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MRI and Histology of Collagen Template Disc Implantation and Regeneration in Rabbit Temporomandibular Joint: Preliminary Report

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ABSTRACT

Introduction. We aimed to evaluate regeneration of injured temporomandibular joint (TMJ) discs following reconstituted collagen template implantation in rabbits using contrast-enhanced magnetic resonance imaging (MRI) and to correlate these findings with histology.

Methods. Twenty-four adult rabbits were divided into five groups: group A, partial discectomy without implantation ($n = 6$); group B, partial discectomy with collagen template implantation ($n = 6$); group C, partial discectomy with subdermal graft implantation ($n = 6$); group D, sham operation ($n = 4$); and group E, control ($n = 2$). All rabbits received baseline MRI scans before surgery and follow-up MRI studies at 3 months after surgery. All rabbits were sacrificed for histologic analysis after the follow-up MRI.

Results. In group A, follow-up MRI showed marked joint effusion in all six injured TMJs, which was accompanied by bony erosion at the tympanic fossa and mandibular condyle. In group B, MRI showed a homogenous low signal intensity in five of six discs, suggestive of regeneration. One disc showed higher signal intensity at its lateral portion than that of the original disc, indicating partial regeneration. MRI of group C depicted a low signal intensity, bandlike regenerative structure in four of the six discs. One disc with partial regeneration demonstrated relatively high signal intensity. The disc in the sixth animal of this group showed no evidence of regeneration. All of the MRI findings were in agreement with the histologic findings.

Conclusion. TMJ discs can regenerate following implantation of a reconstituted collagen template in discectomied rabbits. Contrast-enhanced MRI can be used to monitor and determine the degree of disc regeneration.

TEMPOROMANDIBULAR JOINT (TMJ) disorders can lead to degenerative changes of the disc and condylar surface and the retrodiscal tissues.[1] A variety of materials are used to repair the injured TMJ with varying success rates. Collagen materials have been used to repair TMJ discs.[2] Collagen is the most abundant protein component of the extracellular matrix. It provides a scaffold for cell attachment and migration. It also possesses specific, intrinsic mechanical properties important for joint movement and integrity. In our laboratory, a new disc regeneration implant material,[3] consisting of reconstituted collagen template, has been successfully implanted in rabbit TMJ.[4] The temporal healing process of discectomied TMJ has been reported.[4] Consequently, this study focused on the potential value of contrast-enhanced MRI to assess the healing process of injured TMJs after collagen template implantation in a rabbit model at one time point.

MATERIALS AND METHODS

Adult male New Zealand rabbits ($n = 24$; 3 months of age; 2.5 kg) were divided into five groups: group A, partial discectomy without implantation ($n = 6$); group B, partial discectomy with reconstituted collagen template implantation ($n = 6$); group C; partial

