Treatment of Cartilage Defects in Young Shoulders: From the Lab to the Clinic

“Overall, this study provides a solid foundation for continued basic science research.”

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Results

Glenohumeral cartilage defects in young patients are challenging clinical problems given the longer life expectancy after surgery of these patients and the greater demands their more vigorous lifestyles place on their shoulders. Numerous etiologies can lead to glenohumeral cartilage disease: trauma, instability, inflammatory arthritis, post-traumatic degeneration, foreign body reaction, and glenohumeral chondrolysis. The initial treatment of glenohumeral cartilage disease is always nonsurgical, but when measures are needed beyond conservative treatment, we evaluate whether autologous matrix-induced chondrogenesis (AMIC), which involves using a collagen I/III matrix with microfracture, can promote the formation of tissue with similar architecture to native cartilage by organizing adhesion, migration, and differentiation of mesenchymal stem cells to chondrocytes.

In order to understand the potential applications of this basic science research, we have employed a framework of clinical needs, which includes palliative, reparative, restorative, and reconstructive treatments, to guide a clinical management algorithm. Thus, we report on a novel treatment method and discuss the background framework into which it and other pieces of tissue with similar architecture to native cartilage by organizing adhesion, migration, and differentiation of mesenchymal stem cells to chondrocytes.

METHODS

We hypothesized that a collagen I/III matrix superimposed on a chondral defect that has been concomitantly treated with microfracture will provide a superior medium on which functional cartilage will form and heal. To test this hypothesis, we divided 12 rabbits into 3 groups. Each group underwent the same surgical approach to the rabbit glenohumeral joint, including incision and repair of the superior rotator cuff. Group 1, the surgical control, consisted of rabbits that underwent removal of the cartilage layer on the glenohumeral joint only. Group 2 rabbits underwent microfracture to the glenohumeral defects (Figure 1). Group 3 underwent the autologous matrix-induced chondrogenesis (AMIC) procedure: microfracture of the glenohumeral defect followed by the application of a collagen I/III matrix (Figure 2). Each rabbit had 1 operative shoulder and 1 control nonoperative shoulder. All operations were completed with the same exposure and closure.

RESULTS

Based on the assumption that the glenoid cartilage would be approximately 100-500 μm in thickness, we set the micro-CT scanner to 20 μm resolution in all three spatial planes. These scans were carried out at 45 kV, 177 μA, and 300 ms integration time. The average scan consisted of approximately 412 slices. We used analysis of variance (ANOVA) results and Tukey post-hoc testing to determine significant differences between the normalized values. Post-hoc power analysis showed each group would need to have 10 specimens in order to find statistical differences.
Defects in Young Shoulders: Treatment of Cartilage Chondrolysis,1,2 degeneration, foreign body reaction, and glenohumeral trauma, instability, inflammatory arthritides, postinfectious. Numerous etiologies can lead to glenohumeral cartilage disease: demands their more vigorous lifestyles place on their shoulders.

New bioconstructs and collagen matrices to augment cartilage in techniques for cartilage defects in the shoulder. Including palliative, reparative, restorative, and reconstructive treatments, to guide a clinical management algorithm. Thus, we report on a novel treatment method and discuss the background framework into which it and other pieces are being fitted to improve care of shoulder disorders.

