Computer-Assisted Navigation in Patellofemoral Arthroplasty: a New Technique to Improve Rotational Position of the Trochlea

Philippe Hernigou, MD · Charles Henri Flouzat-Lachaniette, MD · William Delblond, MD · Pascal Duffiet, MD · Didier Julian, MD

Received: 7 July 2012/Accepted: 4 January 2013/Published online: 18 June 2013
© Hospital for Special Surgery 2013

Abstract *Background:* Maltracking or subluxation is one of the complications of patellofemoral arthroplasty. *Questions/Purposes:* We questioned whether the computed navigation system can improve patellar tracking in patients with patellofemoral arthroplasty (PFA). *Methods:* Between 2007 and 2010 we performed 15 patellofemoral arthroplasties using the Ceraver PFA and navigation assistance. Fifteen other patients underwent surgery without navigation during the same period and acted as a control group. The rotation of the native trochlea as measured using the epicondylar line as a reference before surgery and the rotation of the trochlear component and the trochlear twist angle were assessed with computed tomography (CT) scan after surgery. *Results:* The mean follow-up was 3 years (range, 2–5 years). The group with navigation had no patellofemoral complications and better clinical scores. The group without navigation had abnormal patellofemoral tracking in 5 of the 15 patients. CT scan demonstrated excessive internal component rotation, as compared with patients without complications. This excessive internal rotation was proportional to the severity of the patellofemoral maltracking. *Conclusions:* The short-term results suggest that navigation can lead to better trochlear rotation which, in our

hands, is associated with fewer cases of patellar maltracking and better overall clinical scores.

Keywords patellofemoral arthroplasty · computer-assisted navigation · knee · patella

Introduction

Recently, patellofemoral arthroplasty (PFA) has gained increased acceptance [1, 2] as a treatment for isolated patellofemoral arthritis. Maltracking or subluxation [2, 7, 9] is one of the complications of this surgery. Computer-assisted navigation tools have been developed to allow accurate implantation of total knee arthroplasty (TKA) prosthesis.

The Ceraver patellofemoral arthroplasty (Ceraver Osteal, Roissy, France) is a second generation PFA and has been designed (Fig. 1) to reproduce the design of the trochlear part of the patellofemoral joint of the Ceraver Hermes Ceraver total knee replacement. Since 2000 this total knee replacement (TKR) has been implanted by our surgical team with Ceravision, the system of computer navigation assistance. This navigation system can also be used for implantation of the patellofemoral arthroplasty since the designs are similar. The design of the trochlear implant is similar to the natural trochlea and was designed to facilitate tracking of the patella in the trochlear groove during flexion and also allow free movement for articulation of the patella in extension. The design of the patellar button is dome-shaped and identical to the patellar button of the TKR.

In order to assess the accuracy of this computer-assisted technique, we first developed a technique to measure preoperatively the native trochlear rotation of the knee and postoperatively the femoral component rotational alignment of the PFA using a standard CT scanner. The aims of this study were therefore to (1) compare the patellar tracking in navigated versus non-navigated patellofemoral arthroplasty, (2) to assess whether or not maltracking can be related to inaccurate femoral component rotation, and (3) to assess whether or not a

Level of Evidence: Therapeutic Study Level III. Please see levels of evidence for a complete description.

Electronic supplementary material The online version of this article (doi:10.1007/s11420-013-9328-x) contains supplementary material, which is available to authorized users.

P. Hernigou, MD (✉) · C. H. Flouzat-Lachaniette, MD ·
W. Delblond, MD · P. Duffiet, MD · D. Julian, MD
Hospital Henri Mondor, Avenue du Marechal de Lattre de Tassigny,
Creteil, 94000, France
e-mail: Philippe.hernigou@wanadoo.fr

P. Hernigou, MD · C. H. Flouzat-Lachaniette, MD ·
W. Delblond, MD · P. Duffiet, MD · D. Julian, MD
University Paris East,
61 Avenue du Général de Gaulle,
Creteil, 94010, France

Fig. 1. The Ceraver Hermes arthroplasty is displayed.

computer-assisted technique improves the accuracy of rotational placement of the femoral component in navigated PFA compared to PFA implanted without navigation.

