Journal of Orthopaedics 13 (2016) 285–289

Contents lists available at ScienceDirect

Journal of Orthopaedics

journal homepage: www.elsevier.com/locate/jor

Original Article

Evaluation of lower limb axial alignment using digital radiography stitched films in pre-operative planning for total knee replacement

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ARTICLE INFO

Article history:
Received 8 June 2016
Accepted 21 June 2016
Available online

Keywords:
Total knee replacement
Valgus correction angle
Whole leg radiography
Digital radiography

ABSTRACT

Background: For patients with knee osteoarthritis, even slight anatomical variations in the femur or the tibia could affect total limb alignment during total knee replacement (TKR). Our hypothesis implies that the femoral valgus correction angle (VCA) in patients indicated for TKR, is variable and higher than the reported norm of 6° utilized in most intramedullary instrumentation systems, and that tibial bowing may result to a disparity of the tibial mechanical axis to the anatomical axis.
Methods: Our study is a retrospective review of 216 pre-operative arthritic knees, which investigated the lower limb axial alignment using digitally-stitched films. Patients excluded from the study are those with history of previous tibial or femoral osteotomy, secondary gonarthrosis, rheumatoid arthritis, previous femoral or tibial fracture, patients for bilateral TKR, or history of hip surgery.
Results: The mean age was 68-years old (range 39–86 years). The mean VCA was 7° (4.7–9.3) for men and 6.6° (4.9–9) for women. However, 71 patients (33%) had more than 7° VCA. Subsequently, 46 patients (21%) had tibial bowing producing an angle >1.5° between its mechanical and anatomic axis.
Conclusions: The 6° standard when used as a guide may result in suboptimal prosthesis positioning during conventional TKR surgery. Therefore our findings suggest that the femoral valgus correction angle has a broad range, and using standard femoral intramedullary guides should not be overlooked.

1. Introduction

It has been a long-standing tenet in total knee replacement (TKR), to restore the overall neutral alignment of the knee. The importance of attaining neutral coronal alignment, could not more be emphasized through several finite element analysis,[1] bio-mechanical,[2] and clinical studies[3–6] supporting it. A total knee replacement with varus alignment has been shown to fail substantially earlier than those with neutral or valgus alignment as reported by Ritter et al.[5] In a series of 3152 TKRs, Berend et al.[7] noted that varus tibial alignment of more than 3° is the most important risk factor for medial bone collapse, leading to tibial component failure. On the contrary, the importance of neutral alignment has been contested with recent publications by Parratte et al.[8] and Matzoilis et al.[9] The conclusions from these reports indicated that clinical outcome and survivorship of the varus-outliers (>3° varus) in TKR had no significant difference with neutral-aligned knees. However, it should be noted that both these authors emphasized that correct component alignment should be intended in every operation. Moreover, surgeons should be reminded that there is no extensive data that any alignment but neutral provides a significant advantage in TKR.

Accurate preoperative planning for TKR is critical to obtain the desired alignment and produce a successful result. Standing radiographs views of the whole lower limb is the benchmark for measuring alignment of the knee, in terms of identifying both load bearing axis and any deformity that might influence the surgery. With the increase frequency of digital imaging, so have the computer-assisted tools clinicians can use when measuring the mechanical axis. Recent publications by Sled et al.[10] and Marx

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http://dx.doi.org/10.1016/j.jor.2016.06.013
0972-978X/

et al.[11] demonstrated higher inter- and intra-reader reliability with a range of lower limb measurements including mechanical axis, favoring digital over conventional standing lower limb images.

A valuable radiographic measurement for restoration of correct lower limb alignment is the valgus correction angle (VCA). This is the angle between the anatomical and mechanical axis of the femur. It also correlates with the angulation of the distal femoral cut needed to make it perpendicular to the femoral mechanical axis. Moreland et al.'s[12] landmark series of evaluating the radiographs of 25 Caucasian subjects (mean age: 30 years), established the norm of 6° VCA. This was later on reinforced by Tang et al.,[13] with his series of 25 male and 25 female Chinese subjects (mean age: 24 and 25 years respectively). Subsequently, majority of conventional intramedullary distal femur cutting guides are manufactured with a 6° VCA. However, the subjects involved were young adults without signs and symptoms of knee arthritis. Symptomatic patients with knee OA who have profound femoral and tibial bowing, distortion of the bony canal, mal-united fractures and/or metabolic bone disease further limit the accuracy of an intramedullary alignment system.[14–18] The present study investigated a group of middle aged to elderly patients of multi-racial origin with knee arthritis scheduled for TKR. We hypothesize that femoral VCA is significantly greater compared to the reported 6° valgus, and that tibial bowing may result to a disparity of the tibial mechanical axis to the anatomical axis. These circumstances may have some bearing on instrument sets for total knee replacement that use intramedullary guides.

2. Materials and methods

A retrospective investigation of radiographs was done involving 216 knees in 216 patients diagnosed with primary gonarthrosis scheduled for unilateral TKR, who were seen in our institution from May 2009 to May 2011. Patients excluded from the study are those with history of previous tibial or femoral osteotomy, secondary gonarthrosis, rheumatoid arthritis, previous femoral or tibial fracture, patients for bilateral TKR, or history of hip surgery. Approval from the institution's Human Research Ethics Committee was obtained for this project.

