Chapter 6 Remodelling in the Articular Surface of the Temporomandibular Joint in Man.

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Chapter 6.

Remodelling in the Articular Surfaces of the Temporomandibular Joint in Man.

I. Introduction.

The temporomandibular joint in man reaches maturity at about the age of 20 years. However, before that time remodelling is evident within the joint (BLACKWOOD, 1966 a), in response to the functional requirements of the joint.

Changes in the articular surfaces may be pathological, as in the cases of rheumatoid or osteoarthritis, or may be due to functional or age changes. Histologically the difference between early arthritic changes and normal aging changes may be difficult to discern (JOHNSON, 1959). In aged joints the difference between the arthritic changes and normal age changes is basically a matter of degree.

JOHNSON (1959, 1962) has classified the different types of remodelling that are evident in all joints. These he referred to as progressive, regressive and circumferential.

These classifications have been referred to the temporomandibular joint by MOFFETT et al (1964), BLACKWOOD (1959, 1966a 1969) and GRIFFIN et al (1975).

II. Material.

In order to study the remodelling within the articular elements of the temporomandibular joint a lateral and medial sagittal section from two of the aged human joints were included, while a lateral sagittal section of the third was considered. As there was variation in the histological features of sections from different medio-lateral depths of the joint, it was decided to describe the histological features of the lateral and medial sections to obtain an overall impression of the pattern of remodelling that was presented in these joints.

Most sections were stained with H and E but cartilage matrix was identified with aldehyde fuchsin stain.

III. Results.

1. Joint one

A. Lateral.

A low power view of a lateral section from joint 1 (Fig. 6-1), showed that the condyle had been affected by remodelling, especially on the anterior articular slope of the condyle and the articular eminence of the temporal bone.

