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What is This?
Normal Age Changes in the Rat Mandibular Joint

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SYNOPSIS IN INTERLINGUA

Alterationes Normal de Invetulation in le Articulation Mandibular del Ratto.—Esseva studiate le normal crescentia e morphologia del articulation mandibular del ratto. Le articulationes studiate includeva specimens ab 15 differente gruppos de etate ab 1 die ad 2 annos. Le alterationes causate per le processos normal del invetulation es describite pro le areas principal del articulation, i.e., le fossa del articulation, le disco articular, e le condylo mandibular. Marcate alterationes esseva observate in le osso del fossa articular e del condylo. Alterationes de character plus subtil esseva notate in le disco articular. Le constatation le plus remarcabile esseva le constanția del spissitâte del cartilagine condyolar post le cinquantesime die del vita.

Research workers in many branches of medicine and dentistry are becoming increasingly aware of the value of utilizing the rat mandibular joint in their studies of nutritional, hormonal, or functional problems. Numerous investigators have used the rat mandibular joint for study, yet there is a scarcity of information in the literature concerning morphologic changes due to the normal aging process. Because of the scarcity of complete morphologic and developmental studies of changes in this region, a comprehensive study was undertaken.

Materials and Methods

Seventy-five male rats of the Holtzman strain were used in this investigation. They were fed a stock diet with water ad libitum. Litters were kept with their dams before weaning.

Fifteen different age groups, ranging from 1 day to 2 years, were used to determine normal changes due to aging (Table 1).

Following sacrifice, the heads and jaws of all rats were fixed in acetic acid-formalin fixative. After fixation, all heads and jaws were split midsagitally, and lateral and ventral radiographs were taken of each half.

After radiography, all heads and jaws were decalcified in 10 per cent nitric acid in 10 per cent formalin. All material was then processed in the usual manner for embedding in nitrocellulose. Right and left halves were segregated and processed independent of their opposite sides. All tissues were sectioned in the coronal plane at a thickness of 22 to 24 μ.

Alternate cut sections were stained with hematoxylin and triosin, Mallory's connective tissue stain, or Alcian blue or with periodic acid-Schiff counterstained with hematoxylin. Stained sections were mounted for microscopic examination.

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Observations

ONE DAY.—The squamosal bone is not completely formed over the superior surface of the joint cavity in 1-day-old rats. Two different centers of ossification are seen, one on the medial aspect that is arising from the inferior half of the squama of the squamosal bone and the second on the lateral aspect that is arising from the zygomatic process of the same bone. Bony spicules both from lateral and from medial centers of ossification are oriented toward each other (Fig. 1).

The articular disc consists of cellular connective tissue. The superior or squamosal compartment of the joint cavity is completely formed; however, the inferior or mandibular compartment is still not complete at this period. Cleft formation has started on the lateral surface, but the articular disc is still attached to the superior medial aspect of the condyle.

The condyle is a well-defined oval mass of embryonic cartilage (Fig. 1). The long axis of this oval cartilaginous mass is oriented in a superior-inferior direction with a lateral tip of the long axis of about 10 degrees at the superior aspect. A thick fibrous cover encases the entire condyle. Evidence of bone formation is seen along the inferior border of the cartilaginous mass. Bone can be followed superiority on both the medial and lateral surfaces of the condyle for approximately two thirds of the superior-inferior height. The earliest bone formation is on the lateral surface: the bony development in this region is further advanced than on the inferior or medial surfaces. All bone formation is immediately subjacent to the fibrous tissue that encases the condyle.

SEVEN DAYS.—Bone formation has been rapid in the squamosal portion so that the medial and lateral centers of ossification have united and the superior portion of the joint is completely formed. The squamosal portion of the joint is now completely covering the articular disc and the condyle. The inferior or joint surface of this bone is covered with embryonic fibrous connective tissue (Fig. 2).

The articular disc is thick and is composed of young cellular connective tissue. Cleft formation has been completed, and both compartments of the joint cavity are formed.

