Computed tomography scanogram compared to long leg radiograph for determining axial knee alignment

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Background and purpose — Supine computed tomography scanogram (CTS) is a commonly used alternative to weight bearing long leg plain radiograph (LLR) in measuring knee alignment. No published studies have validated its use in the native knee and the post-unicompartmental replacement knee (UKR). We quantified the difference in measurements obtained from CTS and LLR for knee alignment.

Patients and methods — Supine CT scanograms and weight bearing long leg plain anteroposterior radiographs were obtained for 40 knees (in 25 patients), 17 of which were native, and 23 of which were post-UKR. The mechanical and anatomical axes of the tibio-femoral joint were measured. Bland-Altman plots were used to calculate the 1.96 standard deviation limits of agreement between CTS and LLR. Intraclass correlation was used to assess intra-rater and inter-rater reliability (where values > 0.81 indicate very good reliability).

Results — CTS and LLR were equally reliable in measurement of the mechanical and anatomical axes of the tibio-femoral joint (intraclass correlation coefficient (ICC) > 0.9 for all parameters). Statistically significant and clinically relevant differences were found between CTS and LLR in measurement of the mechanical axis (limits of agreement: UKR –3.2° to 6.3°; native –3.2° to 5.6°) and the anatomical axis (limits of agreement: UKR –3.7° to 8.7°; native –2.0° to 8.8°).

Interpretation — Although it is a reliable tool, CTS is not necessarily an accurate one for measurement of knee alignment when compared to LLR. We recommend that CTS should not be used as a substitute for LLR in measurement of the mechanical or anatomical axes of the knee.

Measurement of knee alignment is useful in planning of operative intervention including high tibial osteotomy (HTO), uncompartmental knee replacement (UKR), and total knee replacement (TKR), and in the assessment of postoperative outcomes (Hernigou and Deschamps 2004, Hardeman et al. 2012, Kyung et al. 2013, Pietsch et al. 2013, Chen et al. 2014). The degree of accuracy required is thought to be ± 5° for native knees (Sharma et al. 2011), ± 3° after TKR (Bathis et al. 2004), and ± 2.5° after UKR (Gulati et al. 2009, Weale et al. 2000).

The weight bearing long leg anteroposterior radiograph (LLR) shows loss of cartilage space and ligament laxity, and is therefore thought to be the best method for the measurement of coronal alignment of the knee (Babazadeh et al. 2013). However, some feel that the supine LLR is more suitable for planning in HTO (Ogata et al. 1991, Brouwer et al. 2003).

Several recent papers have used the 2-D supine CT scanogram/scout film (CTS) to assess knee alignment (Moon et al. 2012, Kyung et al. 2013, Bugbee et al. 2013). Clinicians are also using this modality in clinical practice. CTS is severely limited by being a non-weight bearing modality in addition to having the same limitations as LLR (i.e. influence of rotational malalignment and flexion deformity).

Brouwer et al. (2003) compared standing and supine LLR, but patients were excluded if they were unable to stand on one leg, if they had had previous surgery, or if they had a clinical malalignment. Gbejuade et al. (2014) compared CTS and LLR after TKR; however, weight bearing may not be as important a factor in measurement of alignment after TKR.

The present study is the first to determine the differences in knee alignment measurement between CTS and LLR in native knees and after UKR.

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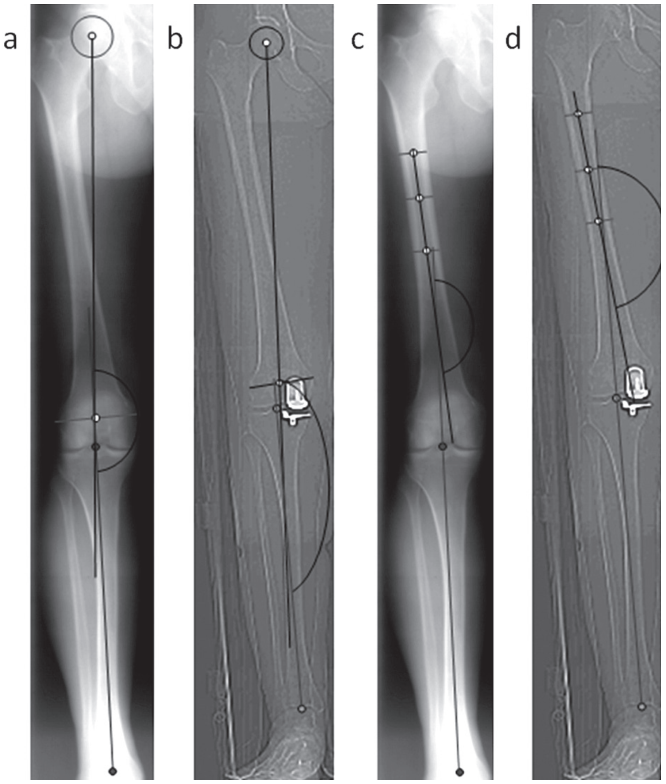

Figure 1. Measurements of knee alignment: mechanical axis for LLR (a) and CTS (b); anatomical axis for LLR (c) and CTS (d).

