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The Knee Osteoarthritis Grading System for Arthroplasty

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ABSTRACT

Background: The aim of this study is to validate the Knee Osteoarthritis Grading System (KOGS) of progressive osteoarthritic degeneration for the tri-compartmental knee. This system defines the site and severity of osteoarthritis to determine a specific knee arthroplasty.
Methods: The radiographic sequence for KOGS includes standing coronal (anteroposterior), lateral, 30° skyline patella, 15° and 45° Rosenberg and stress views in 20° of flexion. Cohen's kappa and related agreement statistical methods were used to assess the level of concordance of the 7 evaluators between A and B cohorts for each evaluator and also against the actual arthroplasty used. Sensitivity and specificity was also assessed for the KOGS in identifying true partial knee arthroplasties (PKAs) and total knee arthroplasties (TKAs) as decided from the cohort A evaluations.
Results: From a cohort of 330 patients who were included in the study, 71 (22.5%) underwent a TKA procedure, 258 (78.2%) a PKA, and 1 (0.3%) was neither a TKA nor PKA. KOGS was able to identify true PKAs (sensitivity) in the range of 92.2%-98.5% across all the different evaluators. The KOGS method was able to identify a PKA or a TKA with an accuracy ranging from 92% to 98.8% across all different evaluators. The surgical results after 20 months are at least comparable with the expected average in the academic literature.
Conclusion: The KOGS classification provides a reliable and accurate tool to assess suitability of an individual patient for undergoing PKA or TKA.

An osteoarthritic (OA) knee patient usually presents to the clinician with varying symptoms including pain, stiffness, instability, and difficulties in activities of daily living. In patients with significant symptoms, the decision of whether to offer a knee arthroplasty is dependent on confirmation of bone-on-bone arthritis in the affected knee [1]. Assessment before the

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implementation of a specific type of knee arthroplasty (KA) includes the history, clinical presentation, special investigations, patient's preference, and surgeon's skill in different available options.

Typically, primary OA tends to start in one compartment and with time progresses to be tri-compartmental. In cases with single compartment disease, partial (or unicompartmental) knee arthroplasty (PKA) provides significant advantages over total knee arthroplasty (TKA). These include better function, reduced morbidity and mortality, and more natural feel of the replaced knee [2]. Although excellent results following PKA are seen in appropriate patients, there is significant variability in outcomes and globally higher revision rates of PKA are observed when compared to TKA. The reasons for this higher revision rate are multi-factorial and include variation in patient selection, surgical technique, as well as differing thresholds for revision of PKA, compared to TKA [3].

At present, guidelines for patient selection for PKA are, at best, based on medium-term data with no externally validated method of patient selection in existence. This is reflected by the variability in current PKA utilization ranging between 0% and 60% of all primary knee arthroplasties [4].

A clinician's decision to consider a PKA is based on his/her interpretation of the pathoanatomy of the knee arthritis which is usually reached by careful examination of radiographs. The radiographs need to assess severity and extent of knee OA in individual tibiofemoral and patellofemoral compartments and also indicate integrity of cruciate and collateral ligaments. This will help the clinician make an informed decision as to the type of KA that will be optimal to an individual patient and whether any supplementary procedure is needed.

Traditional X-ray grading systems such as Ahlbäck classification [5], Kellgren-Lawrence grading [6], and Osteoarthritis Research Society International [7] do not take radiographic signs into account for a single joint compartment in their classification of OA. They typically assess weight-bearing anteroposterior (AP) and lateral radiograph of the affected knee and comment on the status of joint space, presence and severity of osteophytes, and other salient features to diagnose knee OA. Although widely used, these systems are inadequate to classify the tri-compartmental knee degeneration and cannot give an indication of the need for PKA or TKA. To overcome this limitation, additional radiographs and/or atlas-based scoring systems have been developed. These typically include weight-bearing radiographs of a flexed knee and/or varus-valgus stress views. X-KIDS (X-ray Knee Instability and Degenerative Score) [8] and Decision Aid [9] are 2 such systems.

