



The lateral joint space width can be measured reliably with Telos valgus stress radiography in medial knee osteoarthritis

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Abstract

Objective To examine the reproducibility of valgus stress radiographs with the Telos stress device for assessment of lateral compartment degenerative changes in patients with medial osteoarthritis of the knee.

Materials and methods A prospective reliability study was performed. Seventy-nine patients (80 knees) were included, and standardized valgus stress radiographs were obtained using the Telos stress device. Osteophytes and joint space narrowing (JSN) were graded using the OARSI (Osteoarthritis Research Society International) classification, and the joint space width (JSW) was measured in millimeters. Reproducibility was determined as intra- and inter-rater reliability and test–retest reliability. Weighted kappa was used to determine the reliability of osteophyte and JSN grading, and the intra-class correlation coefficient for JSW.

Results Grading of osteophytes had an intra- and inter-rater reliability ranging from 0.40 to 0.83 on the medial side and ranging from 0.39 to 0.87 on the lateral side. Grading of medial JSN had an intra- and inter-rater reliability ranging from 0.62 to 0.84, and grading of lateral JSN had an intra- and inter-rater reliability ranging from 0.32 to 0.65. Intra- and inter-rater reliability of JSW ranged from 0.84 to 0.98 on the medial side, and from 0.59 to 0.89 on the lateral side. Test–retest reliability of JSW of the medial and lateral side ranged from 0.69 to 0.92.

Conclusions Standardized valgus stress radiographs taken with the Telos stress device are a reliable supplement in the assessment of medial OA of the knee. Evaluation of the lateral compartment on valgus stress radiographs is most reliable with measurement of the lateral JSW.

Keywords Stress radiographs · Osteoarthritis · Knee · OARSI (Osteoarthritis Research Society International) classification · Reliability

Introduction

Patient selection is important in securing a good outcome for unicompartmental knee arthroplasty (UKA). Radiographic

assessment of osteoarthritis (OA) is part of the patient selection prior to UKA surgery and aims to ensure a full-cartilage loss in the medial tibiofemoral (TF) compartment, and, equally important, to ensure full-cartilage thickness in the lateral

