Radiography 22 (2016) 152–160

Contents lists available at ScienceDirect

Radiography

journal homepage: www.elsevier.com/locate/radi

Radiography of the knee joint: A comparative study of the standing partial flexion PA projection and the standing fully extended AP projection using visual grading characteristics (VGC)

E. Farrugia Wismayer [a, c], F. Zarb [b, *]

[a] Department of Health, Sir Paul Boffa Hospital, Floriana, Malta
[b] Department of Radiography, Faculty of Health Sciences, University of Malta, Malta

ARTICLE INFO

Article history:
Received 2 July 2015
Received in revised form
9 October 2015
Accepted 12 October 2015
Available online 28 October 2015

Keywords:
Diagnostic x-ray
Knee joint
Bone disease
Osteoarthritis
Osteoarthritis knee

ABSTRACT

Objectives: To compare the diagnostic information in detection and assessment of knee pathology from knee radiographs using either the PA standing with partial flexion projection or AP fully extended standing projection.

Method: A set of 32 knee radiographs was retrospectively compiled from 16 adult patients imaged using both projections over a 2-year period (PA: $n = 16$ and AP: $n = 16$). Repeat radiographs ($n = 6$) were added to the image set facilitating inter and intra observer reliability. Image evaluation was performed by 5 orthopaedic surgeons performing Absolute Visual Grading Analysis assessing image quality based on 6 anatomical image quality criteria specifically developed to evaluate and compare the two projections. The resulting image quality scores were analysed using Visual Grading Characteristics.

Results: Image quality scores were higher for the PA projection but variation between the two projections was not significant ($p > 0.05$). The PA projection was significantly ($p < 0.05$) better in the visualization of 2 anatomical image quality criteria involving the joint space width and tibial spines.

Conclusion: Both projections can be used for general evaluation of the knee joint, however the PA partial flexion projection is preferred for the investigation of specific knee pathology. Recommendations for minimizing variations in radiographic positioning technique are also highlighted.

Introduction

The erect antero-posterior (AP) knee radiograph has been the standard imaging projection for knee radiography for over 30 years.[1] Over the past decade other projections such as the fixed-flexed postero-anterior (PA) standing projection have been utilized as a projection which may have a higher sensitivity and specificity to detect joint space narrowing in the knee joint. There has not been a consensus agreement on which projection provides the best quality images as all of the projections have their limitations which include variation in the positioning of the patient.[2,3]

Literature review

Weight-bearing radiographs taken in slight flexion reflect the width of the cartilage space most accurately as the major contact stresses in the tibiofemoral joint occur when the knee is in 24–28° flexion. Furthermore, cartilage loss mostly occurs in the posterior part of the femoral condyles and osteoarthritic erosions of these condyles mostly occur at a site which makes contact with the tibia at 30 degrees of flexion.[4]

Abbreviations: AP, anteroposterior; AUC, area under the curve; AUC_{VGC}, area under the visual grading characteristics curve; OA, osteoarthritis; PA, posteroanterior; VGA, visual grading analysis; VGC, visual grading characteristics; ViewDex, viewer for digital evaluation of x-ray images.

* Corresponding author. Tel.: +356 23401833.
E-mail addresses: edward.farrugia@gov.mt (E. Farrugia Wismayer), francis.zarb@um.edu.mt (F. Zarb).
[c] Tel.: +356 21374092.

http://dx.doi.org/10.1016/j.radi.2015.10.002
1078-8174/

Table 1
Anatomical criteria for knee radiographs.

Anatomical criteria for knee radiographs
1. Visually sharp reproduction of joint space width/narrowing
2. Visually sharp reproduction of position of the tibial spines relative to the femoral notch – centralized
3. Visually sharp reproduction of lateral compartment of the knee
4. Visually sharp reproduction of medial compartment of the knee
5. Visually sharp reproduction of mid-medial tibial plateau
6. Visually sharp reproduction of patella

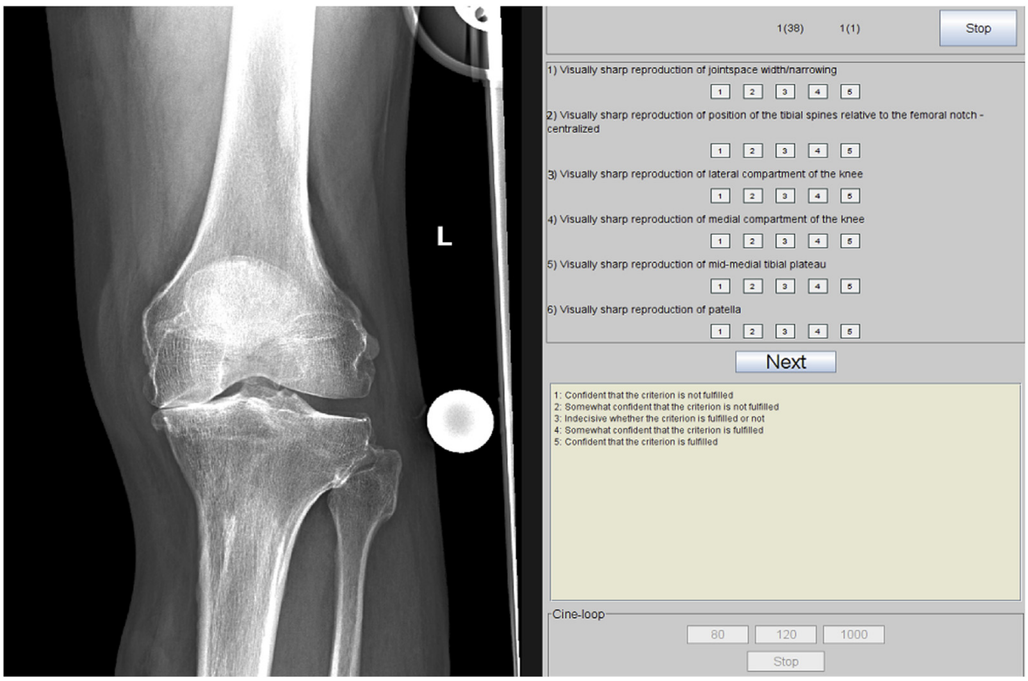

Figure 1. Screenshot of ViewDex 2.0.

