

The X-Ray Knee Instability and Degenerative Score (X-KIDS) to determine the preference for a partial or a total knee arthroplasty (PKA/TKA)

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Abstract

The X-ray Knee Instability and Degenerative Score (X-KIDS) was developed as a tool based on the degenerative and instability patterns seen on routine X-ray views of the weight-bearing compartments and tested on 336 knees, average age 64 years and followed up for 24 months.

It is a study to evaluate the X-KIDS scoring method, which quantifies whether a PKA or TKA is the procedure of choice, comparing it to the surgical procedure done and to a stress X-ray evaluation as a stand-alone when contemplating knee arthroplasty.

Points are allocated to the following features: narrowing (N), osteophytes (O), and subluxations (S).

The assessed score is out of 10. A patient with a score of at least 3 but less than 5 is suitable for a PKA, a score of 5 could be suitable for a PKA or a TKA and a score exceeding 5 requires a TKA.

There was a 95.82% (321) evaluator consensus with the X-KIDS on the X-ray sequence for a PKA or TKA.

92.3% (310) received the procedure assessed by X-KIDS and 2.98% (10) could have received the procedure evaluated.

90.78% of the stress views indicated the preferred procedure and is not as reliable as X-KIDS to determine the procedure.

Key words: knee, arthroplasty, degenerative, instability, X-ray score

Article summary

Article focus

1. Evaluation of the reproducibility of the X-KIDS as a 'diagnostic tool' with the specified X-ray sequence.
2. X-KIDS correlation with the selected surgical procedure and the clinical influence.
3. X-KIDS comparison with the stress views as a stand-alone test.
4. The incidence of significant OA of the patellofemoral joint on the lateral view.

Key messages

1. The X-KIDS is a reliable tool when contemplating a knee arthroplasty procedure.
2. The X-KIDS classifies the degree of degeneration and instability.
3. The study confirms that the stress test as a 'stand-alone tool' is not reliable.
4. Patellofemoral joint (PFJ) degeneration, in this series, is not a dominant decider for PKA/TKA.

Background

The score should be considered with the patients' clinical requirements and preferences.

The score is reliable, inexpensive and reproducible with two 'new' observations which illuminate the wear pattern of the 'unstable' degenerative knee. These propose that the 45° Rosenberg view is more reliable when illustrating lateral pathology (rather than the stress view) and the 'wedge sign' for evaluating the integrity of the healthy compartment. The co-contributors were a combination of medical specialists, namely a radiologist (20 years' experience), neurosurgeon (9 years), two orthopaedic surgeons (24 and 3 years respectively) and a non-medical volunteer, all of whom, apart from the corresponding author, were blinded to the implemented procedure.

The author acknowledges that the co-contributors' reviews were retrospective; however, their evaluations were not focused on any surgical intervention. The X-KIDS may give false results due to the quality of the X-ray views and their possible misinterpretation together with 'fresh' ligament injuries as the X-ray features develop over time with the subluxation effect only visible after the subsequent failure of the secondary stabilisers. The performance of the X-KIDS may be biased by the author's understanding of the radiographic significance, which may have increased the concordance and it therefore requires further validation in other academic centres.

Introduction

Due to the difficulty experienced when assessing and categorising the degree of instability and degeneration of the knee, a new tool has been developed to improve the decision-making process and address the trepidation when contemplating a specific arthroplasty. The quest for a solution to determine whether an arthroplasty is indicated, and the distinction between a TKA and PKA, has become more relevant in light of Riddle's 2014¹ study that indicates the high, 'inappropriate' (34%) use of the TKA in the USA, without a conclusive algorithm of treatment. Willis-Owen in 2009² asserted that 47% of knee arthroplasties are suitable for PKA rather than TKA but the various joint registries point to a high failure rate of the PKA despite better functional scores^{3,4} and blame the infrequent user and inconsistent selection. The interpretation of data assessed is also a problem as illustrated by Goodfellow in his critique about the NZJR (2010).⁵