Methods

Ethics approval was obtained for the analysis of joint imaging in 25 patients who had undergone UKR in a previous computer navigation study (Cobb et al. 2006, REC 03/0087).

Each patient underwent conventional CTS of the limb (patient lying supine, patellae pointing toward the ceiling) and LLR (patient standing erect with patellae facing forward, X-ray beam centered on knee). Images were rejected for analysis if they appeared to be significantly rotated. This gave us a sample size of 40 knees in total, consisting of 23 UKRs and 17 native knees.

Axes were defined according to Paley (2002). Mechanical knee alignment (MA) was measured by comparing the mechanical axis of the femur (center of femoral head to midpoint of femoral surgical epicondyles) with the mechanical axis of the tibia (center of tibial spines to center of talus).

Anatomical knee alignment (AA) was measured by comparing the anatomical axis of the femur (using a line connecting 3 midpoints of the femoral shaft) with the anatomical axis of the tibia (the same as the mechanical axis). This is shown for LLR and CTS in Figure 1.

Statistics

MedCalc for Windows (MedCalc Software, Ostend, Belgium) was used for statistical analysis.

Reliability was assessed using 10 randomly selected paired scans, each measured in triplicate by 2 independent observers at different times. Intraclass correlation coefficient (ICC) scores showed highly reliable intra-rater and inter-rater reliability for all measurements using CTS and LLR (defined by ICC > 0.81 according to guidance set out by Altman, 1990) (Table).

The correlation between CTS and LLR was quantified using Pearson's correlation coefficient. Paired-samples t-tests were used to assess the statistical significance of the mean difference seen in measurements between CTS and LLR. The agreement between CTS and LLR was quantified using Bland-Altman plots, demonstrated by 1.96 standard deviation limits of agreement (LOA). These plots are shown in Figures 2–5.

Results

UKR mechanical axis (Figure 2)

The mean measurement in this group was 2.9° varus (SD 5.3) for LLR and 4.4° varus (SD 3.8) for CTS. The mean difference was 1.5° (95% CI: 0.47–2.57; p = 0.007).

The correlation coefficient r was 0.91 (95% CI: 0.80–0.96; p < 0.001). 8 of 23 measurements were more than 2.5° different.

UKR anatomical axis (Figure 3)

The mean measurement in this group was 3.4° valgus (SD 5.6) for LLR and 0.89° valgus (SD 5.1) for CTS. The mean difference was 2.5° (95% CI: 1.2–3.9; p < 0.001).

The correlation coefficient r was 0.83 (95% CI: 0.63–0.93; p < 0.001). 15 of 23 measurements were more than 2.5° different.

Intraclass correlation coefficient reliability measurements (with 95% confidence intervals)

	Mechanical knee alignment		Anatomical knee alignment	
	LLR	CTS	LLR	CTS
Intra-rater	0.97 (0.93–0.99)	0.97 (0.92–0.99)	0.98 (0.94–0.99)	0.99 (0.98–1.00)
Inter-rater	0.97 (0.89–0.99)	0.91 (0.57–0.98)	0.98 (0.90–0.99)	0.93 (0.75–0.98)

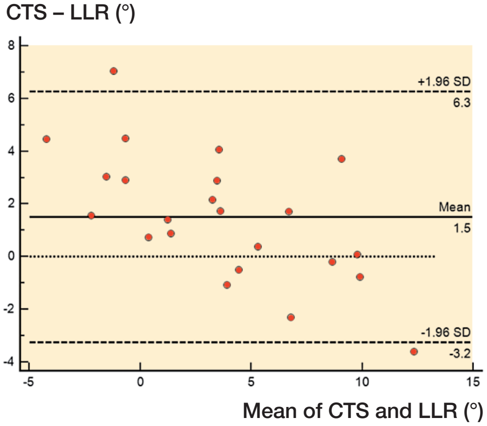

Figure 2. Bland-Altman plot of the differences in measurement of mechanical knee alignment between CTS and LLR (UKR).

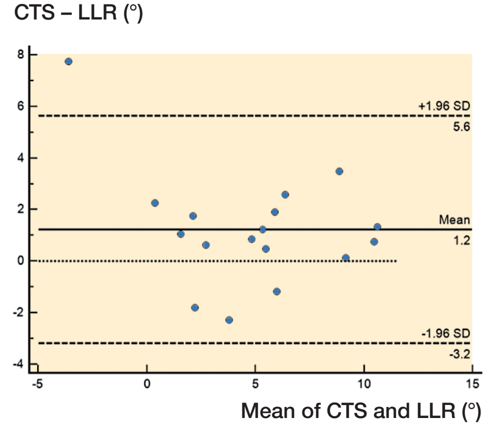

Figure 4. Bland-Altman plot of the differences in measurement of mechanical knee alignment between CTS and LLR (native knee).

