Histopathology associated with malposition of the human temporomandibular joint disc

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Anterior displacement of the temporomandibular joint disc is associated with a general remodeling of the joint’s soft tissues. The anterior part of the posterior attachment becomes fibrotic. The external shape and the internal architecture of the disc change in characteristic ways. The disc appears to overlie more of the lateral pterygoid muscle than is normal. The capsule connecting the anterior band of the disc to the condyle appears to be elongated.

The diagnosis of certain internal derangements of the temporomandibular joint (namely, anterior displacement of the articular disc, with and without reduction) has been made possible by recent advances in arthrography. The relationship between meniscus displacement and clinically observed physical dysfunction of the mandible has been ably described in the above-cited works and in Solberg and Clark and especially Isberg-Holm.

Since the pathosis associated with meniscus displacement has an obvious bearing on mandibular dysfunction and its treatment, the pathologic condition is described in some detail. The observations of Blackwood and Steinhardt on meniscus displacement material will be discussed where pertinent; however, the issue of the etiology of meniscus displacement, which is discussed by Steinhardt and others, is too complex to be discussed adequately in the space available here. This topic will be dealt with elsewhere.

MATERIALS AND METHODS

The pathologic study material consists of three serially sectioned whole joints in the joint collection of the University of Illinois College of Dentistry, Department of Oral and Maxillofacial Surgery, and of menisci removed surgically from fourteen serially treated patients diagnosed as suffering from internal derangements. Several serially sectioned normal whole joints present in the University collection were studied in conjunction with the pathologic material.

The whole-joint specimens were obtained at autopsy from patients who died at the University of Illinois Research and Education Hospital. A medical history was available for each patient, and in no case was any general or temporomandibular joint disease reported. Two of the pathologic temporomandibular joints were removed from men, aged 23 and 64 years, respectively; one was from a 75-year-old woman. These three specimens will hereafter be designated as specimens 1, 2, and 3, respectively.

All of the whole joints were demineralized in equal parts of 50 percent formic acid and 50 percent sodium citrate, embedded in celloidin, and sectioned at 15 to 20 µm. Every fifth section was taken for study. The sections were stained variously by the hematoxylin and cosin, Mallory, Van Gieson, silver, and orcein methods. Except for specimen 2, the joints were sectioned along a plane very nearly at right angles to the long axis of the condyle.

In some regions of specimens 1 and 3, the thickness of the articular coverings and the articular disc was measured in accordance with the method of Hansson and co-workers. Specimen 2 was not measured because the plane of section was oblique to the long axis of the condyle. The measurements were compared with those made by these authors on normal joints. Comparison of measurements made on sections of jaw joints by different workers must be done with care. Hansson and co-workers dissected the joint components free and, although they do not so state, they undoubtedly cut sections perpendicular to the articular surfaces of the components, because in a follow-up paper the importance of perpendicular sections is acknowledged. The only sections of the specimens measured here which are comparable to

This investigation was supported in part by United States Public Health Service Grant DE-01849-01.
Fig. 1. A. Normal joint of a 65-year-old man. Parasagittal section approximately midway between the condylar poles. P, Posterior band of the disc; M, central part of the disc; A, anterior band of the disc; TPA, temporal part of the posterior attachment; CPA, condylar part of the posterior attachment; Pgp, postglenoid process; Pt, lateral pterygoid muscle. (Hematoxylin and eosin stain. Magnification, approximately ×4.) B, Polarizing micrograph of section shown in A. Collagen fibers that lie in the plane of section appear white; those cut in cross section appear dark. Fibers in the central part of the disc run anteroposteriorly to interlace with transverse fibers of the anterior and posterior bands. Fibers also run anteroposteriorly through the CPA and radiate into the posterior aspect of the posterior band. C, Polarizing micrograph of normal joint of a 53-year-old man. Parasagittal section located approximately midway between the condylar poles. The disc and articular surfaces were separated during preparation of the specimen, allowing clear illustration of collagen fiber orientation. Anterior is down and to the right. C, Condyle; E, articular eminence. Small arrows indicate slightly folded CPA. White arrows indicate CPA fibers radiating into the posterior band. (Magnification, approximately ×8.)
those of Hanson and co-workers are those which were taken through what they designate as the laterocentral and mediocentral regions of the joint. This is due to the impossibility of orienting a whole joint so that the plane of section is everywhere perpendicular to the articular surfaces. The comparisons are further limited by the fact that Hanson and co-workers do not report measurements for the laterocentral part of the condyle and articular eminence. The measurements reported here were made on single sections taken from the middle of the mediocentral and laterocentral quadrants of the joints.