The history, clinical examination and routine X-rays with stress X-ray views to assess stability and degeneration, remain the cornerstone for evaluating a knee for PKA or a TKA.^{6,7} The goal is to determine whether the predominant single compartment degeneration presents with intact ligaments, whether anteromedial degenerative pathology in

the varus deformed knee⁸ is present, and whether lateral valgus deformity is suitable for PKA, or to illustrate bicondylar degeneration suitable for a TKA. The X-rays assess wear and knee ligament integrity, e.g. the anterior cruciate ligament (ACL) wear pattern as evaluated by Keys⁹ and Deschamps,¹⁰ and stability on the stress views.⁷

The PKA treatment option has regained popularity due to the improved surgical technique, mini-incision approach, preservation of the ligaments, bone stock and appropriate instrumentation.¹¹⁻¹³ Excellent outcomes have been achieved by centres that have refined the selection and surgical technique.¹⁴⁻¹⁸ The fully congruent mobile PKA demonstrated better functional results^{2,19} and 20-year surgical results comparable to that of the TKA²⁰⁻²⁴ with age, obesity level, state of the patellofemoral joint (PFJ) and chondrocalcinosis not being regarded as contraindications.^{25,26} The results of PKA revision surgery to a TKA are controversial although they are compared with a primary TKA and not to a revision TKA.^{27,28} Overall risk of complications with PKA is 4.3% and with TKA 11.4% (Oxford Group).¹⁹

A new tool has been developed to improve the decision-making process and address the trepidation when contemplating a specific arthroplasty

The PFJ degeneration is rarely seen to alter the outcome of the TKA or the PKA.^{23,24} In the NJR (England and Wales) of 2013,²⁶ singular PFJ replacements amounted to 1% of all replacements and more often occurred in female patients (70% at an average age of 59 years), compared with the TKA at 69 years. The preference for resurfacing the PFJ in TKA was 7% of cementless procedures and 38% in cemented versions.

By improving the selection algorithm with the correct indication and surgical technique, an excellent long-term functional outcome for an arthroplasty can be achieved, suitable for the patient's requirements.

Method

The study reviewed 335 patients over a 3-year period in a knee clinic with the X-KIDS sequence, and compared the results with the stress views as a stand-alone and the procedure implemented. Comparative studies of the outcome of whether the X-KIDS were used or not, are not available. The author correlated the X-ray appearance with the intra-operative findings and the surgical decision.

The cornerstone of the X-KIDS is bone-on-bone wear and was developed by allocating points to features normally found and easily recognised on routine knee X-rays. The features are narrowing (N), osteophyte formation (O) and subluxation (S). The features are common to knee degeneration and the weighting allocated according to the severity of degeneration when each compartment is individually assessed for bone-on-bone wear or narrowing. The weighting is also applied to the instability features as seen on the AP and lateral views.^{8,9}

X-ray observer factors, namely osteophytes (bony projections at the margins of the joint)²⁹ and subluxations (shifting out from the normal position), are included in the score as they have a bearing on the wear and instability assessment. This can unnecessarily affect the decision for a specific procedure if not assessed.

Surgical decisions were taken which did not conform to the score preference and this will be explained, e.g. a TKA was done when the score indicated suitability for a PKA due to excessive valgus (clinical contraindication for PKA > 15°) (Table I).

Although the PFJ was not the focus of this study and rarely influences the decision in arthroplasty as confirmed by Pandit and Beard,^{23,25} the joint was evaluated on the lateral view by three observers as a separate study of 330 of the X-ray sequences to assess 'significant' PFJ degeneration. Skyline views would be preferable in a follow-up study but could not be done due to the extra costs involved.

The long-term results of the surgical cases cannot yet be assessed but the average time since operation is 26.7 months.

Radiographic imaging

- 1) Standing antero-posterior (AP) and lateral (LAT) of the knee (Figure 1)
- 2) PA 15° Rosenberg – medial wear (Figure 2a)
- 3) PA 45° Rosenberg – lateral wear (Figures 2b and 7b)
- 4) Varus stress view in 20° flexion (Figures 3 and 4)

1. **Narrowing (N)** (point count = medial 3; lateral 3) = 6 (Figures 1, 2a, 2b, 3, 7)

Bone-on-bone contact between the femoral condyle and the tibial surface suitable for arthroplasty attracts 3 points (joint line narrowing). The contralateral joint must be >5 mm (= 2.5 mm on femur and tibia) and parallel and if less attracts 3 points and precludes the PKA option.^{6,30-33}

