Tissue Reactions of the Temporomandibular Joint Following Retrusive Guidance of the Mandible

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Abstract

Tissue reactions in monkey temporomandibular joints (TMJs) were studied following retrusive guidance of the mandible. Eleven adult Macaca fascicularis monkeys were used (four experimental animals and seven controls). Interferences between intercuspal position and retruded position were eliminated in the experimental animals. Bilateral interferences were then introduced to guide the mandible into retruded position during mouth closure. The experimental period lasted for five weeks.

After radiographic examination, the joints were histotechnically processed, and sagittal sections were taken throughout the joints for light microscopy. In contrast to the untreated animals, the experimental monkeys demonstrated pathological changes in the posterior band of the disk and posterior disk attachment. The flattening of the posterior band of the disk that occurs with retrusive guidance may predispose subjects to anterior disk displacement.

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Tissue Reactions of the Temporomandibular Joint Following Retrusive Guidance of the Mandible

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Several forms of dental treatment entail an altered mandibular position and can be expected to influence the temporomandibular joint (TMJ). In one study, advanced mandibular protrusion of adult monkeys seemed to slightly increase the thickness of the superior condylar cartilage zone of proliferation.[1] Otherwise, adult monkeys have been shown to be unresponsive to mandibular protrusion.[1–4] Infant monkeys, however, quickly adapt to mandibular protrusion with an increased thickness of the posterior condylar cartilage[5,6] and posterior condylar growth through endochondral ossification.[4]

It has been shown that retrusive forces to the mandible markedly affect both infant and adult monkey TMJs. The main histological features are regressive condylar remodeling with bone resorption of the posterior part of the condyle and the anterior aspect of the glenoid spine, and bone apposition to the anterior part of the condyle. Thus the retrusive force causes a positional change of the condyle.[4,7,8] The temporal fossa seemed to be resistant to altered mandibular guidance.

Studies on the effect of occlusal perturbation on the TMJ have focused on bone and cartilage reactions while observations concerning the disk and disk attachments have been given little attention. The aim of our study was therefore to produce a retrusive guidance of the mandible during mouth closure and to study its effect on the TMJ tissues, including the disk and disk attachments.

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Material and Methods

The material consisted of 11 adult Macaca fascicularis monkeys comprised of four experimental animals and seven controls. The experimental animals were anesthetized with i.v. Mebumal®* to allow intraoral measures to be undertaken. The mesially oriented facets of the upper jaw premolars and molars and posteriorly oriented facets of the lower jaw cuspids were ground to eliminate interferences between intercuspal and retruded position. The intercuspal and retruded position contacts were checked with 8 μm thick GHM foils.† In two experimental animals the mesio-buccal facets of the lower first premolars were etched with 40% phosphoric acid for 15 seconds followed by careful rinsing with water. Profile® enamel bond‡ in combination with Profile® composite filling was then applied to the etched facets. The fillings were adjusted to give bilateral interferences, thus guiding the mandible backward into retruded position.

The animals were examined on a weekly basis. Adaptation to the new interarch relationship occurred, creating new interferences in retruded position. These were removed weekly and the fillings were adjusted to preserve a constant guidance into retruded position during mastication.

The remaining two experimental animals were given cast gold crowns on the first lower premolars to create a similar posterior guidance of the mandible. The only difference between the two methods

* Mebumal—ACO-läkemedel, Solna, Sweden.
† GHM foils—Hanel-Medizinal, Nurtingen, West Germany.
‡ Profile enamel bond—S.S. White Dental Products International.

was that the crowns were left unadjusted during the entire experimental period.

The experimental period lasted for five weeks. The monkeys were then sacrificed with an overdose of Mebumal injected intravenously. Immediately after death the thorax was opened and a 2-mm gauge needle was inserted into the brachiocephalic artery. Physiological saline was perfused through the head, followed by a 4% neutral buffered formaldehyde solution with an effective osmolarity of 300 mOsm.*

Radiography of the jaws was performed to ascertain that the monkeys were adult as had been judged from the level of dental development. The TMJs were radiographically examined in the following projections: submentovertical, postero-anterior, and lateral transcranial with the x-ray beam parallel to the long axis of the condyle. Additional tomography was carried out in the lateral and frontal projections with 1 mm between layers. The tomography layers were parallel and perpendicular to the long axis of the condyle. This radiographic examination was undertaken to detect any changes in the hard tissue and joint space.