Consequently, if the projection used is an AP extended projection, the cartilage space would still appear normal since most of the anterior cartilage is still well maintained. Although it should also be noted that increased flexion alone can result in apparent joint space loss of up to 25% in the medial compartment[5] indicating that there is still disparity regarding the optimal knee flexion angle.[6] That said, the sensitivity to detect narrowing of the joint space when using the fixed flexion PA is only slightly better when compared to the standard standing AP.[1] Therefore, the different projections would fulfil different criteria especially if looking for a range of pathologies and not just joint space narrowing in osteoarthritis (OA).

The purpose of this study was to compare the diagnostic information in detection and assessment of knee pathology from knee radiographs using either the PA standing with partial flexion projection or AP fully extended standing projection.

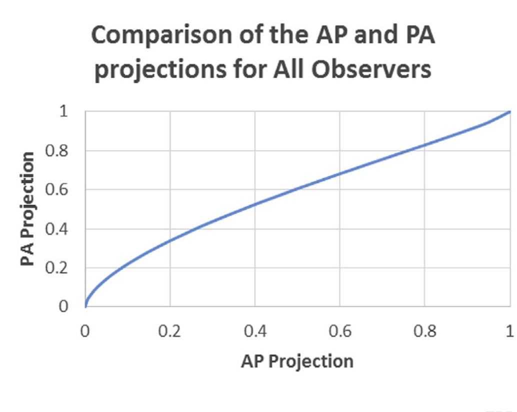

Figure 2. VGC Curve for the 5 observers combined comparing the AP Projection and the PA Projection of the knee. The resultant AUC_{VGC} is 0.583.

Method

In this study a retrospective approach was undertaken. X-ray images were randomly selected for review by orthopaedic surgeons. Ethical approval was sought and obtained to perform the study (Ref: UREC 21-6-2013).

An image data set was compiled, consisting of 16 patients' images who had a knee X-ray performed on two occasions: once in the AP projection ($n = 16$) and a follow-up performed using the PA projection ($n = 16$) together with 3 images of each projection which were repeated to facilitate inter and intra rater reliability.

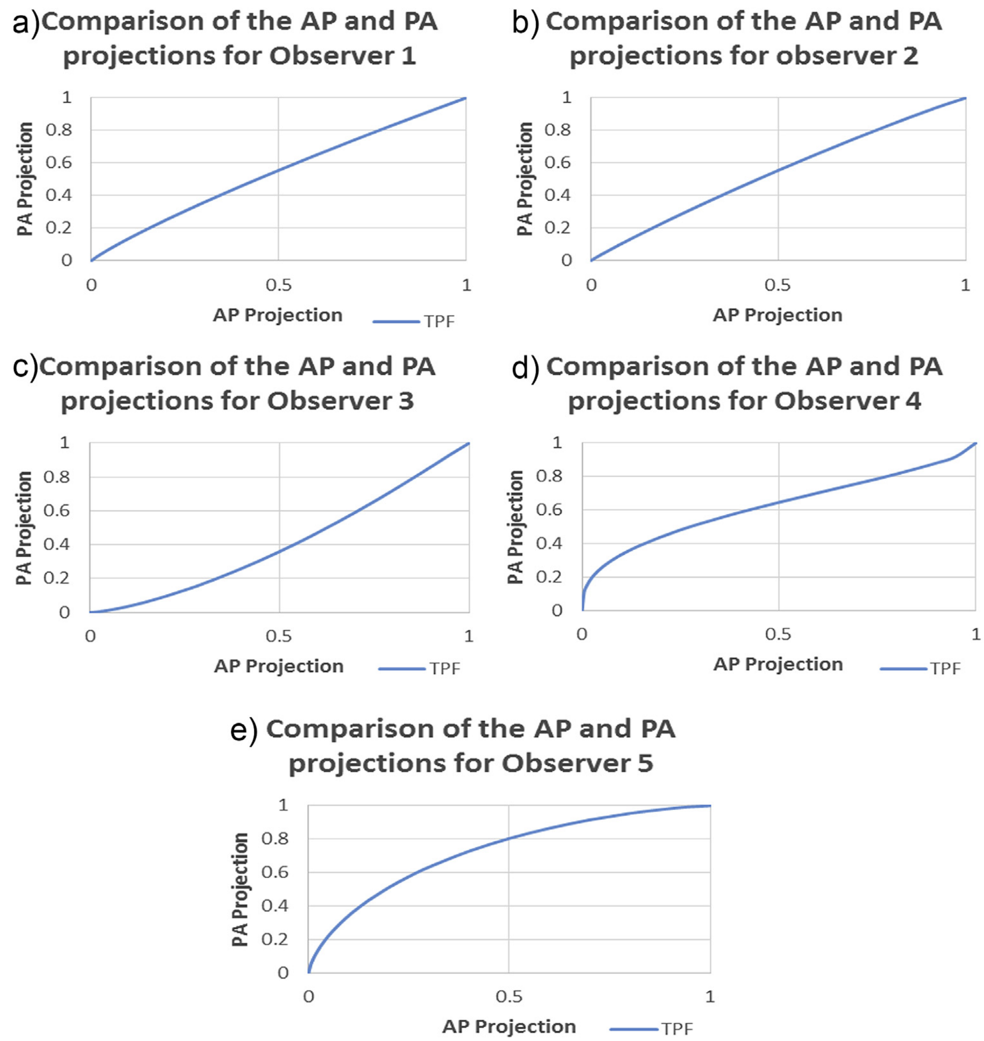

Figure 3. **a**. VGC Curve for Observer 1 comparing the AP Projection and the PA Projection of the knee. The resultant AUC_{VGC} is 0.541. **b**. VGC Curve for Observer 2 comparing the AP Projection and the PA Projection of the knee. The resultant AUC_{VGC} is 0.583. **c**. VGC Curve for Observer 3 comparing the AP Projection and the PA Projection of the knee. The resultant AUC_{VGC} is 0.406. **d**. VGC Curve for Observer 4 comparing the AP Projection and the PA Projection of the knee. The resultant AUC_{VGC} is 0.624. **e**. VGC Curve for Observer 5 comparing the AP Projection and the PA Projection of the knee. The resultant AUC_{VGC} is 0.729.

