# *Editorial Commentary:* Save the Meniscal Root, Why Not?

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**Abstract:** The repair of the meniscal root in medial meniscal posterior root tears is receiving increasing interest as more and more research highlights the positive effects of this procedure on the biomechanical restoration of the meniscus. As a testament to the findings of these studies, an international consensus statement recently acknowledged, with several supporting findings from both biomechanical and clinical studies, the effectiveness of meniscal root repairs. Various root repair techniques have been developed with the overarching goal of restoring the structure and function of the meniscus. Yet several challenges such as obtaining robust and long-term healing of degenerative tissue and minimizing meniscal extrusion remain to be overcome.

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"The devil is in the detail": This famous idiom is often said to point out a mysterious element that is hidden in the details.[1] This idiom originates from another phrase—"God is in the detail"—first coined by a French novelist, Gustave Flaubert.[1] How does this phrase relate to treating the meniscus? How does one achieve good healing of the medial meniscal posterior root? The answer is in the details. The debates surrounding the necessity, efficacy, and techniques of repair of medial meniscal root tears have led to systematic investigation of biomechanical studies such as ours.[2] This has allowed us to analyze details. Analyzing the details helps us to investigate factors such as techniques, indications, and rehabilitation programs that may influence the outcome of repairs of medial meniscal posterior root tears (MMPRTs). Doing this will not only contribute toward improving current standards to treat meniscal tears but also help protect more patients from osteoarthritis. After all, what is there to lose to know that God, or the devil if you wish, may be in the detail?

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*The author reports that he has no conflicts of interest in the authorship and publication of this article. Full ICMJE author disclosure forms are available for this article online, as supplementary material.*



*0749-8063/19271/$36.00*
*https://doi.org/10.1016/j.arthro.2019.03.002*

MMPRTs are frequent in middle-aged patients. One of the key pathologies of impaired meniscal function is loss of hoop tension. As a result, these tears often place patients at higher risk of early-onset osteoarthritis.[3,4] Recently, an international consensus statement was made that emphasized the greater effectiveness of the meniscal root repair over meniscectomy and conservative treatments.[5,6]

In my opinion, the study by Jiang, Everhart, Abouljoud, Kirven, Magnussen, Kae, and Flanigan[7] entitled "Biomechanical Properties of Posterior Meniscal Root Repairs: Systematic Review" provides excellent insight for clinicians to determine the appropriate surgical technique for MMPRTs. The authors systematically reviewed the literature for the biomechanical properties of several meniscal root repair techniques: the fixation method (transtibial pullout repair and suture anchor repair), the configuration and material of the suture used in transtibial pullout repair, and the location of fixation (anatomic vs nonanatomic). They concluded that (1) anatomic root repairs are associated with better results than nonanatomic repairs, (2) there is no consensus on the biomechanical superiority between transtibial pullout repair and suture anchor repair, (3) two sutures provide better fixation than one, and (4) the modified Mason-Allen configuration is superior to the simple suture configuration for transtibial pullout repair.

A biomechanical study by Allaire et al[3] showed that the mechanical properties of tibiofemoral contact, including peak contact pressure and contact surface area, are significantly worse in a torn root than in a healthy root and showed that a root repair restores tibiofemoral contact mechanics. Similarly, meniscal root repairs have been reported to restore tibiofemoral contact mechanics.[2,4] In support of these biomechanical studies, meniscal root repairs have been shown to have favorable clinical outcomes.[8,9] In a long-term follow-up study, we reported high survival rates (99% at 5 years, 98% at 6 years, 95% at 7 years, and 92% at 8 years) after transtibial pullout repair of MMPRTs.[10] Given this favorable clinical and biochemical evidence for meniscal root repairs, I believe that the recent increase in the interest in meniscal root repairs is indeed meaningful. Therefore, the current study aims to add valuable insight toward the considerations for choosing the right treatment for MMPRTs.

