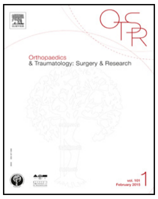
Orthopaedics & Traumatology: Surgery & Research xxx (2017) xxx–xxx

Available online at
ScienceDirect
www.sciencedirect.com

Elsevier Masson France
EM|consulte
www.em-consulte.com/en



Original article

Differences in trochlear parameters between native and prosthetic kinematically or mechanically aligned knees

C. Rivière [a,*], F. Iranpour [a], S. Harris [a], E. Auvinet [a], A. Aframian [a], S. Parratte [b], J. Cobb [a]

[a] *MSK Lab, Charing Cross Hospital, Imperial College London, W6 8RP London, UK*
[b] *Service de chirurgie orthopédique, hôpital Sainte-Marguerite, université Aix-Marseille, 13009 Marseille, France*

ARTICLE INFO

Article history:
Received 13 June 2017
Accepted 27 October 2017

Keywords:
Kinematic alignment
Total knee arthroplasty
Trochleae
Stuffing

ABSTRACT

Introduction: Kinematic (KA) and mechanical (MA) alignment techniques are two different philosophies of implant positioning that use the same TKA implants. This might generate differences in the resulting prosthetic trochleae parameters between the two techniques of alignment. Our study aim was to test the following hypotheses : (1) mechanically or kinematically aligned femoral implant understuffs the native trochlear articular surface and poorly restores the native groove orientation, and (2) the orientation of the prosthetic trochlear groove and trochlear fill are different between MA and KA.
Methods: Three-dimensional models of the femur were made from segmentation of preoperative Magnetic Resonance Imaging scans (MRIs) of ten subjects with isolated medial tibiofemoral osteoarthritis. In-house planning and analysis software kinematically and mechanically aligned a modern cruciate retaining femoral component and determined differences in parameters of the trochlear fit between native and prosthetic trochleae, and between KA and MA prosthetic trochleae.
Results: The MA prosthetic trochleae did not fill (understuffed) the entire length of the native medial facet and the proximal 70% of the native groove and lateral facet, and oriented the trochleae groove 8° more valgus than native. The KA prosthetic trochleae understuffed the proximal 70% of the native trochleae, and had a groove 6° more valgus than native. The KA trochleae understuffed the medial facet distally and oriented the groove 2° less valgus and 3° more internally rotated than the MA trochleae.
Conclusion: MA and KA prosthetic trochleae substantially understuff and create a prosthetic groove more valgus compared to native trochlear anatomy, and they also differed between each other regarding trochleae stuffing and groove alignment. Although randomized trials have not shown differences in patellofemoral complications between KA and MA, a femoral component designed specifically for KA that more closely restores the native trochlear anatomy might improve patient reported satisfaction and function.
Level of evidence: Level 2 controlled laboratory study.

1. Introduction

The patella is a sesamoid bone that acts as a lever to facilitate knee extension, and increases the quadriceps moment arm. The native patella initially follows a circular path, which is guided by the circular trochlear groove of the femur, before articulating with the inner part of both the medial and the lateral condyles [1–3]. The function of the lateral facet is to prevent the patella from subluxing laterally in early flexion, and as flexion increases, the patella is guided by the floor of the groove and not the facets [3,4].

For decades, total knee arthroplasty (TKA) has tried, with the use of serial implants, to accommodate varying patients anatomy by systematically creating an almost similar “biomechanically friendly prosthetic knee” favouring long-term survivorship, rather than aiming at restoring the constitutional knee anatomy (either tibiofemoral or patellofemoral joint) which would have favour the functional outcomes [5]. To optimize the forces at the bone-implant interface with the aim of long-term implant survivorship, mechanical alignment (MA) technique for TKA aims at creating a straight limb with perpendicular tibiofemoral joint line. In general, the femoral implants in current use have trochlear grooves that are extended more proximally and oriented in more valgus compared to the native one. Also, prosthetic trochleae have a larger groove’s radius and a higher sulcus angle, with the aim of ‘understuffing’ trochleae prosthetic surfaces relative to the native one.

---

* Corresponding author. Charring Cross Hospital, Joint replacement, Fulham Palace Road, W6 8RF London, UK.
E-mail address: rivierech@gmail.com (C. Rivière).

https://doi.org/10.1016/j.otsr.2017.10.009

Please cite this article in press as: Rivière C, et al. Differences in trochlear parameters between native and prosthetic kinematically or mechanically aligned knees. Orthop Traumatol Surg Res (2017), https://doi.org/10.1016/j.otsr.2017.10.009

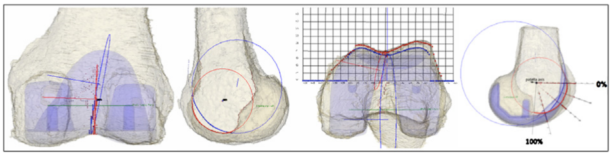


Fig. 1. In-house analysis software. Cutting plane revolves around the patellar axis.

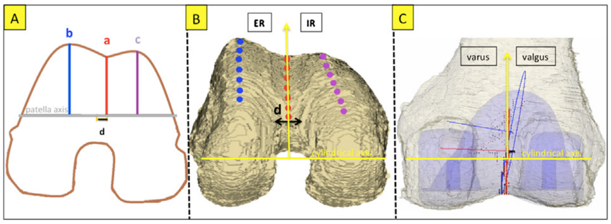


Fig. 2. Measured trochlear parameters. Axial (B) and frontal (C) groove rotations are assessed relative to the cylindrical axis. Lateral (b) and medial (c) facets heights, and groove height (a) are assessed relative to the patella axis. Mediolateral groove translation (d), external groove rotation (ER), internal groove rotation (IR). Valgus and externally rotated groove orientations are represented as positive value.