The surgically extirpated menisci, pathology reports, patient records, and arthograms were made available for study by Dr. Clyde Wilkes. Parasagittal sections were cut at 7 to 10 μm through areas representative of the pathologic condition and were stained with orcein and/or hematoxylin and eosin. The extirpated menisci represent two male and twelve female subjects ranging in age from 17 to 53 years. The diagnosis of meniscal displacement with or without reduction made in each case from history, clinical findings, and arthograms was confirmed at surgery, without exception. In five of the cases the displacement was reducing. Measurement of the extirpated menisci was not done because the sites of section could not be determined with sufficient accuracy for comparisons with the data of Hanson and co-workers.

OBSERVATIONS

Normal joints

Normal joint morphology has been described many times.\cite{1,12,28,31} The thicknesses of the articular coverings of the condyle and eminence and of the various parts of the disc are reported by Hanson and co-workers.\cite{13} Only those normal features directly pertinent to the pathologic conditions described below will be dealt with here.

**Gross form of the articular disc.** In normal joints, when the jaws are closed the posterior band of the disc overlies the superior aspect of the condyle; the central part of the disc lies between the anterosuperior surface of the condyle and the posteroinferior aspect of the articular eminence; and the anterior band of the disc lies just anterior to the condyle (Fig. 1). (See also illustrations in Wright and Moffett,\cite{28} DuBrul,\cite{4} Griffin and co-workers\cite{13} and Steinhardt.\cite{31}

**Internal architecture of the disc.** The collagen fiber organization within a normal disc has a characteristic pattern in joints sectioned near the junction of the mediocentral and laterocentral quadrants of the condyle.\cite{28,31} The descriptions below apply to this region.*

The fibers in the central part of a normal disc take a predominantly anteroposterior course and interlace with transversely oriented fibers in the thickened anterior and posterior bands (Fig. 1, B, and C). Strauss and co-workers\cite{23} also report the existence of vertical fibers in the central part of the disc (that is, fibers oriented more or less perpendicular to the surface of the disc), but these are not usually conspicuous in microscopic material. However, fibers more or less perpendicular to the surface are obvious in the posterior band, where they are interlaced with the transverse fibers. Some of these fibers are derived from the condylar part of the posterior attachment.

**Posterior attachment.** The normal posterior attachment of the disc is usually described as having a superior and an inferior stratum.\cite{1,4,31} The superior stratum consists of a loosely organized meshwork of elastic and collagen fibers, fat, and blood vessels.\cite{28} A substantial venous plexus is frequently observed. The superior stratum is attached posteriorly to the anterior face of the postglenoid process, the bony auditory meatus of the temporal bone, the cartilaginous meatus, and the fascia of the parotid gland. The superior stratum will hereafter be abbreviated TPA (for "temporal part of the posterior attachment") (Fig. 1).

The inferior stratum normally consists of a fairly compact, inelastic sheet of collagen fibers that attaches to the posterior surface of the condyle below its articular covering.\cite{28,31} The inferior stratum will hereafter be abbreviated as the CPA (for "condylar part of the posterior attachment") (Fig. 1).

Anteriorly, both strata of the posterior attachment are continuous and have a characteristic relation with the posterior band of the disc. At the posterior band, fibers of the CPA splay out radially to become interlaced with transverse fibers of the band and the anteroposteriorly oriented fibers derived from the central part of the disc (Fig. 1, B and C). The fibers of the TPA interlace with those of the posterior band above and the CPA below. The union of the TPA and CPA at the posterior band is usually fairly distinct (Fig. 1, B and C).