2. **Osteophytes (O)** (point count = medial 1 or lateral 1) = 1 in total (Figures 1, 2a, 2b, 3, 4)

This may be evident on femoral and tibial margins with one point given medially or laterally, irrespective of the degree. These 'spurs' may reflect degeneration and extra-articular traction due to 'laxity' of the ligaments caused by pseudo-instability.³⁴

3. **Subluxation (S)** (point count = AP 1 and lateral 2) = 3 (Figures 4 and 5)

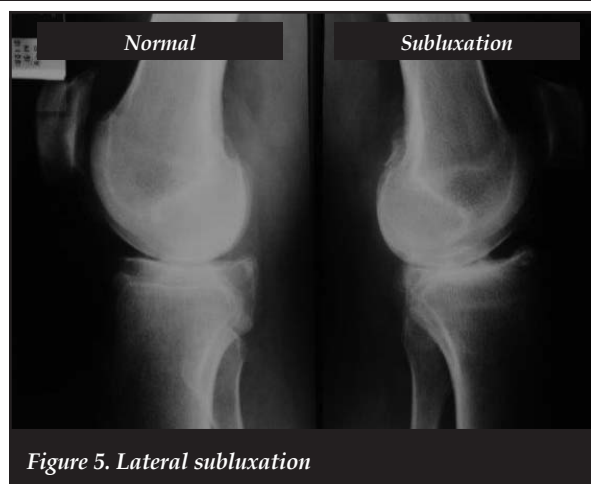
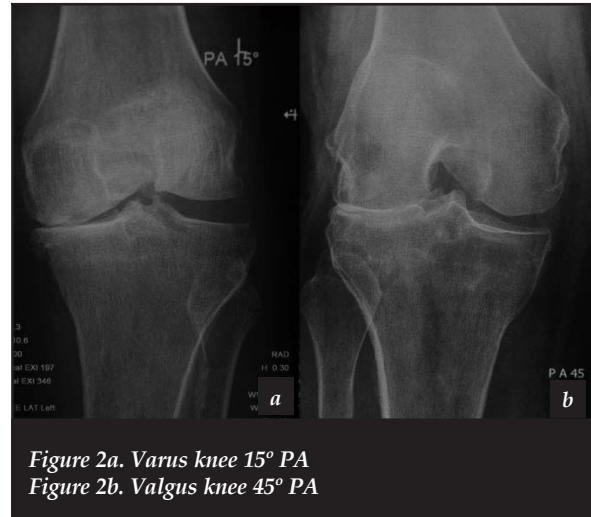
AP view: Subluxation with increasing varus and increasing valgus is seen due to excessive wear in the medial or lateral compartments and the loss of ligament integrity. This attracts a single point but if reduced on the stress view and the healthy joint is maintained >5 mm and parallel, it is subtracted from the accumulated total (Figure 4).

Assessed points: $N_3O_1S_1 = 5 - 1 = 4$ points

Lateral view: Anterior subluxation of the tibia and posterior wear of the medial tibial plateau as seen with ACL deficiency (Figure 5)

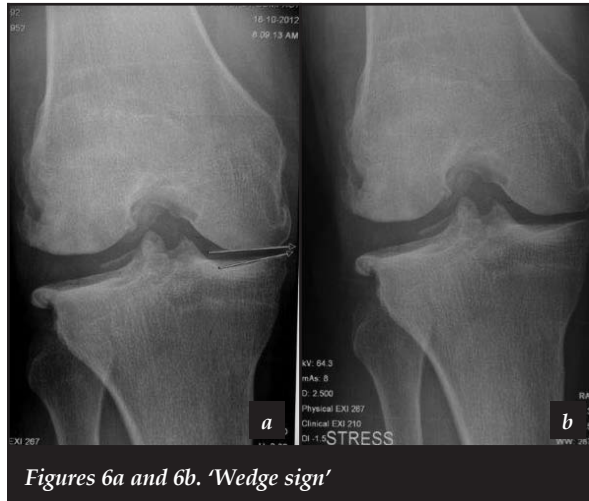
Table I: Reasons for alternative treatment to score for PKA (includes patients' and clinical preferences)