X-KIDS [8] assessment is based on 6 radiographic views (standing AP, lateral, standing Posteroanterior (PA) in 15° flexion, standing PA in 45° flexion, and varus and valgus stress views in 20° flexion). Knees are scored for narrowing, osteophytes, and subluxation in both the coronal and sagittal plane. Overall, the knee could receive a maximum of 10 points with a score of 3 or 4 indicating PKA to be the treatment of choice, 5 indicating that PKA may be appropriate pending clinical findings and surgical correlation, and a score of greater than 5 indicating that TKA is indicated. In an internal validation study, Oosthuizen et al [8] reported X-KIDS to be 92% accurate at determining the optimum treatment option in 336 knees. This system does not address the patella-femoral joint (PFJ) and includes presence of osteophytes as a predictor. Therefore, it does not help in assessing the suitability for a PFJ arthroplasty and presence of osteophytes has been shown to be unrelated to the long-term success of a PKA [10]. Decision Aid [9], an atlas-based system, was developed and validated by Hamilton et al. It consists of 5 sections, each assessing one of the 5 criteria, with radiographic view and exemplar radiographs provided that demonstrates when the criteria are met, as well as exemplar radiographs that demonstrate when the criteria are not met. It has been validated but only for medial PKA.

The Knee Osteoarthritis Grading System (KOGS), a radiological grading system (Figure 1) of degenerative arthritis of the knee, was developed to provide the clinician with a comprehensive system which is easy to use and has the ability to evaluate all 3 compartments of the knee to aid the surgeon's decision on the type and timing of knee arthroplasty. The system complements clinical evaluation as a tool to improve surgical decision. Patients with severe enough symptoms to consider a KA have 6 radiographs taken of the affected knee with no involvement by the clinician: AP standing, lateral, 30° skyline view, PA 15° (medial OA) and PA 45° (lateral OA) flexion views, and stress views in 20° flexion. The proviso for considering a joint arthroplasty is that at least one compartment has bone-on-bone contact (Kellgren and Lawrence grade 4). In addition to assess functional integrity of a tibiofemoral (TF) compartment, it must be more than 5 mm in width and parallel to the opposing joint surfaces on the stress view. When a stress view causes an increased joint line convergence angle (>2°), the "stress wedge deformity" in the ipsilateral compartment, it indicates ligamentous instability or more wear in the healthy compartment than anticipated [11].

The grading system consists of 4 deteriorative grades with a variety of possible treatment options to be implemented.

Grade 1 is an isolated medial, lateral TF or PFJ OA with ligament stability and 2 functionally intact compartments.

Grade 2 is a deteriorating isolated lesion with ligament stability and a correctible coronal subluxation.

Grade 3 (2 pathologies) includes an isolated medial or lateral TF OA and concomitant pathology such as anterior cruciate ligament deficiency (3A) or grooving of PFJ or patellectomy (3B).

Grade 4A includes cases of bi-compartmental TF OA without concomitant ligament instability and 4B with ligament instability.

Both Grade 1 and 2 affected joints are suitable for a partial KA, while Grade 3 and 4 are suitable for a TKA.

The overall objective of the study is to validate KOGS as a reliable determinant of pathology and suitability for a PKA by using a structured deteriorative radiological assessment in combination with an atlas-based Decision Aid. The primary aim of this study is to establish inter-rater reliability of a new Decision Aid aimed at assisting the clinician in choosing PKA as a possible treatment option for an individual patient presenting with symptomatic knee OA. It also aims to confirm the face validity of the tool and establish short-term outcomes of PKA in patients who underwent the intervention based on the KOGS algorithm.

Materials and Methods

The X-ray sequence was produced as a routine requirement at a single radiological facility. Ethical approval was obtained from an institutional review board and all patients provided informed consent for inclusion in the study. A cohort of 330 complete X-ray sets was included.

To establish face validity, these radiographs were independently assessed by 7 experienced orthopedic surgeons from Europe and South Africa with the aim of establishing whether a given patient is suitable for a PKA or a TKA. Patients were followed up to establish the incidence of short-term failures.

A cohort of 330 X-ray sequences (cohort "A") were evaluated for the implementation of a PKA or TKA by 7 experienced knee surgeon evaluators; the same cohort was scrambled into cohort "B" and evaluated according to KOGS and compared with the A and B results of the individual surgeons.