**Articular surface of the condyle and eminence.** Steinhardt\cite{31} has shown that collagen fibers in the

*Consideration of this region alone is sufficient for the present purpose of characterizing the grosser derangement of collagen fibers in the pathologic material to be considered and obviates study of more lateral and medial parts of the disc where collagen fiber arrangements are more difficult to evaluate in sectioned material.
Fig. 2. Meniscus displacement, specimen 1, 23-year-old man. Sections cut perpendicular to the long axis of the condyle. (Magnification, approximately ×3.) A and C stained with hematoxylin and eosin; B, hematoxylin and eosin counterstained with orcein for elastin. (Magnification, approximately ×3.) A, Section through the mediocentral quadrant. B, Section midway between the condylar poles. C, Section through the laterocentral quadrant. V, Veins; f, fibrotic part of posterior attachment; D, disc. Large arrow in A indicates anterior extent of joint recess. Large arrow in C indicates site of modified fiber pattern in the articular surface (see Fig. 8). Other symbols as in Fig. 1.
superficial layers of the articular coverings have a general, anteroposterior orientation (Fig. 1, B and C). More detailed description of fiber orientation is not necessary for the present purpose.

Pathologic joints

**Gross form of the disc.** The whole-joint specimens of meniscus displacement had several abnormalities in common. In each, the bulk or all of the posterior band lay anterior to the condyle. The central part of the disc lay below or slightly anterior to the summit of the articular eminence, and the anterior band lay well forward of the condyle adjacent to the anterior slope of the eminence (Figs. 2, 3, and 4). In each specimen, the disc appeared to overlie more of the lateral pterygoid muscle than is normal. The anterior position of the disc was also reflected by the apparent increase in the maximum length of the anteroinferior part of the joint capsule and adjacent joint recess (Figs. 2, 3, and 4). In specimen 3, the capsule arched up against the central part of the disc and in some sections in the mediocentral quadrant of the joint appeared to adhere to it (Fig. 4, A). Farther medially, the capsule was continuous with a mass of collagen fibers lying below the central part of the disc (Fig. 4, B).

The degree of deformity of the disc differed in the whole-joint specimens. The deformity in specimen 2 was slight. The deformity in specimens 1 and 3 was clearly greater, but the dimensions of the disc in these specimens fell within normal limits (Table I). While the extirpated menisci were not measured for reasons indicated above, it was apparent in some cases that the posterior band was grossly thickened. Thickening of the posterior band observed in sections of the extirpated menisci was not correlated with the occurrence of reduction of the displacement in the presurgical arthrograms. In specimen 4 (Fig. 5), for example, the posterior band showed the greatest hypertrophy of the extirpated discs, but the displacement reduced at approximately one half of maximum jaw opening in the arthrogram. In other cases with less or no thickening of the posterior band, the displacement did not reduce upon opening.

In specimen 2, the disc was displaced more or less straight anteriorly and the shape of the disc was not greatly different at medial and lateral levels of the joint. In specimen 3, the shape of the disc changed gradually from medial to lateral levels, with the distinction between parts of the disc preserved at each level (Fig. 4). In specimen 1, however, the shape of the disc differed strikingly in medial and lateral
Fig. 4. Meniscus displacement, specimen 3, 75-year-old woman. A, Section through laterocentral quadrant, nearly midway between the condyle poles. (Hematoxylin and eosin stain. Magnification, approximately ×5.) Arrow indicates site of apparent adhesion of capsule to disc. Other symbols as in Figs. 1 and 2. B, Section through the mediocentral quadrant. (Mallory stain. Magnification, approximately ×12.) E, Articular eminence; C, condyle. Arrow indicates anterior limit of joint recess. X, Mass of collagen fibers connecting the capsule to the anterior band. Other labels as in Figs. 1 and 2. C, Polarizing micrograph of section shown in B.
parts of the joint, and it is clear that in it the bulk of the disc was displaced anteromedially. Medially, the posterior and anterior bands were observable as separate entities. At progressively more lateral levels, however, the bands approximated each other and coalesced into a single mass in which the distinction between parts of the disc was lost (Fig. 2, A to C). The parts of some of the extirpated discs were also indistinct.

**Internal architecture of the disc.** The abnormal collagen fiber arrangements important to the present thesis are those that occurred (1) in the posterior band and central part of the disc and (2) at the transition between the posterior band and the posterior attachment. The latter are better considered later.

The disruption of collagen fiber pattern in the posterior band and in the central part of the disc varied from slight to considerable. Except for specimen 2, in which the collagen fiber pattern was essentially normal, three general abnormalities in collagen fiber pattern were observed.