Materials and Methods

On average we perform 30 PFAs each year at the Henri Mondor Hospital including knees with primary patellofemoral osteoarthritis and osteoarthritis related to dysplasia or previous traumatism. In this comparative study, the test group consisted of 15 patients who underwent patellofemoral arthroplasty using the Ceraver PFA implanted with navigation between 2007 and 2010. In the control group, 15 patients underwent surgery without navigation during the same period by the same surgeon. The average age of the 30 patients at the time of surgery was 62 years (range, 55–74 years). All patients had isolated symptomatic osteoarthritis proven radiographically by CT arthrography. All had failed conservative management. All patients had fixed flexion less than 10° and radiologically normal tibiofemoral joints, and the ligaments and menisci were present at surgery. They had no knee dysplasia and no subluxation on the preoperative skyline view of the patella. Patients in both groups were rehabilitated in the same manner under the guidance of the physiotherapists and were allowed to fully weight-bear immediately post operation as pain allowed.

For the surgical technique, a median parapatellar incision was made. The tibiofemoral compartments, fat pad, and meniscus were inspected. The exposure should be long enough to allow visualization of the trochlea, eversion of the patella for resurfacing, and implantation of the pins for navigation. There was an anterior cut and removal of a minimal amount of bone from the trochlea. In both groups with and without navigation, the surgeon strived to implant the trochlear component parallel to the epicondylar line, using navigation or palpation of the epicondyles. The next step was the preparation and fixation of the patellar implant. In a fashion similar to the implantation of the patellar button of a TKR femur, a guide was used to assess the center, size, and location of the trial button. A cut of the patella was performed, and the patellar component was aligned based on the superior and inferior orientation of the patella. The

patellar and trochlear components were cemented into place in the usual fashion, with one peg for the trochlear implant and two vertical pegs for the patella. There was no lateral release in either group.

For computer-assisted PFA, a distal femoral reference array each with three reflector spheres were inserted via two pins. For some patients, the incision needed to be extended or a separate mini-incision is made to insert the arrays. The trochlear groove and the distal femoral anatomy were visualized using a “bone morphing” algorithm to create a virtual image on the computer display of the non-radio-graph-based navigation system (CeraVision navigation system). It is an “image-free system” using an infrared sensor for collecting anatomical landmarks to perform the registration process. The accuracy of this system is 2° for the determination of the medial sulcus and lateral condyle with inter and intraobserver registration error of 1° [8]. The patient’s anatomy is then compared to a series of 500 knees (data included in the memory of the computer) to assess size, rotation, and flexion and extension positions of the trochlear component. The anterior bone cut was navigated using the infrared pointer attached (Fig. 2) to the square bone plate, which is usually used in the verification of the tibial bone cut of the TKA. It was then positioned on the cutting surface of the anterior cutting jig for the trochlea; with reference to the navigation system, final adjustments were made to obtain correct flexion, extension, and rotation of the anterior cut (Fig. 3). Pre-osteotomy and post-implantation alignment measurements were recorded. There was no navigation for the patellar cut.

Preoperative CT (Fig. 4) and postoperative CT scans (Fig. 5) were obtained to determine the rotation of the trochlea before and after the PFA. This technique is applicable to any CT scanner. The patient was placed supine on the CT scanning table with the involved extremity in full extension with the extremity adjusted to allow the scans to be perpendicular to the mechanical axis of the knee. Computed tomography images with 1.5 mm in thickness were obtained through the epicondylar axis on the femur. On this CT image, two lines were drawn before surgery. The first line, the anterior trochlear line, connects the lateral and the medial prominences of the trochlea. The second line, the surgical epicondylar axis, connects the lateral epicondylar

Fig. 2. A picture of the navigation jig used for verification of correct rotational alignment of the trochlear cut.

Fig. 3. Our method for checking the orientation of the trochlear cut.

prominence and the medial sulcus of the medial epicondyle. The angle subtended by these two lines was measured and considered as the trochlear component twist angle.

Patellofemoral malalignment was defined as proposed by Schutzer [11, 12] on the computed tomography scan by tilt and subluxation. The congruence was measured between a line bisecting the femoral sulcus angle and the patellar apex. The tilt angle was measured between a line parallel to the lateral facet and a line connecting the posterior femoral condyles.

Statistics

We determined any differences in angles using Student's *t* test or nonparametric Mann–Whitney *U* test.

Results

Navigated PFAs had fewer patellar tracking problems than the un-navigated PFAs. No patients were lost to follow-up. The mean follow-up was 3 years (range, 2–5 years). No short-term or long-term problems relating to surgery were encountered. Considering the group of 15 patients without navigation, 10 had no patellofemoral problems, and 5 patients had clinically irregular tracking categorized on CT scan as lateral patellar tracking and tilt for three knees and subluxation for two knees. Without navigation six knees had excellent results, four good results, and five poor results using the Crosby and Insall scoring system [4]. Considering

Fig. 4. The preoperative CT scan allows measurement of the trochlear twist angle.