The evaluators were selected based on their expertise in the field. Each evaluator assessed the radiographs and opined on

whether the patient was suitable to undergo a KA and if so whether they would recommend a PKA or a TKA based on the X-ray assessment (cohort A). This was considered as the gold standard for that particular assessor. To establish content validity of KOGS, the same observers were provided with the KOGS atlas with the same set of radiographs in a random fashion, after an interval of 4 weeks. Based solely on the KOGS, the observers were asked to opine the suitability of the patient for PKA or TKA or no joint arthroplasty (cohort B). To establish construct validity, these results were compared with the surgical choice made by the surgeon (based on intra-operative findings) to ascertain the type of KA a patient was offered.

Statistical analysis was performed using STATA 14 [12]. All the assessments from the 7 evaluators were analyzed for agreement based on the assessment method used. Concordance and agreement methods were used in this study. Concordance analysis is needed to establish the validity of a new diagnostic measuring or rating technique or to demonstrate the near-equivalence of multiple measuring or rating techniques [13]. The generalized Cohen's kappa coefficient for nominal measurements was used as well as Gwet's first-order agreement coefficient (AC1) [14]. Cohen's kappa is used to show the degree to which different measuring or rating techniques agree with each other and takes into account the expected agreement that is purely by chance [13]. Strength of agreement between assessors is rated as per the value of kappa coefficient (poor: <0.00, slight: 0.00-0.2, fair: 0.21-0.4, moderate: 0.41-0.6, substantial: 061-0.8, and almost perfect: 0.81-1.00) [15]. However, Cohen's kappa has some weaknesses, that is, it is susceptible to trait prevalence and to balance these Gwet's AC1 coefficient was implemented. The latter is usually very stable in the presence of trait prevalence [16]. The agreement, kappa and Gwet's AC1 coefficient results were interpreted according to benchmarks developed by Landis and Koch [17] and recommended by Viera and Garrett [15] and Wongpakaran et al [16].

Results

From a cohort of 330 patients who were included in the study, 71 (22.5%) underwent a TKA procedure, 258 (78.2%) a PKA, and 1 (0.3%) was neither a TKA nor PKA. Of those undergoing a PKA, 205 underwent medial, 49 lateral, and 4 patellofemoral arthroplasties. The mean follow-up after the index procedure was 20 months (range 19-24). None of the patients were lost to follow-up. Seven patients experienced complications, 5 in the medial PKA group—3 for medial-bearing dislocation and 2 for subsidence—and 2 in the TKA group underwent further surgery (1 TKA for dislocation and 1 for patella fracture).

Table 1 assesses the agreement between the actual arthroplasty performed on the patients and the 2 assessment procedures, that is, the X-ray method (radiography assessment) and the KOGS. Each evaluator's assessment based on these 2 approaches is contrasted to what procedure the patient actually received. For the X-ray method, the percentage agreement with the procedure that was actually performed was 84% or higher for all assessors. Cohen's kappa was 0.56-0.68. Gwet's AC1 was 0.83-0.88 (Table 2). Cohen's kappa indicates a fair agreement, while Gwet's AC1 coefficient indicates an almost perfect agreement among the 7 assessors in their evaluations. For the KOGS method, the percentage agreement with the procedure that was actually performed was 84% or higher for all assessors. Cohen's kappa was 0.56-0.68. Gwet's AC1 was 0.84-0.87. Cohen's kappa indicates a fair agreement, while Gwet's AC1 coefficient indicates an almost perfect agreement among the 7 assessors in their evaluations.

Table 2 shows the inter-assessor concordance or agreement in the implementation of the X-ray procedure and then the KOGS for the 330 patients. Inter-assessor agreement was examined using the Cohen's kappa and Gwet's AC1 coefficient for the results of X-ray and KOGS evaluations. Percentage agreement between the 7