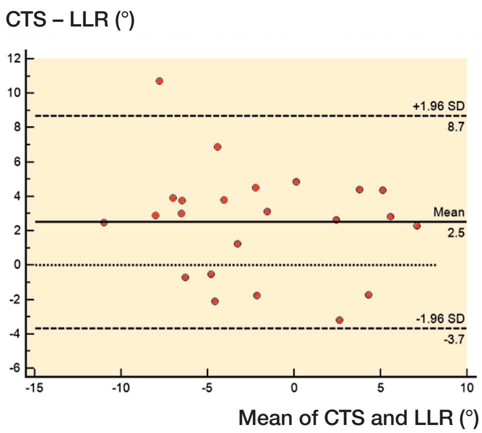

Figure 3. Bland-Altman plot of the differences in measurement of anatomical knee alignment between CTS and LLR (UKR).

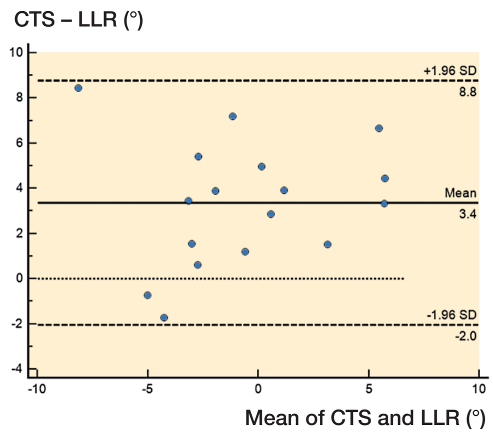

Figure 5. Bland-Altman plot of the differences in measurement of anatomical knee alignment between CTS and LLR (native knee).

Native knee mechanical axis (Figure 4)

The mean measurement in this group was 4.2° varus (SD 4.3) for LLR and 5.4° varus (SD 3.6) for CTS. The mean difference was 1.2° (95% CI: 0.08–2.4; $p = 0.04$).

The correlation coefficient r was 0.85 (95% CI: 0.63–0.95; $p < 0.001$). 1 of 17 measurements was more than 5° different.

Native knee anatomical axis (Figure 5)

The mean measurement in this group was 2.3° valgus (SD 4.0) for LLR, and 1.4° varus (SD 4.3) for CTS. The mean difference was 3.4° (95% CI: 1.9–4.8; two-tailed probability $p < 0.001$).

The correlation coefficient r was 0.78 (95% CI: 0.49–0.92; $p < 0.001$). 4 of 17 measurements were more than 5° different.

Discussion

We found that measurements of knee alignment using CTS and LLR were statistically significantly different (in the native and post-UKR knee).

Given that differences of ± 5° from neutral for native knees are thought to be important in terms of disease progression (Sharma et al. 2011), our results that 6–24% of measurements differed by more than 5° are potentially clinically significant.

Given that differences of ± 2.5° for UKR are used to determine the accuracy of implant positioning in research (Gulati et al. 2009, Weale et al. 2000), our results that 39–65% of measurements differed by more than 2.5° are potentially clinically significant.

We found a mean difference of 1.2° to 3.4° more valgus in CTS than in LLR. Brouwer et al. (2003) evaluated supine LLR with weight bearing LLR in 20 patients, and found a mean of 2° more varus in the weight bearing LLR than in the supine LLR. Patients were exluded from Brouwer's analysis if valgus alignment was identified on clinical examination, which may partly explain the difference in results.

Gbejuade et al. (2014) compared weight bearing LLR with supine CTS in 24 patients after TKR, and found good overall agreement in measurement of the mechanical axis angle but a substantial under-detection of malalignment (> 5°) in the CTS group. They therefore advised caution in the use of CTS for measurement of knee alignment in patients after TKR.

Emerging technologies such as the EOS 2D/3D imaging system have the potential to image the weight bearing limb with simultaneous AP and lateral images, low radiation doses, and 3D reconstruction. Currently, however, the National Institute for Health and Clinical Excellence does not recommend its routine use in the National Health Service (NHS) due to a lack of clinical evidence to quantify the extent of patient benefits (NICE Diagnostics Guidance DG1, 2011).

In summary, supine CT scanogram, when compared to the reference standard of weight bearing long leg radiographic measurement of knee alignment, had similar precision (repeatability/interobserver error), but poor accuracy (closeness to the true value as measured by weight bearing long leg radiograph). We therefore recommend that it should not be used as a substitute for long leg weight bearing plain radiographs in measurement of the mechanical axis or anatomical axis of the knee.

All the authors contributed to the design of the study and review of the manuscript. Measurements were done by TJH and KH.

No competing interests declared.

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