Editorial Commentary: Radiographic Measurements of Knee Joint Space Are Inadequate for Demonstrating Chondral Restoration

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Abstract: Orthopaedic advancements into the 21st century will increasingly focus on chondral restoration to either halt or reverse degenerative processes. Researchers and clinicians will need tools beyond patient-reported outcomes to measure the effectiveness of these treatment efforts. The use of joint space width (JSW) as a surrogate for chondral restoration is inadequate. At a minimum, such observations must standardize load transmission across the joint to be useful. Simple, readily available, standardized, and clinically useful measures of knee chondral restoration would facilitate and accelerate advances in the field. For now, it may be that improvement in JSW after chondral restoration could be attributable to changes in mechanical alignment of the knee and not the chondral restoration. JSW is an inadequate surrogate for chondral restoration, and anyone doing a stress radiograph of a unicompartmental degenerative knee recognizes this point.

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The endeavor to understand all facets of our world is fraught with instances of initial misunderstanding, only followed by enlightenment with better, and more thorough observation. In the 1800s, light was identified to be an electromagnetic wave. All waves up to that point moved through a medium. It was widely accepted that light must therefore propagate through an unobserved medium, then called the "luminiferous ether." It was only with Albert A. Michelson and Edward W Morley's landmark experiments using an interferometer floating in a pool of mercury at Case Western Reserve University in 1887 that observations improved enough to cast serious doubt on this concept.[1] Physics continues these types of observations with increasingly sensitive instruments to this day.[2]

The clinical question of whether realignment surgery regenerates articular cartilage is not as storied as light propagation theory but is of significance to millions of knees around the globe. The concept can be traced to Koshino and Tsuchiya in 1979 and their review of 136 high tibial osteotomies (HTOs).[3] The authors reported on 2 patients who had a second evaluation of the cartilage of their knees, one post-mortem and one following an arthrotomy for an intra-articular loose body. Both patients were reported to have regenerative fibrocartilage in their previous defects. Also during 1979, Fujisawa et al.[4] suggested that chondral regeneration was initiated by surviving chondrocytes in the affected area.

In 1992, Odenbring et al.[5] reported on a study of 28 patients undergoing a comparison between cast and brace immobilization after HTO, with 16 of these patients permitting second-look arthroscopy and cartilage biopsies. The authors reported 8 of 14 (57%) tibial plateaus and 9 of 14 (64%) femoral condyles had cartilage regeneration. This suggests that 39% of explored surfaces failed to have regenerative cartilage.

Kanamiya et al.[6] in 2002 reported on 58 knees with complete or partial fibrocartilage coverage in 55% of joint surfaces and scattered fibrocartilage in another 35%. Only 3 knees (5%) showed no regenerative change.

Twenty-four years after first reporting their HTO results, Koshino et al.[7] reported on 146 patients who underwent second-look arthrotomy during hardware removal. The authors' reporting included observational data as well as biopsy of 28 knees. They documented 47

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knees (32%) to be "entirely covered by a white cartilage layer." In 86 knees (59%), they reported the knee "to be covered partially by … fibrocartilaginous tissue." Only 9% of knees had no reported regenerative chondral effects. The authors significantly associated under correction of the osteotomy with failure of the knee to regenerate chondral-like tissue.

These studies include many initial dramatic arthroscopic pictures and photos showing a denuded articular surface at index surgery, only to be replaced with apparent normal chondral tissue upon second-look arthroscopy. Invariably, these pictures are challenging to orient and never quite positioned how we would like, leaving the reader to wonder the contribution of observational bias or malpositioning in the results.

Upon this foundation, authors Moon, Choi, Yoo, Jung, Lee, Byun, and Kim set out in their paper, "An Increase in Medial Joint Space Width After Medial Open-Wedge High Tibial Osteotomy Is Associated With an Increase in Postoperative Weight-Bearing Line Ratio Rather Than With Cartilage Regeneration: Comparative Analysis of Patients Who Underwent Second-Look Arthroscopic Assessment" to determine if the degree of osteotomy correction was affecting the restoration of joint space width (JSW) instead of chondral restoration.[8] They quite rightly point out that JSW has become an accepted surrogate for chondral regeneration in osteoarthritis studies and by the public generally. Their question is a worthwhile one, because accepting that the JSW increase is caused exclusively or partly by chondral regeneration and restoration influences our understanding and interpretation of all research in the area.

They undertake this by dividing their cohort of patients who underwent HTO into those that had improvement in their JSW (group 1) and those who did not (group 2). The authors then conducted a rigorous methodology in their measurements and their statistical analysis. Of particular commendation is their use of 2 observers performing radiographic measures and their assessment for intra- and interobserver reliability. The authors are commended for attempting increasingly sensitive methodologic studies, much as Michelson and Morley did in 1887.

The multivariate analysis they perform showed the difference between the 2 cohorts was attributable to increased weight-bearing line ratio in group 1 than 2. The weight-bearing line ratio is a measure of the mechanical alignment of the limb before and after surgery, represented radiographically in their very useful Figure 3. Thus, they conclude that the degree of correction of the osteotomy was causing the increase in JSW in their study. They also observed clinically relevant improvements in International Knee Documentation Committee score in group 1, the patients with JSW improvement.

Next, they attempted to determine if the increased JSW was being caused by regenerative cartilage formation, using the system developed by Koshino et al. in 2003. In this staging system, Stage A shows no

Fig 1. Comparison AP radiographs of a left knee with medial unicompartmental osteoarthritis taken on the same day. The radiograph on the left is an anteroposterior valgus stress view. The radiograph on the right is a weight-bearing anteroposterior view.

regenerative findings, Stage B showed partial regeneration, and Stage C showed total coverage of fibrocartilage or hyaline-like cartilage. Interestingly, group 2, the patients without JSW improvement, showed better chondral restoration than group 1, although these differences were not statistically significant. If the chondral restoration was responsible for the improvement in JSW, the opposite relationship would have been expected.

Also, the present study showed a greater rate of patients with Stage A findings, 28.9% of total, without chondral regenerative response. Their rate without chondral response is greater than the earlier reports by Koshino and Kanamiya.[3,6,7] Their outcomes in this area are more in-line with the results of Odenbring et al.[5] It is unclear why this would be. Like many of the studies in the area of cartilage restoration/regeneration, arthroscopic examples are included for the reader to ponder.

In particular, the Stage C example leaves you wanting more. Not only do these images leave us with a sense of the limitations of static arthroscopic images, it leaves us with a desire to understand why degenerative findings do or do not cause clinical symptoms. Why did the patients with these stage C improvements not do much better than patients with stage A changes?

While the study cannot answer that question, it does lead to one useful conclusion. The improvement in JSW was attributable to change in mechanical alignment of the knee and not chondral restoration. This finding should be useful as we further attempt to answer the bigger questions about degenerative knee conditions. JSW is an inadequate surrogate for chondral restoration, and anyone doing a stress radiograph of a unicompartmental degenerative knee recognizes this point (Fig 1). The same is true of anyone reading an in-flight magazine advertising the latest restorative procedure for knee cartilage—JSW is an inadequate surrogate for chondral restoration.

Now that Dr. Moon and colleagues have shown us this, perhaps we can design better and more sensitive studies to discern the true nature of osteoarthritis without having to try and work through the luminiferous ether.

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