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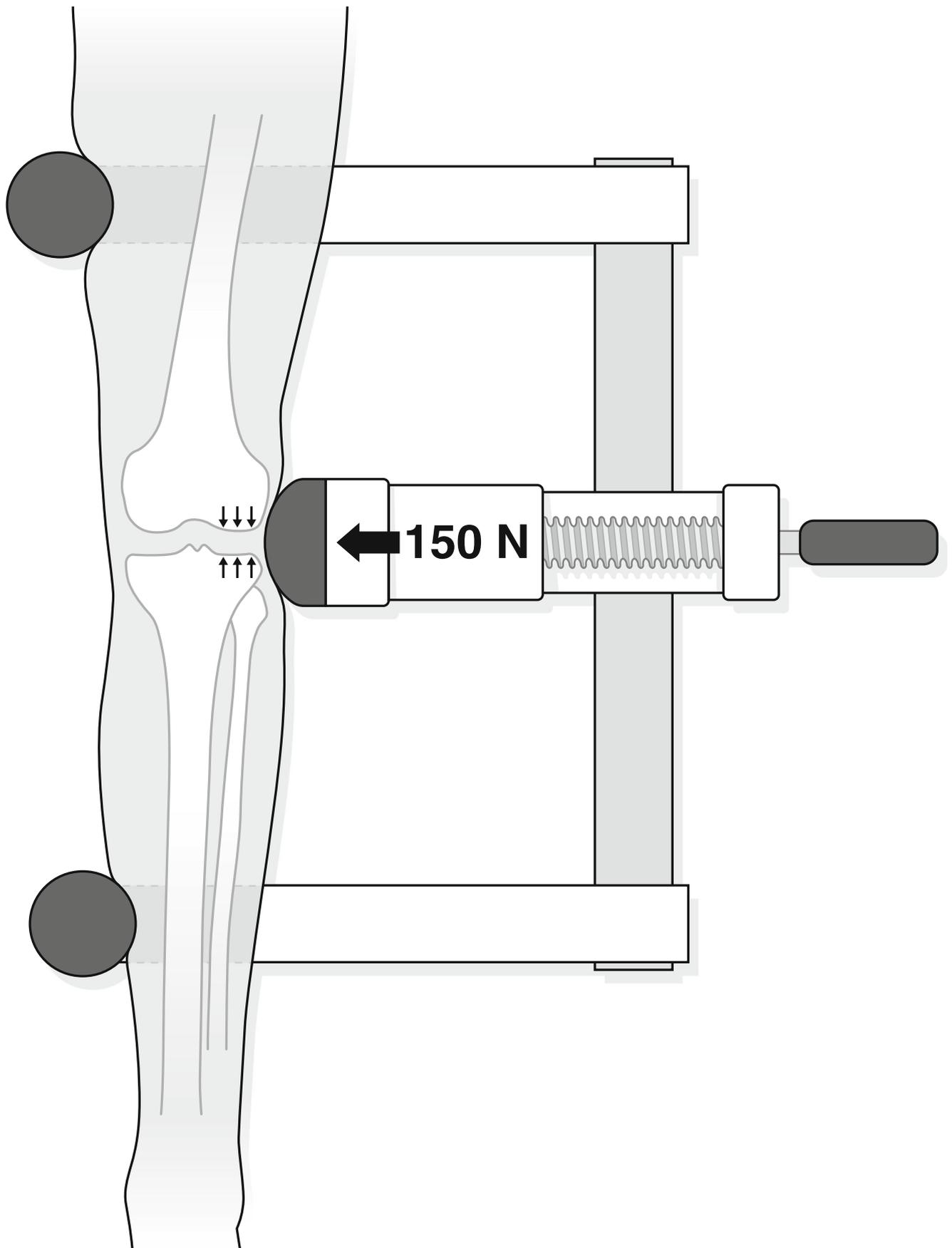
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◀ **Fig. 1** Illustration of the knee placed in the stress device

compartment [1]. The degree of OA in both the medial and lateral TF compartments are evaluated on posterior-anterior weight-bearing radiographs. In a knee without OA, joint space width (JSW) is assumed to be minimum 5 mm [1]. As a supplement to weight-bearing radiographs, valgus stress radiographs can be used in the evaluation of the lateral compartment [1–5]. One method to obtain stress radiographs is the application of a stress device [3, 4]. A stress device enables application of a standardized amount of valgus stress and minimizes the radiation exposure to the radiographic staff compared with manually applied valgus stress [3, 4]. Stress radiography with a stress device is well defined in examining ligament instability [6] and has shown greater narrowing of the JSW than weight-bearing radiographs [3, 4]. Valgus stress radiography with the Telos stress device has not been validated for assessment of lateral OA of the knee joint.

This study aimed to examine the reproducibility of valgus stress radiography with the Telos stress device for assessment of lateral compartment degenerative changes in patients with medial osteoarthritis of the knee. Reproducibility is defined as the intra- and inter-observer reliability as well as the test–retest reliability of the radiological set-up. The hypothesis was that a substantial (weighted kappa/ICC 0.61–0.80) reliability [7] can be obtained with stress radiographs taken with the Telos stress device.

Subjects and methods

Patients were included in a prospective reliability study at our Knee Clinic from January 2015 to January 2016. Inclusion criteria were medial OA on weight-bearing fixed-flexion postero-anterior radiographs on referral and patient age above 18 years. Medial OA was defined as joint space narrowing (JSN) of the medial compartment on posterior-anterior fixed-flexion weight-bearing radiographs, assessed by two orthopedic surgeons. There were no other exclusion criteria. A total of 79 patients (80 knees) were included in the study. There were 32 men and 47 women; the mean age was 66 years (range, 39–90 years).