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RESULTS
The results for total cartilage volume and average cartilage thickness in both native and operative shoulders are displayed in Figures 3 and 4. There were no significant differences in the statistical results between all groups; however, there was a trend toward increased defect fill and thickness in the microfracture and AMIC groups (Groups 2 and 3, respectively). The topographical surface maps for the surgical control and AMIC procedures are shown in Figure 5 as an illustrative example of the subjective improvement in the AMIC fill patterns. There were also no significant trends in the attenuation values of the defect fill. Post-hoc power analysis showed each group would need to have 10 specimens in order to find statistical differences.
DISCUSSION
The current study evaluates whether a collagen I/III matrix with microfracture can promote the formation of tissue with similar architecture to native cartilage by organizing adhesion, migration, and differentiation of mesenchymal stem cells to chondrocytes. These techniques consist primarily of arthroscopic debridement, capular or loose body removal. Arthroscopic debridement is appealing because it is technically straightforward, has low surgical morbidity, and does not preclude other, more advanced, reparative and reconstructive interventions in the future. In a few published series, arthroscopic debridement has led to good or excellent results in roughly 80% of patients at short follow-up intervals.12 Cameron et al10 reported on a series of patients with grade IV osteochondral defects and found that 88% experienced significant improvement in pain and function for an average duration of 28 months. Weinstein et al also reported 80% good or excellent results at a mean follow-up of 34 months. The largest series in the literature was reported by Van Thiel, Romeo, Verma, Cole et al.9 The authors retrospectively reviewed 81 patients who underwent arthroscopic debridement for glenohumeral osteoarthritis. Of the 81 patients, 71 were available for follow-up at an average of 27 months, and 58 of the 81 (82%) were satisfied with the results of the surgery and would have it again. They also experienced a statistically significant improvement in postoperative functional outcome scores and a decreased level of pain. Of the 71 patients, 16 (23%) experienced surgical failures and required arthroplasty at a mean of 10.1 months after debridement. Grade IV bipolar disease, joint space less than 2 mm, and the presence of large osteophytes constituted the most significant risk factors for failure. Overall, arthroscopic debridement is a very reasonable and predictable first-line surgical option that offers relief of pain and improvement in functionality in approximately 80% of cases.

REPARATIVE TREATMENTS
Reparative treatment includes marrow stimulation techniques like chondroplasty, subchondral drilling, and microfracture to replace the damaged cartilage with fibrocartilage (Figure 7). However, despite its reported effectiveness in the knee joint, we are aware of only three series that report clinical outcomes following arthroscopic microfracture of the humeral head or glenoid surface.3 (20%) had subsequent shoulder surgery and therefore, their initial surgeries were considered to be failures. Additional research is needed before definitive statements can be made, but microfracture does appear to be a viable treatment option for select patient populations.

RESTORATIVE TREATMENTS
Restorative treatments aim to reestablish hyaline or hyaline-like cartilage by transferring hyaline cartilage via osteochondral grafting (autograft or allograft) or by growing hyaline-like cartilage using autologous chondrocyte implantation (ACI). At present, osteochondral autograft and ACI require a shoulder arthroscopy and a second surgical procedure at the knee for graft harvest. Consequently, both procedures are more invasive and more technically demanding, and they expose the patient to significantly greater surgical morbidity than arthroscopic palliative or reparative techniques. Therefore, restorative modalities are best reserved for the young, active individual with a distinct chondral lesion of the humerus or glenoid who has already failed conservative, palliative, and reparative treatment. Habermeyer et al10 have published good results for 7 patients who received osteochondral autograft transfer from the knee to the shoulder with almost 9-year follow-up. The authors based their results on both functional as well as MRI criteria. Osteochondral allograft transfer employs a similar technique, matching a donor plug to a recipient site, but without the concern for donor-site morbidity. Therefore, allograft transfer can be used to treat more sizable lesions than can be treated effectively by autograft transfer.
DISCUSSION

The current study evaluates whether a collagen I/III matrix with microfracture can promote the formation of tissue with similar architecture to native cartilage by organizing adhesion, migration, and differentiation of mesenchymal stem cells to chondrocytes. The data suggest that both microfracture and autologous matrix-induced chondrogenesis (AMIC) have the ability to fill a glenohumeral cartilage defect in a rabbit model significantly more than the surgical control, based on micro-CJ data. Although the current study does not reveal significant differences, there are some very important conclusions that can be drawn. One, further research is needed to characterize the trends seen in this study. We currently have a much larger trial underway that will use histology and MRI to corroborate the results reported here. Two, the rabbit glenohumeral model is a very good model to study glenohumeral cartilage defects (Figure 6). Overall, this study provides a solid foundation for continued basic science research. However, basic science research in isolation cannot address the issue of glenohumeral cartilage defects without clinical corollaries. In order to understand the potential applications of this basic science research, we reviewed the aforementioned areas of palliative, reparative, restorative, and reconstructive techniques in the shoulder joint to provide a framework to guide a clinical management algorithm.

