Defining radiographic incidence and progression of knee osteoarthritis: suggested modifications of the Kellgren and Lawrence scale

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In the 1950s, Kellgren and Lawrence carried out the first large-scale epidemiological studies of osteoarthritis. Obtaining x-rays on multiple subjects from the populations of various communities in England, they defined a grading scale for osteoarthritis that is still widely used and called by their names, the Kellgren and Lawrence (K&L) scale. [1] This osteophyte-based scale is used in most large and small-scale clinical and epidemiological studies to define whether osteoarthritis is present or absent on the radiograph.

Unfortunately, neither Kellgren and Lawrence nor subsequent users of their scale were consistent in how they described each of their grades. Importantly, for grade 2, which usually defines whether osteoarthritis is present, it has been labelled as 'definite osteophyte' to 'definite osteophyte with possible narrowing of the joint space'. As noted by Schiphof and colleagues, [23] as investigators have come up with various descriptions of K&L grade 2, each of these studies may have identified a somewhat different group of persons with radiographic knee osteoarthritis.

With the emergence of large longitudinal studies of osteoarthritis have come questions about how to define new-onset disease and progressive disease, questions that the K&L scale was never designed to address. Even so, many studies, especially large epidemiological investigations, have used the K&L scale to identify knees with new-onset disease or progressive disease. In the Framingham and Rotterdam Studies, [45] for example, investigators have defined new-onset disease as the emergence of K&L grade 2 disease in knees that had previously been graded as either K&L grades 0 or 1. Rotterdam Study investigators have alternatively used as disease incidence the new onset of K&L grade 1 in knees previously graded as grade 0. [5] Progression of extant disease has also been characterised using K&L grades with progression by one grade or more often listed as one criterion for disease progression. [5–7] Given the inconsistencies in how K&L grades have been described cross-sectionally and applied in different studies, discrepancies in longitudinal definitions are likely to exist across studies. Knees will be characterised as having incidence or progression in a non-uniform manner. The goal of this paper is to evaluate critically whether the K&L scale should be used to define incident disease and if so, how and whether it should be used to evaluate whether a knee has experienced progression of disease.

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New-onset or incident radiographic osteoarthritis could be defined as the development of a new osteophyte, but that ignores evidence as to whether there has been cartilage loss in the joint, the signature pathological feature of osteoarthritis. While cartilage loss is not ascertainable on the x-ray, joint space narrowing correlates modestly with such loss[8] and usually serves as a proxy for loss. As longitudinal studies of osteoarthritis are increasingly characterised by standardisation of x-ray acquisition [9] in such a way that joint space is evaluated comparably at each visit with the cranial–caudal beam angle fixed, incident disease could include evidence of longitudinal joint space loss. Not only does the osteophyte definition of incidence not capture the major issue of joint space narrowing, but it is practically challenging to apply. In knee x-rays, the eventual incident knee often starts with a tiny, barely visible osteophyte (a grade 1 K&L film) and the osteophyte enlarges so that the knee meets the definition of grade 2. This is a common pattern for the development of definite osteophytes in osteoarthritis; osteophytes do not arise completely de novo from an entirely normal x-ray but rather develop from a tiny and borderline earlier osteophyte. To characterise such knees as new onset K&L grade 2 raises questions about when that knee's osteophyte crossed the line from questionable to definite. There is another problem with using definite osteophytes only to define incident osteoarthritis. While x-ray acquisition has now been well standardised to optimise characterisation of the joint space, it has not necessarily been similarly optimised to standardise knee rotation. Osteophytes are three-dimensional structures that circumnavigate the tibial plateau or femoral condyle. With changes in knee rotation on the x-ray, an osteophyte previously invisible often becomes obvious and vice versa, so that a baseline osteophyte can on later films become invisible as the knee is rotated out of the plane where the osteophyte is the largest (see figures 1 and 2). Using a definite osteophyte to define incident disease (and to characterise K&L grade 2) would produce misclassification of incidence and leave persistent questions about the threshold above which an osteophyte becomes definite.

The K&L scale does not provide an obvious opportunity to define incident disease clearly; the most obvious interpretation would be that incidence would constitute the development of a new definite osteophyte. In the MOST Study and in the Osteoarthritis Initiative (OAI) where our research group serves as the principal reader for publicly released images, we have, like investigators in other studies, defined incidence as new-onset K&L grade 2; but because of the concerns elaborated here, we have modified the scale also to require for incident disease that both narrowing and osteophytes be present at the time of incidence. As cartilage loss serves as the defining feature of osteoarthritis and as it is most closely related to joint space loss on the x-ray that is now measurable over time, we suggest that incident disease include the incorporation of joint space loss. Therefore, in MOST and OAI we define incident radiographic osteoarthritis as a new-onset K&L grade 2, but we elaborate this definition so that new-onset disease in the knee has to have both narrowing and an osteophyte, with at least one of these being new.