The left and right TMJs were removed *en bloc*. The specimens were put in a formaldehyde solution for seven days before decalcification in 40% EDTA at 37° C. The progress of the decalcification was checked radiographically. After adequate demineralization the specimens were routinely processed and carefully embedded in paraffin with the cutting plane perpendicular to the long axis of the condyle. Sections were collected throughout the joint at intervals of 0.5 mm. The sections were stained with hematoxylin-eosin and hematoxylin/van Gieson for tissue identification.

The sections were examined under a light microscope equipped with polarizing filters. The thickness of the condylar cartilage, connective tissue layer and disk were measured with a graded eyepiece. The measuring points on the condyle were in the posterior and anterior load-bearing areas and at the top of the condyle. The disk was measured at the thickest part of the posterior and anterior bands and also at the thinnest central portion. The sections to be measured were selected at the sagittal level corresponding to the glenoid spine, which forms the posterior part of the glenoid fossa.

* Formaldehyde solution—Histofix—Histolab, Göteborg, Sweden.

The untreated control animals underwent the same sacrificing and histotechnical procedures as those described for the experimental animals.

Radiology Results

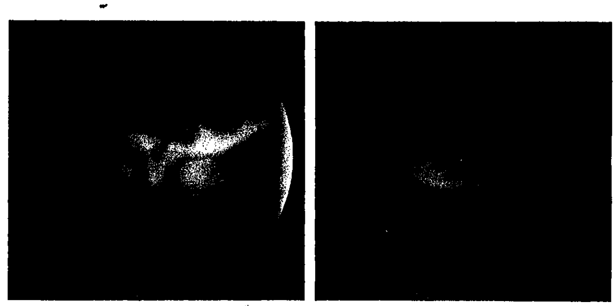
The outlines of the mandibular and temporal components of all the joints were defined by a normal cortical bone layer without sclerosis or erosions (**Figure 1**). No difference in joint space could be seen between the experimental and control joints.

Histology Results

Condyle

In the control animals the condylar cartilage was uniform in the posterior, anterior, and superior parts. The thickness of the cartilage layer varied between specimens from 100 to 300 μm (**Figure 2**). In two of the 14 control joints, however, the cartilage layer was three times thicker in the posterior than in the anterior area.

In the experimental animals the cartilage layer covering the superior and anterior parts of the condyle showed a thickness equal to that seen in the controls. The posterior part of the condyle had a considerably thicker layer than that of the anterior and superior region in all joints but one (**Figure 3**). This one joint demonstrated an overall even thickness of cartilage. The condylar articulating connective tissue layer (i.e., the tissue covering the zone of proliferation and the cartilage layer) showed increasing thickness posteriorly with an average of 50 μm anteriorly compared to 200 μm posteriorly (**Figures 2 and 3**). No difference could be seen between the



Figures 1A and 1B
Tomographic sections of the right and left temporomandibular joints of a control animal showing well-defined hard tissue structures.

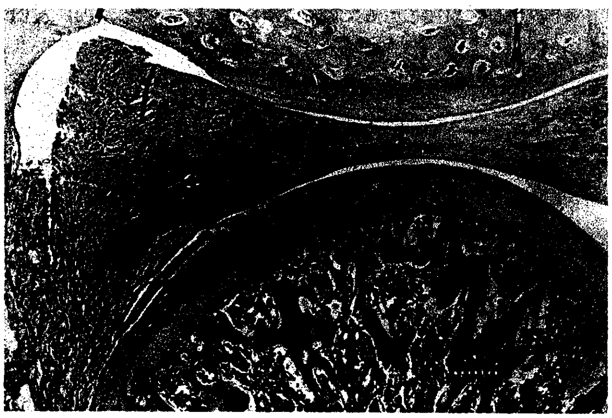


Figure 2
The TMJ of a control animal. The posterior band (P) of the disk has a normal configuration and a thickness four times that of the central thin part of the disk (D). Note the thick and well-developed posterior disk attachment (A) composed of a rather loose connective tissue. The cartilage layer of the condyle has an even thickness in the load-bearing areas (arrows). Anterior is to the right. The bar equals 330 μm. Hematoxylin-eosin stain.

