The Journal of Arthroplasty xxx (2016) 1–6

Contents lists available at ScienceDirect

The Journal of Arthroplasty

journal homepage: www.arthroplastyjournal.org

Original Article

Do Patients' Perceptions of Leg Length Correlate With Standing 2- and 3-Dimensional Radiographic Imaging?

Jean Y. Lazennec, MD, PhD [a, b, c], Adrien Brusson, MS [c], Marc A. Rousseau, MD [b, c, d], Christopher B. Robbins, PhD [e], Aidin Eslam Pour, MD [e, *]

[a] Department of Orthopaedic and Trauma Surgery, Pitié-Salpêtrière Hospital, Assistance Publique—Hopitaux de Paris, UPMC, Paris, France
[b] Biomechanics Lab (LBM), Arts et Metiers Paris-Tech, Paris, France
[c] Department of Anatomy, UPMC, Paris, France
[d] Department of Orthopaedic and Trauma Surgery, Avicenne hospital, Assistance Publique—Hopitaux de Paris, Bobigny, France
[e] Department of Orthopaedic Surgery, University of Michigan, Ann Arbor, Michigan

ARTICLE INFO

Article history:
Received 8 December 2015
Received in revised form
11 March 2016
Accepted 28 March 2016
Available online xxx

Level of Evidence:
level-IV diagnostic case series

Keywords:
leg length
three-dimensional radiography
knee alignments
arthroplasty
femur
tibia

ABSTRACT

Background: This study compared 2- and 3-dimensional (2D and 3D) radiographic measurements of anatomical and functional leg length and knee coronal and sagittal alignments and correlated these measurements with patients' leg-length perceptions.

Methods: Patients without symptomatic spinal pathology, previous surgery of the spine, and lower extremities (140 lower extremities) were evaluated on EOS images obtained in standing position. Numerous measurements of each limb were compared to the contralateral limb. All 2D/3D measures were evaluated and compared for repeatability and reproducibility.

Results: Mean 2D functional and anatomical lengths were 78.7 cm (64.7-88.4, confidence interval [CI] 95%: 77.4-80) and 78.3 cm (64.9-87.9, CI 95%: 77-79.6), respectively. Mean 3D functional and anatomical lengths were 78.9 cm (65.1-88.7, CI 95%: 77.6-80.2) and 78.9 cm (65.6-88.3, CI 95%: 77.8-80.5), respectively ($P < .001$). Mean 2D and 3D knee varus/valgus angles were $-1.9°$ (-26.4 to 9.1, CI 95%: -3.5 to -0.7) and $-0.9°$ (-19.2 to 11.8, CI 95%: -2.4 to 0.2), respectively ($P = .004$). Multiple regression analysis found that patients with $>10°$ of flexum/recurvatum were 2.1× more likely to perceive unequal length ($P < .1$). Patients with irreducible varus/valgus knee deformity were 4× more likely to perceive unequal length ($P < .04$).

Conclusion: EOS imaging allows more accurate assessment of anatomical and functional lengths. Patients' perceptions of lower extremity length may correlate more closely with coronal and sagittal alignments of the knee than with femoral or tibial length. This study highlights the importance of physical examination of all the joints and 3D measurements in functional standing position.

The accurate assessment of leg length is essential for planning the correction of deformities and limb-length discrepancy. Limb-length discrepancy is a common finding in degenerative hip and knee disorders and congenital or trauma-related lower extremity deformities. It is also a common postoperative complication after total hip and knee arthroplasty [1-4], which can result in patient dissatisfaction, limping, need for shoe lift, low back pain, hip instability, and revision surgery [5-11]. Limb-length discrepancy can also result in medicolegal complaints. Upadhyay et al. [12] surveyed members of the American Association of Hip and Knee Society regarding medical malpractice litigations. Limb-length discrepancy was the second most common reason for litigation, and 8% of surgeons had been a defendant in a legal case secondary to this complication.

Most radiographic analyses of arthroplasty patients are based on anteroposterior (AP) radiographs in the standing position and computed tomography (CT) scans in the supine position. Despite its better accuracy, CT measures anatomical length in the supine position but does not evaluate functional length in the standing position, the position in which limb-length discrepancy is perceived by patients. Functional length integrates both the lengths

This study was unfunded.

No author associated with this paper has disclosed any potential or pertinent conflicts which may be perceived to have impending conflict with this work. For full disclosure statements refer to http://dx.doi.org/10.1016/j.arth.2016.03.065.

* Reprint requests: Aidin Eslam Pour, MD, Department of Orthopaedic Surgery—Adult Reconstruction, University of Michigan, 2912 Taubman Center, SPC 5328, 1500 E. Medical Center Dr, Ann Arbor, MI 48109.

http://dx.doi.org/10.1016/j.arth.2016.03.065
0883-5403/

of the femoral and tibial bones and the coronal (varus/valgus) and sagittal (genu flexum/recurvatum) knee alignments. It also integrates the spine-pelvis junction and its effect on the pelvic obliquity.

These questions were asked: (1) Do the 2- and 3-dimensional (2D and 3D) radiographic measurements of leg length and knee coronal and sagittal alignments differ substantially? (2) Do patients' perceptions of leg length correlate with the 2D and 3D anatomical and functional limb lengths or knee coronal and sagittal alignments?

Our hypotheses were that the anatomical and functional lengths would differ substantially between the 2D and 3D images and that genu flexum, genu recurvatum, severe varus, and valgus deformities, especially those that are correctable, would affect patient perception of functional leg length more than just anatomical length.

