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Coronal alignment on the single-limb stance radiograph in posterolateral rotatory instability, osteoarthritis and healthy knees☆

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ABSTRACT

Background: We aimed to determine whether coronal alignment measured on the single-limb stance (SLS) radiographs differs from those on the double-limb stance (DLS) images. We also investigated whether the size of such differences was affected by the knee pathology, lower limb alignment, and geometry of the tibia or femur.

Methods: We measured coronal alignment with mechanical tibiofemoral angle (MTFA) on the DLS and SLS radiographs in patients with posterolateral rotatory instability (PLRI, 30 knees), osteoarthritis (OA) with varus deformity who were scheduled for high tibial osteotomy (HTO) (60 knees), and in normal control (60 knees). The measurements on the SLS radiographs were compared with those on DLS images and the size of the differences were compared between the three groups. The correlation between the radiograph-related differences of coronal alignment and the limb alignment or geometry of tibia/femur was investigated. In the OA group, the size of the radiograph-related differences before HTO were compared with those after surgery.

Results: The coronal alignment on the SLS radiographs indicated varus accentuation compared to those on the DLS radiographs in the PLRI and OA groups (1.6 and 2.4°, respectively), while it was negligible in the normal group. Greater varus inclination of the tibial plateau was related to greater varus accentuation ($r = 0.249$). The HTO decreased the extent of varus accentuation in the OA group (reduction of varus accentuation = 1.5°).

Conclusions: Coronal alignment on the SLS radiograph is different from static alignment measured on the DLS radiograph, which may reflect dynamic alignment.

1. Introduction

Accurate measurements of coronal alignment of the lower extremities are crucial for appropriate management of knee disorders related to ligament laxity or osteoarthritis, combined with malalignment. Concurrent alignment correction is sometimes

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required for patients undergoing anterior cruciate ligament reconstruction with varus malalignment [1–3]. High tibial osteotomy can be an initial surgical treatment in posterolateral rotatory instability with varus deformity [4]. Inaccurate preoperative alignment information may cause under- or overcorrection after osteotomy. Traditionally, a full-length standing anteroposterior (AP) radiography taken with patients in double-limb stance (DLS) has been used as a gold standard to measure the coronal alignment [5,6]. DLS radiographs can only reflect static alignment; however, dynamic alignment may provide different information [7–9]. Dynamic alignment can be measured better on the gait analysis rather than on the static radiographic measurement, but it requires special equipment and facility [10–12].

The coronal alignment on the single-limb stance (SLS) full-length standing AP radiograph may be different from the static alignment measured on the DLS radiograph as the entire body weight is transmitted through the single limb [13]. Previous reports revealed that the differences in weight bearing on the knee joint could result in differences in coronal alignment [8,14]. In addition, the SLS radiograph theoretically simulates the stance phase of a gait cycle so the SLS radiograph might reflect the dynamic alignment of the lower limb despite its inherent static nature. [6–8,13]. Several previous studies reported increasing varus deformity on the SLS radiographs than on the DLS images in patients with arthritic knees with varus deformity [8,14,15]. However, whether such differences in coronal alignment between SLS and DLS radiographs are observed in other knee conditions, such as posterolateral rotatory instability (PLRI) or normal knee, are not reported in the literature. Furthermore, factors which are associated with increased differences in the coronal alignment measurement between SLS and DLS radiographs are not thoroughly investigated yet. Magnitude of malalignment and geometry of the knee joint may be plausible candidate, as they can affect the moment across the knee joint [16–18]. Because high tibial osteotomy (HTO) alters lower limb alignment and proximal tibial geometry, the changes after HTO may give some insight about the effect of magnitude of malalignment and the geometry of proximal tibia.

Therefore, we sought to determine whether the coronal alignments measured on the SLS radiograph differ from those on the DLS images in patients with various knee conditions such as normal, PLRI and OA with varus deformity. We also aimed to determine whether these resultant differences were affected by the alignment of the lower limbs and geometry of the knee joint. Finally, we also wanted to determine whether these radiograph-related differences in the coronal alignment changed after correction of the malalignment in the patients with medial OA who underwent HTO.

2. Materials and methods

2.1. Study design

This retrospective study was conducted using the following three patient groups with different knee conditions from the consecutive patient cohort of our institute: 1) normal group (n = 60), 2) PLRI group (n = 30) and 3) OA with varus deformity group who underwent HTO (n = 60). The patients were excluded in this study if the accurately-taken whole-limb standing radiographs were not available, e.g. the patella was not 'facing forwards' or the flexion contracture of the knee was greater than 10° (n = 14). The PLRI group included 30 consecutive patients who underwent posterolateral complex reconstruction for knee joint laxity and/or high tibial osteotomy for combined malalignment from 2005 through 2013. All the patients had prior traumatic injury but the patients with acute injury within three months were not included in this study. The diagnosis of PLRI was done by physical examination (external rotation recurvatum test, varus stress test at 30°, dial test at 30° and 90°, posterolateral drawer test) and magnetic resonance image (MRI) findings (injury of lateral collateral ligament and/or popliteofibular ligament and/or popliteus tendon). For the normal group, we selected 60 patients with non-symptomatic opposite knees from the 280 patients (247 men and 33 women) who underwent primary anterior cruciate ligament (ACL) reconstruction between August 2008 and March 2012. The normal controls were age- and sex-matched 2:1 with the PLRI group, with selecting the closest match among the available candidates. The OA with varus deformity group consisted of 60 consecutive patients who underwent medial opening-wedge HTO for primary OA in the medial compartment (Kellgren-Lawrence classification III) using TomoFix® system (Synthes GmbH; Solothurn, Switzerland) from August 2005 through March 2012. The patients in OA group were typically elderly females, so we could not match age or gender with other two groups. Compared to the other two groups, the OA group was more frequently female and older and consequently had lower mean weight and height (Table 1). This study was approved by institutional review board of authors' hospital and the written informed consent was waived by the board.

Table 1
Demographic features of the patients in the three study groups

Parameter	Normal (n = 60)	PLRI (n = 30)	OA (n = 60)	p Value
Male (%)	52 (87%)	26 (87%)	6 (10%)	<**0.001**
Age (years)	33.8 (12.1)	33.8 (13.3)	55.5 (5.0)	<**0.001**
Height (cm)	171.1 (7.2)	171.9 (8.0)	156.5 (6.5)	<**0.001**
Weight (kg)	74.5 (12.9)	73.4 (14.5)	65.7 (9.4)	<**0.001**
BMI (kg/m^2)	25.4 (3.6)	24.8 (4.4)	26.8 (2.8)	**0.023**

Data are presented as mean and (standard deviation).
Abbreviations: BMI, body mass index; PLRI, posterolateral rotatory instability; OA, osteoarthritis.
Significant (p <0.05) values are presented in bold.

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