Jiang et al.[7] reviewed the literature for both medial and lateral posterior root repairs. Medial posterior root tears are common in middle-aged women and are often degenerative.[11] Therefore, more stringent surgical indications regarding concomitant degenerative changes and mechanical alignment are needed for patients with medial posterior root tears than those with lateral posterior root tears when one is planning a surgical intervention for MMPRTs. Moreover, because it is challenging to repair a degenerative root, MMPRTs must be selectively determined and a highly qualified expert should perform the suturing. We use the following indications for a meniscal root repair: patients younger than 65 years, symmetrical alignment of the lower extremity (<3° of varus), mild progression of arthritis (Kellgren-Lawrence grade I or II), and mild subluxation of the meniscus.[4] LaPrade et al.[12] also suggested that an anatomic root repair should be attempted whenever possible to prevent meniscal damage and osteoarthritis, except in cases in which patients are poor surgical candidates (advanced age), have diffuse Outerbridge grade 3 or 4 osteoarthritis, have nonsymptomatic chronic meniscal root tears, or have significant limb malalignment.[13] Applying these surgical indications strictly, I select approximately 20% of patients with MMPRTs for meniscal root repair in the outpatient clinic annually.

In vitro biomechanical experiments tend to be time-zero studies, so interpretations from these studies may implicitly ignore the role of biological factors, for instance, the healing status of repaired tissue or normal hoop tension, each of which can influence the extent of meniscal extrusion and retear. Other environmental factors should be considered, such as the healing process of the meniscal root during postoperative activity and rehabilitation. For example, further clinically meaningful results can be teased out from investigating the period of immobilization, type of muscle exercise, and weight-bearing techniques used.

Nevertheless, biomechanical studies on root properties are helpful when deciding which technique is more likely to manifest better repair properties and fixation than other techniques. Thus, the systematic review by Jiang et al.[7] divided 17 biochemical studies into 5 distinct categories on the basis of their ability to influence repair outcome.

LaPrade et al.[12] have argued that anatomic root repair is critical to restore tibiofemoral contact mechanics. I strongly agree with them because a nonanatomic repair is highly likely to lead to arthritis-inducing meniscal extrusion. However, one of the challenges to root repairs on the native anatomic attachment is the narrow medial compartment. Releasing the medial collateral ligament is an effective solution to this, and we have in the past reported the advantages of releasing the distal attachment of the medial collateral ligament to obtain a wider working space and better visualization during root repair procedures without experiencing significant complications.[14] As an alternative to medial collateral ligament release, posterior portals increase accessibility to the posterior root area.[15]

For the comparison between transtibial pullout repair and suture anchor repair, we compared the findings of the study by Chung et al.[16] (transtibial pullout repair) with those of Feucht et al.[8] (suture anchor). We concluded that currently, there is no consensus on the biomechanical superiority between the 2 techniques. Making a direct comparison of the findings between the 2 studies is not feasible because they rely on different criteria to evaluate the results. Chung et al. evaluated tibiofemoral contact mechanics, including peak contact pressure and contact surface area, whereas Feucht et al. evaluated maximum load to failure, stiffness, and displacement at failure but not tibiofemoral contact mechanics. Chung et al. dealt with end-to-end anastomosis between the torn meniscal remnant and the meniscal body and used an all-inside repair device with the Fast-Fix 360 system (Smith & Nephew, Andover, MA) but not direct bony fixation on the root attachment. Feucht et al. used suture anchors (5.5-mm Corkscrew FT II; Arthrex, Naples, FL) that were fixed at the tibial bone, whereas Chung et al. used an all-inside meniscal device without suture anchors. Because direct statistical comparisons cannot be made, a different approach must be used to compare these 2 techniques (transtibial repair and suture anchor repair). The suture anchor repair showed superior biomechanical results compared with the transtibial repair, but the "all-inside soft tissue fixation method" showed inferior results in comparison with the transtibial repair. I suggest that the transtibial technique has its biological advantage in establishing a bony bed that promotes recruitment of growth factors and progenitor cells from the bone marrow.[17] In the future, more randomized comparative studies from a clinical prospective are needed.