We are aware of the dilemma caused by this alternative definition of incidence, which is the lack of clarity in characterising knees that develop large definite osteophytes but without narrowing. If all incident disease requires joint space loss, then these knees with only osteophytes will be unclassifiable. For these knees, we recommend a new K&L score that could be called 2/osteophyte, which designates that the knee has developed definite osteophytes alone.

To investigate whether these 2/osteophyte knees are different from incident grade 2 knees that include joint space loss, we evaluated Framingham Osteoarthritis Study knees in which both x-rays and MRI were acquired. We divided K&L grade 2 knees into those with grade 1 joint space loss and those with grade 0 joint space loss (using the Osteoarthritis Research Society International (OARSI) atlas for grading joint space, which is scored 0–3) (see table

1). Of 189 knees from 165 subjects, 28 had joint space scores of 0 (the rest had narrowing scores of 1). MRI readers using the whole-organ magnetic resonance imaging score (WORMS) scale were not privy to x-ray images in this study. A WORMS score of 4 or greater (scale 0–6) connotes diffuse joint space loss (in grades 5 and 6, this loss extends to bone). Of knees with K&L grade 2 but with no x-ray narrowing, only three out of 28 knees (4%) had WORMS scores 4 or greater in any tibiofemoral region. However, in K&L grade 2 knees with grade 1 or greater narrowing, 73/161 (44%) knees had a score of 4 or higher in a tibiofemoral weightbearing region (difference $p<0.001$ by χ^2). When we used other thresholds for WORMS cartilage loss, results were similar. This analysis reveals that cartilage loss is far more common in grade 2 K&L disease with narrowing than it is in grade 2 disease with no narrowing.

If the K&L grade is to be used to define incidence, we suggest a new approach in which new-onset osteophytes are differentiated from a combination of narrowing and osteophytes. We also note that using grades for individual radiographic features (as in using the OARSI atlas to score osteophytes and narrowing) may make this problem moot. As there is no clearcut definition of osteoarthritis or disease incidence using grades for individual features, the modification of the K&L approach we propose may be preferable.

The K&L grading system has also been used to define progression in some studies. [45] As with incidence, approaches to defining progression using this grading system have varied from study to study. [56] In previous work, [7] we have shown that using individual radiographic features, especially joint space loss, to define progression results in more knees being accurately characterised as having progressive disease than using the cruder K&L scale. K&L grade 3 creates special difficulties in defining progression. Grade 3 requires definite joint space narrowing, but such narrowing can range from mild to almost bone on bone narrowing. Both levels of narrowing would fit within K&L grade 3, and therefore a knee with marked progression of joint space over time in a study might not have any change in K&L grade. Changes in narrowing are readily captured either by quantitative joint space narrowing or by semiquantitative scoring of joint space. [7] Progression is usually conceptualised as cartilage loss operationalised on the x-ray by joint space loss. By the way, if joint space loss defines progression, then it would make sense that incidence be defined using a similar concept.

The solution proffered is not a panacea for classification problems with x-rays of osteoarthritis. To evaluate joint space narrowing, we recommend the use of an atlas that provides narrowing (and osteophyte) grades such as the OARSI atlas. [10] While this may standardise the reading of x-rays, it does not necessarily eliminate variability from knee to knee in the appearance of narrowing because of variability in the beam angle or changing knee flexion. Indeed, the degree of narrowing seen on the x-ray is highly sensitive to positioning changes. Nor do our suggestions solve the inherent problem with interpretation of joint space narrowing, that it may arise from cartilage loss, meniscal loss or both. [11–13] Also, a knee could develop a definite osteophyte (a grade 2/ost) followed later by the development of joint space narrowing (a grade 2). Also, we advocate a traditional definition of radiographic disease here, but we recognise that cartilage loss and other elements of disease may be present in the context of a normal x-ray and that 'x-ray incidence' sometimes actually represents progression of disease.

The proposed approach to defining incident disease does not necessarily agree with cross-sectional approaches to defining prevalent osteoarthritis according to the K&L scheme, but as noted recently by Schiphof *et al*, [3] the scheme has varied with at least one version allowing for definite osteophytes and possible joint space narrowing for grade 2, while other versions demand only definite osteophytes and say nothing about narrowing. In their

recommendation for the use of versions requiring possible narrowing to reach grade 2, Schiphof *et al*[3] are implicitly suggesting an approach consistent with that proposed here, but leave unclassified the knee with large osteophytes but no narrowing. We are unsure how to classify such knees, but suspect that they should be labelled as having osteoarthritis in some but not all analyses. We suggest that cross-sectional approaches may also need to allow for a new 'definite osteophytes'-only grade.