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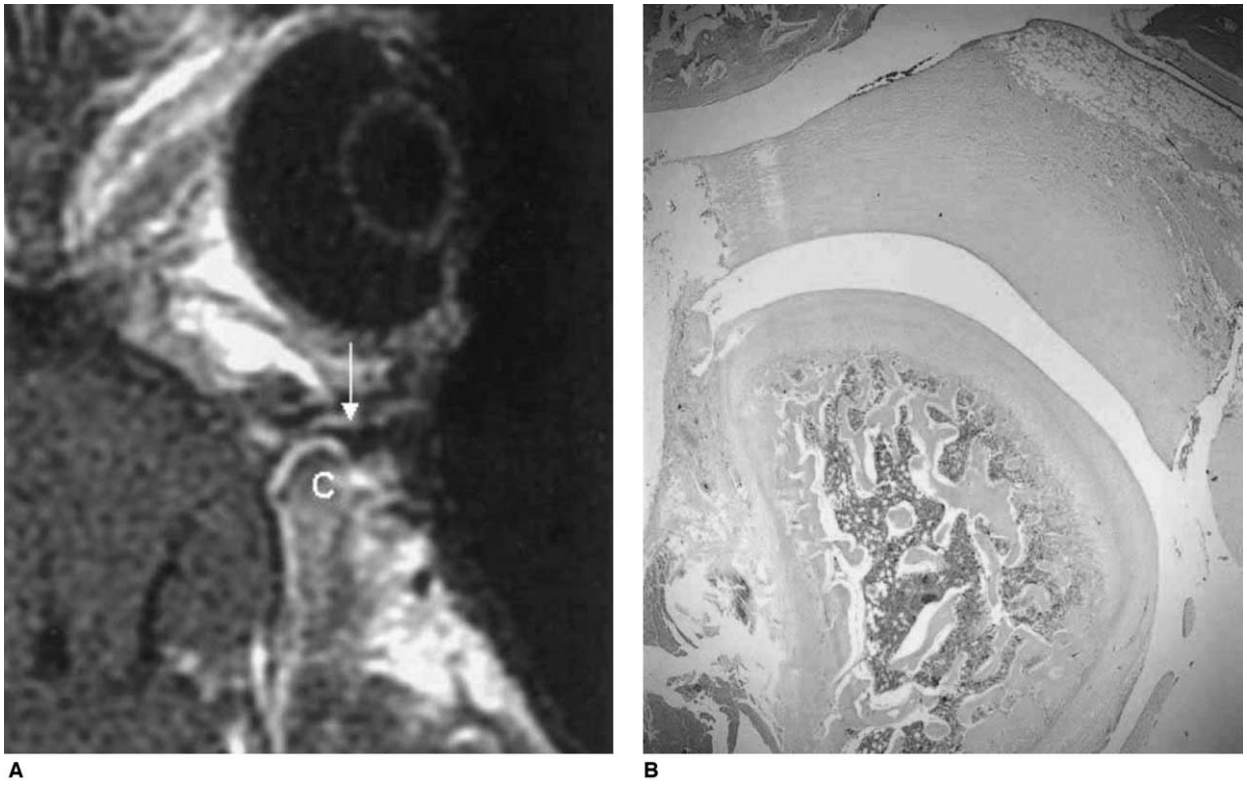

Fig 1. Partial discectomy with collagen template implantation: complete regeneration. (**A**) Follow-up contrast-enhanced MR image (TR = 300 ms, TE = 25 ms) of TMJ after partial discectomy with collagen template implantation shows a homogeneous low signal intensity of the regenerative disc. The lateral regenerative portion of the disc (arrow) is thicker than the parent (original) residual disc at the medial portion. C = mandibular condyle. (**B**) New collagen bundles are noted at the lateral portion of the disc. There is moderate proliferation of chondroblasts and neovascularization in the regenerative disc. (H&E stain, magnification ×60.)

discectomy with subdermal graft implantation ($n = 6$); group D, sham operation ($n = 4$); and group E, normal control ($n = 2$). All MRI studies were performed at week 0 (baseline) and at 3 months after surgery. All rabbits were sacrificed after the follow-up MRI scans.

The reconstituted collagen templates were freshly prepared in our laboratory.[3] Bovine collagen (major type I, Sigma, Chemical Co, St Louis, Mo, USA) was pepsinized and reduced by β-mercaptoethanol. This process resulted in α-helix peptides, which were then reconstituted with glutaraldehyde to form a glutaraldehyde polymer-amine complex. After lyophilization, the reconstituted collagen formed a nestlike scaffold template. The reconstitution of the collagen template exhibited an increased resistance to biological degradation by collagenase and an optimal pore size of 50 to 150 μm. A partial discectomy, approximately 3.5×5 mm^2 of the disc, was performed under general anesthesia on the posterioateral portion of the TMJ disc for groups A, B, and C. Reconstituted collagen templates were implanted in group B, and subdermal grafts were implanted in group C.

MRI was performed with a 0.5-T magnet (Vectra, General Electric, Milwaukee, Wis, USA) using a commercial surface coil. All MRI studies were obtained with the rabbits in the closed-mouth position. MR images of all rabbit TMJ discs were obtained in the coronal plane using T1-weighted (TR = 300 ms, TE = 25 ms) images with reference to the mandibular condyle, and 3-D T1-weighted (300/25) images without and with fat saturation after intravenous administration of 0.2 mmol/kg gadopentetate dimeglumine (Magnevist; Berlex Laboratories, Wayne, NJ, USA) into the ear. Other imaging parameters included 6-cm field of view, 1.5-mm slice thickness, 128×192 pixel matrix, and four excitations.

