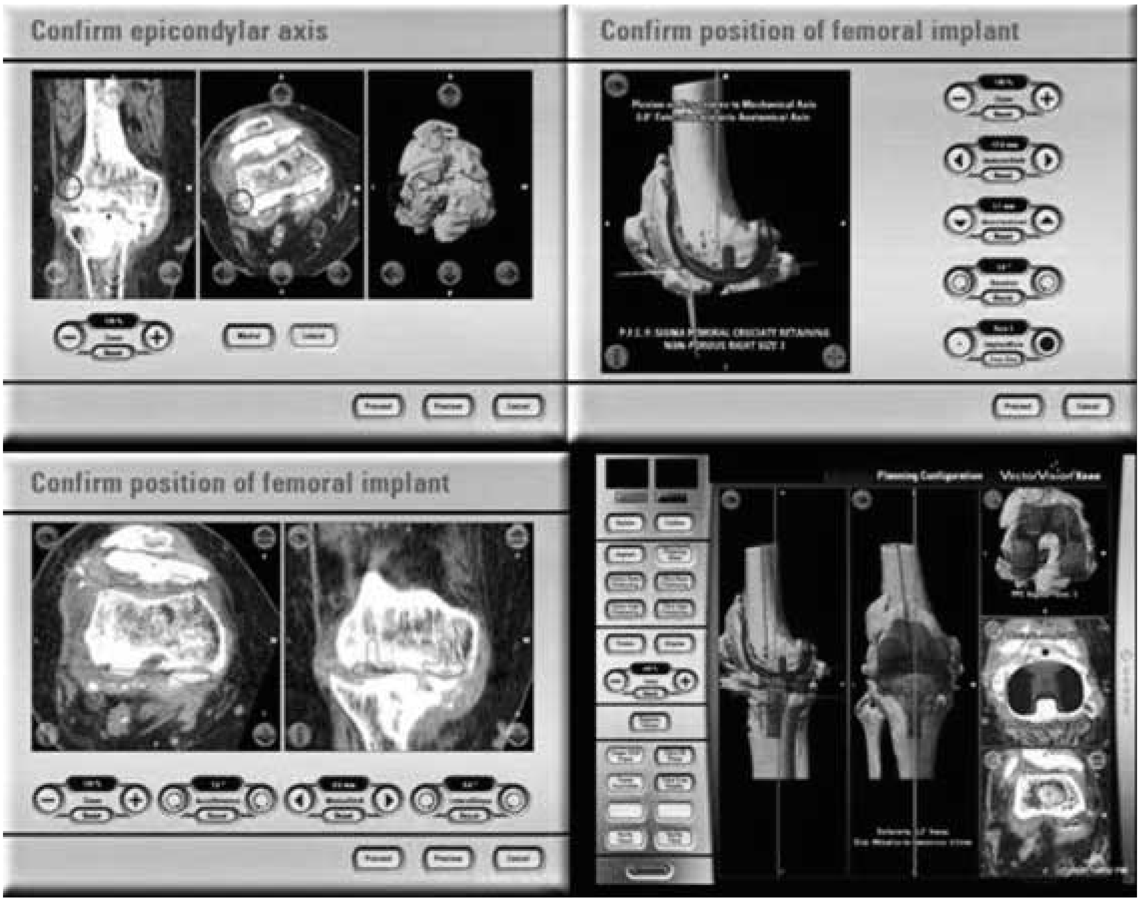

Fig. 3. — Screenshots from the planning procedure (Case 2). Alignment of the femoral component regarding axial rotation and mechanical axis.