First, transverse fiber bundles were observed to extend forward to varying extent into the posterior end of the central part of the disc. These fibers were traced through the serial sections of the whole-joint specimens, and most were found to be homologous with the transverse fibers of the posterior band. However, as indicated by the obvious increase in number of transverse fibers in some specimens, some of the fibers must represent neomorphic additions to the disc. The transverse fibers adjacent to or in the central part of the disc in specimens 4, 5, and 6 (Figs. 5 and 6), for example, would appear to have been added to the disc as it remodeled to accommodate forward displacement of the posterior band.

Second, the presence of transverse fibers in the central part of the disc disrupted to varying degrees the compact anteroposterior orientation of collagen fibers normal for this region. In some specimens the anteroposterior fibers were virtually absent (Fig. 6, A and B).

Finally, fibers oriented more or less perpendicular to the surface were sometimes visible within the central part of the disc (compare Fig. 6, A with Fig. 1, B and C). Whether these fibers were increased in number or merely made more conspicuous by reorganization of fibers within the disc cannot be determined from the specimens studied.

In some specimens, the disc was flexed either upward or downward in its central part. The acuteness of the flexure and the collagen fiber pattern at the site of the flexure varied sufficiently to make broad generalizations difficult, but some tendencies were apparent. On the acute side of the flexure some fibers radiated perpendicularly or at acute angles from the surface. These were sometimes separated by transversely oriented fibers at the surface of the disc (Fig. 6, B). Collagen fibers on the obtuse side of the flexure ran anteroposteriorly, more or less parallel to the surface of the disc across the flexure (Figs. 6, B and 7, B and C). The acuteness of the flexure sometimes varied regionally within a given specimen. In the central region of the disc in specimen 3, the flexure site on the inferior aspect of the disc was fairly sharp (Fig. 7, C). Farther medially the flexure
site was formed into a more elongated arch (Fig. 4, C).

The arthrograms of seven of the patients treated by meniscectomy showed clear evidence of flexure of the disc. In some cases the flexure was evident in both jaw-closed and jaw-open positions. Five cases of upward flexure and two cases of downward flexure were observed. The form of the arthographic silhouette of the disc in each of the patients was compared to the form of the disc in the sectioned preparations (Table II). In three cases of upward folding in meniscus displacement without reduction, the arthographic silhouette of the disc matched the profile of the sectioned disc.

The question arises as to whether the collagen fiber patterns observed at the flexures represent transient deformations or nonreversible remodeling changes. If the central part of the disc is modeled simply as a compact elastic slab of parallel collagen fibers, a fold in the slab caused by a force applied along the long axis of the fibers should extend the fibers lying along the obtuse side of the fold; those on the acute side should be bent at the flexure point but remain essentially parallel to the adjacent surfaces. At the flexure site, the fibers throughout the slab would also be expected to be displaced somewhat laterally to the plane that contains their ends. The elasticity of the slab would restore the initial fiber pattern upon removal of the force.

The fiber pattern observed on the acute side of the flexure in the discs whose sectioned profile matched the flexure observed in the arthrograms was not consistent with the pattern expected in a reversible folding of a slab of parallel collagen fibers. In each of these specimens, many fibers on the acute side of the flexure were perpendicular to the surface. Virtually no fibers were parallel to the surface in the plane of section (Fig. 6, B). It seems clear that the fiber...
Fig. 8. A, Higher-power micrograph of the region adjacent to that indicated by arrow in Fig. 2, C, B, Polarizing micrograph of specimen shown in A. Collagen fibers at the condylar surface immediately behind the remains of the disc have lost their normal anteroposterior orientation and are formed into a small fusiform elevation (arrows).
Table II

<table>
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<th>Type of flexure of disc observed in the arthrogram</th>
<th>Definitely matches postsurgical posture of disc</th>
<th>Definitely does not match postsurgical posture of disc</th>
<th>Is opposite to that observed in postsurgical specimen</th>
<th>Cannot be matched with specimen because latter is too deformed</th>
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<td>Upward folding</td>
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specimen and within different regions of the same specimen by transversely and obliquely oriented fibers (Figs. 5 and 7).