Setup valgus stress radiography

The weight-bearing fixed-flexion postero-anterior radiographs were supplemented with valgus stress radiographs. The patient was supine with the patella positioned in the midline. The knee was flexed approximately 20° by placing a wedge under the knee. The Telos stress device (Metax GmbH, Hungen-Obbornhofen, Germany) was applied according to the manufacturers' guidelines [8]. The pressure

pad was placed in line with the lateral articular space. Two counter supports were placed medially on the femur and tibia, as far away from each other as possible (Fig. 1). A pressure of 150 N was applied to the pressure pad. A calibration marker (diameter = 30 mm) was placed medial of the medial joint line. The radiograph was aligned on the joint line of the lateral compartment (Fig. 2). Double measurement radiographs were taken within 15 min after repositioning of the patient and reapplication of the Telos stress device. Radiographs were stored in DICOM format (4096 pixels). Radiographs were obtained by experienced radiology technicians.

Radiographic assessment

Radiographs were graded on the degree of osteophytes and JSN according to the OARSI classification (Table 1), using the 'Atlas of individual radiographic features in osteoarthritis, revised' by Altman et al. [9]. This is a commonly used classification system for the degree of OA, having a good validity and reliability [10]. An advantage of the OARSI classification compared with other classifications is that it describes the grade of OA in the medial and lateral compartment separately, instead of the degree of OA in the entire TF joint [10].

The JSW in the medial and lateral compartment was measured quantitatively in millimeters using a digital caliper. JSW was measured from the midpoint of the medial/lateral femoral condyle to the midpoint of the corresponding tibial condyle (Fig. 3) [11, 12]. Measurements were corrected for magnification by use of the calibration marker. All grading and measurements were performed on a picture archiving and communication system (PACS) (Impax system; AGFA Healthcare N.V. Belgium).

Two orthopedic surgeons and a radiologist assessed all the stress radiographs twice, as well as the double measurement radiograph. A plenary session was held before the start of the study, where the OARSI atlas and the method for measuring JSW were discussed. No further education was received by the readers. To ensure nondependent assessments, radiographs were examined with a minimum period of 2 weeks between assessments, and all raters were blinded for the clinical data [13].

Analysis

To determine intra- and inter-rater reliability, as well as test–retest reliability, weighted kappa (κ) and 95% confidence intervals (95% CIs) were determined for the OARSI scores on osteophytes and joint space narrowing (JSN), as these are categorical data [8]. Weighted κ with squared weighting was used to correct for disagreement in terms of their seriousness [7]. For interpretational reasons, the percent of agreement is given besides weighted κ [14].

The intra-class correlation coefficient (ICC) was used to evaluate the reliability of the JSW measurement of the medial and lateral compartment, as these are continuous data [14].

Results were interpreted with the guidelines of Landis and Koch [7] and Fleiss and Cohen [15], translating the κ coefficient and the ICC [14] into a strength of agreement: ≤ 0 = poor, 0.01–0.20 = slight, 0.21–0.40 = fair,

0.41–0.60 = moderate, 0.61–0.80 = substantial, 0.81–1 = almost perfect.

According to Walter et al. [16], to be able to detect a difference between a κ coefficient of 0.40 and 0.60, using three observers, a sample size of 51.5 was sufficient. The study has been reported in accordance with the STARD guidelines for diagnostic accuracy studies [17].

