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A comparison of radiographic anatomic axis knee alignment measurements and cross-sectional associations with knee osteoarthritis

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Objective: Malalignment is associated with knee osteoarthritis (KOA), however, the optimal anatomic axis (AA) knee alignment measurement on a standard limb radiograph (SLR) is unknown. This study compares one-point (1P) and two-point (2P) AA methods using three knee joint centre locations and examines cross-sectional associations with symptomatic radiographic knee osteoarthritis (SRKOA), radiographic knee osteoarthritis (RKOA) and knee pain.
Methods: AA alignment was measured six different ways using the KneeMorf software on 1058 SLRs from 584 women in the Chingford Study. Cross-sectional associations with principal outcome SRKOA combined with greatest reproducibility determined the optimal 1P and 2P AA method. Appropriate varus/neutral/valgus alignment categories were established using logistic regression with generalised estimating equation models fitted with restricted cubic spline function.
Results: The tibial plateau centre displayed greatest reproducibility and associations with SRKOA. As mean 1P and 2P values differed by >2°, new alignment categories were generated for 1P: varus <178°, neutral 178–182°, valgus >182° and for 2P methods: varus <180°, neutral 180–185°, valgus >185°. Varus vs neutral alignment was associated with a near 2-fold increase in SRKOA and RKOA, and valgus vs neutral for RKOA using 2P method. Nonsignificant associations were seen for 1P method for SRKOA, RKOA and knee pain.
Conclusions: AA alignment was associated with SRKOA and the tibial plateau centre had the strongest association. Differences in AA alignment when 1P vs 2P methods were compared indicated bespoke alignment categories were necessary. Further replication and validation with mechanical axis alignment comparison is required.

Introduction

Knee osteoarthritis (KOA) is a major health burden with a 45% projected lifetime risk[1], and accounts for the majority of total knee replacements (TKRs) leading to TKR rates trebling between 1991

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and 2006[2]. Its aetiology is multifactorial. Knee alignment is a known risk factor for KOA progression[3–8] with data on incidence being less clear[3,8–10]. Malalignment either, varus or valgus influences load distribution across the knee joint, leading to subsequent degenerative changes[11].

The gold standard alignment measurement is the mechanical axis (MA) measuring the hip–knee–ankle angle on a full limb radiograph (FLR)[12,13]. Drawbacks with this are radiation exposure and specialist radiography equipment and expertise makes it costly. A proposed alternative alignment measurement, the anatomic axis (AA) method, is comparable to the MA method[5,14–18]. The AA method measures the femoral–tibial angle on a standard limb radiograph (SLR) which unlike FLRs are typically obtained in clinical practice, thereby allowing alignment measurements in existing population cohort studies. Less radiation is received, making it safer and more cost-effective.

Consensus defining the optimal AA alignment method is not agreed[19]. Current literature contains variation in measurement technique using different knee joint centres (KJCs); tibial spine base mid-point[8], tibial spine tips mid-point[9,16,18,20,21], or unspecified centre of tibial spines[14,15,22,23].

In addition, the majority of AA alignment studies use a one-point (1P) AA method which measures the AA angle formed between the femoral anatomic axis (FAA) and the tibial anatomic axis (TAA) based on a single 1P KJC location. However, most MA alignment studies use a two-point (2P) method where the angle measured is formed by two separate axes: the femoral axis originating from the femoral head centre to the femoral intercondylar notch point, and the tibial axis originating from the KJC location to the ankle tibial plafond mid-point. More recent MA vs AA comparative alignment studies[5,17,24] use a 2P AA vs a 2P MA method, but it is not clear if using a 1P or 2P AA method is optimum.

Previous work by McDaniel[19] comparing performance metrics of AA methods using different KJCs against the gold standard MA method recommended standardising AA measurements using either tibial spine base mid-point or centre of tibia, and suggested comparing 1P and 2P methods in larger studies. Past studies examining alignment and KOA predominantly use radiographic knee osteoarthritis (RKOA) as their main clinical outcome which is limited as symptoms are not considered[3,4,6–10,25]. This study uses symptomatic radiographic knee osteoarthritis (SRKOA) as the primary outcome which is relevant for both clinical diagnosis and for measuring the true KOA public health burden[1,26]. We are not aware of alignment studies using pain as an outcome therefore knee pain, in addition to RKOA, are included as secondary outcomes. This cross-sectional AA alignment study has the following aims:

1) To determine the optimal 1P and 2P AA method based on reproducibility and associations with clinical outcomes.
2) To define appropriate varus, neutral and valgus alignment categories for the chosen method.
3) To describe cross-sectional associations of the chosen method with SRKOA, RKOA and knee pain.

Method

Study population

The Chingford Study is a prospective cohort study of osteoarthritis and osteoporosis comprising 1003 women aged 44–67 years at baseline derived from a general practice register in Chingford, whose demographic characteristics are similar to the UK population[27]. Women attending the year 10 (Y10) visit with accompanying knee SLRs and clinical variables were included in this study (Fig. 1)and their clinical characteristics are shown in Table 1.

Imaging

Antero-posterior (AP) fully extended weight bearing bilateral knee SLRs were taken using a standardised protocol established at baseline and repeated for subsequent radiograph visits[28]. Plain film SLRs were digitally scanned at 600 pixels per inch (ppi) with a grey scale pixel depth of 16 bits allowing computerised alignment readings to be made.

All Y10 radiographs were graded (DJH) for Kellgren & Lawrence (K&L)[29,30], osteophytes and joint space narrowing (JSN) using the Chingford Atlas[31]. Radiographs were read individually, blinded to clinical information. Good intraobserver reproducibility was previously reported[32].

Alignment measurement

AA alignment was measured by manually placing points on each SLR image using the KneeMorf computer software[33,34]. A total of six, three 1P [Fig. 2(a)–(c)] and three 2P [Fig. 2(d)–(f)] methods of measuring AA were tested using three tibial KJCs:

a) tibial spine base mid-point (KJC1)
b) tibial spine tips mid-point (KJC2)
c) tibial plateau centre (KJC3)

Table I
Clinical characteristics. Where AA = anatomic axis, BMI = body mass index, IQR = interquartile range, KJC = knee joint centre, K&L = Kellgren & Lawrence grade, n = number, RKOA = radiographic knee osteoarthritis, SD = standard deviation, SRKOA = symptomatic radiographic knee osteoarthritis, 1P = one-point, 2P = two-point

Characteristic	Included Y10 cohort (n = 1058 knees)	Excluded Y10 cohort (n = 566 knees)	P value*
Age, median (IQR) years	62 (57–67)	63 (57–69)	**0.004**
BMI, median (IQR) kg/m^2	26.2 (23.6–29.3)	26.3 (23.4–29.7)	0.69
Knee injury, %	16.5	15.9	0.78
Knee pain ≥15 days, %	13.4	15.4	0.28
RKOA ≥2 K&L grade, % (n)	27.9	27.9 (n = 544)	0.98
SRKOA, % (n)	6.1	8.3 (n = 544)	0.09
Mean AA angle° (±SD) (n)			
1P KJC1	180.23 (3.70)		
1P KJC2	182.72 (3.40)		
1P KJC3	180.11 (2.93)		
2P KJC1	182.47 (2.78)		
2P KJC2	183.64 (2.66)		
2P KJC3	182.53 (2.51)		

Statistically significant P value is represented in bold.
* P values compare age and BMI using Kruskal Wallis test; knee injury, knee pain, RKOA and SRKOA using chi-square test.