THE DEVELOPMENT OF THE HUMAN MANDIBULAR JOINT

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INTRODUCTION

The mandibular joint has long been of interest in that phylogenetically it represents a new joint replacing the older one between the articulare (malleus) and the quadrate (incus). In this connexion considerable controversy has arisen over the formation of the articular disc and its relation to the lateral pterygoid muscle. Furthermore, the mode of formation of the mandibular joint is somewhat different from that of most other synovial joints.

In the literature, so far as I have found, the only previous workers who studied the development of the human mandibular joint by means of a series of specimens are Kjellberg (1904), Vinogradoff (1910) and Mundaca (1948) The earliest stage described by any of these three workers is one of 35 mm. C.R. length.

A considerable period before there is any sign of a joint-cavity the chief elements of the mandibular joint have been mapped out. This is particularly true with regard to the condylar process of the mandible. Even as early as the 22 mm. stage in the human embryo there is some indication of its form.

MATERIAL AND METHODS

The materials used in this work were one embryo of 22 mm. C.R. length and a series of foetuses of 30, 34, 40, 48, 57 (two specimens), 60, 65, 70 (two specimens), 95, 150, 180 mm. (two specimens) C.R. length and one of full term. The material was fixed in formalin, dehydrated and cleared by routine methods and embedded in paraffin. One of the 57 mm. specimens, the 180 mm. and the full-term specimens, however, were treated by a double embedding method.

OBSERVATIONS

22 mm. stage

A considerable amount of bone-formation has taken place and formed a plate on the lateral side of Meckel's cartilage; this plate is in the substance of, and is surrounded by, that mesodermal condensation which outlines the mandible and precedes the formation of bone. The plate of bone is confined to the region of what approximately corresponds to the future body of the mandible, but the mesodermal condensation can be traced further backwards, always, of course, on the lateral side of Meckel's cartilage and the associated branches of the mandibular nerve. The condensation admittedly becomes gradually much less sharply defined but is still distinguishable from the surrounding tissue. Finally, some distance beyond the limit of bone-formation, the lateral pterygoid muscle can be seen running into and outlining the terminal part of the mesodermal condensation. This is the first indication

of the condylar process in my series (Pl. 1, fig. 1). Meckel's cartilage with the inferior dental and lingual nerves on its upper surface lies medial to this rudimentary condylar area and inferior to the lateral pterygoid muscle.

30 mm. stage

The mesodermal condensation of the mandible is now everywhere clearly defined. In a section, the head of the condyle appears as a distinct oval-shaped mass to which the fibres of the lateral pterygoid are attached. Above and lateral to the condyle is an oval condensation, in the centre of which is a small area of bone-formation. This is the first indication of the temporal element of the articulation in my series. Already the outermost cells of the condylar condensation form a distinct layer and the temporal condensation shows the same feature but to a less marked extent. This is the first indication of the future layer of fibrous tissue which will cover the articular surfaces of the condyle and the temporal bone.

34 mm. stage

The tissue forming the condylar process has been invaded by an extension of the membrane bone from the ramus. A considerable proportion of the condylar neck and the anterior half of the head are occupied by this membrane bone, but there is only a slight indication of it in the posterior half of the head. In the early stages, a coronal section through the condyle head shows the zygomatic arch, since the condyle is well ventral to the temporal region compared with its definitive position (Pl. 1, fig. 2). There is a wide interval between the condylar and zygomatic condensations, which is filled with a loosely formed tissue apart from a dense strip lying close to the condyle. A few fibres of the lateral pterygoid muscle can be traced into the medial side of this strip of tissue. In the previous stage there is already an indication of this narrow condensation, also connected to the lateral pterygoid.

Traced farther back to the point where the condyle is decreasing in size, the zygomatic condensation changes its oval shape and bends medially as a horizontal shelf forming the anterior root of the zygoma and the roof of the future mandibular joint. Some bone had been formed in this condensation and it is continuous with the bone forming in the temporal region lateral to the middle ear. The distinction of the superficial layer of the condylar and zygomatic condensations noted at the previous stage has become more marked and the fibrillar element of this layer is now apparent.

40 mm. stage

Very few changes, except for a general increase in size, are to be seen compared with the preceding stage. There is a greater amount of membrane bone-formation in both the head of the condyle and the zygomatic condensation. There is the same arrangement of a wide area of loosely formed tissue and a narrow strip of denser tissue between the zygoma and the condyle, the future intra-articular region. On the medial side the connexion of this narrow strip with the lateral pterygoid is maintained (Pl. 1, fig. 3).