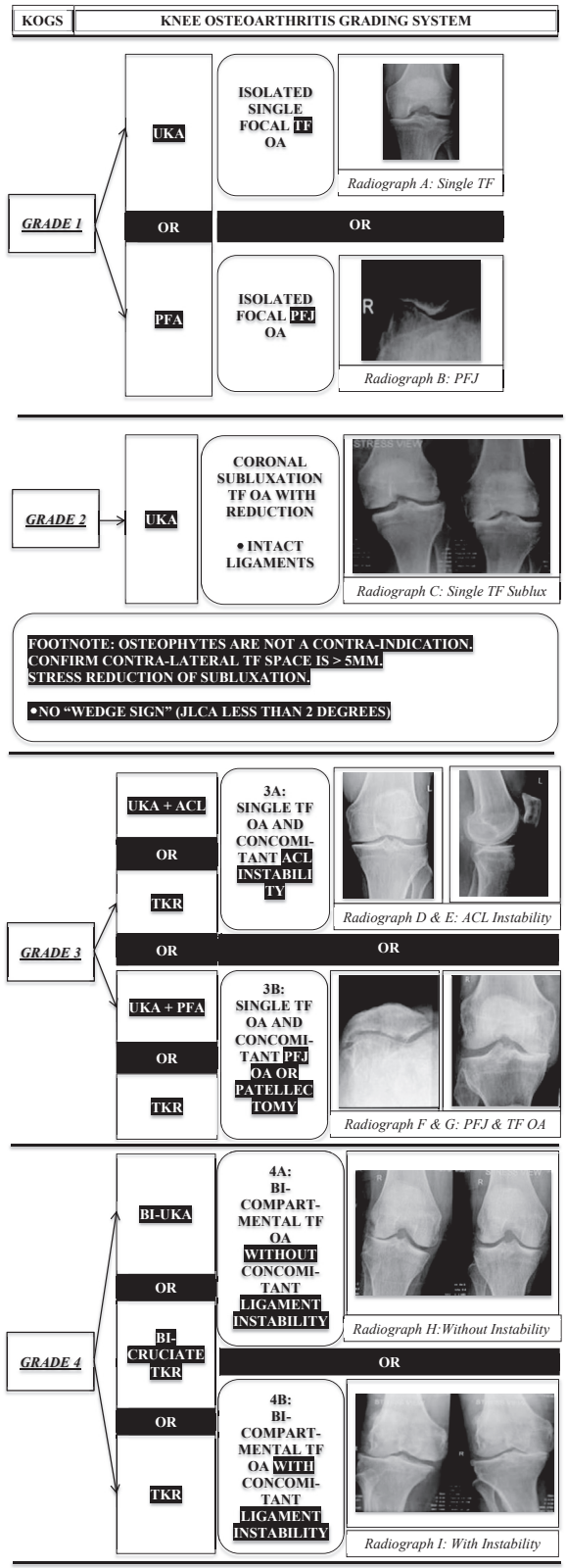

Fig. 1. KOGS flowchart with radiographs. UKA, Unicompartmental knee arthroplasty; PFA, Patellofemoral arthroplasty; BI-UKA, Bi-Unicompartmental knee arthroplasty; TF, Tibiofemoral; OA, Osteoarthritis; PFJ, Patella-femoral joint; JLCA, Joint line convergence angle; ACL, Anterior cruciate ligament..

Table 1
X-Ray and KOGS Raters' Agreement With the Type of Knee Arthroplasty Performed.

Rater	X-Ray (Cohort A)			KOGS (Cohort B)		
	Percent Agreement	Gwet's AC1	Cohen's Kappa	Percent Agreement	Gwet's AC1	Cohen's Kappa
#1	0.870 [0.833-0.906]	0.844 [0.799-0.890]	0.608 [0.504-0.716]	0.870 [0.834-0.906]	0.841 [0.795-0.887]	0.639 [0.541-0.737]
#2	0.861 [0.824-0.898]	0.834 [0.788-0.880]	0.563 [0.452-0.674]	0.842 [0.803-0.881]	0.808 [0.758-0.858]	0.557 [0.453-0.661]
#3	0.897 [0.864-0.930]	0.877 [0.837-0.917]	0.683 [0.584-0.782]	0.894 [0.861-0.927]	0.873 [0.832-0.914]	0.682 [0.585-0.779]
#4	0.888 [0.854-0.922]	0.868 [0.827-0.909]	0.627 [0.519-0.735]	0.864 [0.830-0.901]	0.837 [0.791-0.883]	0.590 [0.483-0.697]
#5	0.864 [0.827-0.901]	0.832 [0.785-0.879]	0.644 [0.550-0.738]	0.870 [0.834-0.906]	0.839 [0.793-0.885]	0.659 [0.566-0.752]
#6	0.876 [0.840-0.912]	0.852 [0.808-0.896]	0.618 [0.515-0.721]	0.879 [0.844-0.914]	0.855 [0.811-0.899]	0.630 [0.526-0.734]
#7	0.894 [0.861-0.827]	0.876 [0.836-0.916]	0.646 [0.540-0.752]	0.864 [0.827-0.901]	0.838 [0.792-0.884]	0.577 [0.467-0.687]