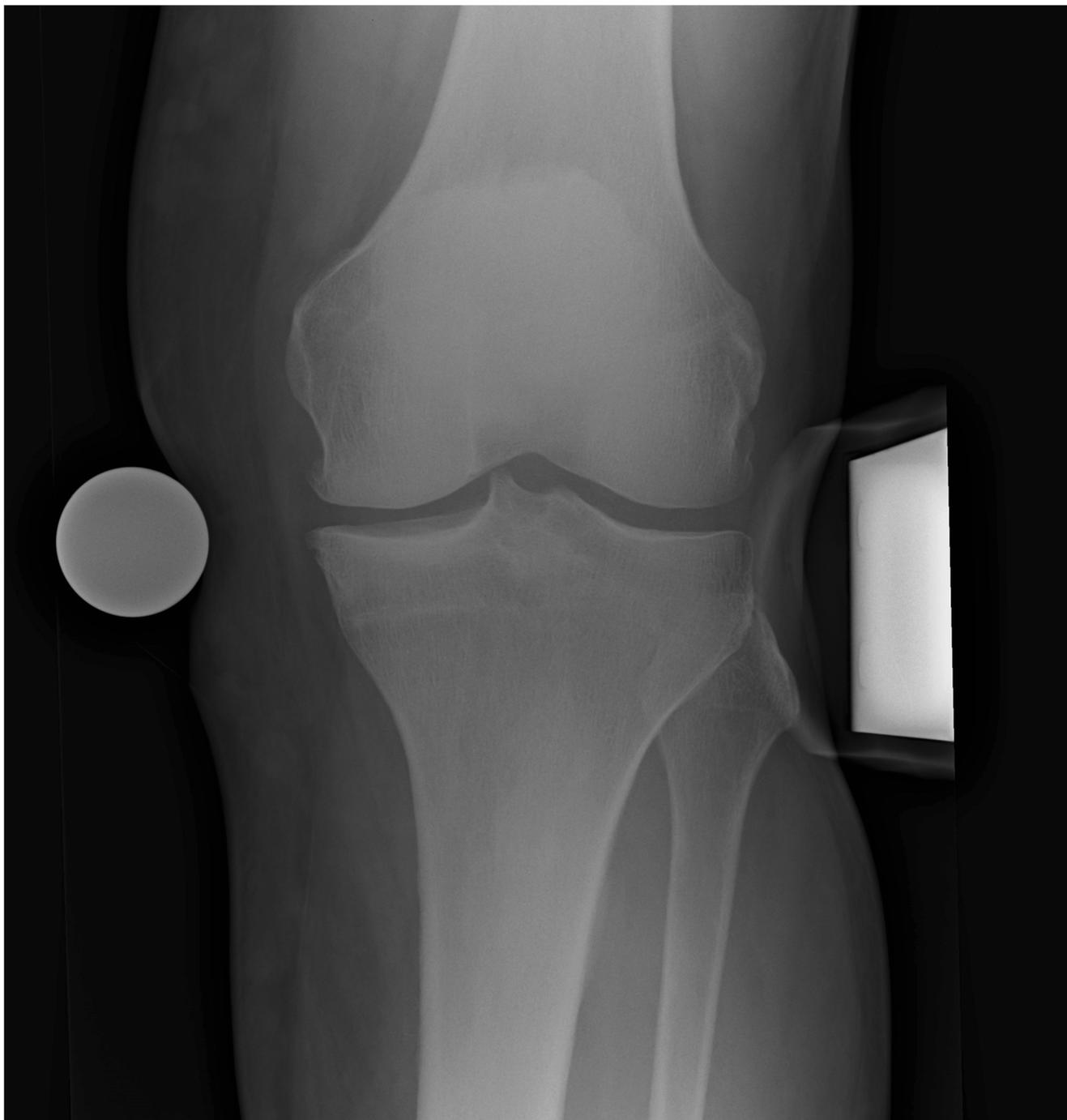


Fig. 2 Valgus stress radiograph of the knee

Table 1 OARSI score for osteoarthritis of the knee [9]

Marginal osteophytes	
Medial femoral condyle	0–3+
Medial tibial condyle	0–3+
Lateral femoral condyle	0–3+
Lateral tibial condyle	0–3+
Joint space narrowing	
Medial compartment	0–3+
Lateral compartment	0–3+

(0 = normal, 1 = mild change, 2 = moderate change, 3 = severe change)

Results

Results of the intra- and inter-rater reliability, as well as the test–retest reliability, are shown in Table 2. Due to missing or incomplete calibration (no magnification correction possible), 15 radiographs were not available for evaluation of the JSW.