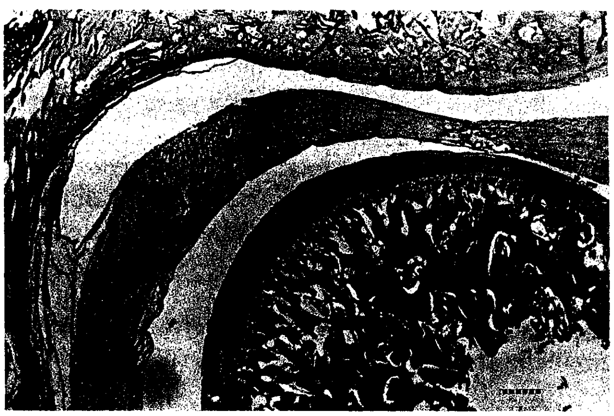


Figure 3
The TMJ of an experimental animal. The posterior band of the disk (P) has lost its normal configuration and is very flat. The posterior disk attachment (A) consists of a rather dense collagenous tissue. The condylar cartilage layer (arrows) is thinner in the anterior region (to the right) than in the posterior area. The bar equals 330 μm. Hematoxylin-eosin stain.

experimental and control joints with regard to the condylar connective tissue. In one joint the cortical bone and cartilage of the posterior part of the condyle was replaced within an area of 1.5 × 2 mm by connective tissue. This connective tissue formed a channel containing a vessel connecting underlying marrow spaces with the condylar articulating connective tissue (**Figure 4**).

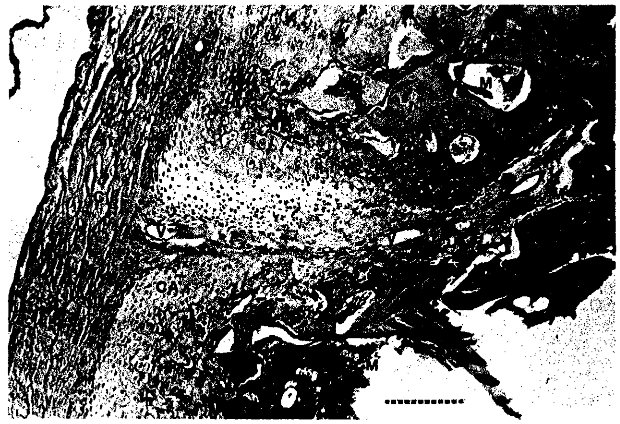


Figure 4
The condylar connective tissue (C) protrudes throughout the zone of cartilage (CA) and bone, creating a vessel (V) containing a soft tissue communication to some marrow spaces (M). The expected borderline between mineralized and unmineralized tissue is indicated with a dotted line. The bar equals 200 μm. Hematoxylin-eosin stain.

Disk

Among the controls the articulating disk was consistently biconcave with approximately equal thickness of the anterior and posterior bands ranging from 1100 to 1500 μm between joints. The central thin part of the disk had a thickness ranging from 170 to 450 μm between specimens (**Figure 2**). The collagenous fibers of the central part of the disk ran parallel and dispersed in various directions within the posterior and anterior bands.

In three of the experimental animals, the posterior band of the disk was found to be flattened and thinner in both joints compared with both the anterior band in the same joint and the posterior band in the control animals (**Figure 3**). However, the disk of one experimental joint remained unchanged. The central thin part of the disk in the experimental animals' joints had a thickness comparable to that measured in the control animals.

In the experimental animals the parallel collagenous fibers of the thin part of the disk continued to run parallel throughout the flattened posterior band of the disk in contrast to the controls.

Posterior Disk Attachment

The posterior disk attachment of the control specimens was composed of vascularized, moderately loose connective tissue. The superior and inferior borders of the attachment lining the upper and lower joint compartments were covered by a single layer of synovial cells under which minor well-defined capillaries were seen (**Figure 5**).

All the experimental animals' joints demonstrated an increased number of widened, endothelium-lined vessels throughout the entire thickness of the disk attachment. In the subsynovial tissues the number of widened vessels was even more pronounced (**Figure 6**). In one experimental joint a homogeneous structureless eosinophilic substance was found close to the subsynovial vessels (**Figure 7**). No inflammatory reaction was seen in any joint.

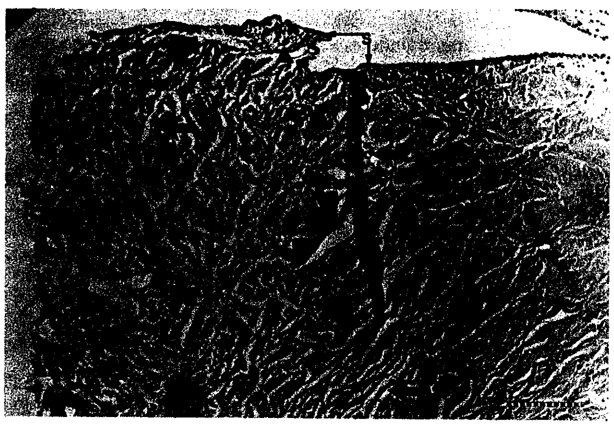


Figure 5
The synovial membrane (S) in a control joint is composed of a single layer of cells, and delicate capillaries can be seen underneath (arrowheads). The deeper portion contains capillaries (arrows) of normal shape and size. The upper joint compartment is to the top and left. The bar equals 200 μm. Hematoxylin-eosin stain.