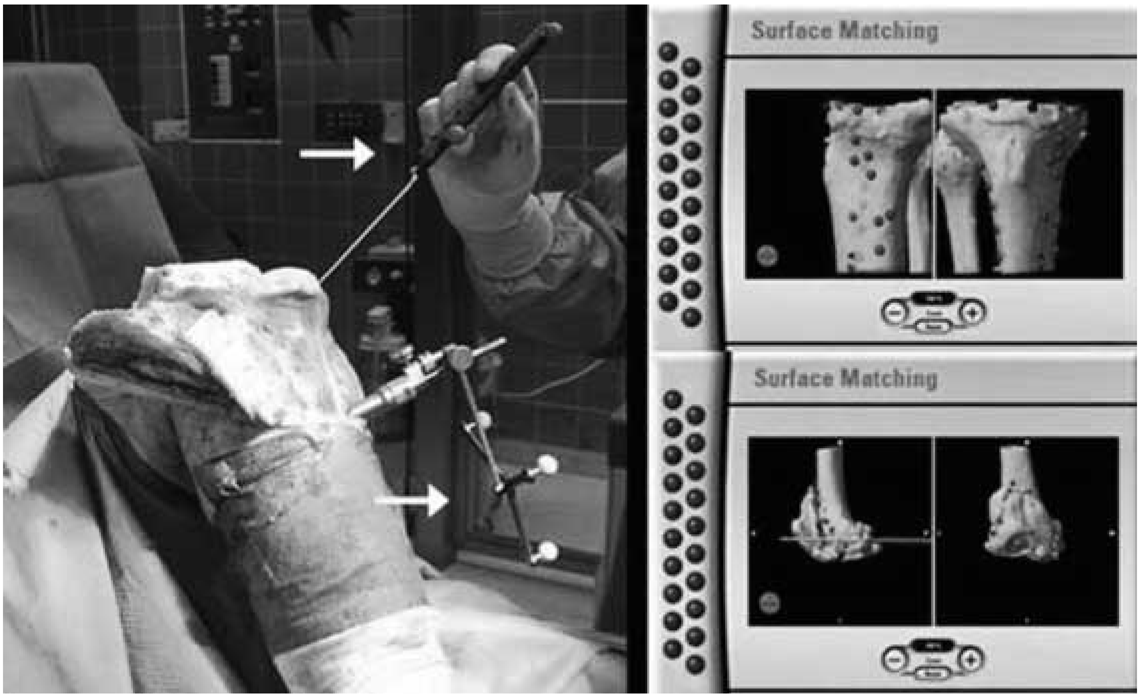

Fig. 4. — Tibia surface matching (case 1) : left - reference clamp attached to the proximal tibia (arrow) ; pointer contact to cement (arrow) ; osteotomy of the tibial tuberosity. Right – screenshot navigation system.

Fig. 5. — Navigation of the distal femoral cutting plane in real time (case 2).

matching, 20 points of free choice were marked on the bone-cement surface of both the femur and tibia (fig 4). Even in the case with the broken spacer blocks, acceptable accuracy was achieved for each surface matching process. The distal femoral cutting block and the four-in-one cutting block were then navigated in real time visualisation (fig 5). The same process was performed for preparation of the proximal tibia.

In both cases, a cemented standard posterior stabilised prosthesis (PFC-Sigma, posterior stabilised with stem extension, DePuy, Warsaw, USA) was implanted. In case 1, the bony insertion of the medial collateral ligament was re-fixed using two cancellous screws. Postoperative radiographs showed correct alignment of the implants and limb axis. In case 1, a 10-mm PE inlay was used, in case 2, a 15-mm insert was necessary to achieve a balanced flexion and extension gap (fig 6).

DISCUSSION

We performed two-stage revision using a CT-based navigation with articulating cement spacers in two cases. Based on published results, debridement, irrigation and component removal with delayed reimplantation appears as the most appropriate treatment of chronically infected TKA and

Fig. 6. — Postoperative radiographs – correct alignment of the implants. Right side : Case 1 – screw fixation of the insertion of the medial collateral ligament. Left side : Case 2.

the most successful method for eradication of infection with success rates ranging from 53 to 100% (7). Single-stage exchange arthroplasty has been successful in single cases or small series (3). Despite the advantage of less surgery and soft tissue damage, as well as maintenance of motion and lower costs, results and patient outcome in one-stage are inferior to those in two-stage exchange arthroplasty (7). In 1987 Borden and Gearen (3) first used antibiotic-impregnated cement beads or a block spacer for two-stage delayed reimplantation. They found a 90% eradication rate. The use of an articulating PMMA spacer is helpful to maintain flexibility of soft tissue during the period of prolonged explantation of components (10).

Accurate restoration of normal limb alignment is crucial for the long-term survivorship of total knee arthroplasty (TKA) (16).

Several studies demonstrated that errors in limb alignment restoration can occur with conventional intramedullary orientation. Petersen and Engh (15) reported the results of 50 primary knee arthroplasties. Twenty six percent (13/50) failed to achieve a satisfactory postoperative limb alignment (+/- 3°). Nuno-Siebrecht *et al* (13) showed that minor deviations in the insertion point of intramedullary instrumentation during TKA can result in malalignment of several degrees.

Exact axial rotational orientation of the femoral implant has been emphasised by Figgie *et al* as an important factor, affecting patient outcome after total knee arthroplasty (5). In primary TKA the posterior condylar line, the epicondylar axis and the Whiteside axis are commonly used for femoral alignment. However, in revision surgery the posterior condyles are not available as references, because of their resection at primary TKA. According to Hoeffel and Rubash (6) determination of the Whiteside line might be even more complicated due to additional bone loss associated with nearly all cases of revision surgery. The surgical epicondylar axis remains available for rotational referencing in most revision cases. It has been shown to highly consistently recreate a balanced flexion space in primary TKA (14). This is supported by the findings of Millers *et al* (12) that alignment parallel to the epicondylar axis resulted in optimal patellofemoral tracking, minmized patellofemoral shear forces and optimized tibiofemoral kinematics.