PALLIATIVE TREATMENTS

Palliative techniques for the management of glenohumeral cartilage disease are designed to alleviate symptoms without replacing or restoring the injured articular cartilage. These techniques consist primarily of arthroscopic debridement, capsular release, ligament, and loose body removal. Arthroscopic debridement is appealing because it is technically straightforward, has low surgical morbidity, and does not preclude other, more advanced, restorative and reconstructive interventions in the future. In a few published series, arthroscopic debridement has led to good or excellent results in roughly 80% of patients at short follow-up intervals.12 Cameron et al10 reported on a series of patients with grade IV osteochondral defects and found that 88% experienced significant improvement in pain and function for an average duration of 28 months. Weinstein et al also reported 80% good or excellent results at a mean follow-up of 34 months. The largest series in the literature was reported by Van Thiel, Romeo, Verma, Cole et al.10 The authors retrospectively reviewed 81 patients who underwent arthroscopic debridement for glenohumeral osteoarthritis. Of the 81 patients, 71 were available for follow-up at an average of 27 months, and 58 of the 81 (82%) were satisfied with the results of the surgery and would have it again. They also experienced a statistically significant improvement in postoperative functional outcome scores and a decreased level of pain. Of the 71 patients, 16 (23%) experienced surgical failures and required arthroplasty at a mean of 10.1 months after debridement. Grade IV bipolar disease, joint space less than 2 mm, and the presence of large osteophytes constituted the most significant risk factors for failure. Overall, arthroscopic debridement is a very reasonable and predictable first-line surgical option that offers relief of pain and improvement in functionality in approximately 80% of cases.

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Given this versatility of osteochondral allografts, a number of case reports describe the use of side-to-side and -to-matched osteochondral allografts for large Hill-Sachs lesions at the site of recurrent instability.1,3

Cole and McCarthy4 took the allograft transfer one step further and completed an osteochondral allograft humeral head resurfacing in combination with a lateral meniscal allograft glenohumeral resurfacing (Figure 8). In this case report, a 16-year-old girl with symptomatic bipolar glenohumeral chondrolysis after arthroscopic thermal capsulorrhaphy was treated with the meniscal and osteochondral allografts. At 2-year follow-up, the patient reported complete resolution of her shoulder pain, and radiographs showed maintenance of the glenohumeral joint space.

Romeo et al5 published a case report on the use of ACL in a 16-year-old baseball player with a humeral head lesion (Figure 9). Restoration was performed with a 2-stage harvest (knee) and implantation (shoulder) technique with a peristaltic graft from the itibia. At 1 year, the patient had full range of motion with no pain. These case reports offer hope to young patients with end stage disease of the glenohumeral joint, but further research is needed to determine the long term outcome in a larger patient population.

RECONSTRUCTIVE TREATMENTS

Reconstructive techniques can use a combination of prosthetic and biologic components to repair the humeral head and glenoid and include soft-tissue repair with autograft or allograft, Achilles tendons, alloplastic bone, and biologic glenoid (GraftJacket®). Wright Medical Technology, Inc., Arlington, Texas, and lateral meniscal allografts. With experience in these techniques is generally limited to a few institutions and literature reporting long-term outcomes is sparse.

Burkhart and Hutton proposed biological resurfacing of the glenoid as a means of improving the surface area of the glenoid for the treatment of osteoarthritis.6 They hypothesized that by increasing the surface area of the glenoid, the glenohumeral joint’s congruency would improve.7

In 2002, a 16-year-old baseball player with a Hill-Sachs lesion (Figure 9) was treated with the meniscal and osteochondral allograft transfer with the meniscal and osteochondral allograft transfer technique with harvest of a periosteal (shoulder) technique with harvest of a periosteal (shoulder) technique with harvest of a periosteal flap.8

In 2006, Campana et al9 reported the initial results of a novel technique to manage cartilage defects in the rabbit glenohumeral joint and (2) to synthesize clinical data regarding the management of glenohumeral lesions in young patients. We hypothesize, and our data suggest but have not yet proven, that a collagen I/III matrix superimposed on a chondral defect that has been concomitantly treated with microfracture will provide a superior medium on which functional cartilage will form and heal. Future research will continue to yield new treatment modalities with the goals of increasing function and improving outcomes.

REFERENCES


11. McCarty LP III, Cole BJ. Reconstruction of the glenohumeral joint using a lateral meniscal allograft (LMA) in young patients with end stage disease of the glenohumeral joint, but further research is needed to determine the long term outcome in a larger patient population.