Five (5) orthopaedic surgeons with more than two years' experience in knee review participated in the study. The orthopaedic surgeons reviewed the image data set using ViewDex using Visual Grading Analysis (VGA), where they scored their confidence in visualising 6 anatomical criteria identified specifically for knee radiographs (Table 1). The anatomical criteria were based on literature findings, while their appropriateness in the assessment of knee radiography was validated by an orthopaedic consultant and a consultant musculoskeletal radiologist.

The scoring scale used was as recommended by Båth & Månsson, (2007),[7] where a score of:

1 means that the reviewer was 'Confident that the criterion is not fulfilled';
2 means that the reviewer was 'Somewhat confident that the criterion is not fulfilled';
3 means that the reviewer was 'Indecisive whether the criterion is fulfilled or not';
4 means that the reviewer was 'Somewhat confident that the criterion is fulfilled';

Table 2
Statistical One-Sample *t*-test for each criterion and for overall criteria.

One-sample *t*-test				Test Value 0.5	
Criterion	Number of observers	Mean AUC_{VGC}	p-Value	95% confidence interval	
				Lower	Upper
Overall	5	0.57	0.27	−0.08	0.21
1	5	0.62	0.00	0.07	0.16
2	5	0.59	0.00	0.06	0.13
3	5	0.55	0.58	−0.18	0.27
4	5	0.56	0.36	−0.11	0.24
5	5	0.55	0.47	−0.13	0.24
6	5	0.53	0.64	−0.15	0.22

5 means that the reviewer was 'Confident that the criterion is fulfilled'.

ViewDex 2.0 was utilized for a more efficient study process. The program presents the observer with anonymized images and in a random fashion with also the facility of scoring the criteria directly onscreen (Fig. 1).

Visual grading results in an ordinal scale, therefore, a nonparametric rank-invariant statistical test was indicated for the analysis of the data. The visual grading characteristics (VGC) method introduced by Båth & Månsson (2007) was chosen for this VGA study, where a set of frequency tables was set up with the number of test results in each rating category listed separately for the different projections being compared. In VGC the statistical power depends on the number of observers, the number of criteria and the number of images being evaluated.[7] The frequency tables were based on 960 scores (5 (orthopaedic surgeons) x 6 (anatomical criteria) x 32 (images)). These tables were then used to calculate the VGC points of these comparisons to plot the VGC curve. The VGC curve describes the relationship between the proportions of fulfilled image criteria for the two projections compared. The area under the VGC curve (AUC_{VGC}) gives the resulting measure of image quality. The AUC_{VGC} can range from 0.0 to 1.0 with 0.5 corresponding to equal image quality for both projections.

Results

Comparison of the AP and PA projections for all observers

A VGC curve (Fig. 2) was plotted comparing the AP Projection with the PA Projection for the 5 orthopaedic surgeons combining all the image quality criteria scores. The VGC curve comparing the AP and PA projections resulted in an AUC_{VGC} of 0.58. This value is close to 0.5 and to the diagonal (Fig. 2). Since the curve is skewed more towards the Y-axis, this indicates a better outcome for the PA projection.

Comparison of the AP and PA projections for each observer individually

To establish whether or not both projections could be considered as having equal image quality it was essential to verify if the curve differed significantly from the 0.5 diagonal values. Therefore, it was necessary to check each of the plotted VGC curves of each

