Active Appearance Models using DXA Imaging for the assessment of knee OA

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Aim

- Can Active Appearance Models (AAM) reflect Bone Mineral Density (BMD) distribution in Dual Energy X-ray Absorptiometry (DXA) images of the knee?
- How effective is the model for evaluating the severity of Knee Osteoarthritis (OA)?

Conclusions

- AAM incorporates textural changes reflecting BMD distribution into a model of Knee OA in DXA images.
- The resulting AAM is strongly linked to KL grade and may be a sensitive marker for Knee OA severity.

Background

- Active Shape Modelling (ASM) of the hip has previously identified those at greatest risk of developing OA and those who progressed most rapidly to a total hip replacement (THR) before clinical signs were apparent1.
- Active Appearance Modelling (AAM) is an extension of Active Shape Modelling to include the variation of image intensity within a defined shape and describe both in terms of linearly independent variables (modes of variation).
- DXA is used to measure Bone Mineral Density (BMD). DXA images are similar in appearance to a radiograph, with a lower radiation dose, (typically 1-2% of a pelvic radiograph), but also lower resolution.
- We have previously shown that DXA images are as good as radiographs for repeatable scoring of Kellgren-Lawrence grade (KLG). In this study we evaluate their suitability for use with an AAM of the knee in a cohort of volunteers with a range of severities of OA.

Methods

- The Grampian NHS Radiology Information System was used to identify 107 patients who had had radiographs of both knees in the previous 12 months.
- Volunteers were grouped into severity groups based on their KLG
  - 37 controls (Both knees KLG 0)
  - 24 mild OA (KLG 0 & KLG 1)
  - 22 moderate OA (Max KLG 2)
  - 24 severe OA (Max KLG 3 or 4)
- Each volunteer had a knee DXA (GE Lunar iDXA).
- An 85 point AAM was developed using the AAM toolkit (Manchester University, UK)2 and Pearson correlations and one-way ANOVAs were used to test the relationships between mode scores, age and KLG.

Results

- The first 4 modes were significantly correlated with KLG following Bonferroni correction for 15 modes. All were independent of age. [Table 1]
- A one-way ANOVA (Sidak post-hoc test) found significant differences between the KLG in all 4 modes ($P < 0.01$).
- Mode 2 had the strongest relationship with KLG ($R = 0.68$, $P < 0.001$). [Figures 1 & 2]
- Post-hoc analysis of Mode 2 identified significant differences between each pair of KL grades (except 3 and 4).

Results

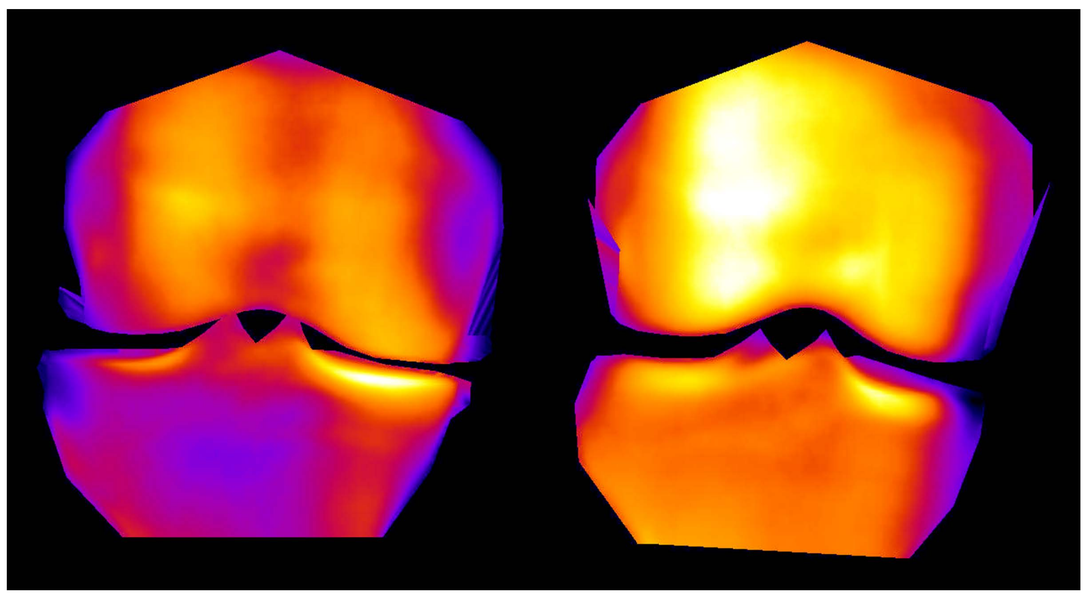

Figure 1.
False-colour images of mode 2 (±2 st. dev.) from AAM of the knee built from DXA images (medial compartment on the right). Low mode 2 scores (left) showed joint space narrowing, bilateral osteophytes on both the femur and tibia, a wider medial femoral condyle, a shallower intercondylar notch and a more uneven distribution of BMD, particularly in the tibia. The lateral tibial plateau is extended beyond the lateral femoral condyle, possibly indicating malalignment.

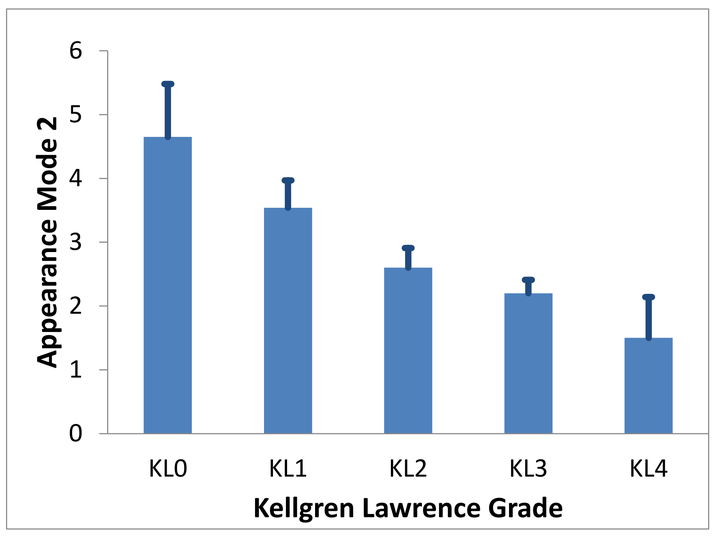

Figure 2.
Plot of the mean score (± st. dev.) for Appearance mode 2 at each KL grade

Table 1.
Correlations between Mode scores and KL grade.

Pearson Correlation	Mode 1	Mode 2	Mode 3	Mode 4
KL Correlation Coefficient	-2.0 *	-0.68 *	0.2 *	-0.21 *
P-Value	0.003	<0.001	-0.003	0.002

* Significant after Bonferroni correction for the 15 modes compared ($P \leq 0.003$)

References

[1]Gregory JS et al. Early identification of radiographic osteoarthritis of the hip using an active shape model to quantify changes in bone morphometric features: can hip shape tell us anything about the progression of osteoarthritis? Arthritis Rheum 2007 Nov;56(11):3634-43
[2]Cootes TF, Taylor CJ. Statistical models of appearance for medical image analysis and computer vision. Imaging Science and Biomedical Eng., University of Manchester, Manchester, United Kingdom. 2001 p. 236-48