Behind the fibrotic anterior part of the posterior attachment, the TPA and the CPA were usually identifiable as separate entities in both the whole-joint and the surgical specimens. The feature that distinguished them was the greater vascularity of the TPA. However, the relation between the TPA, and the CPA could not be adequately studied in the surgical specimens because the posterior attachment was commonly sectioned above the region of greatest vascularity and because the recoil of sectioned elastic fibers in the TPA distorted the fiber patterns. The whole-joint specimens showed interesting differences in the posterior attachment.

In specimen 1, the venous channels of the TPA were conspicuously dilated and in the lateral part of the joint appeared to be located more superiorly than normal (Fig. 2). Also in the lateral region of the joint, the attachment of the TPA to the temporal bone extended abnormally far anteriorly, through the entire glenoid fossa to the posterior end of the articular eminence (Fig. 2, C). Because of this, the soft tissue covering the fossa was thicker than normal. The CPA in the lateral part of the joint was attached more superiorly than normal, and its attachment site was marked by progressive remodeling of the condyle (Fig. 2, C). None of these features was present in specimens 2 and 3.

Articular surfaces. Local areas of progressive and regressive remodeling were identifiable in all of the whole-joint specimens, but in most cases the integrity of the articular tissues covering these sites was not obviously affected. The surface of the articular eminence in specimen 3 showed some irregularity (Fig. 4, A). One unequivocal area of disturbed fiber organization was observed on the anterolateral surface of the condyle in specimen 1 (Figs. 2, C and 8). Specimen 1 had what might be interpreted as a small, blunt osteophyte at the anterior margin of the condylar surface in the medial part of the joint (Fig. 2, A). Specimen 2 had a small but definite osteophyte projecting from the posteroinferior aspect of the condyle (Fig. 3).

Comparison of measurements from specimens 1 and 3 with the data of Hansson and co-workers shows that the articular coverings on the posteroinferior slope of the eminence and the posterior aspect of the condyle were thicker than normal in specimen 1 (Table I). The thickenings appeared to be due to hypertrophy of the prechondroblastic and chondroblastic zones of the subarticular cartilage. These zones were apparent far inferiorly on the posterior aspect of the neck of the condyle. The articular coverings of the condyle and eminence were actually thickest at other loci in the mediocentral part of the joint, but since Hansson and co-workers did not report measurements from these sites, it cannot be shown that they are abnormal. The thickness of the articular coverings in specimen 3 were within normal limits; however, the thickness varied regionally. In the more central parts of the joint the condylar covering was fairly thin, but more laterally and medially the covering was thicker.

MORPHOLOGIC DIAGNOSIS OF MENISCUS DISPLACEMENT

Specimens of entire human temporomandibular joints obtained for microscopic study are rarely accompanied by any clinical oral health history; the work of Bauer is the only apparent exception. Whether pathologic change is present in such material must be determined wholly from features intrin-
sic to the specimens themselves. It is therefore important to define the criteria which distinguish a pathologic displacement of the meniscus from one that is a postmortem artifact. The following features of the whole joints described above indicate the diagnosis of anterior displacement of the meniscus:

1. The condyle lies behind the posterior band of the meniscus, the latter being identified as a mass of transversely oriented collagen fibers lying in front of the condyle.

2. The anterior part of the posterior attachment has a fibrotic character. The normal pattern of collagen fibers at the union of the posterior attachment and the posterior band is replaced by a compact mass of fibers which contains fewer or none of the small vessels normally present.

The central feature of meniscus displacement is the location of the posterior band of the disc anterior or anteromedial to the condyle when the jaws are at rest and prior to reduction, if it occurs at all, when the jaws are opened. It is inferred that all of the pathosis described above is a reaction of joint tissues caused by the abnormal position of the disc. Clearly, the morphologic criteria for diagnosis of meniscus displacement in whole-joint specimens will apply only when the displacement has been present long enough for the joint tissues to have remodeled.

Discussion

Pathosis of the disc

Gross form. The loss of distinction between parts of the disc observed in some of the specimens described here has also been reported by Steinhardt in connection with meniscus displacement. The thickening of the posterior band of the disc in cases of meniscus displacement described and figured by Steinhardt and consistently observed by surgeons was not present in any of the whole-joint specimens (Table 1) but was subjectively apparent in some of the extirpated discs. It may be concluded, therefore, that while the disc may be grossly misshapen in meniscus displacement, its posterior band is not always thicker than normal.