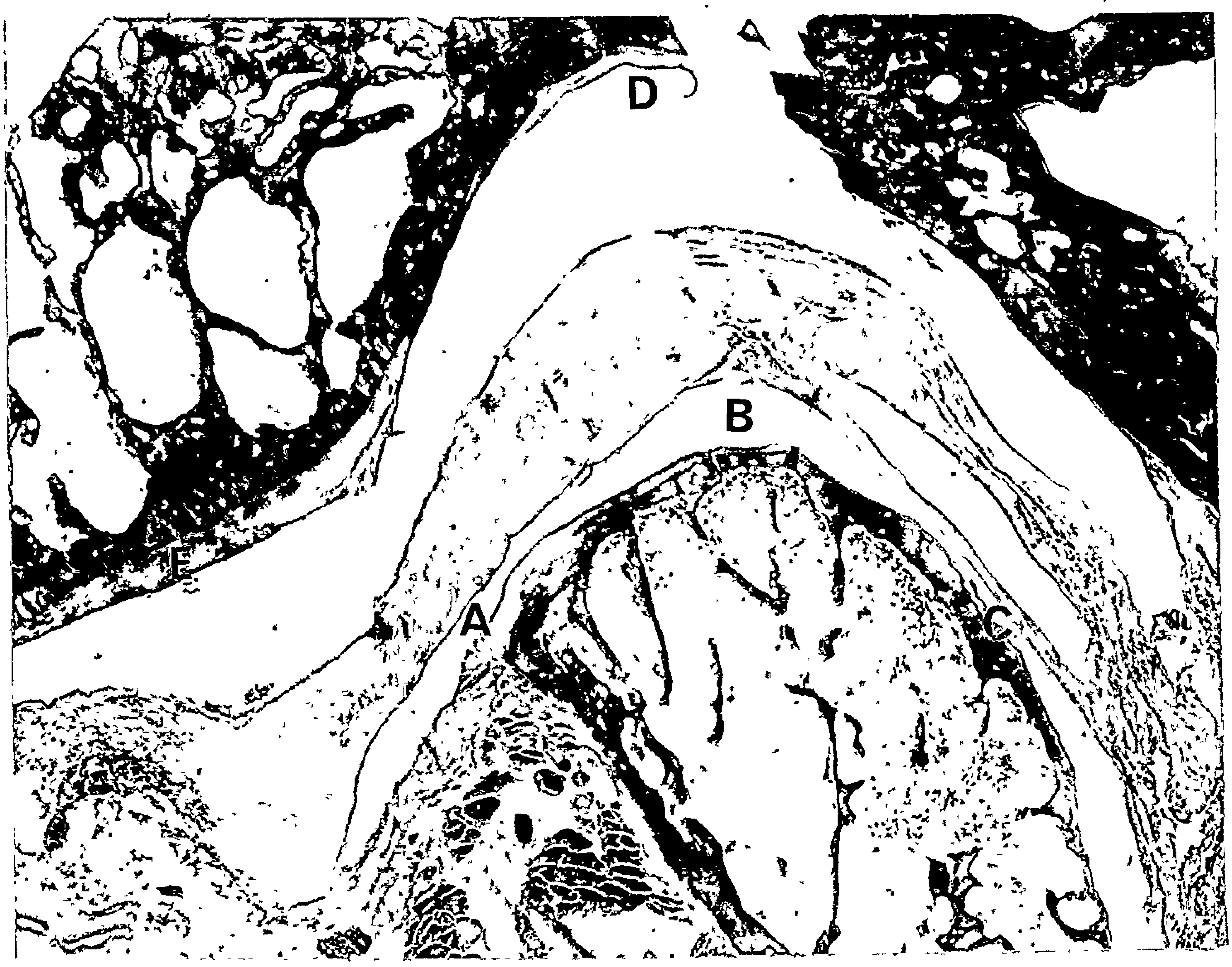

Figure 6-1. Lower power photomicrograph of joint 1, lateral section x 4 (H and E).

A	-	Anterior articular slope of condyle
B	-	Crest of condyle
C	-	Posterior articular slope of condyle
D	-	Roof of mandibular fossa
E	-	Articular eminence

The posterior articular surface of the condyle also appeared to have been remodelled. The bilaminar zone of the meniscus appeared to have split, although this could have been a sectioning artefact.

i. Anterior Articular Slope of the Condyle.

The anterior articular slope of the condyle exhibited an interesting pattern of remodelling. In the more anterior part (Figs. 6-1, 6-2 and 6-3) there was a thickening of the articular connective tissue covering the cortical compacta of the condyle. This articular tissue was composed of several layers.

The superficial layer was a relatively thin strip of fibrous tissue in which there were a number of flattened fibroblastic cells. Below this fibrous tissue was a thick layer of fibrocartilaginous tissue, within which were roundish cells that resembled chondrocytes. This tissue was identified as fibrocartilage because the matrix, in certain areas, was aldehyde fuchsin positive. This tissue did not appear to be well orientated but rested upon a thin layer of well orientated tissue that had numerous small flattened chondrocytes. This layer resembled the zone of young and flattened chondrocytes that was found in the young monkey.

Figure 6-2. Surface of the articular tissue of the anterior extremity of the anterior articular slope of the condyle. x 300 (H and E).