48 mm. stage

The secondary cartilage of the condyle is seen for the first time at this stage. It appears as a broad fringe of tissue at, and continuous with, the tip and lateral side of the core of membrane bone in the condyle, and is covered superficially

by a thick fibrous layer, the deeper cells of which are continuously adding to the cartilage. At this stage the cartilage consists of large round cells which, in the one direction, can be traced in series with the cells of the fibrous-tissue covering which gives origin to them, and in the other direction are incorporated in the lacunae of the adjacent bone; that is, there is a continuous series from cells that are fibroblasts, through this cartilage-like tissue, to cells that are osteoblasts. The intercellular substance of the cartilage in the direction towards the fibrous-tissue covering it becomes less in amount and is continuous with its fibrillar network, while in the other direction it merges with the intercellular element of the bone.

57 mm. stage

The condylar cartilage is now in the form of a cone whose tapering end extends forwards into the ramus of the mandible. The innermost cells of the fibrous-tissue layer outlining the condyle have become more definitely flattened and spindle-shaped, and are arranged with their long axes parallel to the condyle surface. These cells, traced towards the centre of the condyle, gradually become rounded and merge into the area of cartilage (Pl. 1, fig. 4). Towards the anterior end of the condylar cartilage the cell-spaces have become larger, and the intercellular material appears as more sharply defined bars between the cells, as if it had been compressed.

At this stage there is the first sign of joint-cavity formation. This appears as a thinning-out of the loose tissue on either side of the strip of dense tissue above the condyle (Pl. 1, fig. 4). It is now obvious that this strip of tissue is the future articular disc; like the superficial layers of the condylar and zygomatic-temporal condensations, it is still quite cellular. A similar picture was found in another foetus of the same size. There is already a certain indication of a capsule as, from the lateral side of the zygomatic-temporal condensation, a narrow extension passes downwards to link up with the lateral margin of the future articular disc and reach towards the lateral side of the condyle.

60 mm. stage

Joint-cavity formation is somewhat advanced compared with the preceding stage. The strip of dense tissue above the head of the condyle is now readily identifiable with the articular disc as the lower joint cavity has appeared as a distinct cleft. This cleft-like lower joint-cavity is limited to the central area of the condyle. The formation of an upper joint-cavity does not appear to have progressed so far.

65 mm. stage

The condyle has greatly increased in size and is completely occupied by cartilage, apart from the area of proliferation of the cells of the fibrous-tissue covering. This area is now confined to the articular surface of the condyle, except for a noticeable extension into the lateral half of the condyle head. The larger size of the cartilage cells and the compressed appearance of the intercellular material, first seen at the 57 mm. stage, now affect the bulk of the cartilage, and, in the older more anterior part of the tissue, the cells show some degenerative changes, being shrunken and distorted.

Joint-cavity formation is considerably advanced, particularly in the lower joint-

cavity. This is well formed over the whole of the upper surface of the condyle. The upper joint-cavity is confined to the posterior part of the articular region and does not extend medially and laterally to the same extent as the lower joint-cavity. Between the well-formed lower joint-cavity and the developing upper joint-cavity the articular disc is clearly defined, though in front of the area where formation of the upper joint-cavity has commenced it is still connected to the zygomatic region. With the marked increase in the size of the condyle, the temporal and condylar articular surfaces have been approximated, so that all sign of the wide area of loosely formed tissue which previously intervened between the superficial layer of the temporal condensation and the future articular disc has disappeared.

70 *mm. stage*

The same appearance in the mandibular element of the joint is to be seen at this stage, except for one important feature: this is the appearance of irruptions of vascular mesenchyme in the ramus part of the cartilage, which break down the tissue in their path (Pl. 1, fig. 5). The cartilage in this area has become calcified.

Both joint-cavities may be said to be completely formed though they are still crossed by a number of delicate strands of tissue connecting the articular disc to the respective articular surfaces. The bone in the temporal region is greatly increased in amount and has extended so as to form a roof for the joint—the glenoid fossa—wider than the articular surface of the condyle. Fibre-bundles are beginning to appear in the disc and the layers of tissue covering the temporal bone and the condyle. On the lateral side, indication of the capsule is confined to a linking up of the fibrous-tissue layers covering the temporal bone and the condyle with the substance of the articular disc. On the medial side this is obscured by the attachment of the lateral pterygoid to the condyle and the disc.