Location of the posterior band anterior or anteromedial to the condyle creates an obstruction to movement of the condyle in these directions. It is reasonable to expect a correlation between the size of the obstruction and the absence of reduction of the displacement upon jaw opening. However, such correlation was not consistently observed in the patient specimens and arthograms. Despite the fact that the arthographic procedure itself may induce the reduction, these observations suggest that whether reduction of the displacement occurs is a function of the ability of the elastic fibers of the TPA to generate sufficient tension to overcome the force of the condyle pushing the disc forward as the jaws are opened.

Flexure of the disc observed in the arthograms studied here has also been reported by Blaschke, Katzberg and co-workers, and Wilkes. The greater frequency of upward flexure observed here is consistent with the observations of these workers.

Internal architecture. The internal architecture of the disc was abnormal in all but one of the specimens. The forward location of the transverse fibers of the posterior band and the neomorphic addition of transverse fibers that disrupt the normal fiber pattern of the central part of the disc are interpreted as remodeling responses caused by abnormal loading of the disc by the condyle.

Steinhardt and Blackwood observed folding of the disc in microscopic material but did not describe fiber patterns at the flexure site. In some of the specimens described here, it was apparent that the fiber pattern observed at the flexure could not be interpreted as a reversible mechanical deformation and that it was, in fact, due to remodeling. Remodeling associated with fixation of the disc in a flexed posture is presumptive evidence of long-standing meniscus displacement.

Pathosis of the posterior attachment

The fibrosis observed in the anterior part of the posterior attachment in the specimens studied here was also apparent in several of Steinhardt's and one of Blackwood's specimens. As suggested by Blackwood, the fibrosis would appear to be a remodeling brought on by compressive loading of the posterior attachment. Other than fibrosis, whole-joint specimens 2 and 3 did not show any apparent noteworthy features of the posterior attachment. However, the posterior attachment in specimen 1 had several interesting features.

In specimen 1 it was clear that the bulk of the meniscus was displaced anteromedially. Mechanically moving the posterior band of the disc from its normal position above the condyle to a position anteromedially in front of the condyle would be expected to increase tension posterolaterally in both the TPA and the CPA. It was in the posterolateral region of the joint that fixation of the TPA and the CPA was abnormal.

The abnormal superior location of the attachment of the CPA and progressive remodeling of the condyle at its attachment site may be interpreted as remodeling responses to excessive traction. The abnormal forward location of the attachment of the TPA may have a similar explanation. When the jaws are opened, the forward thrust—or anteromedial
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thrust in the case of a balancing side excursion—of the condyle against the posterior band of the disc would be expected to actively stretch the TPA. The fibrosis discussed above should have the maladaptive consequence of markedly reducing the elasticity of the anterior part of the TPA and of shortening the otherwise normal elastic fibers in the posterior part of the TPA. Since elastic modulus is a function of length, the relative strain on the remaining normal elastic elements should be augmented. Moving the anchorage of the TPA forward would have the effect of decreasing traction on the elastic elements when the jaws were at rest and reducing their relative elongation when the posterior band of the disc was moved anteromedially under the motive force of the advancing condyle.

If these interpretations are valid, then the effect of the abnormal extension of the TPA and the CPA at their bony attachment sites was different. Progressive remodeling was observed at the attachment of the CPA. The forward-located bony attachment of the TPA was not associated with any obvious remodeling of the temporal bone. This difference may be due to the relative differences in the normal elasticity of the TPA and the CPA.

Specimen 1 also showed a conspicuous dilation of the veins of the TPA which was not observed in specimens 2 and 3. That the dilation was not simply an incidental finding is suggested by Steinhardt’s reporting and figuring of it in cases of meniscus displacement. In normal subjects opening and protrusion of the jaw cause negative pressures in the TPA. In experimental animals the veins of the posterior attachment dilate when the jaws are opened wide. Prima facie interpretation of these findings is that negative pressures cause venous dilation and flow of blood into the posterior attachment. As the joint parts move, the volume and shape of the posterior attachment change. The flow of blood into and out of venous spaces provides ready accommodation to these fluctuations. Rees, Batson, Zenker, and others have made similar observations. The presence of postmortem venous dilation suggests that, in life, the TPA of specimen 1 was subjected to a chronic negative pressure because of displacement of the disc.