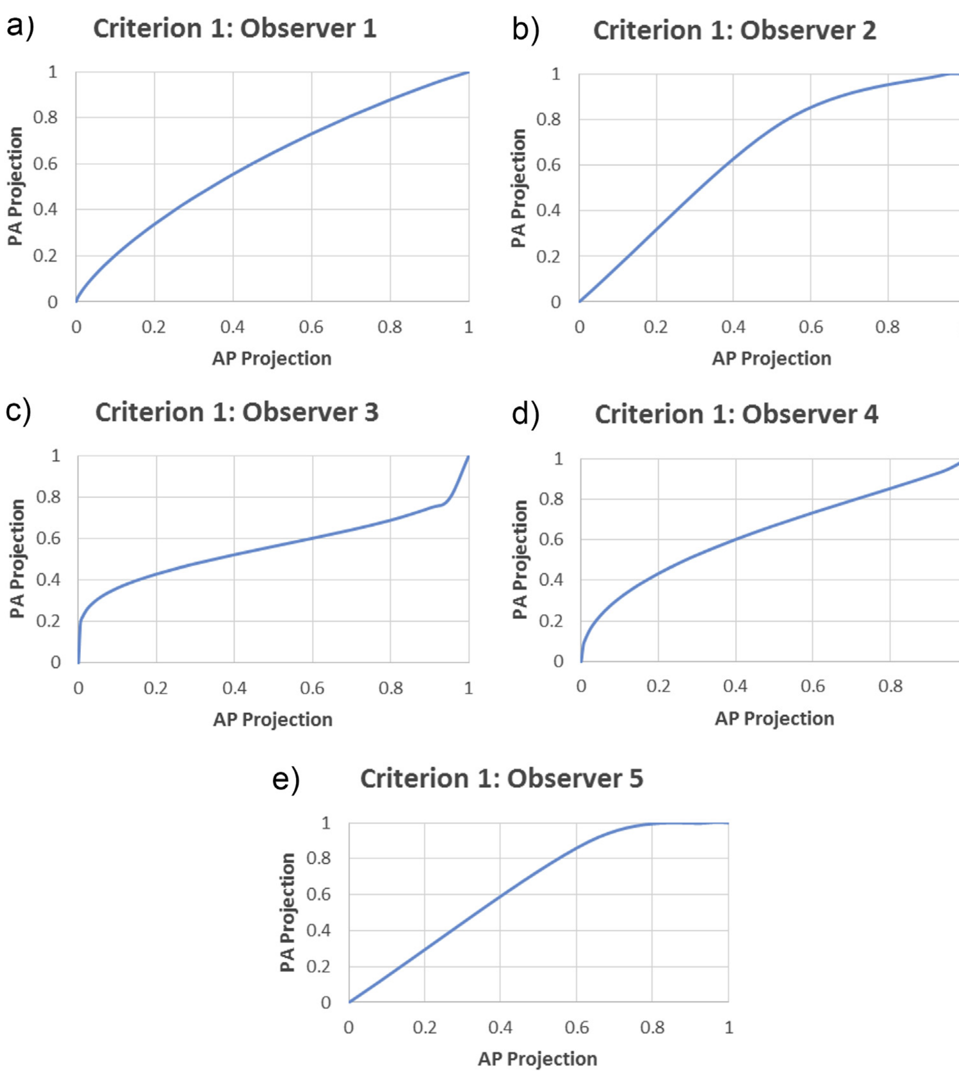

Figure 4. **a**. VGC Curve for Criterion 1 comparing the AP and the PA projections for Observer 1. Resultant AUC_{VGC} is 0.608. **b**. VGC Curve for Criterion 1 comparing the AP and the PA projections for Observer 2. Resultant AUC_{VGC} is 0.637. **c**. VGC Curve for Criterion 1 comparing the AP and the PA projections for Observer 3. Resultant AUC_{VGC} is 0.559. **d**. VGC Curve for Criterion 1 comparing the AP and the PA projections for Observer 4. Resultant AUC_{VGC} is 0.640. **e**. VGC Curve for Criterion 1 comparing the AP and the PA projections for Observer 5. Resultant AUC_{VGC} is 0.634.

observer summing all the image quality criteria (Fig. 3a to e). In these VGC curves it is shown that the PA projection is favoured by the majority of the orthopaedic surgeons where the curve is skewed towards the Y-axis and evidenced by the AUC_{VGC} values >0.5 except for orthopaedic surgeon 3.

The one-sample *t*-test was utilised to identify whether the mean AUC_{VGC} values from the observations of the 5 orthopaedic surgeons varied significantly from the 0.5 similarity value for each set of projections (Table 2). The mean score is >0.5 value, meaning that the PA projection scored better than the AP projection but this difference in the scores is not significant ($p > 0.05$), indicating that the two projections could be considered to produce X-ray images that have comparable image quality.

For each of the 5 orthopaedic surgeons VGC curves were plotted to identify variations in image quality for each image quality criterion (Figs. 4 to 9). The one-sample *t*-test was again utilised to determine whether the AUC_{VGC} values differ significantly from 0.5 for each criterion. The Mean overall score, was >0.5 value meaning that the PA projection scored better than the AP projection. The one-sample *t*-test completed for criterion 1 and 2 showed that the mean score for Criterion 1 and 2 was 0.62 which is >0.5 value, meaning that the PA projection scored better than the AP projection and since the p-value is <0.05, this difference in the scores is significant (Table 2).

With regards to criterion 3 to 6 the mean scores were >0.5 value, meaning that the PA projection scored better than the AP projection but since the p-value is >0.05, this difference in the scores is not significant (Table 2).

Discussion

Criterion 1 focuses on the visualisation of the joint space width and is therefore more confidently assessed and interpreted using the PA projection. This result also conforms to Dervin's et al. (2001)[3] findings, that the PA flexion projection is more sensitive for