A different solution to the problems we have identified would be to dispense with the K&L grades and use individual radiographic features to define disease prevalence, incidence and progression. There are two problems with this approach: first, it would make the extensive historical record that has used K&L grades impossible to overlay with new approaches. Second, there is evidence [14] that a global grading system produces grades that have a stronger relation with knee pain than grades of individual features, even using a combined feature score. Additional elements of the film are evaluated such as sclerosis, cysts, changes in bone shape and others and these can inform the K&L grade. This suggests that readers make use of K&L grades to summarise the amount of osteoarthritis.

In conclusion, the K&L grading scale is a widely accepted scale that is used to define the presence or absence of osteoarthritis, usually using grade 2 disease as the threshold. For longitudinal studies, the inconsistency in K&L scales in how grade 2 is defined creates special problems, and an osteophyte-based definition of osteoarthritis is conceptually troublesome and practically challenging. We recommend that incidence be defined by the new combination of joint space loss and definite osteophytes on x-ray in a knee that in previous x-rays did not have this combination. We propose an alternative definition of incidence that characterises a knee as incident when it develops only definite osteophytes, but for this alternative, we would propose a new K&L grade (grade 2/ost). We have operationalised these definitions in two large-scale studies, MOST and OAI, by requiring both joint space loss and osteophytes to define a knee as having new osteoarthritis and have developed an alternative K&L grade 2 (2/ost) when only definite osteophytes are present. For progression, the K&L grading system is likely to be too insensitive to detect many cases of progression especially as grade 3 is so broad. For progression, we recommend a focus on narrowing alone using either a semiquantitative approach that has been shown to pick up definite cases of progression and has construct validity[7] or a quantitative approach assuming that x-rays had been acquired in such a way as to allow for a valid quantitative approach to be used.