| Clinical factors | Outcome |
|---|------------------------------------|
| A: 4.77% Scored as PKA by evaluators and received a TKA (n = 16) | |
| 5: Instability of ACL (not assessed on X-ray) | Score failure* |
| 3: Arthroscopy pre-arthroplasty | Score failure* |
| 3: Valgus >15 degrees | Clinical contraindication (Oxford) |
| 3: Wanted TKA | Patient request |
| 1: Patella non-union and Lat. OA | Clinical contraindication |
| 1: PFJ OA and med OA | Clinical contraindication |
| B: 2.8% Scored as TKA by evaluators and received an PKA (n = 10) | |
| 3: ACL deficient - (Fixed Bearing PKA) | Surgical preference |
| 1: Young patient (ballet dancer) | Patient preference |
| 2: Posterior wear (medial ACL intact) PKA | Anatomical aberration* |
| 1: ACL deficient (lat. PKA and ACL recon.) | Surgical preference |
| 3: ACL deficient (med. PKA and ACL recon.) | Surgical preference |
| *(Score failure 10 = 2.98%) | |



When there is a healthy weight-bearing compartment with anterior subluxation of the tibia which can be rectified and stabilised with an ACL reconstruction, the 2 points assessed can be subtracted and can become suitable for a PKA if an ACL reconstruction is done.

Example of assessed points:
 $N_3O_1S_2 = 6 - 2 = 4$ points



Figures 6a and 6b. 'Wedge sign'

Anteromedial wear (varus Figures 2a, 2b and 3)

Confirm bone-on-bone wear and the integrity of the lateral joint space with the stress views. The 15° PA is reliable but does not confirm the integrity of the lateral joint space.³⁷

Lateral wear (valgus Figures 2a, 2b, 3, 7a and 7b)

Confirm the lateral compartment wear pattern with the 45° PA. The 20° stress views are best used to confirm the medial joint space retention.

Stress views in 20° flexion do not demonstrate the pathological lateral compartment as reliably, due to the wear pattern laterally being central and often posterior (on the 20° flexion views, the intact antero-lateral tibial cartilage is stressed and this compartment can appear to be intact Figure 7).