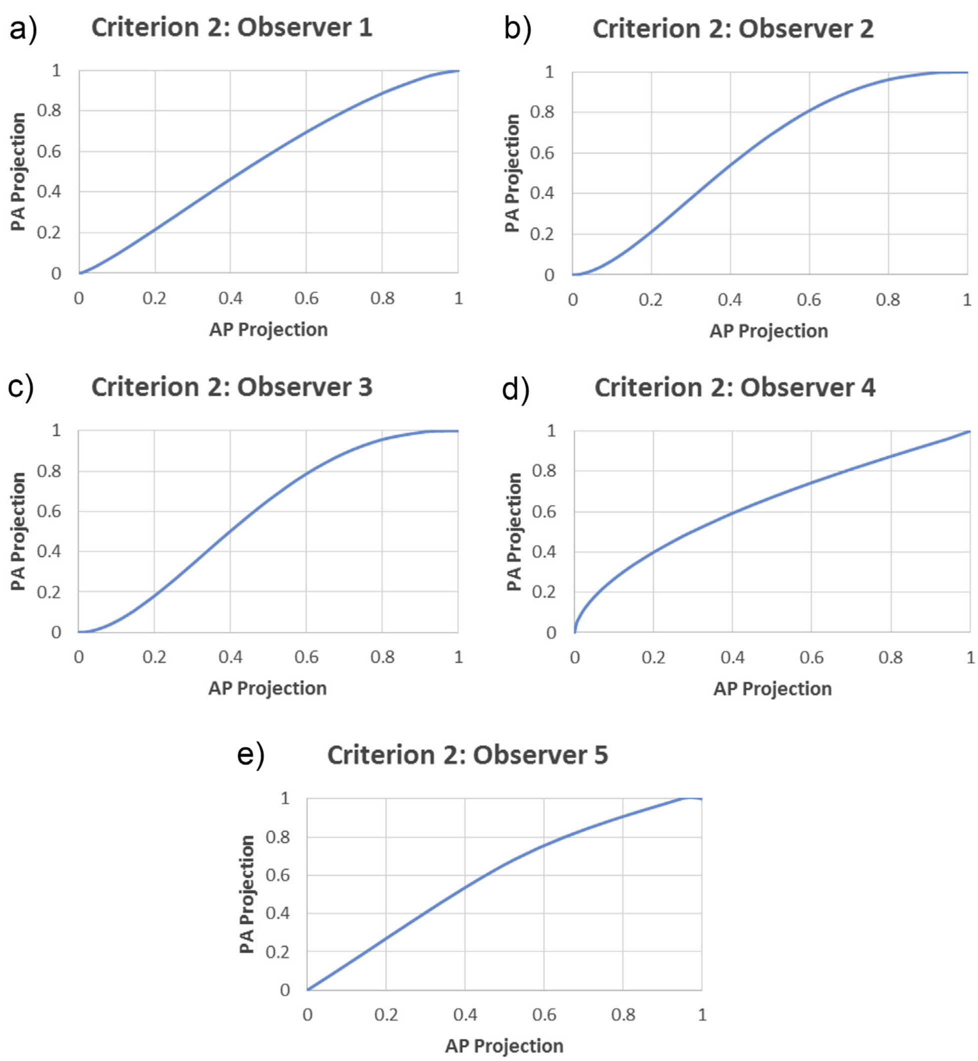

Figure 5. **a**. VGC Curve for Criterion 2 comparing the AP and the PA projections for Observer 1. Resultant AUC_{VGC} is 0.555. **b**. VGC Curve for Criterion 2 comparing the AP and the PA projections for Observer 2. Resultant AUC_{VGC} is 0.606. **c**. VGC Curve for Criterion 2 comparing the AP and the PA projections for Observer 3. Resultant AUC_{VGC} is 0.585. **d**. VGC Curve for Criterion 2 comparing the AP and the PA projections for Observer 4. Resultant AUC_{VGC} is 0.634. **e**. VGC Curve for Criterion 2 comparing the AP and the PA projections for Observer 5. Resultant AUC_{VGC} is 0.587.

joint space narrowing which is a sign mainly attributed to osteoarthritic changes.

In clinical practice the PA projection also achieves a better and more visually sharp reproduction of the position of the tibial spines relative to the femoral notch over the AP projection. Hence, the PA projection would be more indicated to identify knee joint pathology. In the accurate imaging of the knee, it is essential that the tibial spines are centralised in relation to the femoral notch as described and confirmed through fluoroscopy. Once the tibial spines are centralised indicating correct knee positioning, assessment of the alignment of the lateral aspect of the femoral condyle with the head of fibula and medial aspect of the femoral condyle with the outer aspect of the tibia may be evaluated. Misalignment may be an indication of a fracture of the tibial plateau.[8] It was concluded from the outcome of the results that the PA projections are significantly better than the AP projection with regards to identifying knee joint anatomy and is hence more relevant to diagnose pathology in this area of the knee.

In the evaluation of projections obtaining a visually sharp reproduction of the lateral compartment of the knee it was concluded from the results of the study that even though the PA projection was better at indicating knee joint anatomy than the AP projection, this was not significant and hence would not have such a great impact with regards to application of one projection or the other for diagnostic evaluation. The results obtained differ from those reported in the literature as seen in the study of Merle-Vincent et al. (2007)[9] whereby the lateral compartment was reported to be best interpreted from the PA projections. This difference could be attributed to the presence of atypical patients with uncommon joint space wear as described in the study of Dervin et al. (2001).[3] However, since this is not a common occurrence and is improbable that the random patients selected were mostly of this sort, the results obtained are likely due to other uncontrolled factors such as non-standardised projections.

The values obtained from the comparison of the AP and PA projections with regards to visually sharp reproduction of the medial compartment of the knee indicated that the PA projection is more useful in detection of pathology in this compartment. However, this difference is not significant and hence would not have such a great impact on diagnostic value between the two