Acknowledgments

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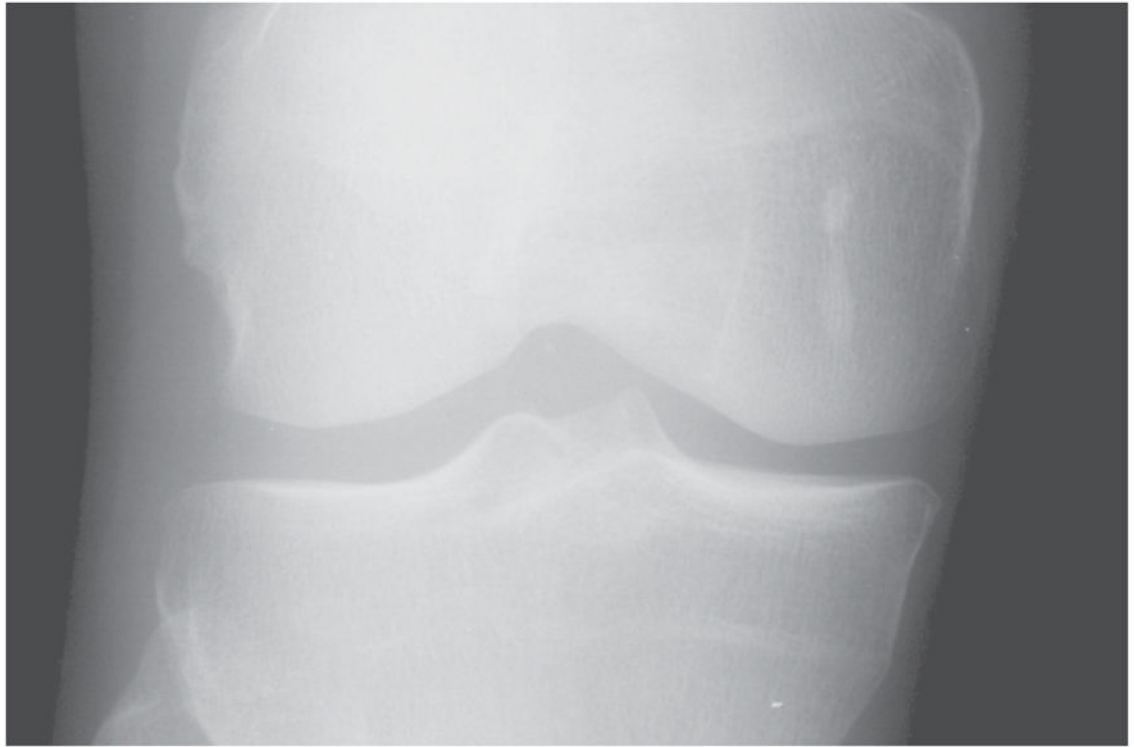
Figure 1.
Baseline x-ray from the MOST Study. Note tibial osteophyte.
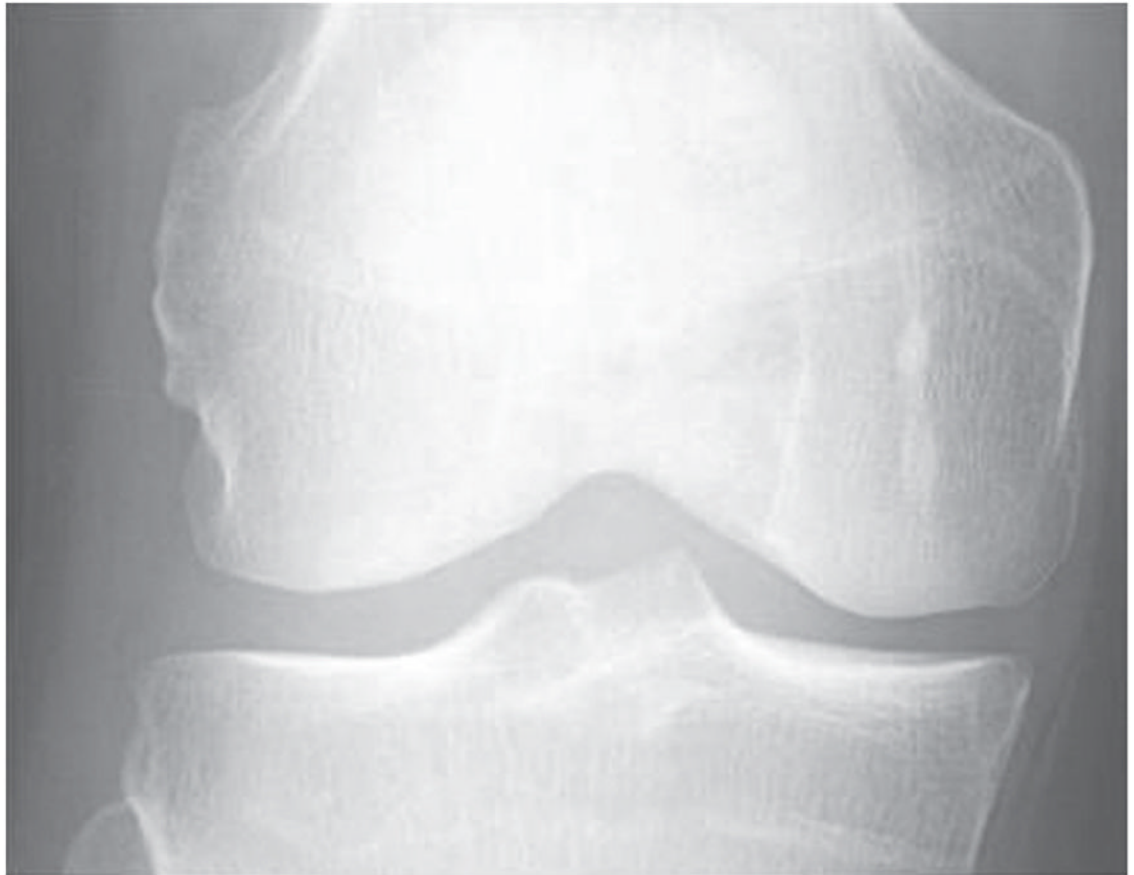
Figure 2.
x-ray from same subject in the MOST Study at 30-month follow-up. Tibial osteophyte is not visible.

Table 1

Maximum grade of tibiofemoral joint space narrowing on PA view *vs* maximal and individual WORMS reading on 10 tibiofemoral subregions

| | Max TF JSN=0 on PA view (N=28) | | | | | | | | Max TF JSN 1 on PA view (N=161) | | | | | | | |
| | WORMS cartilage morphology score | | | | | | | | WORMS cartilage morphology score | | | | | | | |
	0	1	2	2.5	3	4	5	6	0	1	2	2.5	3	4	5	6
Maximum cartilage score of 10 subregions (%)	8 (28.6)	0 (0.00)	5 (17.9)	2 (7.1)	10 (35.7)	1 (3.6)	2 (7.1)	0 (0.00)	11 (6.9)	0 (0.00)	12 (7.5)	1 (0.6)	64 (39.8)	24 (14.9)	46 (28.6)	3 (1.9)

Framingham Osteoarthritis Study—limited to knees scored Kellgren and Lawrence grade 2.

JSN, joint space narrowing; PA,; TF, tibiofemoral; WORMS, whole-organ magnetic resonance imaging score.