95 *mm. stage*

The breaking down of the condylar cartilage, first seen in the preceding stage, has become more extensive, the whole anterior two-thirds of the cartilage being invaded by more numerous and larger areas of vascular mesenchyme. In the temporal element of the joint, bone-formation has occurred to a marked degree at the postero-medial angle of this surface. The bone in this region, being of open texture and with such large cell-spaces, has almost the appearance of an area of secondary cartilage.

150 *mm. stage*

The process of breaking down of the condylar cartilage has continued so that, at this stage, the only part of the cartilage unaffected is that which occupies the upper half of the condylar head beneath the proliferating fibrous tissue; this tissue no longer extends into the lateral half of the condyle head, being confined to the area immediately below the articular surface. The vascular mesenchyme does not produce a total removal of the cartilage; instead, narrow trabeculae of the cartilage are carved out which are surrounded by wide marrow spaces. The more anterior of these trabeculae have become surrounded by new bone-formation, and the whole area is sharply outlined by the membrane bone of the ramus.

In the temporal region an area of secondary cartilage has appeared. It is in the same part of the joint surface as that which showed the extensive bone-formation in the preceding stage.

180 mm. stage

In the mandibular element of the joint a new feature has appeared. In the cartilage zone several wide channels are to be seen which pass through the cartilage from the covering layer of fibrous tissue and link up with the marrow spaces beneath the cartilage. These channels contain blood-vessels.

In the medial part of the temporal region of the joint secondary cartilage is still present. In a sagittal section from the medial part of the joint a distinct connexion between the articular disc and Meckel's cartilage can be seen, the disc being continuous with the tendon of the lateral pterygoid muscle (Pl. 1, fig. 6).

Full term

There is little difference between this stage and the preceding one except for an increase in size. In the condyle, however, the cartilage is reduced to an even narrower zone beneath the covering layer of fibrous tissue than at the 180 mm. stage. In the zone of cartilage the vascular channels, first seen at the 180 mm. stage, are still present. All trace of active growth of secondary cartilage has disappeared from the temporal region of the joint. There is no sign of the formation of an eminentia articularis, the bone forming the temporal surface of the joint being almost flat, except for a shallow concavity. The articular disc is composed of dense fibre-bundles. It is well vascularized peripherally but is avascular in its central part. At this stage it contains no cartilage cells, nor are there any such cells in the actual covering layers of the articular surfaces. Thus even the condyle may only be considered as being covered with fibro-cartilage if the secondary cartilage deep to the surface layer of fibrous tissue is considered.

DISCUSSION

The mandibular joint is primarily produced by the growth of the sclerogenous tissue of the developing mandible towards the corresponding tissue in the temporal region. This tissue first produces bone in both elements. These areas of bone, however, and the fibro-cellular condensations surrounding them, are always separated by a wide intra-articular fibrous-tissue filled interval. The final approximation of the mandible to the temporal surface in a dorsal and cranial direction is brought about by the development of the secondary cartilage in the condylar process. Thus the formation of the mandibular joint is considerably different from that of most other synovial joints in that the elements of the joint when first outlined in mesenchyme, and for some time after, are widely separated and are only finally approximated by the growth of a special tissue. This cartilage appears towards the 50 mm. stage and produces a marked increase in the size of the condyle between this time and the 65 mm. stage. By this rapid growth of the condyle, the previously wide intra-articular interval is largely obliterated. The only intervening tissue left is that strip of dense tissue immediately above the upper surface of the condyle which

appears as early as the condylar condensation itself, and which is connected to the lateral pterygoid muscle from the beginning. This strip of tissue becomes the articular disc and would appear to be an extension of the tendon of the lateral pterygoid into the joint area. A similar conclusion was reached by Harpman & Woollard (1938), who decided that the medial portion of the disc, at any rate, arises from the tendon of the lateral pterygoid. Harpman & Woollard also demonstrated that at the 53 mm. C.R. length stage the tendon of the lateral pterygoid extended backwards to be attached to that part of Meckel's cartilage which becomes the malleus; this confirmed the similar observation of Kjellberg (1904) in a human foetus of 55 mm. Definite support for this has been obtained from my own series. In serial sagittal sections from the foetuses of 34 and 57 mm. C.R. length the tendon of the lateral pterygoid was traced beyond its attachment to the condyle of the mandible and reaching to Meckel's cartilage. This connexion was found also in the foetus of 180 mm. C.R. length (Pl. 1, fig. 6).