Long radiographic views of the whole limb in stance were ideal for measuring alignment of the knee, in terms of both the load bearing axis and the other joint angles that may contribute to any deformity. Conventional hard copy full-leg plain radiographs (51 in. film) are cumbersome to use in measurements. Over the last decade subsequent research has shown that when comparing measurements of axial alignment between conventional and digital images, digital is as good and in some cases better than conventional.[19–21] Furthermore when conventional images were digitalized and measurements were made from these images, it showed minimal changes in measurement accuracy.[22] When it comes to spatial resolution, conventional imaging reigns supreme producing 2.5–15 lines/mm, compared to digitals' 2.5–5 lines/mm.[23] However, diminished spatial resolution in digital films has been shown to have no effect on diagnostic accuracy.[23,24] Digital imaging makes up for this shortcoming with superior image processing and analysis, reduced radiation per dose, and a wider linear dynamic range.[25,26]

For this study, digital reconstructed composite radiographs of the entire lower limb from the hip to the ankle joint were obtained using a digital X-ray system (Digital Diagnost VS, Philips Medical Systems) applying a standard acquisition protocol. Each subject was placed in a weight bearing platform with the patella at 90° to the coronal plane against a motorized vertical detector stand (Phillips Vertical Stand VS) and 120 cm rule at a standard source-to-image distance of 260 cm from the motorized X-ray tube. A series of three separate overlapping radiographic images were taken and automatically digitally stitched using a software algorithm (Phillips' Digital Diagnost) to generate a composite image of the entire limb. Scrutiny of the appearance of the fibular head and the lesser trochanter profile was done, to ensure that the limb was not internally or externally rotated. The authors obtained measurements through computer-assisted method using IMPAX 6.4.0.3125 software for precise and easy measurement of lower extremity axes based on the load bearing axis of the knee. The Legogram films (17 in. × 14 in.) are then printed out from digital pasted films of the whole leg in standing, which is reduced in size similar to a regular chest radiograph for easier carriage. The limb alignment and angles were measured based on the methods described by Moreland et al.[12] with some modifications. The centers of the femoral head, the knee, and ankle, as well as other essential radiographic measurements documented were described as follows (Figs. 1 and 3):

(a) Femoral head center – determined using Mose circles.
(b) Femoral shaft center I – a point located by bisecting the proximal to distal length of the femur (as defined by a line from the superior aspect of the femoral head to the distal part of the medial condyle) and the mid-shaft medial-to-lateral width of the femur.
(c) Femoral shaft center II – a point midway between the medial and lateral cortex of the femur, at 10 cm above the lowest femoral condyle surface.
(d) Distal femur center – the center of the femoral intercondylar notch.
(e) Proximal tibia center – the midpoint between the tips of the tibial spines.

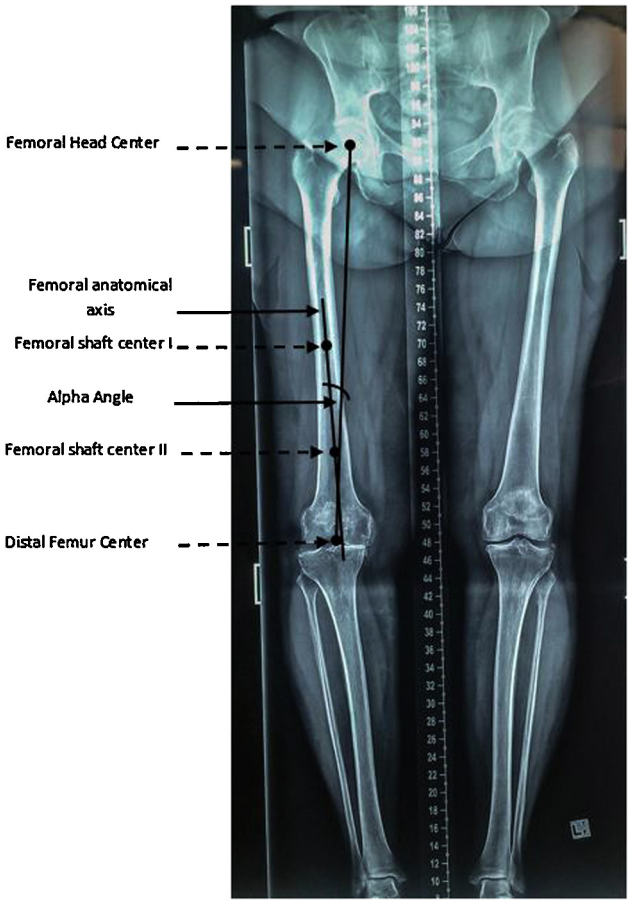

Fig. 1. A representation of the reconstructed composite image for the measurement of axes and angles in the femur. This digital image is developed as a similar dimension print out called Legogram film. The femoral valgus correction angle is depicted as the alpha angle.