Intra-rater reliability

Intra-rater agreement showed substantial to almost perfect agreement for assessment of the femoral and tibial osteophytes. Agreement for assessment of JSN ranged from substantial medially to fair–moderate laterally. Agreement for JSW measurement in both the medial and lateral compartment showed almost perfect agreement.

Inter-rater reliability

Inter-rater agreement of osteophytes was substantial for the tibial condyle, both medially and laterally. JSN and JSW showed substantial (JSN) to almost perfect (JSW) inter-rater reliability on the medial side.

Test–retest reliability

Test–retest agreement on the grade of osteophytes was substantial on the tibial condyle. Agreement for assessment of femoral osteophytes ranged from slight to substantial, and assessment of JSN showed fair to moderate agreement in the medial and lateral compartment. Agreement on medial and lateral JSW was substantial to almost perfect.

Discussion

This is the first study to examine the reliability of valgus stress radiographs with the Telos stress device in patients with medial OA of the knee. As valgus stress radiographs are used to evaluate the lateral compartment for OA, the most interesting finding of this study was the grading of the lateral compartment. Although an acceptable level of reliability is not defined

in the literature [14], a substantial reliability has been suggested as a minimum [18]. Our results showed that assessment of the lateral compartment was best done with the JSW, having an almost perfect intra-rater reliability and a substantial inter-rater reliability. The OARSI criteria showed more variation in both intra- and inter-rater reliability, ranging from fair to almost perfect for assessment of osteophytes, and from fair to substantial for assessment of the lateral JSN.

Intra- and inter-rater reliability

Similar reliability has been obtained in other studies using different stress device methods. Using a self-developed stress device applying a force of 10 kg or as much as tolerated, Eriksson et al. [4] found increased JSN with varus and valgus stress radiographs compared to standard weight-bearing radiographs. Inter-rater reliability for JSW (ICC), determined by re-examining ten radiographs, showed an almost perfect reliability [3]. Manually applied valgus stress radiographs were compared with the intraoperative grading of OA by Waldstein et al. [11]. They found an almost perfect intra-/ and inter-rater reliability (ICC) of the medial and lateral JSW for a subset of 20 patients.

Studies with standard weight-bearing radiographs of the knee have also shown comparable or even better reliability for measuring the joint space. A moderate inter-rater reliability and substantial intra-rater reliability (weighted κ) for JSN was reported by Gossec et al. [19], and a moderate to almost perfect inter- intra-rater reliability (weighted κ) for scoring medial and lateral JSN was shown by Riddle et al. [10]. The Kellgren and Lawrence (K/L) classification system and the OARSI score was compared on weight-bearing radiographs by Culvenor et al. [20]. They found a substantial intra-rater reliability for measuring JSW. Specifically for the OARSI criteria, an almost perfect intra-rater reliability and substantial inter-rater reliability (weighted κ) for both osteophytes and JSN were seen, which is somewhat higher as our results. The association between the radiographic severity of OA and preoperative function was assessed by Dowsey et al. [21]. They found a substantial intra-rater reliability (κ) for grading of medial and lateral osteophytes as well as for JSN. In a study of the reliability of radiographic grading of non-clinician readers compared to a radiologist, Kara et al. found a fair to almost perfect intra-rater reliability and a moderate to almost perfect inter-rater reliability among non-clinician readers for osteophytes and JSN [22]. Our study showed similar results with no large differences in reliability between the two orthopedic surgeons and the radiologist.