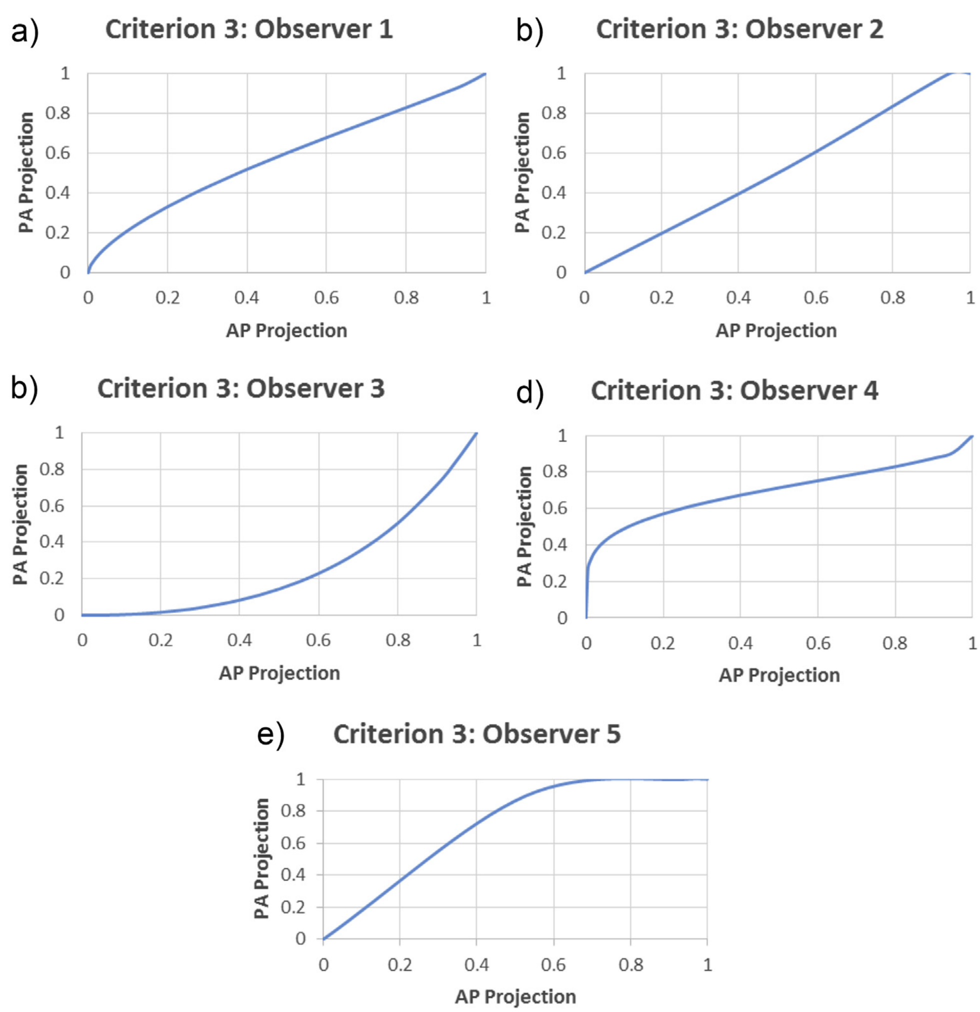

Figure 6. a. VGC Curve for Criterion 3 comparing the AP and the PA projections for Observer 1. Resultant AUC_{VGC} is 0.578. **b**. VGC Curve for Criterion 3 comparing the AP and the PA projections for Observer 2. Resultant AUC_{VGC} is 0.512. **c**. VGC Curve for Criterion 3 comparing the AP and the PA projections for Observer 3. Resultant AUC_{VGC} is 0.256. **d**. VGC Curve for Criterion 3 comparing the AP and the PA projections for Observer 4. Resultant AUC_{VGC} is 0.696. **e**. VGC Curve for Criterion 3 comparing the AP and the PA projections for Observer 5. Resultant AUC_{VGC} is 0.687.

projections. The findings are consistent with the results obtained from the study of Merle-Vincent et al. (2007)[9] whereby it was concluded that both the AP and the PA projections give a very comparable result for the medial compartment hence further confirming that image quality for this criterion is not affected by the projection used.

These results show that the sharp reproduction of the mid-medial tibial plateau was comparable in both the AP and PA projections. This means that although the visualisation of this anatomical structure was higher in the PA projection, the difference was not significant therefore both projections offer similar image quality for this structure.

Visually sharp reproduction of the patella can be useful in evaluation of overall image quality in view of interpretation of the findings. This would be expected to be more evident in the PA projection since the patella is closer to the X-ray receptor, however although the PA actually scored better indicating better visualisation of this structure, the variation in image quality is not significant.

Even though the overall results indicate that the mean score for the PA projection is higher than that for the AP projection, hence indicating better visualisation of the structures, this difference is not significant, meaning that both projections can be used in clinical practice providing similar image quality. Ultimately, when taking into consideration all the criteria used in this study, the superiority of the PA projection in the visual reproduction of joint space width and tibial spines, puts this projection ahead to the AP projection.

However, the findings of the study need to be considered while recognizing the study's limitations. Variations in patient positioning technique could have influenced the presentation of the anatomical criteria under evaluation. Such variations may have been caused by: changes (positioning & anatomy variation) between the first and second imaging on follow-up of the patient or inaccuracy and variation in technique by the performing radiographers. The limited sample size of both evaluators and image data set although providing generalizability within the cohort under study could be considered more of a pilot study. The assumption

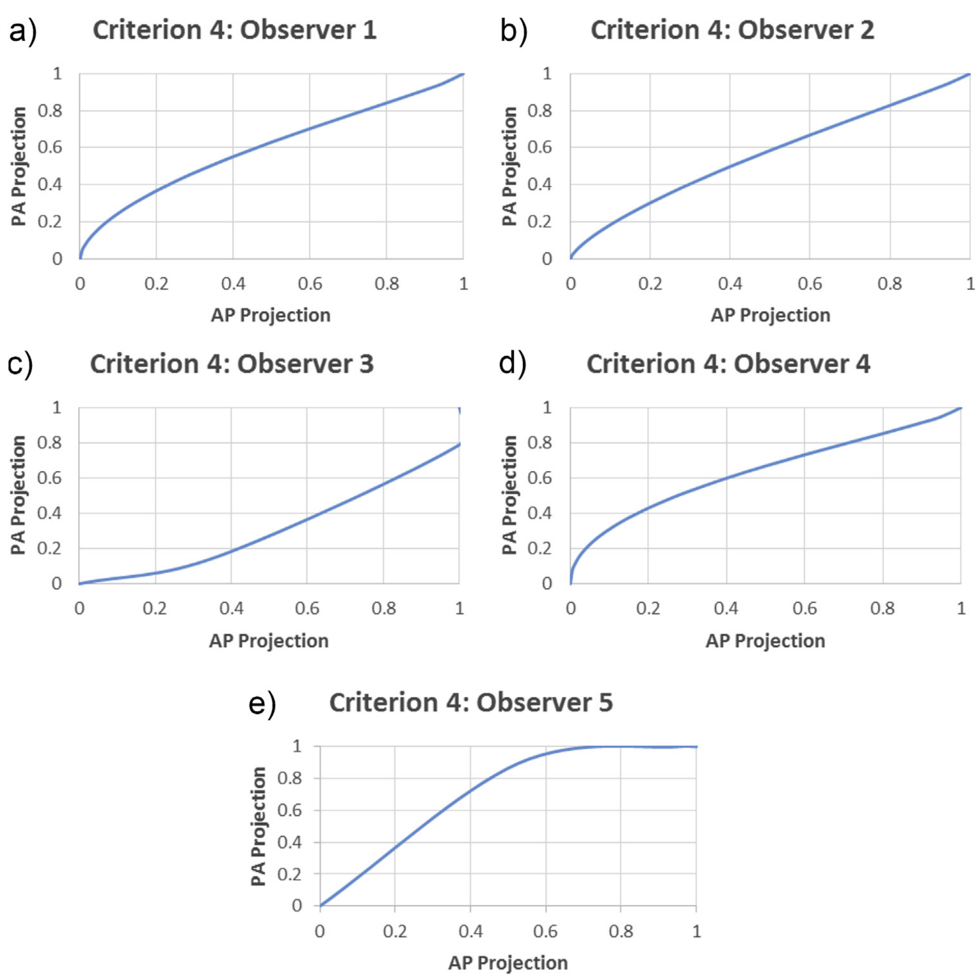

Figure 7. **a**. VGC Curve for Criterion 4 comparing the AP and the PA projections for Observer 1. Resultant AUC_{VGC} is 0.602. **b**. VGC Curve for Criterion 4 comparing the AP and the PA projections for Observer 2. Resultant AUC_{VGC} is 0.565. **c**. VGC Curve for Criterion 4 comparing the AP and the PA projections for Observer 3. Resultant AUC_{VGC} is 0.328. **d**. VGC Curve for Criterion 4 comparing the AP and the PA projections for Observer 4. Resultant AUC_{VGC} is 0.638. **e**. VGC Curve for Criterion 4 comparing the AP and the PA projections for Observer 5. Resultant AUC_{VGC} is 0.687.