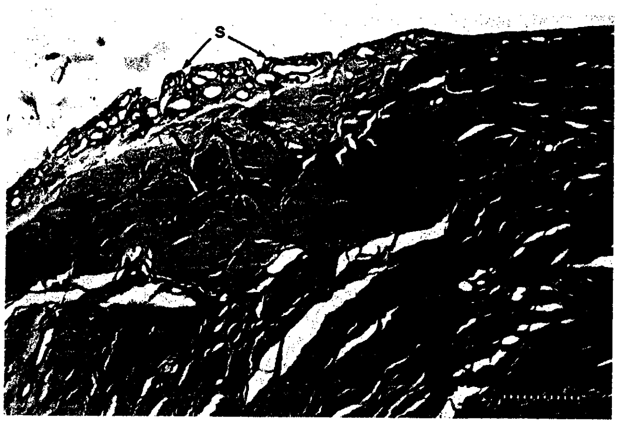


Figure 6
The posterior disk attachment of an experimental animal's joint. Underneath the synovial membrane (S) enlarged capillaries can be seen (arrowheads). Note the widened vessels (arrows) in the deeper portion of the attachment. The bar equals 200 μm. Hematoxylin-eosin stain.

Temporomandibular Joint Component

The articular fossa in both the experimental and the control animals was outlined by well-defined osteoblasts on the posterior wall. At the most inferior part of the glenoid process, slight osteoclasia was found. No difference between control and experimental animals was noted in this respect.

No dissimilarity in TMJ tissue reaction was noted between the experimental animals with composite fillings and those with cast gold crowns.

Discussion

The biconcave shape of the disk of both human and monkey TMJs has been regarded as a functional adaptation. The biconcavity may contribute to keeping the disk in a normal position over the condyle during jaw movements. A flattening of the posterior band of the disk, as seen in the experimental monkeys in this study, may allow the condyle to slide behind it. A flattened posterior disk band could thus be one predisposing factor in the development of anterior disk displacement.

Figure 7
A homogeneous structureless eosinophilic substance (arrow) in the subsynovial tissue of the posterior disk attachment (A) of an experimental animal's left joint. The posterior capsule (C) is to the right. The upper joint compartment is JC. The bar equals 80 μm. Hematoxylin-eosin stain.

Another etiological factor suggested for anterior disk displacement is incompetence of the posterior disk attachment.[9–11] The tissue changes in the posterior disk attachment caused by the retrusive guidance of the mandible in this study might well have led to incompetence of the attachment if allowed to progress over a longer period of time than the five-week period used here.

Following surgical extirpation of a TMJ disk with the diagnosis of internal derangement, hemorrhage often arises from a highly vascular posterior disk attachment.[12] This hemorrhage has been explained as being due to the presence of largely dilated venous channels in the posterior attachment, a feature associated with internal derangement.[13] The mechanism behind this dilation is not known. Scapino[13] interpreted these findings as the result of an absence of negative pressure during mouth opening which would allow circulatory obstruction to occur in the posterior disk attachment. Since the condyle is often pushed backwards in the fossa following anterior disk displacement,[11,14] it is likely to compress the posterior attachment and posterior joint capsule and its vessels. Such nonphysiologic pressure on the posterior attachment was created in our study on monkeys and resulted in distinctly dilated vessels. The vasodilatation could also have been caused by substances released as a result of the tissue trauma associated with the disk displacement. Such a substance is Substance P, which is a potent vasodilatator released by nociceptive nerve fibers at tissue trauma.[15]

The reaction of the compressed posterior disk attachment may be similar to that of the periodontal membrane during orthodontic movement, when fibrinogen is found on the compression side during the first week of treatment.[16] The structureless eosinophilic substance found close to the subsynovial vessels in one experimental joint in our study might be a fibrinogen deposit due to vascular injury.

Hard tissue changes of the TMJ could hardly be expected to be seen radiographically or histologically after a five-week experimental period of guiding the mandible into retruded position. The defect on the posterior condylar cortical bone layer found in one TMJ is probably of developmental origin rather than a pathological reaction brought about by the experimental procedures. Wright and Moffett[17] found similar vascular connective tissue communications through the condylar cartilage layer in young humans.

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Erratum

Please see Cranio Book Review in this issue for a correction to Figure 8 from Isacsson and Isberg's earlier article, "Tissue Identification of the TMJ Disk and Disk Attachments and Related Vascularization," *Cranio*, 1985; 3(4): 374–379.