Test–retest reliability

We found that reproducibility of valgus stress radiographs with repositioning the patient and reapplying the Telos stress

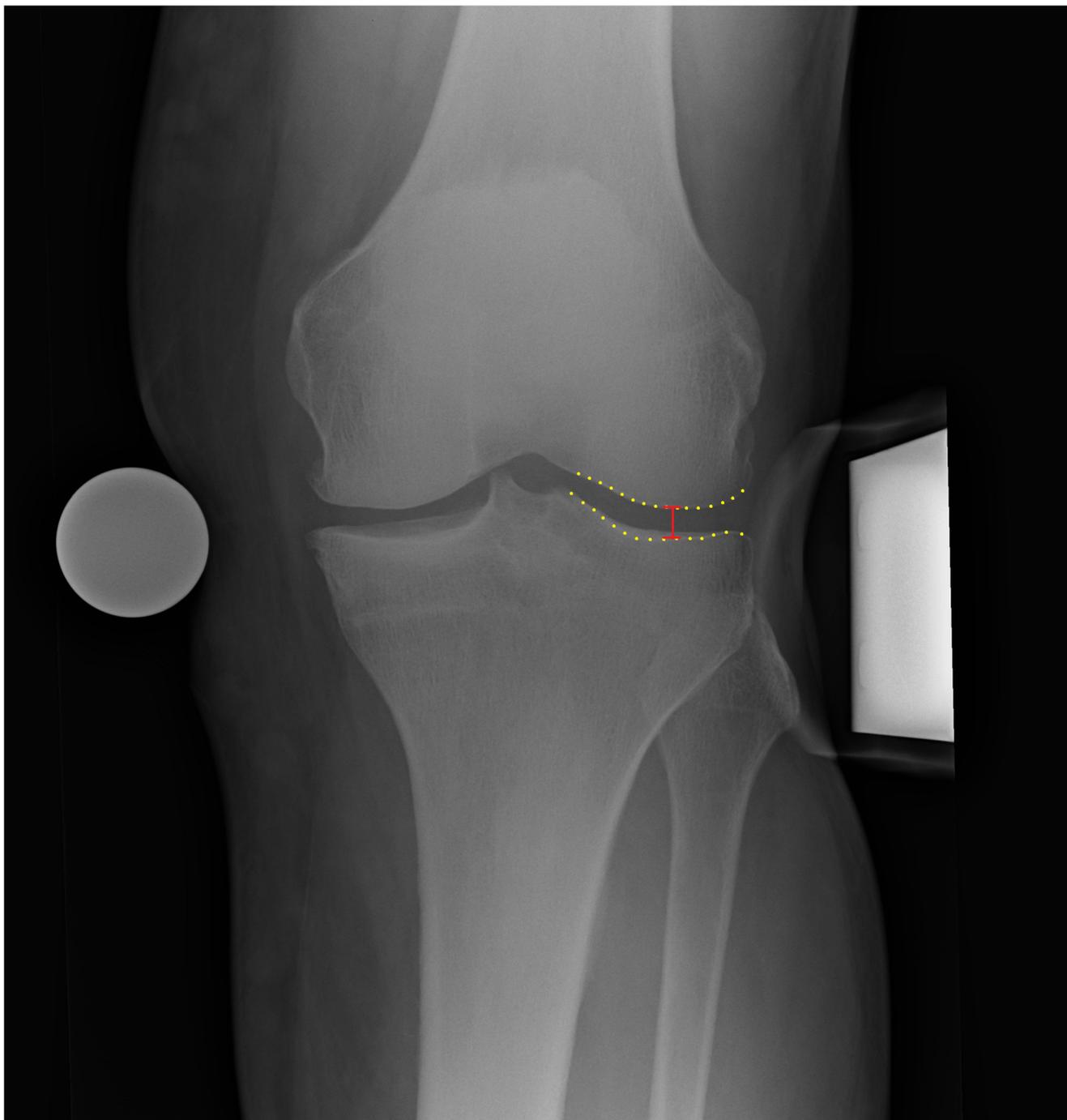


Fig. 3 Measurement of JSW (mm)

device was best done with the JSW, which showed almost perfect intra-rater reliability and substantial to almost perfect inter-rater reliability for measurement of the medial and lateral JSW. An almost perfect inter-rater reliability (ICC) for the measurement of JSW on test–retest weight-bearing, fixed-flexion radiographs was found by Nevitt et al. [23]. The reproducibility of test–retest weight-bearing, semiflexed knee radiographs was studied by

Buckland-Wright et al. [24] and showed a very good reliability in measuring JSW. For the OARSI criteria, we found lower and more varied reliability.

