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Assessment of glenoid chondral healing: comparison of microfracture to autologous matrix-induced chondrogenesis in a novel rabbit shoulder model

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Background: Management of glenohumeral arthrosis in young patients is a considerable challenge, with a growing need for non-arthroplasty alternatives. The objectives of this study were to develop an animal model to study glenoid cartilage repair and to compare surgical repair strategies to promote glenoid chondral healing.

Methods: Forty-five rabbits underwent unilateral removal of the entire glenoid articular surface and were divided into 3 groups—untreated defect (UD), microfracture (MFx), and MFx plus type I/III collagen scaffold (autologous matrix-induced chondrogenesis [AMIC])—for the evaluation of healing at 8 weeks (12 rabbits) and 32 weeks (33 rabbits) after injury. Contralateral shoulders served as unoperated controls. Tissue assessments included 11.7-T magnetic resonance imaging (long-term healing group only), equilibrium partitioning of an ionic contrast agent via micro–computed tomography (EPIC-μCT), and histologic investigation (grades on International Cartilage Repair Society II scoring system).

Results: At 8 weeks, x-ray attenuation, thickness, and volume did not differ by treatment group. At 32 weeks, the T2 index (ratio of T2 values of healing to intact glenoids) was significantly lower for the MFx group relative to the AMIC group ($P = .01$) whereas the T1ρ index was significantly lower for AMIC relative to MFx ($P = .01$). The micro–computed tomography–derived repair tissue volume was significantly higher for MFx than for UD. Histologic investigation generally suggested inferior healing in the AMIC and UD groups relative to the MFx group, which exhibited improvements in both integration of repair tissue with subchondral bone and tidemark formation over time.

The procedures in this study were performed under Institutional Animal Care and Use Committee approval.

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Discussion: Improvements conferred by AMIC were limited to magnetic resonance imaging outcomes, whereas MFx appeared to promote increased fibrous tissue deposition via micro–computed tomography and more hyaline-like repair histologically. The findings from this novel model suggest that MFx promotes biologic resurfacing of full-thickness glenoid articular injury.

Level of evidence: Basic Science Study, In Vivo Animal Model.

Keywords: Glenohumeral; articular cartilage; microfracture; autologous matrix-induced chondrogenesis; animal model

Management of glenohumeral arthrosis in a young patient population is a considerable challenge. In active patients with increased longevity, there is a need for non-arthroplasty alternatives to reliably reduce pain and improve function,[10] primarily because of concerns related to glenoid implant loosening.[41,47] Unfortunately, alternative strategies such as biologic resurfacing procedures (eg, using lateral meniscus or dermal allografts) and glenoid osteochondral grafting result in unacceptably high rates of failure.[22,49] However, bone marrow–stimulating procedures such as microfracture (MFx)[12,36] and concentric reaming of the glenoid[7] have shown promising short-term and midterm results.

A variety of reparative treatment strategies have been developed for the management of focal articular cartilage defects, with most investigations to date focusing on the knee. Although MFx remains a commonly performed procedure,[48] more recent techniques incorporate synthetic and biologic scaffolds (with or without implanted cells) to facilitate the organized adhesion, migration, and differentiation of mesenchymal stem cells to chondrocytes, thereby facilitating cartilage regeneration.[9,14] One such approach, autologous matrix-induced chondrogenesis (AMIC), is a single-step procedure combining MFx and a type I/III (bilayer) collagen patch, and it has yielded promising results in both preclinical and retrospective clinical studies.[11,16,17,51]

Presently, very little is known regarding the reparative capacity of injured glenohumeral joint (GHJ) articular cartilage. Although numerous animal models across multiple species have been developed for detailed investigation of knee cartilage repair strategies,[6] very few models exist for reliable assessment of glenohumeral chondral injuries (eg, defect models). Therefore, the objectives of this study were to develop an in vivo rabbit model and to compare surgical repair strategies to promote glenoid chondral healing. We hypothesized that both the MFx- and AMIC-treated glenoids would exhibit a superior repair response when compared with untreated defects (UDs).

Materials and methods

Experimental design

A total of 45 male New Zealand white rabbits (weighing 4-5 kg at the time of surgery) were randomized into 3 experimental groups and underwent unilateral shoulder surgery. Full-thickness cartilage defects of the entire glenoid were created on the left shoulder and immediately treated with MFx alone, treated with MFx augmented with a collagen scaffold (AMIC), or left as UDs. Contralateral shoulders served as intact controls. Twelve rabbits (4 rabbits per group) were euthanized 8 weeks after surgery for equilibrium partitioning of an ionic contrast agent via micro–computed tomography (EPIC-μCT) followed by histologic analyses, whereas the remaining 33 rabbits (11 rabbits per group) were euthanized at a mean of 32 weeks after surgery for magnetic resonance imaging (MRI), micro–computed tomography (EPIC-μCT), and histologic investigation (Fig. 1). Because of the need for preparation of cored, cylindrical specimens for EPIC-μCT assessment, which rendered the peripheral glenoid tissue unusable, the initial 15 rabbits (5 rabbits per group) in the long-term study were assigned to the histologic study only, thus allowing us to examine the morphology of the entire glenoid articular surface.

Surgical injury model

The reader is referred to prior studies detailing the anatomy of the rabbit rotator cuff and GHJ.[21,27,54] Under isoflurane anesthesia and by use of a posterolateral approach, a 6-cm craniolateral incision was made on the dorsum of the left shoulder, superior and medial to the GHJ (Fig. 2, *A* and *B*). Skin and soft tissue were dissected down to the junction of the cervical and thoracic trapezius, whose fibers ran perpendicular to the initial incision. The trapezius was reflected along its fibers. The deltoid was then split longitudinally and tagged on both ends to expose the rotator cuff tendons (Fig. 2, *C* and *D*). Next, the supraspinatus tendon was transected transversely at the midline between its musculotendinous junction and its insertion on the humeral head. The supraspinatus was then reflected medially and tagged with a suture. The infraspinatus tendon was similarly incised and reflected medially to expose the joint capsule, which was incised anteriorly. A custom-designed Fukuda-type retractor (Fig. 2, *E*) was used to retract the humeral head posteriorly, providing adequate access to the glenoid in addition to protecting the humeral head cartilage. To create the cartilage defect, a 4-mm arthroscopic burr was used to ream the entire glenoid cartilage surface down to the calcified cartilage layer (Fig. 3, *A*). To avoid mechanically or thermally compromising the humeral cartilage or the surrounding soft-tissue envelope, we performed burring at low speeds and under copious saline solution irrigation. These steps constituted creation of the UD.

Subsequently, in animals assigned to the MFx or AMIC group, 10 MFx holes were created in the subchondral bone with a high-speed 0.7-mm drill to promote bleeding and ingress of bone marrow products (Fig. 3, *B*). The lesion was then irrigated with