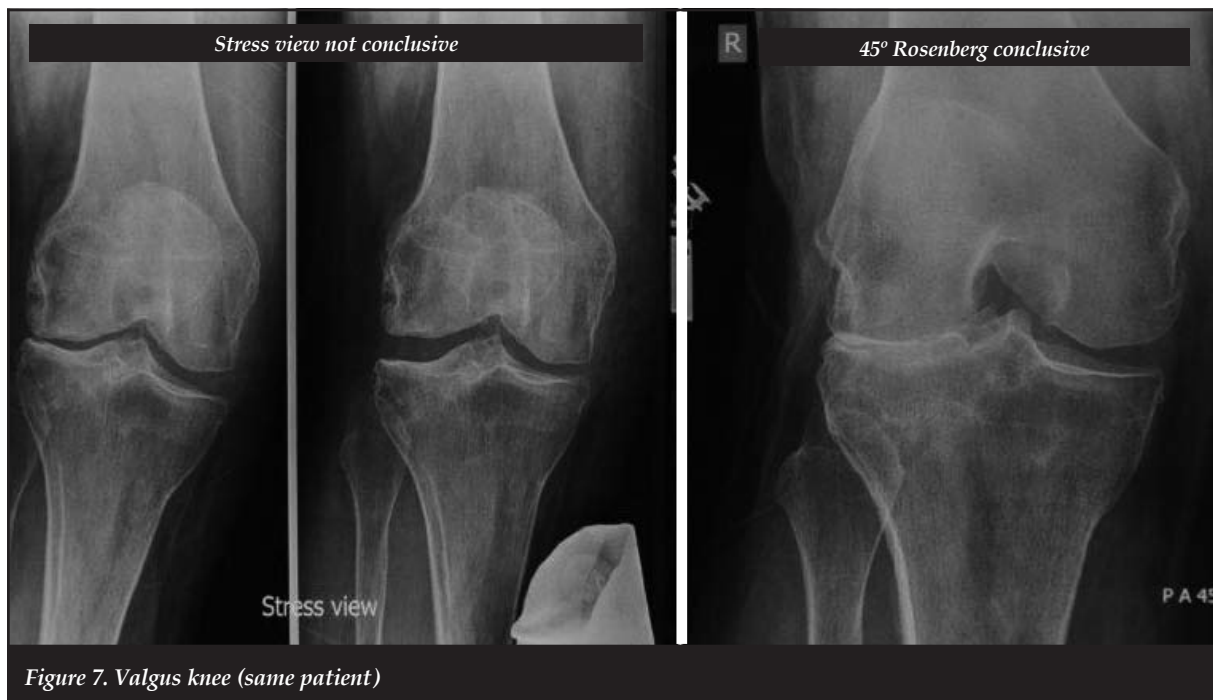


Figure 7. Valgus knee (same patient)

The 45° Rosenberg view evaluates the lateral compartment with, specifically, the predilection for central and posterior wear and the 15° Rosenberg displays the anteromedial pathology (Figures 2, 7a and 7b).^{34,35}

On the stress views the normal compartment must maintain a parallel space of more than 5 mm which relates to 2.5 mm of cartilage on the femur and tibia respectively (Figures 1, 2, 3 and 6).^{29,33,36-38} If the healthy compartment does not maintain the parallel opposing surfaces (indicating normal cartilage, correctable intra-articular varus, an intact collateral MCL/LCL³² and ACL) and becomes angled, the knee should be regarded as a risk for PKA ('wedge sign') (Figure 6).

It is important to prevent rotation and magnification of the knee during the stress views.

Scoring formula

A maximum of 10 points can be accrued with the X-KIDS ($N^3_3 + O^1 + S^1_2$).

1. X-KIDS of 3 and 4 points = PKA (mobile preferred or fixed).
2. X-KIDS of 5 is considered for a PKA (mobile or fixed) (NB clinical findings and surgical corrections).
3. X-KIDS > 5 points a TKA is indicated.

The cornerstone of the X-KIDS is bone-on-bone wear and was developed by allocating points to features normally found and easily recognised on routine knee X-rays

Table II: X-KID Score versus the actual procedure performed

| Outcome | n | F | % |
|--|-----|-----|--------|
| X-KID Score: Evaluator consensus with the procedure required | 335 | 321 | 95.53% |
| X-KID Score: Received the procedure scored | 335 | 310 | 92.3% |

Results

The average age of the 335 patients was 64 years (\pm SD of 10 years) and the majority were female (54.8%). The average age of the female patients ($n = 184$) was 65 ± 9 years and for the male patients ($n = 151$) 63 ± 9.3 years. The actual PKA accounted for 77.9% ($n = 261$) (98.9% mobile and 1.1% fixed bearing) of the procedures performed and the actual TKA for 22.1% ($n = 74$).

The cohort composition is due to the surgeon being a referral centre for predominantly PKA procedures (see Table II).

1. In 95.82% of the cases the X-KIDS achieved consensus with all five of the evaluators as they agreed on the procedure to be performed based on the X-KID Score calculated. The agreement of multiple evaluators is recapitulated with Light's Kappa of 0.872 (bootstrapped $CI_{95\%}$ [0.819; 0.912]). This indicates almost absolute agreement between evaluators. In 2.98% of the cases the X-KIDS was incorrect in predicting the actual procedure required (undetected ACL deficiency and arthroscopic decision).
2. The score failed in ten patients (2.98%) (eight undiagnosed ACL and two incorrectly diagnosed ACL). Twenty-six ($26/336 = 7.38\%$) patients did not receive the procedure according to the score. This was influenced by the patients' preferences and pre-operative clinical factors, e.g. pre-operative arthroscopic pathological decisions (three), pre-operative PKA contraindications (five), instability of ACL which received a reconstruction ACL and mobile PKA (three) or a fixed-bearing PKA (three) (Table I). In 16 (4.77%) cases the evaluators scored a PKA but a TKA was performed. In ten (2.98%) cases the evaluators scored a TKA but a PKA was performed. The agreement between the X-KIDS and the actual procedure is recapitulated with Cohen's Kappa of 0.753 (bootstrapped $CI_{95\%}$ [0.674; 0.834]). Since an indeterminate score does not agree with any actual procedure, the measure is conservatively estimated. This indicates substantial, but not absolute agreement (see Table I).
3. A discrepancy between the X-KIDS and the stress test assessment as a stand-alone test was observed in 31 (9.23%) of the 335 cases. In 5.97% of the 335 cases the discrepancy was due to the non-detection of ACL deficiency ($n = 20$) and 3.27% was due to clinical exclusions not detected ($n = 11$). As the ACL efficiency group is routinely treated with a TKA this comprises a failure rate of 27.03% (20 out of 74 patients receiving TKA).