In the opinion of Vinogradoff (1910) the formation of the articular disc is intimately connected with the movement of the articular surfaces, especially of the condyle, towards one another, the tissue between the articular surfaces being compressed and so forming the disc. According to Vinogradoff it is only when the articular surfaces are closely approximated that the disc appears. However, it has been seen that the tissue of the future articular disc is quite distinct long before this approximation, thus ruling out the possibility of a direct formation of the disc by a compression of the intra-articular tissue. The formation of the joint-cavities on either side of this strip of tissue is associated, in time at least, with the great increase in the size of the condyle and its approach to the temporal element of the articulation.

I cannot support the observations of Mundaca (1948) that the elements of the mandibular joint have not appeared at 35 mm. and that they are only beginning to be outlined at the 46 mm. stage. In the 34 mm. specimen in my series, these elements are as well formed as Mundaca describes and figures them at the 46 mm. stage, and are assuming this appearance even at the 30 mm. stage.

It would appear that the lateral pterygoid is of importance in the definition not only of the articular disc but also of the condyle. At the 22 mm. stage the lateral pterygoid is running into and outlining the future area of the condylar process even though the mesodermal condensation for the mandible has not quite reached that level.

In the temporal element of the joint areas of secondary cartilage occur, thus paralleling the condylar element. These areas appear later, are much smaller in size than the condylar cartilage, and have disappeared before birth. Their appearance is localized and is apparently associated with a quite local and transient necessity for rapid growth.

SUMMARY

1. The development of the human mandibular joint has been studied in one embryo of 22 mm. C.R. length, and a series of fifteen foetuses from 30 mm. C.R. length to full term.

2. The elements of the human mandibular joint are fully sketched-out at

34 mm. C.R. length, having been indicated even earlier. The lateral pterygoid appears to assist in the outlining of the condylar element.

3. Joint-cavity formation has begun at 57 mm. C.R. length. Both joint-cavities are completely formed between 65 and 70 mm. C.R. length.

4. From its first appearance the tissue of the articular disc is connected to the lateral pterygoid muscle and seems to be an extension of the fibrous part of the muscle.

5. The lateral pterygoid muscle is connected through the medial part of the articular disc to the malleus. This connexion persists until at least 180 mm. C.R. length.

6. Areas of the temporal element of the joint pass through a secondary cartilage phase, but in contrast to the condylar cartilage, these areas are smaller in size, later in appearance, and have disappeared before birth.

I am indebted to Prof. J. D. Boyd for the loan of the 60 mm. C.R. specimen and to Dr J. H. Scott for the loan of one of the 180 mm. C.R. specimens.

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EXPLANATION OF PLATE

List of abbreviations

Cond.	Condyle of the mandible	*L.N.*	Lingual nerve
Sec.C.	Condylar secondary cartilage	*L.Pt.*	Lateral pterygoid muscle
F.C.A.	Future condylar area	*M.C.*	Meckel's cartilage
I.D.N.	Inferior dental nerve	*Zyg.*	Zygomatic arch

All the figures are of coronal sections through the head, except for fig. 6 which is a sagittal section.

Fig. 1. 22 mm. C.R. Showing the first indication of the area of the condyle of the mandible. Haematoxylin and eosin. × 90.

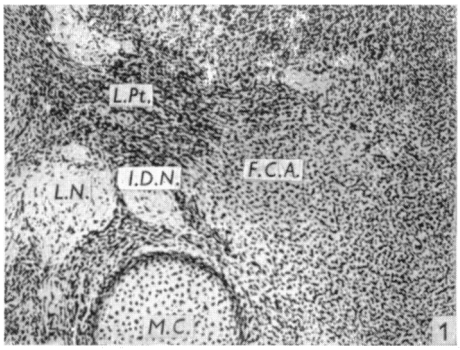
Fig. 2. 34 mm. C.R. Showing the main elements of the joint well mapped out. Note the connexion of the strip of tissue above the condyle of the mandible to the lateral pterygoid muscle. Mallory. × 55.