Regarding the suture configuration, suture techniques with a locking mechanism have better biomechanical properties than those without it.[18,19] Several suture techniques with a locking mechanism have been introduced and evaluated biomechanically. We have used the modified Mason-Allen repair for MMPRTs since 2011 because it showed good biomechanical properties for rotator cuff tears of the shoulder, which are pathologically similar to MMPRTs.[17] In this study, we found that the modified Mason-Allen repair has biomechanical properties similar to or better than those of all other techniques in terms of maximum failure load and stiffness. Regarding tibiofemoral contact mechanics, the modified Mason-Allen repair showed better outcomes than simple repairs and the all-inside repair, leading to a more restored contact surface area.[16] Our comparative study between the modified Mason-Allen repair and simple repairs found that the former technique is associated with better reduction of meniscal extrusion. Our findings suggest that the modified Mason-Allen repair can prevent arthritic changes, resulting in favorable clinical outcomes.[20]

For the number of tibial tunnels, a study by LaPrade et al.[21] showed no significant differences in displacement after cyclic loading and maximum load at failure. The double—transosseous tibial tunnel root repair was first introduced by Ahn et al.[22] as a technique that can obtain better fixation, as well as a wider contact area, and promote healing at the root-bone interface. During simple repairs, I suggest that the double transosseous tunnels provide broader coverage of the root attachment. Despite the controversy concerning the use of shiny white fibers and supplemental fibers, structural properties should nevertheless be considered in medial meniscal posterior root attachment.[23]

The findings from a recent anatomic study described the meniscal posterior root as an insertional ligament firmly attached to the tibial plateau and its transition into the fibrocartilaginous structure of the meniscal body.[24] This study suggested that a root ligament reconstruction with an autologous graft may be an interesting approach.[25,26] Wu et al.[27] reported that autologous graft reconstruction exhibits lower elongation, higher stiffness, and lower maximum failure load than the modified Mason-Allen repair. However, I have several concerns about the root reconstruction for degenerative tissue: The relatively thick tendon grafts can cause meniscal damage or result in an unfavorably elongated or truncated reconstructed root. The innate tendon graft is intolerant to axial compressive loading as opposed to tensile loading.[28] Although tendon grafts generally show favorable biomechanical properties in time-zero studies, future studies should evaluate the clinical results of root reconstruction under chronic conditions.

It is important to consider the biomechanical properties of the meniscal repair in MMPRTs. Most biomechanical studies analyzed in our systematic review have focused predominantly on the biomechanical properties of the suture configuration. A meta-analysis that pools data from these studies would be more informative for readers. Moreover, some of these studies are suitable for performing meta-analysis; for example, various biomechanical outcomes may be integrated in terms of the suture configuration and presented as a forest plot.

The suture configuration is an important factor to consider when reducing displacement and cutoff during postoperative rehabilitation but in my opinion is not the most critical factor. More important than the suture configuration is tibiofemoral contact mechanics because the main purpose of root repair is to prevent osteoarthritis. We postulate that restoring normal tibiofemoral contact mechanics after root repairs is most critical. In this view, more biomechanical studies on tibiofemoral contact mechanics are needed in the future to address problems associated with root repairs from a different perspective.

Critical challenges to root repair remain. As of yet, arthritic changes are not completely preventable with MMPRTs even though their progression is slowed. Other challenges include attaining a complete level of meniscal healing and reduction of meniscal extrusion, achieving effective management of concomitant cartilage complications, and choosing the degree of mechanical alignment that is most appropriate. In facing these challenges, we will continue to improve our surgical and perioperative management to repair, save, and restore the meniscus and normal knee function after MMPRTs.

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