The Cohen's Kappa between the stress test assessment and the actual procedure is 0.699 (bootstrapped $CI_{95\%}$ [0.592; 0.790]). Although still substantial, the level of agreement is less than the level of agreement between the X-KIDS and the actual procedure.

4. 'Significant' PFJ changes of 330 patients were considered and 46.67% of the cases presented with significant changes. In the PKA group 41.40% ($n = 106$) of the 256 patients presented with PFJ degenerate changes. This is significantly lower than the TKA group where 64.86% ($n = 48$) of the 74 patients presented with significant changes ($p = 0.0003$, one-tailed Fisher's Exact Test). Significant PFJ OA changes did not influence the PKA decision.
5. Four failures were treated after 24 months: 1 medial PKA treated after traumatic ACL rupture with a thicker bearing; and 3 medial PKA procedures treated with lateral PKAs.

Discussion

There have been attempts to classify knee osteoarthritis, e.g. the initial Kellgren–Lawrence 1957 classification,³⁹ Ahlback (1968),³⁸ the Atlas of Line Drawings by Nagaosa Classification 2000,⁴⁰ the more modern imaging scoring (Whole Organ Magnetic Resonance Imaging Score 'WORMS'),⁴¹ and the Boston Leeds Osteoarthritis Knee Score (BLOKS)(2010)³¹ have been devised. There are the proponents of MRI-only visualisation, e.g. Guermazi (2011)³² and the comparative studies done by Jeffrey Duryea (2001)³⁰ on radiographic joint space width to the cartilage morphometry.

The conclusion drawn is that the two are comparable but the 'gold standard' is still X-ray imaging.

The X-KIDS is different from all the previous evaluation systems, as it incorporates the stability of the knee ligaments and the severity of the weight-bearing degeneration. This can assist the surgeon to improve his decision for a specific arthroplasty which will lead to optimal treatment. The X-KIDS can be used as a classification of degenerative knee pathology and a reference to improve research on arthroplasty selection.

The stress test as a stand-alone tool is unreliable in detecting the required procedure as it cannot evaluate ACL deficiency adequately.

The PFJ rarely determined the procedure implemented. Only one clinically painful PFJ had a TKA (1/335) when scored for a PKA.

The X-KIDS must be understood and applied with due consideration to the clinical indications and contraindications for the PKA and TKA and when used appropriately, the X-KIDS is more than 95% reliable and confirms the appropriate surgical intervention in at least 92% of knees evaluated.

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Appendix

Please take note of Appendix 1 and 2 after the original article for further clarification.