Figures in brackets represent 95% confidence intervals.
KOGS, Knee Osteoarthritis Grading System.

evaluators on the X-ray method for the 330 patients (cohort A) was 86.6% with a confidence interval of 84.5-88.7 suggesting an almost perfect agreement. Cohen's kappa was 56.6% [CI 49.9-63.3]. Gwet's AC1 was 84.1% [CI 81.4-86.8]. Cohen's kappa indicates a fair to almost perfect agreement, while Gwet's AC1 coefficient indicates an almost perfect inter-assessor agreement among the 7 assessors in their evaluations.

Table 3 shows the intra-assessor agreement for the 2 evaluation methods, that is, the X-ray and the KOGS methods. Percentage agreement between the 2 cohorts for the same assessor ranged from 88.5% to 99.5% suggesting an almost perfect agreement. Cohen's kappa was 62.3%-95.2%, while Gwet's AC1 was 86.4%-98.2% (Table 3). Cohen's kappa indicates a fair to almost perfect agreement, while Gwet's AC1 coefficient indicates an almost perfect intra-assessor agreement for each of the 7 assessors in their evaluations.

KOGS was able to identify true PKAs (sensitivity) based on X-ray method in the range of 92.2%-98.5% across all the different evaluators. The KOGS method was able to identify a PKA or a TKA with an accuracy ranging from 92% to 98.8% across all different evaluators (Table 4).

Discussion

This study validates KOGS and confirms its suitability in being used as a reliable tool for assessing suitability of a patient to undergo a PKA or a TKA. It also confirms high sensitivity and accuracy of KOGS as a diagnostic tool. The strengths of the study are the size of the cohort of required X-rays, the comparison of the experienced PKA and TKA surgeons' own assessment to a subsequent scrambled cohort KOGS evaluation with the actual implemented KA. The lower values achieved in Table 2, where the actual implemented procedures are compared with the rating, are partly due to the surgical decisions taken on clinical grounds, for example, excessive valgus, undiagnosed anterior cruciate ligament deficiency, patients preference, or even the surgical decision that does not relate to the X-ray grading.

Key prerequisite for a KA in patients with significant OA symptoms is the presence of full-thickness cartilage loss in at least one compartment of the knee. However, partial thickness cartilage loss is seen in over a quarter of secondary care consultations for OA that have failed non-operative treatment [18,19]. In most cases, the pain and functional scores of these patients are the same as, if not worse than, patients with more advanced structural changes. However, if a KA is offered to such patients not only the improvement in symptoms is significantly less and unreliable but also the revision rates are significantly higher [1,20–22].

Escobar et al [23] developed a TKA appropriateness algorithm based on pain, function, physical examination, radiographic signs of OA, and history of prior knee surgeries. Based on this algorithm, at least 20% of TKA are judged inappropriate. Riddle et al [24] adapted the appropriateness algorithm of TKA in the United States and found 34% of the TKA to be inappropriate. In a follow-up publication, the improvement after surgery in the inappropriate group was only 2.3 Western Ontario and McMaster Universities Osteoarthritis Index points versus 19.8 in the rest of the cohort [25]. This is, in part, due to the ill-defined indications for a TKA without a reliable grading system of degeneration as a guide regarding indications for arthroplasty.

Magnetic resonance imaging (MRI) provides a more accurate evaluation of cartilage degeneration compared to standard radiography. However, the standard X-ray is still the most accessible, user-friendly, cost-effective, and reliable system for general uses and is FDA approved in arthroplasty [26]. The research publication from Adelani confirms MRI as not the most suitable examination as therapeutic indicator when the joint space is less than 50% of normal [27]. Furthermore, treating surgeons often have limited funds to incorporate MRI in the treatment algorithm of knee OA and generally relies on the varied interpretation from the radiologist with no clinical experience. MRI sensitivity in establishing patient suitability for a PKA remains a problem. An abnormal finding on MRI does not always correlate with the outcome of a PKA. Hurst et al [28] have demonstrated no difference in clinical outcomes following PKA in knees with MRI contraindications to PKA compared with those without questioning the clinical relevance of MRI findings.