RESULTS

The average weight of rabbits in the four groups at 3 months was 1.2 kg (group A), 1.5 (group B), 1.4 (group C), and 1.8 kg (group D), representing a gain over baseline. In group E, MR images showed well-delineated concave morphology of low signal intensity discs in the coronal plane. The histology revealed that the discs were coronally concave in shape and composed of dense connective tissue. In group D, all sham-operated TMJ discs had morphology and signal intensity similar to other discs on baseline MR images and to the rabbits in the control group. In group A, follow-up MRI showed marked joint effusion in all six injured TMJs, which was accompanied by bony erosion at the tympanic fossa and mandibular condyle.

The histology revealed active fibroblasts with enlarged nuclei scattered among disorientated collagen bundles. The condyle and tympanic fossa were markedly eroded, absorbed, and deformed. In group B, the MRI showed a homogenous low signal intensity in five of six discs (Fig 1),

suggestive of regeneration. One disc showed a higher signal intensity at its lateral portion than that of the original disc, indicating partial regeneration. Histology revealed that the regenerative discs had new collagen bundles (Fig 1).

Primitive mesenchymal cells were scattered in the newly matured collagen bundles. The partial regenerative disc showed moderate proliferation of chondroblasts and neovascularization in the regenerative part of the disc. In group C, the MRI showed a low signal intensity with bandlike regenerative structures in four of the six discs. One disc with partial regeneration demonstrated a relatively high signal intensity. The disc in the sixth animal of this group showed no evidence of regeneration. All of these MRI findings agreed with the histologic findings.

DISCUSSION

Alteration of the distribution of proteoglycans and water content can contribute to the signal changes in the MRI of the TMJ disc.[5] The MRI contrast agent used in the present study has two negative charges, which should accumulate in the tissue inversely to the negative charges of glycosaminoglycans of the proteoglycans in cartilage, resulting in a decreased T1 relaxation time of the tissue. Our findings support the observation by previous authors[6] that the MRI appearance of TMJ discs and template correlate well with the increase or decrease in glycosaminoglycans. In our study, all normal discs showed a low-signal intensity indicating predominant proteoglycans. A normal disc is composed of connective tissue with synovial fibroblasts and chondrocytes/chondroblasts. The rabbit TMJ disc appeared concave in the coronal plane, in contrast to the bow tie shape in humans, as shown in the sagittal plane.

In human TMJs, the central portion of the posterior band has a higher signal intensity on T1-weighted images, because it contains more chondroid tissue and is composed of less dense collagen fibrils.[7] Remodeling is associated with thinning of the disc.[8] In our study, the partially regenerative discs appeared thinner with higher signal intensity than the original discs and with chondroblast proliferation. In contrast, the number of new collagen bundles increased and the signal intensity of the regenerative disc decreased. The inflammatory tissue had a high signal intensity on contrast-enhanced T1-weighted images.

In our study, proliferation of fibrosis and increased joint effusion were observed in discectomied discs or failed graft implantations. In clinical practice, where an inflammatory process exists, there were bony erosions and increased joint effusions. In summary, TMJ discs can regenerate following implantation of a reconstituted collagen template in discectomied rabbits. Contrast-enhanced MRI may be used to determine the degree of disc regeneration.

REFERENCES

1. Wilkes CH: Arch Otolaryngol Head Neck Surg 115:469, 1989
2. Feinberg SE, McDonnell EJ: J Oral Maxillofac Surg 53:535, 1995 (discussion 543)
3. Lai W-F: US Patent 5876,444. USA, 1999
4. Lai W-F, Tsai YH, Su SJ, et al: Int J Oral Maxillofac Surg 2004 (in press)
5. Bashir A, Gray ML, Hartke J, et al: Magn Reson Med 41:857, 1999
6. Nieminen MT, Rieppo J, Toyras J, et al: Magn Reson Med 46:487, 2001
7. Drace JE, Young SW, Enzmann DR: Radiology 177:73, 1990
8. Kircos LT, Ortendahl DA, Mark AS, et al: J Oral Maxillofac Surg 45:852, 1987