Study limitations

Our study had some limitations. First, selection bias was present in our study, as only referred patients with mild to severe

Table 2 Intra- and inter-observer reliability as well as test–retest reliability

	Osteophytes				Joint space narrowing		Joint space width	
	Medial femoral condyle	Medial tibial condyle	Lateral femoral condyle	Lateral tibial condyle	Medial	Lateral	Medial	Lateral
Intra-rater 1	0.70 (0.55; 0.74) 91.3%	0.83 (0.81; 0.89) 95.8%	0.55 (0.14; 0.80) 96.0%	0.82 (0.78; 0.87) 96.7%	0.77 (0.69; 0.79) 95.3%	0.32 (0.10; 0.37) 94.7%	0.86 (0.77; 0.91)	0.81 (0.68; 0.88)
Intra-rater 2	0.68 (0.61; 0.79) 90.1%	0.77 (0.70; 0.86) 95.8%	0.69 (0.58; 0.77) 92.9%	0.76 (0.73; 0.84) 96.5%	0.73 (0.54; 0.83) 94.1%	0.59 (0.51; 0.79) 96.9%	0.86 (0.78; 0.92)	0.81 (0.69; 0.88)
Intra-rater 3	0.82 (0.76; 0.89) 95.3%	0.82 (0.78; 0.84) 96.7%	0.87 (0.82; 0.94) 98.2%	0.85 (0.81; 0.87) 98.2%	0.84 (0.78; 0.88) 98.5%	0.65 (0.44; 0.87) 97.2%	0.98 (0.97; 0.99)	0.89 (0.81; 0.93)
Inter-rater 1-2	0.46 (0.43; 0.52) 79.9%	0.65 (0.51; 0.70) 91.9%	0.39 (0.26; 0.44) 88.8%	0.76 (0.71; 0.81) 96.0%	0.67 (0.55; 0.71) 93.1%	0.52 (0.28; 0.80) 95.9%	0.84 (0.74; 0.90)	0.59 (0.33; 0.75)
Inter-rater 1-3	0.40 (0.33; 0.51) 80.3%	0.74 (0.67; 0.74) 94.3%	0.55 (0.36; 0.67) 94.7%	0.73 (0.62; 0.77) 95.8%	0.65 (0.46; 0.74) 93.4%	0.62 (0.61; 0.70) 96.6%	0.87 (0.78; 0.92)	0.69 (0.49; 0.81)
Inter-rater 2-3	0.70 (0.65; 0.74) 91.5%	0.76 (0.67; 0.81) 95.1%	0.67 (0.54; 0.75) 93.8%	0.75 (0.65; 0.79) 96.5%	0.62 (0.52; 0.67) 92.2%	0.45 (0.28; 0.60) 95.6%	0.87 (0.80; 0.92)	0.79 (0.66; 0.87)
Test-retest 1	0.47 (0.45; 0.71) 84.2%	0.57 (0.50; 0.61) 88.5%	0.07 (-0.07; 0.30) 93.1%	0.67 (0.62; 0.82) 94.2%	0.47 (0.30; 0.54) 90.9%	0.36 (0.25; 0.52) 95.6%	0.84 (0.74; 0.90)	0.69 (0.50; 0.81)
Test-retest 2	0.57 (0.48; 0.63) 88.2%	0.78 (0.69; 0.89) 96.4%	0.48 (0.31; 0.51) 86.5%	0.77 (0.65; 0.88) 97.1%	0.54 (0.33; 0.55) 90.3%	0.54 (0.38; 0.61) 96.3%	0.80 (0.68; 0.88)	0.82 (0.70; 0.89)
Test-retest 3	0.71 (0.62; 0.80) 92.4%	0.71 (0.62; 0.75) 95.0%	0.76 (0.51; 0.84) 96.8%	0.74 (0.71; 0.80) 97.1%	0.45 (0.43; 0.49) 90.0%	0.37 (0.11; 0.63) 93.8%	0.92 (0.87; 0.95)	0.90 (0.83; 0.94)