The condyle has not changed in shape and is still covered by fibrous connective tissue. Changes are seen in the cartilage composing the condyle. First signs of hypertrophy are seen in the embryonic cartilaginous zone at the region farthest from the peripheral fibrous connective tissue covering the condyle. This hypertrophy increases in degree as the center of the condyle is reached.

FOURTEEN DAYS.—The squamosal bone is well formed at 14 days, and the surface forming the superior portion of the joint

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**Fig. 1.** One-day-old rat. The condyle consists of cartilage with a thick fibrous covering. The articular disc is still not completely separated from the condyle in the region of the mandibular compartment. Two centers of ossification, one lateral (L) and one medial (M), are seen in the squamosal bone.

**Fig. 2.** Seven-day-old rat. First signs of endochondral bone ossification are seen in the mandibular condyle. Both outer and inner compartments of the articular disc are well defined. The disc is still composed of cellular connective tissue. The squamosal ossification centers have now joined, and the articular fossa completely covers the condyle and the articular disc. L = lateral.
cavity is covered with fibrous connective tissue.

The shape of the condyle is unchanged, but the fibrous covering along the peripheral surface is becoming thinner. More endochondral bone is seen in the inferior third of the condyle.

The articular disc is still thick but is becoming fibrous.

TWO-NINE DAYS.—The squamosal bone is well calcified and large marrow spaces are seen at 21 days. The articular surface is covered with dense fibrous connective tissue that is considerably thicker than was seen previously.

The articular disc is becoming fibrous. On the lateral aspect of the condyle, the attachment of the articular disc ends in a well-defined cul-de-sac. Fibers from the inferior half of the disc attach to the lateral surface of the condyle, and fibers from the superior half appear to fuse with squamosomandibular ligament. On the medial aspect, the fibers of the disc disperse into the connective tissue between the squamosal bone and the neck of the condyloid process (Fig. 3).

The condyle is changed in shape. It is becoming more flattened superiorly and is slightly broader in this region. The cartilage at the superior aspect of the condyle forms a cap and is divided into the three usual zones.

Fig. 3.—Twenty-one-day-old rat. The squamosal bone is denser and better organized. The articular disc is still composed of cellular connective tissue. The condyle is flattened medially on its superior aspect. Considerable endochondral bone is seen. Notice the squamosomandibular ligament. The attachment of the articular disc to the neck of the condylid process forms a cul-de-sac on the lateral surface of the condyle. L = lateral, S = squamosomandibular ligament, C = cul-de-sac.

Fig. 4.—Forty-day-old rat. There is an increased thickness of the fibrous connective tissue covering the condyle. The condyle shows an increase in density with a thickening of the bony trabeculae. The size of the marrow spaces is decreased. There is a narrowing of the cartilaginous cap of the condyle. Cellular elements of the cartilaginous cap are now clearly differentiated. No change is seen in the articular disc. The squamosal bone is becoming more dense.

Inferiorly, endochondral bone is seen. This bone now has large marrow spaces. There is a space between the older cartilage and the bone itself. The endochondral bone formation extends to the superior fifth of the condyle. The superior portion of the condyle tilts laterally. Attachment of the external pterygoid muscle is seen. The attachment of the squamosomandibular ligament is seen on the lateral aspect of the condyle.

THIRTY DAYS.—The squamosal bone is well formed and calcified at 30 days and has large marrow spaces. The articular surface is covered with dense fibrous connective tissue.

The cellular elements of the articular disc are still primarily embryonic in character. Fibers of the external pterygoid muscle are seen entering the disc on its medial aspect.

The condyle is covered with a thin layer of dense fibrous connective tissue. The cartilaginous layer, or cap, is divided into the three usual zones.

Bony lamellae in the condyle run in a superior-inferior direction in a fairly parallel pattern. Large marrow spaces are seen between the bony trabeculae.