Fig. 5. The postoperative twist angle is demonstrated on the postoperative CT scan.

the group of 15 patients with navigation, no patient had patellofemoral problems, and clinically, all implants tracked smoothly during a full range of movement with no evidence of instability of the patellofemoral joint. All had excellent results using the Crosby and Insall scoring system [4].

In the five patients with patellofemoral complications, the severity of the patellofemoral complications was associated with excessive internal component rotation. The patients with the finding of lateral tracking and tilting had trochlear component rotation ranging from 4° to 7° excessive internal rotation. The patients with subluxation had trochlear component rotation ranging from 5° to 10° excessive internal rotation. However, no revision surgery was necessary at the actual follow-up.

The navigated PFAs had more accurate rotational placement of the femoral component than the un-navigated PFAs ($p=0.01$). In the group without navigation, the rotation of the trochlear component ranged from 5° excessive external rotation to 10° excessive internal rotation as compared with the native preoperative trochlear angle for the patients with patellofemoral problems. The 15 PFAs implanted with navigation had neutral or external rotation of the trochlear component, ranging from 3° internal rotation to 10° external rotation (average, 0°), as compared with the native preoperative orientation of the trochlea. The trochlear component was parallel to the epicondylar line or in external rotation in 12 knees in the navigated group versus 5 knees in the un-navigated group.

Discussion

Patellofemoral arthroplasty is a relatively new procedure with a beginning in 1955. At that time, McKeever [10] reported the first study of patellar resurfacing as an alternative to patellectomy and patellar shaving to treat patellofemoral osteoarthritis (OA). Due to the variable outcomes, PFA remains a controversial treatment for advanced patellofemoral OA. Many surgeons today continue to perform total knee replacement for isolated advanced patellofemoral OA, rather than PFA, as means of achieving more consistent outcomes. However, lack of attention to the underlying causes of maltracking is the principal cause of the revision

surgery after patellofemoral arthroplasty, the prosthesis having a low failure rate secondary to aseptic loosening. The aims of this study were to (1) compare the patellar tracking in navigated versus non-navigated patellofemoral arthroplasty, (2) to assess whether or not maltracking can be related to inaccurate femoral component rotation, and (3) to assess whether or not a computer-assisted technique improves the accuracy of rotational placement of the femoral component in navigated PFA compared to PFA implanted without navigation. We have demonstrated that intraoperative navigation in performing the Ceraver patellofemoral arthroplasty is safe, reliable, and reproducible, enabling good short-term clinical and radiological results. In primary surgery, navigation has the advantage of helping to reduce maltracking by guiding the surgeon in proper rotational alignment of the femoral component.

Our study has some limitations. First, these are the small number of patients and a short follow-up duration. In this series all the knees with isolated patellofemoral maltracking had excessive combined internal rotation; however, because this investigation was undertaken with the same arthroplasty, the authors are unable to say conclusively that all knees with excessive internal rotation will have patellofemoral maltracking with other arthroplasties.

We used CT scan to compare patellar tracking in navigated versus non-navigated patellofemoral arthroplasty. Computed tomography scan has been frequently used to assess torsions in lower limb of the knee joints [11–13]. Although it has been suggested that torsion is one of the mechanisms responsible for patellar dislocation [5, 6] in the adolescent, the association of torsion with patellar malalignment and dislocation has not been confirmed by computed tomography scan measurement in PFA. To date, this measure of trochlear rotation can be obtained before and after surgery. The lack of an available diagnostic test led to the development of a CT scanner protocol designed to quantify rotational alignment measurements. This protocol is based on the trochlear twist angle determined using axial CT image through the femoral epicondyles. This technique provides a noninvasive method for quantitatively determining the rotational alignment of the trochlear component on any standard CT scanner.

To assess whether or not maltracking can be related to inaccurate femoral component rotation, we isolated all of the patients with patellofemoral problems and found that they had some degree of excessive combined with internal rotation as compared with the preoperative orientation. This was in contrast to the neutral rotation observed in the knees of the patients without patellofemoral problems. Even if it was not statistically significant due to the small number of patients, the severity of the patellofemoral maltracking was proportional to the excessive component internal rotation, indicating that the component rotation is an important factor in these patellofemoral problems. This conformed to the literature data. In a series [14] performed from 1989 to 1995 using the Lubinus patellofemoral arthroplasty, the results showed a satisfactory outcome in only 45% of all knees. Malalignment was a major cause of failure in 32% of the cases.