that all evaluators had the same level of expertise and convenience sampling of the orthopaedic surgeons may have resulted in an atypical representation of the population resulting in some element of bias in the findings.

Conclusion

The AP and PA projections are generally comparable although the PA Projection scored better for all the criteria by all 5 observers. The PA projection scored significantly better for visualising joint space width (criterion 1), and should be the projection of choice for the investigation of the knee for osteoarthritis. The PA projection also scored significantly better for visualising the tibial spines (criterion 2) and should be the projection of choice when investigating tibial plateau fractures.

The use of the AP projection can still be performed with no significant loss in image quality in very specific individuals whereby the PA projection cannot be performed due to physical restraints, unless the clinical question concerns the joint space width and visualisation of the tibial spines.

Furthermore, the PA Projection is more standardised as evidenced from the tibial spines being more sharply visualised centrally relative to the femoral notch, hence, more useful for reproducibility and comparison for follow-up examinations. It is also recommended by the researchers that a positioning frame to facilitate consistent, comparable and reliable images is used and a specific study using the positioning frame should be performed and included as part of the study to evaluate the frame's advantages and disadvantages in clinical practice.

The anatomical criteria developed and used in this study can also be used to determine whether the X-ray image produced is of adequate image quality.

To obtain a more statistically significant and evident difference between the AP and the PA projection a larger scale study with more participating orthopaedic surgeons and subjects producing a larger number of images should be performed based on the same methodology.

The application of VGA and VGC analysis is encouraged in other areas of Radiography where comparison of projections and protocols is being investigated as part of optimisation strategies.

The findings of this study were presented at the European Congress of Radiology (ECR) in Vienna, March 2015 (Scientific session 214 – Musculoskeletal radiography, presentation B-0142).

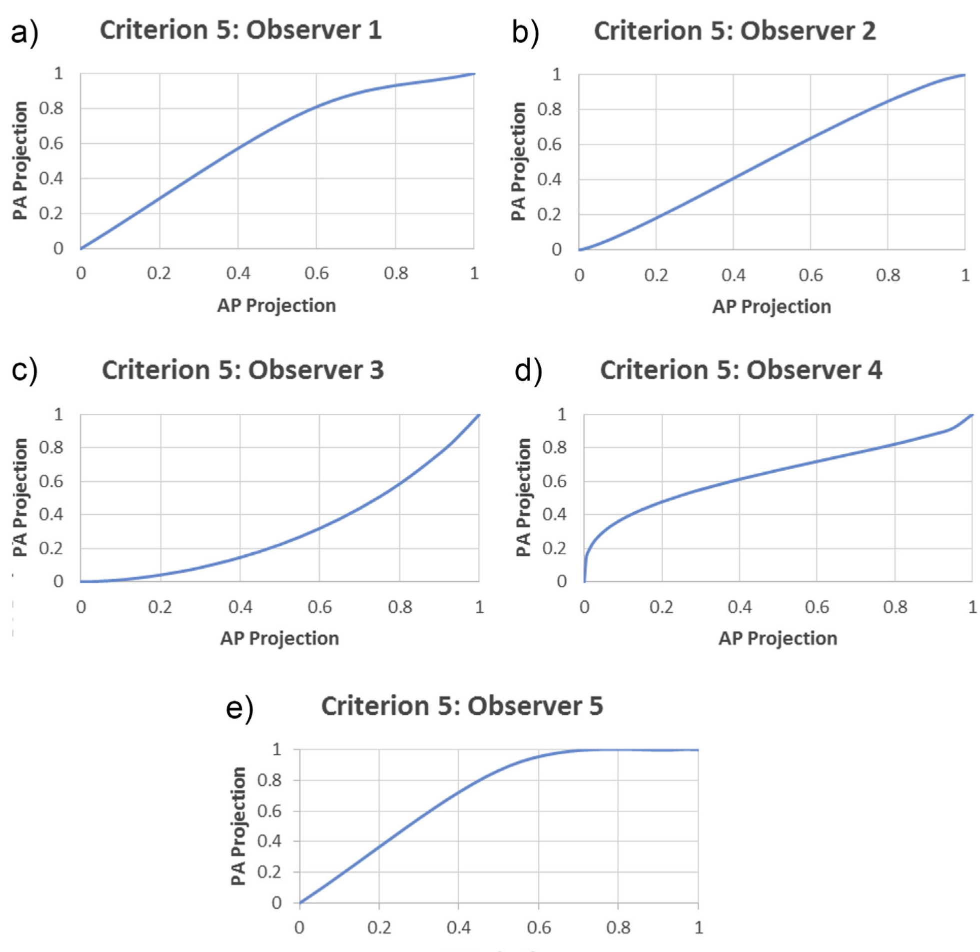

Figure 8. **a**. VGC Curve for Criterion 5 comparing the AP and the PA projections for Observer 1. Resultant AUC_{VGC} is 0.605. **b**. VGC Curve for Criterion 5 comparing the AP and the PA projections for Observer 2. Resultant AUC_{VGC} is 0.516. **c**. VGC Curve for Criterion 5 comparing the AP and the PA projections for Observer 3. Resultant AUC_{VGC} is 0.309. **d**. VGC Curve for Criterion 5 comparing the AP and the PA projections for Observer 4. Resultant AUC_{VGC} is 0.646. **e**. VGC Curve for Criterion 5 comparing the AP and the PA projections for Observer 5. Resultant AUC_{VGC} is 0.687.