FORTY DAYS.—The squamosal bone at 40 days is considerably denser than before, and the articular surface is covered by a thin layer of connective tissue. This fibrous connective tissue on the articular surface of
the squamosal bone shows an increase in thickness when compared to younger specimens. Immediately above this tissue is a layer of young bone (Fig. 4).

The articular disc is now more fibrous than embryonic in character.

The condyle is covered with a thin layer of fibrous connective tissue with a cartilaginous layer immediately subjacent. The cartilaginous cap of the condyle is considerably thinner than was seen in younger rats. Vacuolated cartilage cells are only two deep just above the bone formation. Inferior to the cartilaginous layer is an inner bony trabecular core that comprises the remainder of the condyle. Bone formation is advanced and the marrow spaces, although larger, are well filled.

Two months.—The squamosal bone is well calcified at 2 months. Marrow spaces are filled with hematopoietic marrow. The articular surface is lined with dense fibrous connective tissue.

The articular disc is composed of dense fibrous connective tissue and has assumed its characteristic shape—thin in the center, increasing in thickness as the peripheral regions are reached.

The condyle has flattened mesiolaterally and has assumed its mature morphology. Zoning in the cartilaginous region is clearly defined.

Infiltration of the vacuolated cartilage cells by blood vessels is seen, as is the subsequent destruction of the vacuolated cartilage. Numerous bone lamellas are seen running parallel to the long axis of the condyle.

Four months.—The squamosal bone is very dense and compact at 4 months; otherwise, it remains unchanged. Fewer marrow spaces are seen.

The articular disc is composed of a thin layer of dense fibrous connective tissue.

The condyle is covered by dense fibrous connective tissue. The cartilaginous layers are indistinct as compared to those in the 2-month-old rat. Fibrous connective tissue and embryonic cartilage comprise the first two layers, but the older cartilage and the vacuolated layer seem to be combined. The vacuolated layer is less distinct, and the cells are smaller. The whole cartilage cap is thinner, averaging 90 μ. Lamellas are quite dense, and large marrow spaces are seen. Bone formation is well advanced and is considerably higher than that seen previously. The entire condyle is more rounded on its superior aspect and is considerably narrower at the neck of the process.

Six months.—The squamosal bone is quite dense with fewer marrow spaces. The new bony border on the inferior surface is increased in thickness.

The articular disc is unchanged.

The condyle is high and rounded. The cartilaginous cap extends over periphery from neck to neck. This cap of cartilage is thin and is similar to that seen in the 4-month-old rat. The subjacent bony trabeculae are larger and denser, and few marrow spaces are seen (Fig. 6; compare with Fig. 5).

The primary differences seen at this age
as compared to the 4-month-old rats are principally confined to the increase in size of the bony trabeculae and diminution in size of the marrow spaces. The degree of calcification in the bony trabeculae is greater in the 6-month-old rat.

Eight months.—With the exception of denser bone in the squamosal region and in the condyle (Fig. 7), there is practically no change at 8 months. The fibrous connective tissue is slightly thicker on the articular surface of the squamosal bone, and new bone is seen immediately superior to this tissue.

Ten months.—The squamosal bone and the articular disc are unchanged at 10 months.

The cartilaginous cap of the condyle has remained 90 µ in width, but considerable spacing is seen between the vaculated cells. The bone of the condyle is quite dense with fewer marrow spaces (Fig. 8).

Twelve months.—The cartilaginous cap of the condyle is considerably thinner on the peripheral areas at 12 months. The squamosal bone and articular disc are unchanged. Calcification in the condyle has continued and there are few marrow spaces.

Sixteen months.—No changes are seen in the squamosal bone or the articular disc. The condyle consists of solid bone. This bone appears to be sealed off from the cartilage in the condyle. When bone prevents matrix formation by the cartilage, it could be termed “sealed off.” Actually, some matrix formation and peripheral bone formation may be present, but these were not seen. If such formation occurs, it would have to be at a greatly reduced rate.

Discussion

The mandibular joint of normal rats has been studied by several investigators. In addition, a study of the normal development of the mandibular joint of the mouse was made by Levy, who found a remarkable similarity between the joints of the rat and the mouse.