We were able to find one other report of a navigation system [3] being used in the preparation and orientation of patellofemoral arthroplasty. This report [3] also confirms the utility of a navigation system. In this study, however, there was an increase in surgical time (average of 20 min) and, of course, in costs for the navigation system as compared to the conventional group. It is difficult to know why non-navigated PF components were at higher risk of being positioned in internal rotation in our series. The epicondylar line is the most accurate reference for rotational alignment of the femur considering that the functional axis of the knee is in relation with this line. But the trans-epicondylar line is often difficult to define because the lateral epicondyle is obscured by the everted patella, adipose tissue, and collateral ligament. The medial epicondyle also is difficult to define because the prominence is bolted, and the central sulcus is often difficult to locate for the surgeon. Since in patellofemoral osteoarthritis there is wear of the lateral facet of the trochlea, there is a tendency for the surgeon to correct this wear and therefore a risk to position the trochlear component in internal rotation. In absence of navigation, the Whiteside's line and posterior condylar axis probably should be also checked to improve the rotation.

In conclusion our study addressed the component alignment with the use of a computer-assisted navigation system. Intraoperative navigation using the Ceravision system enabled accurate rotation alignment to be achieved in respect to the trochlear component with the native orientation. At present our study has small numbers of patients and a short follow-up duration. We are unable to say that the native orientation should be kept or changed with preoperative subluxation because we only have chosen knees without any preoperative subluxation for this protocol.

Disclosures

Conflict of Interest: Philippe Hernigou, MD, Charles Henri Flouzat-Lachaniette, MD, William Delblond, MD, Pascal Duffiet MD, Didier Julian, MD declare that they have no conflict of interest.

Human/Animal Rights: All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008 (5).

Informed Consent: Informed consent was obtained from all patients for being included in the study.

Required Author Forms Disclosure forms provided by the authors are available with the online version of this article.

References

1. Ackroyd CE. Development and early results of a new patellofemoral arthroplasty. *Clin Orthop*. 2005;436:7-13.

2. Ackroyd CE, Newman JH, Evans R, Eldridge JDJ, Joslin CC. The Avon patellofemoral arthroplasty. Five-year survivorship and functional results. *J Bone Joint Surg.* 2007;89B:310-315.
3. Cossey AJ, Spriggins AJ. Computer-Assisted Patellofemoral Arthroplasty A Mechanism for Optimizing Rotation. *J Arthroplast.* 2006;21(3):420-427.
4. Crosby EB, Insall J. Recurrent dislocation of the patella. *J Bone Joint Surg Am.* 1976;58A:9-13.
5. Digiulio M, Donaldson WR. Complications of Patello-Femoral Joint Surgery. *Sports Med Arthrosc Rev.* 2004;12(3):172-184.
6. Grelsamer RP. Patellar malalignment. *J Bone Joint Surg Am.* 2000;82-A(11):1639-1650.
7. Grelsamer RP. Stein Da: Patellofemoral arthritis. *J Bone Joint Surg Am.* 2006;88(8):1849-1860.
8. Jenny J-Y, Borei C. Navigation implantation of total knee prosthesis. A comparative study with conventional techniques. *Rev Chir Orthop Reparatrice Appar Mot.* 2001;87:645.
9. Lonner JH. Patellofemoral arthroplasty. In: Lotke PA, Lonner JH, eds. *Master Techniques in Orthopaedic Surgery: Knee Arthroplasty.* 3rd ed. Philadelphia: Lippincott Williams and Wilkins; 2009.
10. McKeever DC. Patellar prosthesis. *J Bone Joint Surg.* 1955; 37A:1074-1084.
11. Schutzer SF, Ramsby GR, Fulkerson JP. Computed tomographic classification of patellofemoral pain patients. *Orthop Clin North Am.* 1986;17:235-248.
12. Schutzer SF, Ramsby GR, Fulkerson JP. The evaluation of patellofemoral pain using computerized tomography. *Clin Orthop.* 1986;204:286-288.
13. Stulberg S, Loan P, Sarin V. Computer assisted navigation in total knee replacement. Results of an initial 35 patients. *J Bone Joint Surg Am.* 2002;84A(Suppl 2):90.
14. Tauro B, Ackroyd CE, Newman JH, et al. The Lubinus patellofemoral arthroplasty. *J Bone Joint Surg.* 2001;83B:696-701.