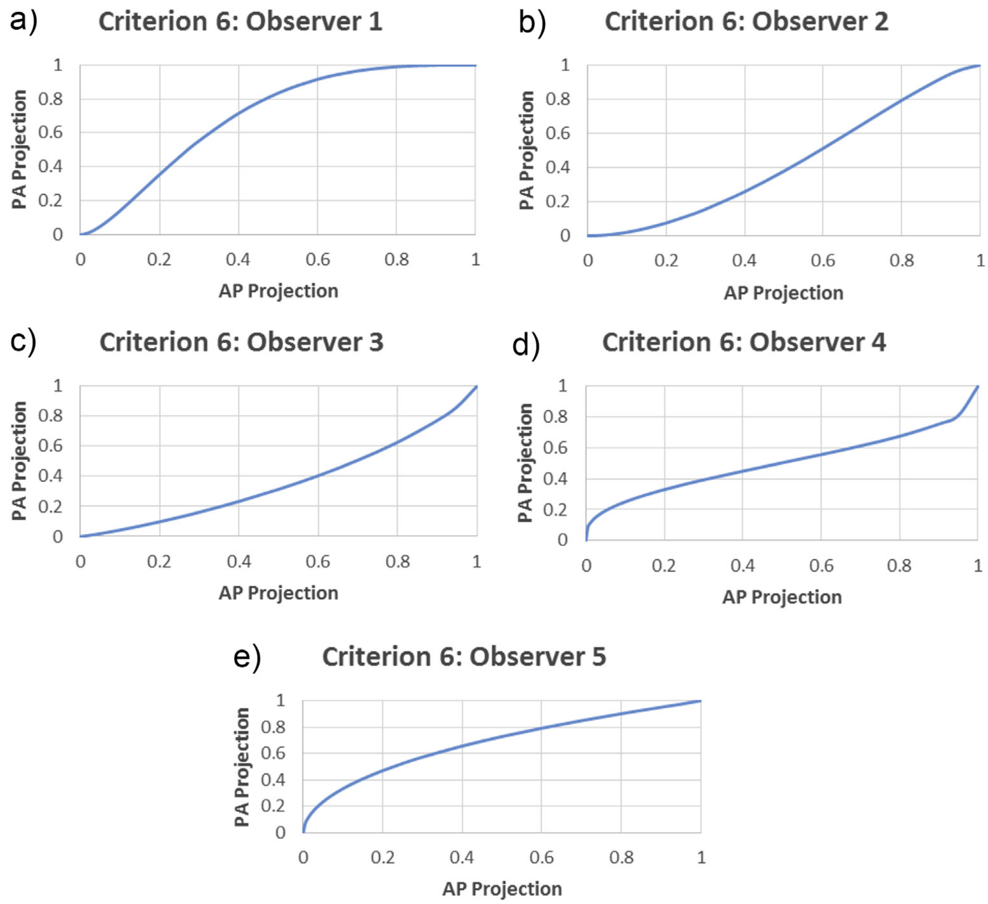

Figure 9. **a**. VGC Curve for Criterion 6 comparing the AP and the PA projections for Observer 1. Resultant AUC_{VGC} is 0.697. **b**. VGC Curve for Criterion 6 comparing the AP and the PA projections for Observer 2. Resultant AUC_{VGC} is 0.427. **c**. VGC Curve for Criterion 6 comparing the AP and the PA projections for Observer 3. Resultant AUC_{VGC} is 0.364. **d**. VGC Curve for Criterion 6 comparing the AP and the PA projections for Observer 4. Resultant AUC_{VGC} is 0.503. **e**. VGC Curve for Criterion 6 comparing the AP and the PA projections for Observer 5. Resultant AUC_{VGC} is 0.682.

Conflict of interest statement

The authors declare that they have no conflict of interest.

References

1. Brandt KD, Mazzuca SA, Conrozier T, Benite P, Dacre JE, Peterfy CG, et al. Which is the best radiographic protocol for a clinical trial of a structure modifying drug in patient with knee osteoarthritis? *J Rheumatol* 2002 Jun;**29**(6):1308–20.
2. Buckland-Wright C. Quantitative radiography of OA. *Ann Rheum Dis* 1994;**63**: 268–75.
3. Dervin G, Feibel R, Rody KGJ. 3 foot standing AP vs 45 degrees PA radiograph for OA of the knee. *Clin J Sport Med* 2001;**11**(1):10–6.
4. Messieh S, Fowler P, Munro T. Anteroposterior radiographs of the osteoarthritic knee. *J Bone Jt Surg Br* 1990;**72**:639–40.
5. Fife R, Brandt K, Braunstein E. Relationship between arthroscopic evidence of cartilage damage and radiographic evidence of joint space narrowing in early OA of the knee. *Arthritis Rheum* 1991;**34**:377–82.
6. Bhatnagar S, Carey-Smith R, Darrah C, Bhatnagar P, Glasgow M. Evidence-based practice in the utilization of knee radiographs-A survey of all members of the Brithish Orthopaedic Association. *Int Orthop* 2006;**30**(5):409–11.
7. Båth M, Månsson L. Visual grading characteristics (VGC) analysis: a non-parametric rank invariant statistical method for image quality evaluation. *Br J Radiol* 2007;**80**:169–76.
8. Ravaud P, Auleley G, Chastang C, Rousselin B, Paolozzi L, Amor B. Knee joint space width measurement : an experimental study of the influence of radiographic procedure and joint positioning. *Br J Rheumatol* 1996;**35**:761–6.
9. Merle-Vincent F, Vignon E, Brandt K, Piperno M, Coury-Lucas F, Conrozier T, et al. Superiority of the Lyon schuss view over the standing anteroposterior view for detecting joint space narrowing, especially in the lateral tibiofemoral compartment, in early knee osteoarthritis. *Ann Rheum Dis* 2007;**66**(6):747–53.