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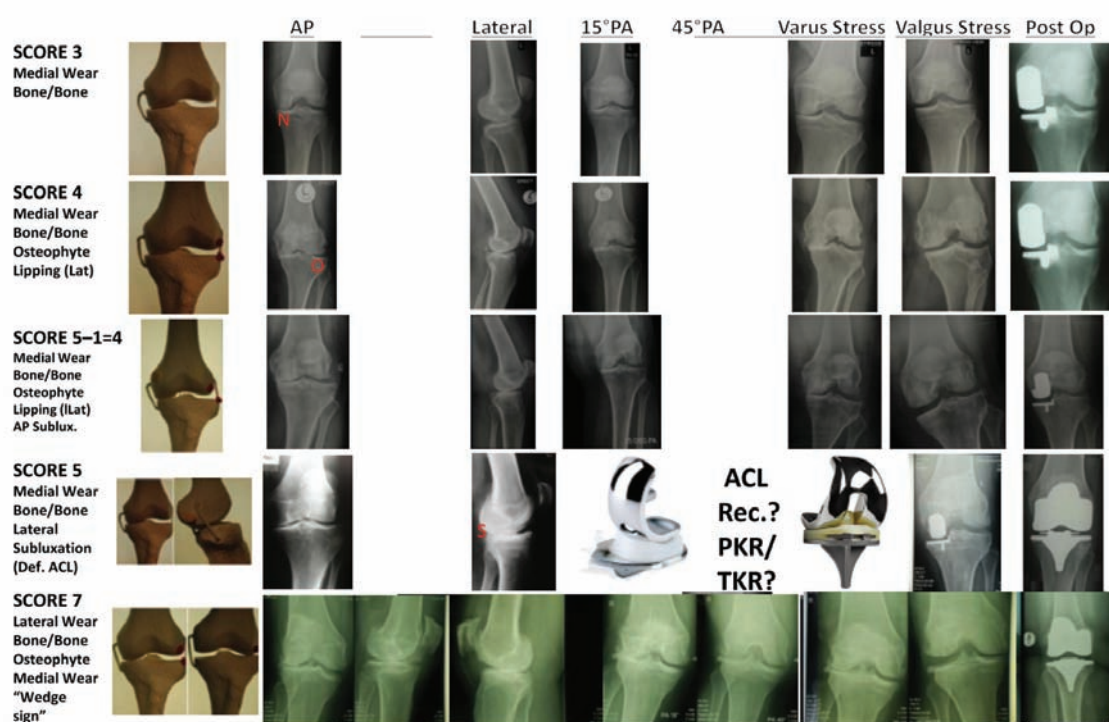
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Appendix 1

X-KID SCORECARD



Appendix 2

The X-ray knee instability and degenerative score (X-KIDS) X-ray score for knee arthroplasty

This is a surgical tool to aid the surgeon in the decision-making process. It does not replace clinical evaluation.
This score is only applicable to the medial and lateral knee compartments.
The score does not consider the patellofemoral joint degeneration.

SCORE 0 – 10

- < 5 Suitable for PKA (fixed or mobile)
- > 5 Suitable for TKA
- = 5 Can be suitable for PKA/TKA

Three X-ray signs are used with values:

| | | | |
|----|---|--|--|
| 1. | Narrowing (N) | - An affected compartment must be bone on bone – 3 points | (N _{3 Lat} ^{3 Med}) |
| | The unaffected compartment must be > 5 mm: – if not, 3 points | | |
| 2. | Osteophytes (O) | - On the unaffected compartment – 1 point | (O ₁) |
| 3. | Subluxation(S) | - AP view and LAT view. AP view – 1 point; LAT view – 2 points | (S _{1 AP} ^{2 Lat}) |

X-ray views for evaluation:

1. Standing AP, LAT
2. Rosenberg views 15° PA (medial) 45° PA (lateral)
Better than stress for lateral OA.
3. Valgus and varus stress view in 20° flexion
Better suited for medial OA.

(The joint line must remain **parallel** in this view and > 5 mm)

NB. Extra-articular 'lipping' (osteophytes) does not compromise the weight-bearing surface.

$$N_{3\text{ Med}}^{3\text{ Lat}} + O_1 + S_{1\text{ AP}}^{2\text{ Lat}} = 10$$

| | | |
|----|---|---|
| 1. | Score = 3 | = Full thickness loss of cartilage narrowing (N_3) in one compartment. |
| 2. | Score = 4 | = Narrowing (N_3^0) with medial/lateral osteophytes (O_1) or AP subluxation (S_2^0) |
| 3. | Score = 5 | = Narrowing (N_3^0) with medial/lateral osteophytes (O_1) and AP subluxation (S_1) |
| | A score of 4 or 5 can obtain a –1 subtraction if the subluxation (S_1) on the AP view can be reduced on stress views (score 5–1=4; see Score Card). | |
| 4. | Score = 5 | = Narrowing (N_3^0) with lateral view subluxation. (S_0^2) (ACL deficient) |
| 5. | Score 6 or 7 due to S_2 ; can subtract 2 points with reconstruction of ACL and then PKA can be done. | |

NB. When evaluating the unaffected compartment, it needs to retain >5 mm of space and stay parallel to the opposing joint surface on the stress views. The 'wedge sign' of a 'healthy' compartment is a contraindication for a partial knee replacement.