Development and Histology of Fibrous Architecture of the Fetal Temporomandibular Joint

By

Yoshikuni OHTA, Fumihiko SUWA, Lianjian YANG*, Meiging WANG* and Huiyun WANG*

Department of Anatomy, Osaka Dental University, 5-31, Otemae, 1-chome, Chuo-ku, Osaka 540, Japan
*Department of Oral Anatomy, Fourth Military Medical University, Faculty of Stomatology, Xi'an, China

—Received for Publication. November 28, 1992—

Key Words: Temporomandibular joint, Articular disc, Development, Human fetus, Histology

Summary: The developmental histology of the temporomandibular joint (TMJ) was investigated in 10 fetuses of 4 to 10 months of gestational age. The S-type structure of the disc is formed by the following bases: 1) the flat upper and concave lower surfaces of the disc; 2) thinner intermediate zone and thicker anterior and posterior bands; 3) the projection of the articular tuberculum and superoposterior growth of the condyle. The posterolateral part of the disc was the thickest and the corresponding part of the fossa was the deepest. The condyle was originally positioned beneath the part of disc that was considered the main force-bearing area. The distribution and arrangement of elastic and collagen fibers in the disc was proportional to disc function. Gross elastic fibers in the posterolateral part of the posterior band were connected with the upper head of the pterygoideus lateralis muscle fibers running medioanteriorly. They were indicated to be antagonistic with each other. At 4 months of gestational age, a few elastic fibers appeared in the bilaminar region and began to form bundles as the fetus grew. At full-term dense elastic fibers were found in the upper stratum of the bilaminar region.

Materials and Methods

Eighteen sides of 10 Chinese fetuses of 4–10 months of gestational age were used. The gestational age and crown-rump length (CRL) of all materials were recorded (Table 1) and prepared by the following methods:

Table 1. Histological management of TMJs of different gestational age groups

<table>
<thead>
<tr>
<th>Months</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRL (mm)</td>
<td>140</td>
<td>190</td>
<td>230</td>
<td>270</td>
<td>300</td>
<td>340</td>
<td>360</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>18</td>
<td></td>
</tr>
</tbody>
</table>

After the induction of labor, the fetuses were stored in a refrigerator for 24 hours. The TMJ including the surrounding tissues on both sides was resected and fixed in 10% formalin for two weeks. After irrigation and decalcification, the TMJs were sectioned sagitally and coronally in two or three slices. After alcohol dehydration and paraffin embedding, serial sections (10 μm in thickness) were made and stained with hematoxylin and eosin, and Weigert's and Van Gieson's stains for light microscopy.

Results

1. Cross structure

   1) Sagittal section: At 4 months of gestational age, the upper and lower cavities were completely
formed. The anterior and posterior bands of the disc were thicker, whereas the intermediate zone was thinner. The superior surface of the disc was flat, suitable for a plane profile of the temporal component, and the inferior surface was concave, suitable for a rounded profile of the condyle (Fig. 1). At 5 months, the articular tubercle gradually protruded and a shallow articular fossa appeared. The inferior obliquity of the anterior band and intermediate zone, and the posterosuperior development of the condyle also began to be apparent at this time.

At full term, the disc was curled along the surface of the condyle and a shallow depression had appeared. The condyle was positioned between the posterior band and intermediate zone of the disc (Fig. 2).

2) Coronal section: After 4 months, the lateral and medial parts of the disc on its middle frontal plane were uniform in thickness, like a cap. The condyle changed from a round process to a plane and the fossa was concave from the posterolateral to the inferomedial parts. The disc became thicker laterally and thinner medially, and the glenoid fossa was observed deeper laterally on serial sections. At the lateral part, the beginnings of firm attachments of the disc were found at the lateral pole of the condyle, and later the temporal site was added. At the medial part, the attachment changed from the pterygoideus lateralis muscle to the medial pole of the condyle.

2. Light microscopy

1) Disc

Sagittal section: The bilaminar region in the 4-month fetus contained elastic fibers scattered in the upper stratum of the disc. Elastic and collagen fibers began to form bundles as the fetus grew. By observing serial sections throughout gestation, it was found that the lateral fiber layer containing dense elastic fiber bundles thickened as it ran anteroposteriorly (Fig. 3), and contained more transverse collagen fibers medially, where the layer became thinner.