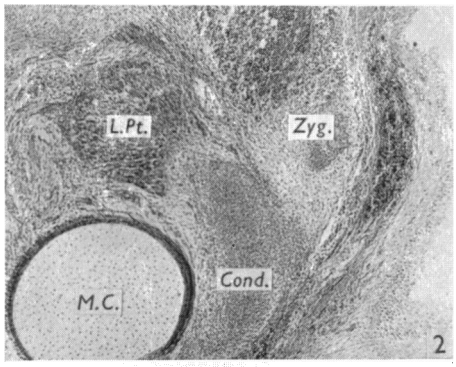
Fig. 3. 40 mm. C.R. Note the continued connexion of the strip of tissue above the condyle of the mandible to the lateral pterygoid muscle, and the wide interval between the condyle and the zygomatic arch. Mallory. × 55.

Fig. 4. 57 mm. C.R. Showing the first appearance of the joint cavities as a thinning-out of the tissue on either side of the strip of dense tissue above the condyle of the mandible (the future articular disc). The secondary cartilage which was first seen at the 48 mm. stage in the condyle is now of quite large size. Mallory. × 55.

Fig. 5. 70 mm. C.R. Showing the full extent of the carrot-shaped mass of the secondary cartilage of the mandibular condyle. The joint cavities are now well formed. Masson. × 20.

Fig. 6. 180 mm. C.R. Showing the connexion of the lateral pterygoid muscle through the articular disc to the malleus. Masson. × 10.


L.Pt.
L.N.
I.D.N.
F.C.A.
M.C.
1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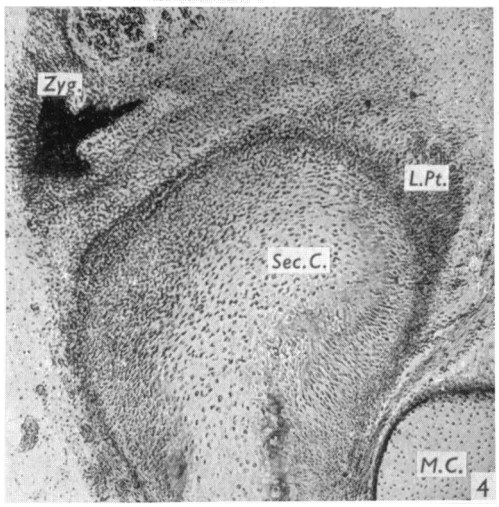
2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L.Pt.
Sec.C.
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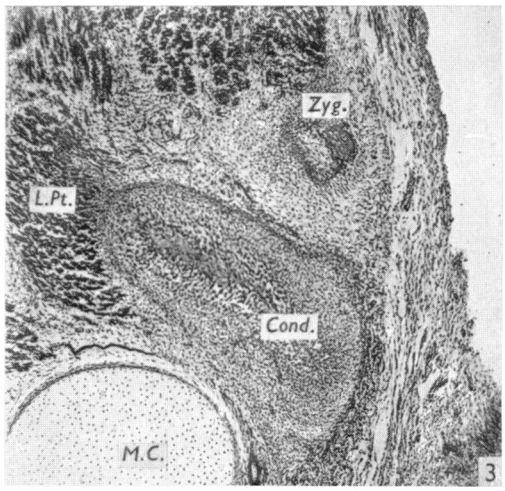
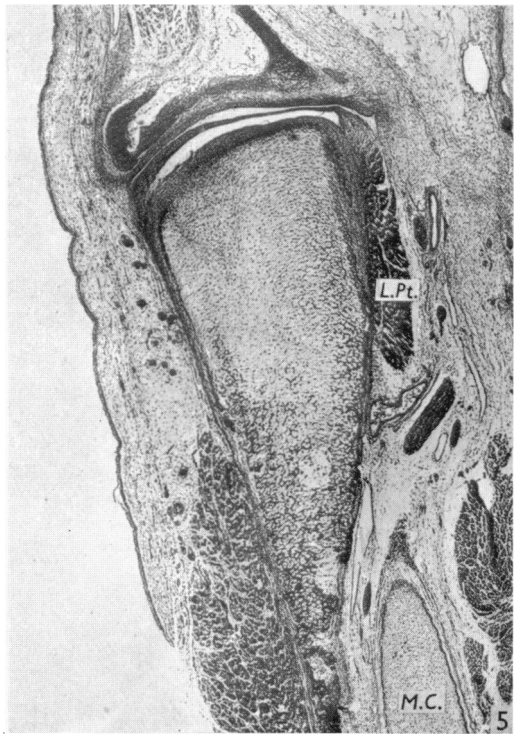
4


Zyg.
L.Pt.
Cond.
M.C.
3


L.Pt.
M.C.
5


Malleus
Incus.
Lat.
pterygoid
m.
6