These features result in a patella that is captured early in flexion, promoting stability without overly constraining the tracking [4,6–11]. This design rationale aims at minimizing patella instability, anterior knee pain from retinacular stretching [12] and accelerated component wear/loosening due to increased contact forces [13]. Clinical results suggest that this theory is translated into practice, with fewer patellofemoral complications with MA TKA [14,15]. However, patellofemoral complications after MA TKA unfortunately do occur despite computer assisted surgery, robotics and enhancements of implant design [16–19]. Those complications have been mostly attributed to abnormal patellar biomechanics [11,20], which has been shown to be influenced by implant positioning and design [21–24].

In order to improve the functional outcomes of total knee replacement, an alternative method of implant positioning, namely the kinematic alignment technique (KA), has been described [25–27]. This technique aims to restore native knee kinematics by restoring the pre-arthritic constitutional frontal and axial tibiofemoral joint line alignments and knee laxity. One step to achieve this goal is to align the femoral component both frontally and axially to the cylindrical (or trans-condylar) axis, about which the tibia flexes and extends around the femur [28]. This alternative philosophy of implant positioning has been found to be clinically effective [28–31]. However, functional assessment has been limited principally to the tibiofemoral joint. Reports of the impact of KA on the patellofemoral joint are limited. Because KA and MA techniques are two different philosophies of implant positioning, which are performed with similar TKA implants, the position and orientation of resulting prosthetic trochleae might differ from the native articular surface and between each other. Our study aim was to test the following hypotheses: (1) mechanically or kinematically aligned femoral implant understuff the native trochlear articular surface and poorly restore the native groove orientation, and (2) the orientation of the prosthetic trochlear groove and trochlear fill are different between MA and KA.

2. Methods

2.1. Material

Ten preoperative magnetic resonance imaging (MRI) scans (3.0 Tesla) of arthritic patients were segmented using Mimics® software (Materialize, Belgium). Patients had end-stage medial tibiofemoral osteoarthritis without significant patellofemoral arthritis (≤ Iwano stage 2 [32]). MRI included "hip, knee, and ankle areas", and therefore ten 3-dimensional bone models (cartilage not segmented), including complete femoral head plus knee and distal tibial plafond, were created. Because images and clinical data were anonymized, their use was not subject to approval by our institutional review board.

Simulation of implant positioning and comparison of native and prosthetic trochlear articular surfaces (Fig. 1). Following a method previously published [25,33], 3-dimensional models of cruciate retaining Persona® femoral component (Zimmer Biomet, Warsaw, USA) were mechanically and kinematically positioned on every bone model (Fig. 1), and a software was used to compare native and prosthetic articular surfaces through cutting planes revolving around the patella axis. Because the prosthetic trochleae extends more proximally than the native one, this extension was assessed via cutting planes translating proximally from the apex of the native trochleae at 1 mm increments. To account for the difference in angular sweep between trochleae, degrees of rotation were converted to a percentage rotation, and measurements were taken at 20% increments across the length of the groove, where 0% and 100% were defined as the most proximal and distal point on the native groove, respectively (Fig. 1). Based on published data [34–36], measurements of native trochleae surfaces were compensated for cartilage thickness by 2 mm for the groove and the distal parts of the trochleae facets (≥ 80% of revolving process – corresponding to the transition zone with extension facets of femoral condyles), and 1 mm for the proximal part of trochleae facets (< 80% of revolving process). Trochlear parameters measured were: varus-valgus and internal-external groove orientations (valgus and externally rotated groove orientations are represented as positive value), mediolateral groove translation, heights of the groove and facets (Fig. 2). Based on previously reported data [12,37], an ideal fit was defined as a difference value less than 2 mm; if the value was larger than 2 mm, overstuffing or understuffing was therefore considered.

2.2. Statistical analysis

To enable comparison of geometric parameters across different sized femora, radial heights were normalized to the mean groove radius and mediolateral translation was normalized to the mean transepicondylar width. The data were determined to be normally distributed by a Shapiro-Wilk test ($p > 0.05$), so the results were analyzed with a repeated measures analysis of variance (Anova) and post-hoc paired *t*-tests. A Bonferoni correction for multiple comparisons was performed, and the significance level (*p*-value) was set at 0.02. Results are presented as mean (SD, min to max). The reliability of measurements was tested by measuring three variables (native and prosthetic groove height at 40° and native coronal plane orientation) in four randomly selected knees (for each group) by two observers (intra- and inter-observer reliability) using the intraclass correlation coefficient (ICC). The ICC was calculated as a one-way random effects model of single measures for each variable, and resulting ICC indicated good agreement (0.71 to 0.84). All statistical analyses were performed with SPSS™ Statistics V22.0 (IBM, Armonk, NY, USA).

3. Results

Results for MA and KA prosthetic trochleae stuffing relative to the native articular surfaces are illustrated in Fig. 3. Figs. 4 and 5 illustrate two cases with different distal femoral joint line (DFJL) obliquity.

Please cite this article in press as: Rivière C, et al. Differences in trochlear parameters between native and prosthetic kinematically or mechanically aligned knees. Orthop Traumatol Surg Res (2017), https://doi.org/10.1016/j.otsr.2017.10.009