In the 4-month fetus the area between the upper and lower strata became extended and contained a few collagen fibers. But as the fetus grew, the collagen fibers increased in number and elastic fiber bundles appeared (Fig. 4).

There were collagen fibers passing anteroposteriorly in the lower stratum in the 4-month fetus. As the gestational age increased, the lower stratum thickened, containing denser collagen fibers and fewer scattered elastic fibers. The lower stratum was the thickest in the lateral area and contained some elastic fibers.

Posterior band: The posterior band of the disc mainly consisted of fibroblasts. There were a few collagen fibers running anteroposteriorly in an area adjacent to the condyle. By 5 months, these fibers appeared undulated, and more transverse fibers were found on the side of the glenoid fossa. Serial slides showed that the lateral part of this band consisted mainly of anteroposteriorly arranged collagen fibers. A few elastic fibers were found only at the fossa site. Most of the medial side contained transversely interlacing fibers. A few fibers ran anteroposteriorly at the condyle site.

Intermediate zone: By 4 months, the main component of the intermediate zone was fibrocytes. At 8 months, the collagen fibers appeared compact and were arranged anteroposteriorly. There were a
few vertical elastic fibers (Fig. 5). More vertical fibers and a few transverse fibers could be found by full-term.

Anterior band: By 4 months of gestational age, there were many collagen fibers, and these were increased in number at full term. The fibers running anteroposteriorly from the fossa’s surface to the condyle’s surface gradually interwove with transverse fibers. On serial sections, more elastic fibers were found on the medial side.

2) Pterygoideus lateralis muscle: At the inferoantero-medial part, the collagen fibers from the anterior band of the disc were directed into the muscle and fasciculated together with the epi- and endomysium. Between the anterior band and this muscle, there was a loose connective tissue including many blood vessels. These structures in the anterior band could be viewed from 4 months of gestational age.

Coronal section: At 4 months of gestational age, there were a few collagen fibers. At the medial part of the disc, the fibers mostly ran anteromedially and...
mixed with the pterygoideus lateralis muscle fibers. At the central part, there were more vertical fibers interweaving with transverse fibers, whereas the lateral part was mainly composed of transverse fibers directed downward compactly and attached to the lateral pole of the condyle, where a few elastic fibers were found. A few mediolaterally-passing collagen fibers were observed on the whole fossa surface.

3) The condyle
At 4 months of gestational age, the cartilagenous layer, covered with an obvious connective tissue, developed to be the thickest. Blood vessels passed vertically. As the fetus grew the cartilagenous layer became thinner. Comparing the anterior and posterior parts of the condyle, it could be seen that the posterior cartilagenous layer was superficially thicker than the anterior layer (Fig. 2), although the proliferative layer maintained a similar thickness.

4) The fossa
At 4 months of gestational age, the superficial fibrous layer was thickened and showed signs of intramembranous ossification. At full term, the collagen fibers on the fossa's surface had compacted. Osseous tissues were prominent at an eminence where bone formation was more active than in its surroundings. There were newly formed osteoids, in which larger osteocytes were scattered in collagen fibers in the deep part.

Discussion

1. Morphogenesis of TMJ
1) Morphogenesis of S-type disc and correlations between the condyle, disc and fossa.
There has been much dispute regarding the morphogenesis of the TMJ S-type disc. Some investigators have considered that a well-developed S-type disc existed at the early fetal stage (Xu et al. 1983, Wong et al. 1985), while others who have studied postnatal materials have pointed out that the disc was still a linear structure at birth, and the S-type disc occurred later (Wright and Moffett 1974, Thilander et al. 1976). In this study, the disc was characterized by a thinner intermediate zone and thicker anterior and posterior bands at 4 months of gestational age, the upper surface was flat and uniform with that of the fossa and concave, and the lower surface was uniform with the round condyle. We believe that the morphogenesis of the upper and lower articular cavities begins to develop from a horizontal fissure and later from a concave fissure. As the fetus grew, the tuberculum began to be prominent, causing the anterior band and intermediate zone to decline downward, and the condyle developed posterosuperiorly. At full term the tuberculum had grown to this deeper fossa. The anterior band and intermediate zone formed a shallow lower cavity. The condyle now was situated posterior to the disc and inferior to the intermediate zone. It could be concluded that, because the tuberculum continued to grow after birth and the anterior band and intermediate zone grew downward quickly, the upper surface of the disc became concave against the tuberculum. At the same time, the condyle developed superoposteriorly and the disc center, being concave against the upper surface, moved posteriorly. This process formed the posterior band into a concave structure. Wright and Moffett (1974) showed that the S-type disc became more obvious at 2 years of age. Thus the S-type disc was gradually formed by the development of the prominent tuberculum and posteriorly grown condyle beneath the thinner intermediate zone, thicker anterior and posterior bands, flat upper surface and concave lower surface.