For osteophytes, joint space narrowing (JSN) reliability is shown as weighted κ and 95% CIs, as well as percent of agreement

For joint space width (JSW) reliability is shown as ICC and 95% CIs

Strength of agreement: 0.01 – 0.20 = slight, 0.21 – 0.40 = fair, 0.41 – 0.60 = moderate, 0.61 – 0.80 = substantial, 0.81 – 1.00 = almost perfect

medial OA were included in the study. Also, patients with severe medial OA can have a contracture of the medial collateral ligament, which limits the extent of possible valgus stress and results in non-optimal loading the lateral compartment and a false-negative outcome on a valgus stress radiograph. However, our study aimed to investigate the reliability of OA staging on valgus stress radiographs obtained with the Telos stress device as part of the assessment for treatment-options with medial OA, and therefore it has not influenced our results. Second, the validity of the valgus stress radiographs was not tested against a gold standard method, as it was only our intention to test the reliability of the stress radiographs and not the validity. Third, nearly 20% of all radiographs had

incomplete calibration due to suboptimal placement of the calibration marker and could not be used for measuring JSW. This is though unlikely to have had a consequence on the results, as there were 65 radiographs available for assessment, which was sufficient according to the power calculation. Fourth, reliability was in some instances low, for example, the test–retest reliability of the femoral osteophytes. This can be explained by a low prevalence, resulting in scores skewed to the lower outcomes. The kappa score accounts for the agreement beyond the expected agreement by chance [13, 14]. Although there is a high percent of agreement, a large part is explained by chance, resulting in a low kappa. The percent of agreement is shown alongside the kappa in Table 2.

Clinical relevance

There is large variation in the preoperative radiographic evaluation of patients with medial OA; in the UK, only 16.5% of the surgeons use varus/valgus stress radiographs as part of their assessment [25]. The unloaded, lateral compartment cannot sufficiently be assessed on weight-bearing radiographs. During surgery, only the lateral femoral condyle is available for visual inspection. The lateral tibial plateau cannot be visualized. Lateral JSW on valgus stress radiographs has shown good correlation with cartilage thickness [26]. Although our results were obtained using a study protocol, the study was performed in a clinical setting. The results are therefore probably generalizable to other clinical settings.

Conclusions

Standardized valgus stress radiographs taken with the Telos stress device are a reliable supplement in the clinical evaluation of patients with medial OA. Evaluating the lateral knee compartment on valgus stress radiographs is best done with measurement of the lateral JSW, which shows substantial to almost perfect intra- and inter-rater as well as test–retest reliability.

Further studies are needed to determine the validity of valgus stress radiography in the clinical assessment of patients with medial OA of the knee in comparison with clinical symptoms, histological changes, and MRI findings.

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Authors' contributions DK participated in the design of the study, performed the statistical analysis, and drafted the manuscript. OGS participated in the design of the study, data interpretation, and critical revision of the manuscript. SM participated in the design of the study and critical revision of the manuscript. SR participated in the design of the study, data acquisition, data interpretation, and critical revision of the manuscript. SKAL participated in the data acquisition and critical revision of the manuscript. MS participated in the design of the study, data interpretation, and critical revision of the manuscript. TBH participated in the conception and design of the study, data interpretation, and critical revision of the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

The study was approved of by the Central Denmark Region Committees on Health Research Ethics (ID number 1-10-72-99-14, date of issue 29-04-2014) and registered at the Danish Data Protection Agency (ID number 1-16-02-709-14, date of issue 20-11-2014). All procedures performed in this study were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

Conflict of interest DK has received support from the Health Research Fund of Central Denmark Region (ref. number 1-31-72-15-14).

The other authors declare that they have no conflicts of interest.

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