We have presented two cases of revision TKA using a CT-based navigation system (VectorVision II compact® – BrainLAB). This system offers the opportunity for precise preoperative planning. On the basis of CT data, the 3D visualisation gives detailed information about bone defects and a possible need for additional grafting. The necessary bony cuts can be performed according to an optimised restoration of the limb axis at the bone-cement interface with minimal bone loss, which appears to be more difficult using a conventional technique.

No reports are available about the implementation of navigation systems in revision TKA, especially for re-implantation after articulating cement spacers. In this situation, the necessary kinematic analysis and acquisition of landmarks, required by imageless navigation systems, is impossible. In addition, imageless systems do not offer the opportunity for preoperative planning.

CONCLUSION

To minimise errors in the alignment of TKA components, we recommend the use of a CT-based navigation system in two-stage revision TKA. Beside the preoperative planning option, it allows for exact alignment of the femoral component and accurate rotation of the tibial tray, even if the tibial tuberosity has been mobilised.

REFERENCES

1. **Anouchi YS, Whiteside LA, Kaiser AD, Milliano MT.** The effects of axial rotational alignment of the femoral component on knee stability and patellar tracking in total knee arthroplasty demonstrated on autopsy specimens. *Clin Orthop* 1993 ; 287 : 170-177.
2. **Booth RE, Lotke PA.** The results of spacer block technique in revision of infected total knee arthroplasty. *Clin Orthop* 1989 ; 248 : 57-60.
3. **Borden LS, Gearen PF.** Infected total knee arthroplasty. A protocol for management. *J Arthroplasty* 1987 ; 2 : 27-36.
4. **Brassard MF, Insall JN, Scuderi GR.** Complications or total knee arthroplasty. In : Insall JN, Scott N (eds) : *Surgery of the Knee, Churchill Livingstone, New York, Edinburgh, London, Philadelphia, San Francisco*, 2001 : 1801-1844.
5. **Figgie HE, Goldberg VM, Figgie MP, Inglis AE, Kelly M, Sobel M.** The effect of alignment of the implant on fractures of the patella after condylar total knee arthroplasty. *J Bone Joint Surg* 1989, 71-A : 1031-1039.
6. **Hoeffel DP, Rubash HE.** Revision total knee arthroplasty : current rationale and techniques for femoral component revision. *Clin. Orthop* 2000, 380 : 116-132.
7. **Hofmann AA, Kane KR, Tkach TK, Plaster RL, Camargo MP.** Treatment of infected total knee arthroplasty using an articulating spacer. *Clin. Orthop* 1995, 321 : 45-54.
8. **Insall JN, Thompson FM, Brause BD.** Two-stage reimplantation for the salvage of infected total knee arthroplasty. *J Bone Joint Surg* 1983, 65-A : 1087-1098.
9. **Jenny JY, Boeri C.** Navigated implantation of total knee endoprostheses-a comparative study with conventional instrumentation. *Z Orthop Ihre Grenzgeb* 2001, 139 : 117-119.
10. **McPherson EJ, Lewonowski K, Dorr LD.** Techniques in arthroplasty. Use of an articulated PMMA spacer in the infected total knee arthroplasty. *J Arthroplasty* 1995, 10 : 87-89.
11. **Mielke RK, Clemens U, Jens JH, Kershally S.** Navigation in knee endoprosthesis implantation – preliminary experiences and prospective comparative study with conventional implantation technique. *Z Orthop Ihre Grenzgeb* 2001, 139 : 109-116.
12. **Miller MC, Berger RA, Petrella AJ, Karmas A, Rubash HE.** Optimizing femoral component rotation in total knee arthroplasty. *Clin Orthop* 2001, 392 : 38-45.
13. **Nuno-Siebrecht N, Tanzer M, Bobyn JD.** Potential errors in axial alignment using intramedullary instrumentation for total knee arthroplasty. *J Arthroplasty* 2000, 15 : 228-230.
14. **Olcott CW, Scott RD.** The Ranawat Award. Femoral component rotation during total knee arthroplasty. *Clin Orthop* 1999, 367 : 39-42.
15. **Petersen TL, Engh GA.** Radiographic assessment of knee alignment after total knee arthroplasty. *J Arthroplasty* 1988, 3 : 67-72.
16. **Ritter MA, Faris PM, Keating EM, Meding JB.** Postoperative alignment of total knee replacement. Its effect on survival. *Clin Orthop* 1994, 299 : 153-156.
17. **Saragaglia D, Picard F, Chaussard C, Montbarbon E, Leitner F, Cinquin P.** Computer-assisted knee arthroplasty : comparison with a conventional procedure. Results of 50 cases in a prospective randomized study. *Rev Chir Orthop* 2001, 87 : 18-28.
18. **Scott WN, Rubinstein M, Scuderi G.** Results after knee replacement with a posterior cruciate-substituting prosthesis. *J Bone Joint Surg* 1988, 70-A : 1163-1173.
19. **Teter KE, Bregman D, Colwell CW.** The efficacy of intramedullary femoral alignment in total knee replacement. *Clin Orthop* 1995, 321 : 117-121.