Methods

This was a nonrandomized, prospective study of the consecutive patients who were assessed with EOS imaging and met our inclusion and exclusion criteria. Patients were recruited in the Department of Orthopaedic and Trauma Surgery, Pitié-Salpêtrière Hospital, between January 2013 and December 2015.

We routinely evaluate all patients in clinic using the EOS imaging system for spine and lower extremity–related pain. The EOS system (EOS imaging SA, Paris, France) is an innovative slot-scanning radiograph system allowing the simultaneous acquisition of orthogonal AP and lateral radiographs while the patient is standing, sitting, or even squatting with less irradiation than standard imaging. After obtaining approval from our institutional review board, we reviewed 70 patients for bilateral lower extremity length assessment. We included all patients (aged 18-80 years) who were assessed in our clinic for hip and knee pain due to different degrees of degenerative joint disease. These patients were all treated nonoperatively for degenerative hip or knee pain before EOS imaging. All patients with symptomatic spinal pathology; previous spinal surgery; lower extremity open reduction; and external fixation, osteotomy, or arthroplasty (hip, knee, ankle) were excluded.

Each patient stood comfortably in the EOS machine. The position was specifically checked to avoid superimposition of anatomical structures on the lateral view (which would make 3D reconstruction impossible). We successively used the AP uniplanar acquisition (an equivalent of standard AP long-leg x-ray) and then the biplanar acquisition of the entire lower extremities (Fig. 1A and B). The biplanar acquisition was used to perform stereoradiographic 3D modeling of each lower extremity using specialized software (sterEOS 3D, EOS imaging SA) according to a previously described method [13]. The bony landmarks used to determine the femoral and tibial torsions in 3D images were identical to those used in the 2D measurements. The parameters measured in both 2D and 3D views were the hip-knee-ankle (HKA) angle and the femoral and tibial mechanical axes (FMA and TMA). The FMA was defined as the line connecting the center of the femoral head to the center of the femoral notch, and the TMA was defined as the line from the center of the tibial plateau (interspinous intercruciate midpoint) extending distally to the center of the tibial plafond (Fig. 2A and B). HKA angle was defined as the angle between the FMA and TMA. Neutral angle was defined as HKA angle of 0. The lengths of the femoral and tibial bones and the anatomical and functional lengths of the lower extremity were also measured. Tibial and femoral rotation and knee flexion/hyperextension angle were also derived from the 3D reconstruction [14].

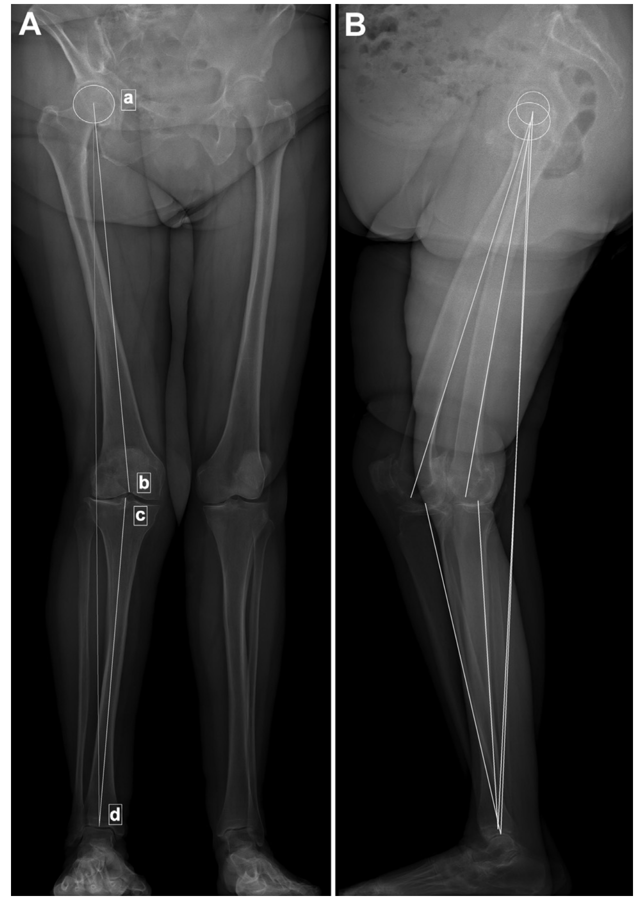

Fig. 1. (A and B) Two dimensional anteroposterior and lateral views of the lower extremity, showing the anatomical length of the femoral (ab) and tibial bones (cd) and the functional length (AD line in anteroposterior view and the line connecting the femoral head to ankle in the lateral view).

We used the following definitions (Fig. 1A):

- Anatomical femoral length: distance between the center of the femoral head (a) and the center of the trochlea (b).
- Anatomical tibial length: distance between the center of the tibial spine (intercondylar eminence) (c) and the center of the ankle joint (d).
- Functional length: distance between the center of the femoral head to the center of the ankle joint (ad).
- Anatomical length: sum of the anatomical femoral and tibial lengths (ab + cd).

Previous studies have shown that mean anatomical leg-length difference is about 5 mm in up to 90% of the general population. Some of these studies also looked into the clinical significance of the anatomical leg-length discrepancy and considered the threshold to be as low as 5 mm [15] and as high as 30 mm [16,17]. For this study, legs were considered to be of equal length when the difference between the anatomical and functional lengths of lower extremities was $\leq$5 mm.

All patients were asked if they perceived equal or unequal limb length. The knee coronal angle (varus/valgus) was also assessed during the physical examination by the senior author with manual varus and valgus stress to see if the varus/valgus deformity was correctable to neutral angle or not. This was done using a goniometer, as validated in previously published work [18]. Patients were categorized into 3 groups based on correctability of deformity: completely