It is an important development that the condyle develops superoposteriorly and the tuberculum protrudes to form the S-type disc. This study also revealed that the superficial posterior part of the condyle in the full-term fetus was covered with a thicker connective tissue layer than that of the superficial anterior part, and the proliferative layer was thinner, although there was no similar feature in the 4-month fetus. This indicates that differentiation from the proliferative layer to the cartilage was very active in the superoposterior part of the condyle, and shows a superficially posterior development of the condyle. Many newly-formed hypertrophic bone cells at the tuberculum indicated that the intramembranous ossification was more active as the tuberculum protruded further. This development of the condyle and tuberculum not only formed the S-type disc but also established functional correlations between the condyle, disc and fossa, that is, at 4 months of gestational age, the condyle was related to the intermediate zone of the disc and flat fossa. The S-type fossa did not develop, but at full term the condyle had already contacted, with the concavity of the S-type fossa intervening in the posterior band.

2) Morphological characteristics of TMJ in the mediolateral direction
The morphological characteristics of the TMJ in the mediolateral direction have remained unclear, especially those of the disc (Wright and Moffett 1974, Xu et al. 1983). In this study the serial sections of the TMJ showed that the lateral and medial sides of the intermediate zone of the disc were similar in
thickness, while the lateral part of the posterior band became thicker. The fossa appeared so concave that it undulated from the superolateral to the inferomedial part. The condyle also was located just below the lateral part of the disc, forming the relationship between the condyle, disc and fossa. Hansson et al. (1977) and Mongini (1984) reported that the reconstruction of the TMJ more often took place at the lateral part of the condyle and posterolateral part of the tuberculum. The adult disc has a tendency to thicken laterally. It can be concluded that the structure of the thickened lateral part of the disc, which contains many transverse collagen fibers attached to the lateral pole of the condyle, helps maintain dynamic equilibrium during TMJ movement.

2. Attachment structures of the disc and its functional movement

Some researchers (Choukas and Sicher 1960, Cohen and Kramer 1976, Bell 1982) have examined attachments of the disc. In this study we found that the collagen fibers in the upper band of the bilaminar region ran from the posterolateral to the medioanterior direction with scattered elastic fibers. In the posterolateral part especially, there were elastic fibers transversely-arranged in bundles. These fibers serve the superior band to extend and retract the disc during movement. The insertion of the pterygoideus lateralis muscle onto the medioanterior side of the disc may be equivalent to the transverse elastic fibers in the superior band. They seem to be an antagonistic factor. The disc attached firmly to the condyle at the medial, lateral and posterior ends, causing the disc to move passively with condyle. The elastic fibers in these attachments enable the disc to move backward during repositioning of the condyle and disc.

Attachments of the disc have a very important effect during mandibular movement (Mongini 1984). During the open movement of the mandible, the upper head of the pterygoideus lateralis muscle contracts but the lower head does not function, giving the condyle an anteroinferior movement with a slight rotation. The disc now passively moves with the condyle and is also pulled by the elastic fibers in the bilaminar region and other attachments. Thus, the disc relates to the posterior rotation of the condyle in such a way that the condyle is identical to the intermediate zone in functional anatomy, although it was previously identical to the posterior band. The condyle therefore can move flexibly in the deep and large fossa.

During closing movement, the disc was affected not only by the posteriorly moving condyle but also actively by the elastic fibers in the bilaminar region. Given this condition, the disc might move backward prior to the condyle's movement, owing to the morphological and functional difference between the two structures. The elastic fibers in the bilaminar region may be antagonistic to the pterygoideus lateralis muscle, making the condyle move anteroinferiorly, while the disc returns to the normal position with the condyle.

References