It is important to develop a valid and user-friendly system for adequate pre-operative diagnosis of bone on bone focal compartmental knee degeneration. It will help in patient selection as well as

Table 2
Inter-Rater Agreement for X-Ray and KOGS for All 7 Raters.

	Percent Agreement	Gwet's AC1	Cohen/Conger's Kappa
X-ray	0.866 [0.845-0.887]	0.841 [0.814-0.868]	0.566 [0.499-0.633]
KOGS	0.845 [0.821-0.869]	0.812 [0.781-0.843]	0.553 [0.491-0.616]

Figures in brackets represent 95% confidence intervals.
KOGS, Knee Osteoarthritis Grading System.

Table 3
Intra-Rater Agreement Coefficients for the 2 Methods.

Rater	Percent Agreement	Gwet's AC1	Cohen/Conger's Kappa
#1	0.952 [0.929-0.975]	0.941 [0.913-0.969]	0.863 [0.798-0.928]
#2	0.897 [0.864-0.930]	0.877 [0.836-0.918]	0.690 [0.599-0.781]
#3	0.985 [0.972-0.998]	0.982 [0.966-0.998]	0.952 [0.910-0.994]
#4	0.915 [0.885-0.945]	0.901 [0.865-0.937]	0.703 [0.601-0.805]
#5	0.894 [0.861-0.927]	0.866 [0.823-0.909]	0.743 [0.663-0.823]
#6	0.885 [0.851-0.919]	0.864 [0.822-0.906]	0.623 [0.517-0.729]
#7	0.927 [0.899-0.955]	0.916 [0.883-0.949]	0.733 [0.632-0.834]

Figures in brackets represent 95% confidence intervals.

Table 4
Sensitivity-Specificity Analysis for KOGS on PKAs.

Assessor	Sensitivity	Specificity	Accuracy
#1	93.9%	100%	95.1%
#2	92.2%	100%	93.4%
#3	92.5%	88.9%	92.0%
#4	98.5%	100%	98.8%
#5	92.8%	81.7%	89.6%
#6	93.3%	84.8%	92.1%
#7	94.6%	87.0%	93.6%

KOGS, Knee Osteoarthritis Grading System; PKA, partial knee arthroplasty.

ensuring that optimal treatment is offered to an individual patient which is evidence based rather than empirical. KOGS can improve the selection of knee OA for smaller and more functional arthroplasty options rather than the tendency to default to a TKA even when isolated focal degeneration is found. The system is a tri-compartmental improvement of the X-KIDS [8] and the Decision Aid [9] as it takes into account the PFJ as well as the status of the ligaments. The KOGS can be used to compare the results of comparable and different stages of degeneration with the various modalities of treatment implemented. The strength of the KOGS includes its accessibility as a tool to differentiate the selection of PKA, general applicability in every-day orthopedic practice, its user-friendliness and cost-effectiveness when compared to MRI while avoiding excessive radiation associated with CT scans.

Independent assessment by 7 raters provides external validation and confirms the generalizability of this tool. Relatively short-term follow up, single surgeon series, and small numbers for patella-femoral arthroplasty are potential weaknesses of this study. The mean follow-up of 20 months is short but it gives a clear indication of success or failure of a PKA. It has been shown that if Oxford PKA is functioning well in the short-term, then the long-term outcome is likely to be satisfactory [29]. The previous long-term studies of the Oxford PKA demonstrated that the failures tended to occur early rather than late. Technical errors and/or patient selection related errors tend to manifest themselves early and long-term problems are rare because of the resistance of the device to wear [30–32]. We therefore believe that this follow-up period including complications encountered provides additional useful information to this study. Although the numbers of cases undergoing isolated PF arthroplasty are small in this series, the lead author primarily used KOGS in these cases to assess tibiofemoral compartments. Indeed, it has been previously shown that early progression of the disease due to under-diagnosed TF OA is the primary reason for high revision rates noted in some series of PFJ arthroplasty [33].

Conclusions

With the correct KOGS sequence and quality of accessible “routine X-rays,” the identification of isolated pathology is achievable by newly introduced or experienced surgeons and routinely available with high sensitivity, specificity, and accuracy. The KOGS is the first tri-compartmental grading that can compare different implant implementations with the pre-operative OA status.

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