Collins and co-workers published a study of the normal development of the mandibular joint of the female rat. Generally, they agreed in their concept of the development of the mandibular articulation with the findings of Cabrini and Erasquin.

Collins and co-workers described the cranial portion of the joint or the squamosal region and stated: “A cartilage-like mass of tissue lies adjacent to the articular surface of the fossa, separated from the joint cavity by only a thin layer of fibrous tissue.” They also claim that this tissue can be found in old rats, even at 465 days of age. In their opinion, the presence of this cartilage-like mass at older age levels gives the articular fossa the ability to remodel itself or change its shape in response to pressure.

This is contrary to the findings of Cabrini and Erasquin as well as the findings of this study. No such cartilage-like mass was described by Cabrini and Erasquin, and no
evidence of cartilage or a cartilage-like mass was found in this study.

Although the Collins study\(^2\) was made on female rats and this study used male rats, an adequate number of mandibular joints from female rats has been studied independently by the author to be certain that sexual or hormonal differences could not account for this variation in findings.

Levy\(^7\) established a standard on which to base future studies of the mandibular joint in mice. One point he emphasizes is that the cranial portion of the joint shows no evidence of the cartilage-like tissue described by Collins and Erasquin.\(^1\)

Bhaskar\(^3\) determined that the articulation between the squamosal bone and the mandible begins to develop in the fetus 19 days after insemination. The findings of this study show the articulation was fully formed by 7 days after birth.

Cunat, Bhaskar, and Weinman\(^4\) examined the structure of the articular disc and the time of its formation. They state: "The superior compartment forms at the nineteenth day of insemination age while the inferior or mandibular cleft is not formed until after birth." The present study shows the inferior compartment of the disc is complete by 7 days after birth.

Cunat and associates\(^5\) also described the growth process taking place in the mandibular condyle both before and up to 30 days after birth. The findings of this study concur with the findings of Cabrini and Erasquin\(^1\) and with the postnatal findings of Cunat, Bhaskar, and Weinman.\(^6\)

At birth, the mandibular condyle is composed entirely of embryonic hyaline cartilage. This cartilage continues to grow both appositionally and interstitially until the mature morphology of the condyle is reached. At the same time, cartilage is also being eroded by endochondral bone formation from the center of ossification. By 21 days, this cartilage forms a cap over the superior surface of the condyle. By 50 days, the condyle has achieved its mature morphology. This is approximately 2 weeks after the eruption of the third molar teeth. At this time, the cartilaginous cap is reduced to 90 μ in thickness. No diminution in thickness of the cartilaginous cap was seen after the age of 50 days.

Certain changes take place during normal aging that are of great interest. As the rat grows older, there is an increase in size of the bony condylar trabeculae and a diminution in size of the marrow spaces. By the age of 10 months, the mandibular condyle precludes the cartilaginous layer from forming a calcifying matrix, and growth is slowed appreciably or stopped entirely. When this stage is reached, the bone can be considered to be sealed off from the cartilaginous matrix.

In the squamosal region, increasing age brings an increased density of bone, again at the expense of the marrow spaces. By the age of 10 months, the zygomatic portion of the squamosal bone consists of solid bone.

The changes in the articular disc are more subtle. In the young rat, the disc and squamosal membrane are cellular connective tissue. With advancing age, this tissue becomes extremely dense. A very slight diminution in the thickness of the articular disc occurs between the ages 2 and 24 months.

**Summary**

The growth and transformation of the mandibular joint of the normal rat has been studied. Rats in 15 different age groups, ranging from 1 day to 2 years old, were examined.

Changes due to normal aging have been described in the principal regions of the joint, namely the joint fossa, the articular disc, and the mandibular condyle.

Distinct changes were observed in the bone of the joint fossa and of the condyle. More subtle changes occurred in the articular disc. Most remarkable was the constancy of thickness of the condylar cartilage after the 50th day of life.

**References**