The absence of migration of the TPA and the CPA and venous dilation in specimens 2 and 3 may have several explanations, the most obvious being that the displacements were less severe in these specimens.

Anterior capsule

In each of the whole-joint specimens the forward position of the disc appears to have drawn out the anteroinferior part of the articular capsule and caused an apparent elongation of the anterior recess of the inferior joint space. Katzberg and co-workers suggest that elongation of the recess is correlated with the magnitude of displacement of the disc, but the data that they present is insufficient for a statistical test of this hypothesis.

Articular coverings

Collagen fiber pattern. The posterior band of a displaced disc obstructs forward movement of the condyle. The load distribution of the surface of the condyle encountering the obstruction would be expected to be abnormal. It can be inferred that the disordered collagen fiber pattern observed in the anterolateral surface of the condyle of specimen 1 was remodeling caused by such loading. However, the inference does not have generality because the pattern elsewhere in specimen 1 and throughout specimens 2 and 3 appeared to be essentially normal. Considering the degree of deformity of the disc in specimens 1 and 3, it is remarkable that the fiber pattern in the bearing surfaces was so little affected. Steinhardt, however, reported degenerative changes in the articular coverings associated with meniscus displacement. It may be concluded that gross change in the structure of the articular surfaces is common but not always manifest in cases of meniscus displacement.

Thickness. The observation of locally increased thickness of the articular tissue in specimen 1 is consistent with the general findings of Hansson and Nordström that the soft-tissue coverings are thicker in joints exhibiting deviations in form and with the findings of Hansson and Nordström, McNamara and Carlson, Blackwood, and Öberg that the deeper layers of the articular covering makes the greatest contribution to dimensional changes in articular tissue undergoing progressive remodeling. Steinhardt’s assessment of thickening of the articular coverings in some cases of meniscus displacement was subjective but would appear to be valid. Owing to the lack of thickening in specimen 3, it may be concluded that thickened articular coverings are frequent but not always associated with meniscus displacement.

The microscopic appearance of the hypertrophic cartilage in the condyle of specimen 1 generally resembled the normal condition expected in a much younger person (compare Fig. 2A here with Fig. 10 of Wright and Moffett). However, the trabeculae in the condyle and eminentia are of the adult proportions expected in the joint of a 23-year-old person (compare Fig. 2 here with Fig. 11 of Wright and Moffett and with Fig. 6 of Ingervall and co-workers). The histogenesis of the hypertrophic
like the meniscal displacement arose in youth, the hypertrophy may be construed as the retention of an immature state. If the displacement arose close to the time of death, the hypertrophy may be construed to reflect secondary enlargement of the chondroblastic layer.

Osteophytes. The only definite osteophyte observed was located on the posterolateral aspect of specimen II. Steinhardt reported osteophytes in this position and also at the anterior margin of the condylar articular surface in some meniscal-displacement cases. The latter he attributed to excessive contractile force of the lateral pterygoid muscle required to overcome the obstruction to forward motion of the condyle caused by the disc. The lack of osteophyte formation in specimen 3 and in other of Steinhardt's specimens indicates that osteophyte formation is not invariably associated with meniscus displacement.

Variation in the pathosis

While certain pathologic features were consistently associated with meniscus displacement, others were variably or only uniquely present. If remodeling and loading of joints are related, as is widely believed by clinicians and pathologists alike, then differences in the pathosis observed in the meniscus-displacement specimens may be due to physical differences in the specimens. A displacement in which the bulk of the meniscus is located medially in the joint would be expected to produce a different loading pattern, and hence remodeling effect, than one located more straight anteriorly. The differences in the gross shape of the disc and the structure of the posterior attachment of specimens 1 and 3 can perhaps be explained in this way.

Another possible source of variation in pathosis is the age of the person at the time of occurrence of the displacement. The striking difference in the thickness of the articular coverings of specimens 1 and 3 suggests that a remodeling response arising in youth may be different from and/or more vigorous than one arising later in life. Animal studies support this idea. Also, to the extent that remodeling progresses continuously after the onset of meniscus displacement, the time the displacement has been present should be correlated with the pathologic features.

These variables, if valid, are pertinent to treatment, and they may be partly responsible for the disparity of symptoms observed by experienced clinicians in meniscus-displacement patients.

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