A - Fibrous layer

B - Fibrocartilage

C - Chondrocyte

D - Cellular layer

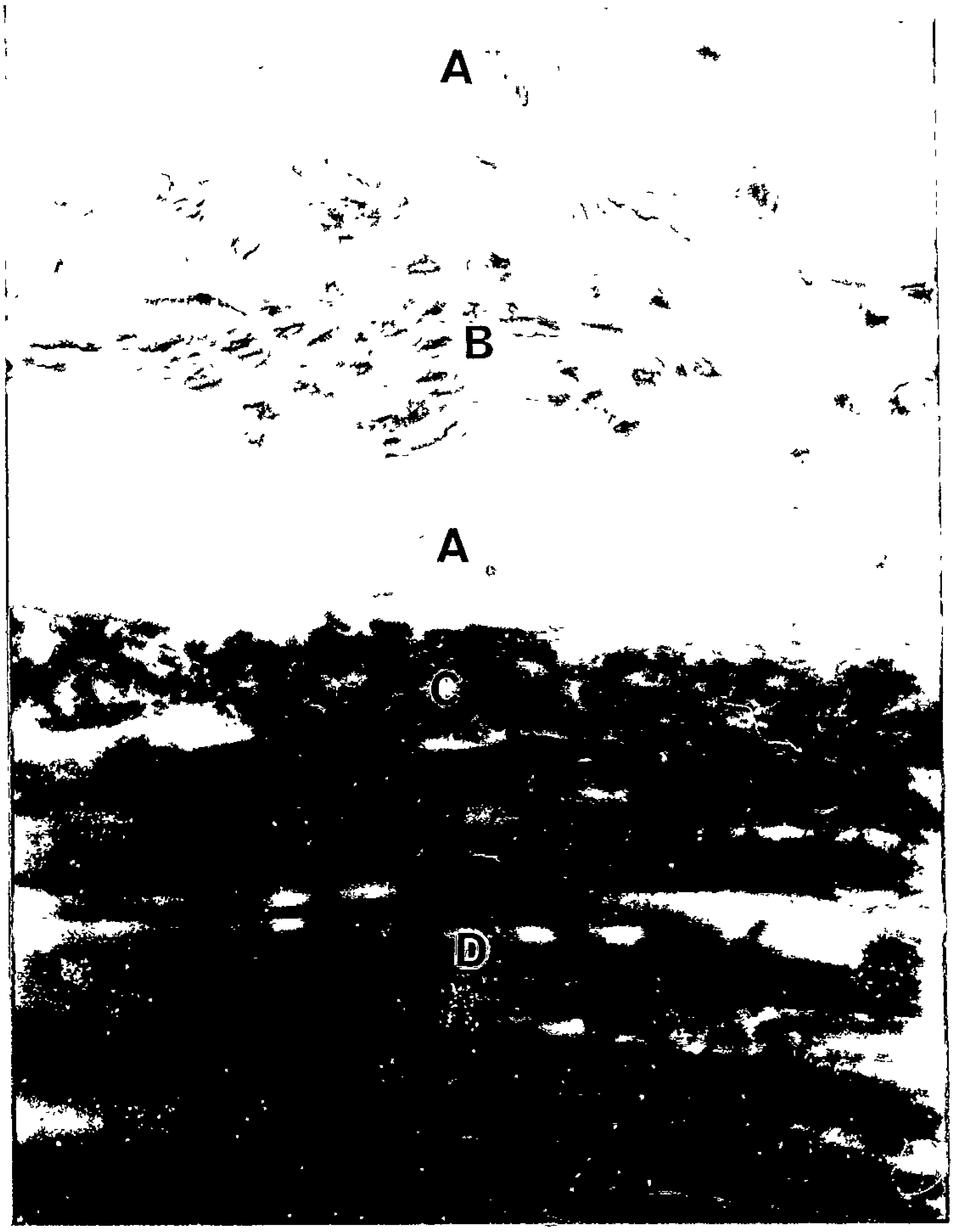

Figure 6-3. Deep layer of the articular tissue of the anterior extremity of the anterior articular slope of the condyle x 300 (H and E).

A - Fibrocartilage

B - Cellular layer

C - Calcified cartilage

D - Cortical compacta

A moderately thick acellular layer separated this tissue from a layer of calcified cartilage that was in contact with the cortical compacta of the condyle. Within the thin layer of calcified cartilage were small chondrocytes. Few osteocytes were present in the bone and there was a marked linear pattern of cement lines in the cortical compacta, which ran parallel to the surface of the condyle.

Slightly posterior to this area (Figs. 6-1, 6-4 and 6-5), the articular tissue was considerably different.

The surface fibrous layer was thick and definitely orientated (Fig. 6-4). Abrasion of the surface of this layer was also evident. This surface tissue was in contact with a fairly thick layer of fibrocartilage, in which there were a small number of chondrocytes. This tissue lay above a thick layer of connective tissue containing remnants of calcified cartilage, which was completely disorganised. A small number of chondroid cells were present within the underlying cortical compacta where horizontal incremental lines could be observed (Fig. 6-5).

Slightly posterior to this region, a similar remodelling process could be observed. (Fig. 6-6).

Figure 6-4. Surface of the articular tissue of the anterior articular slope of the condyle, slightly posterior to (Figs. 6-2 and 6-3) x300 (H and E).

A	-	Fibrous layer
B	-	Abrasion
C	-	Fibrocartilage
D	-	Calcified cartilage

Figure 6-5. Deep layer of the articular tissue of the anterior articular slope of the condyle, slightly posterior to Figs. 6-2 and 6-3 x 300 (H and E).

A - Calcified cartilage

B - Cortical compacta

Figure 6-6. Deep layer of the articular tissue of the anterior articular slope of the condyle, slightly posterior to Figs. 6-4 and 6-5 x 300 (H and E).

A - Fibrocartilage

B - Chondrocyte

C - Calcified cartilage

D - Cortical compacta

ii. Crest of Condyle.

The crest of the condyle was covered by a thin layer of fibrous tissue that contained a number of flattened fibroblasts. These cells were orientated according to the curvature of the condyle (Fig. 6-7). This tissue was in contact with a thin layer of calcified cartilage that formed the superior surface of the cortical compacta. Lacunae and haversian systems were present in the underlying bone (Fig. 6-7).

iii. Posterior Articular Surface of the Condyle.

The posterior articular surface of the condyle was lined by a layer of relatively acellular fibrous tissue, however in the tissue adjacent to the bone some undefined cells were present. There appeared to be defects in the cortical compacta adjacent to the cells in the articular tissue. These defects were not in harmony with the cement lines but presented an appearance similar to that seen in association with bone resorption by osteoclastic activity. There did not appear to be a layer of calcified cartilage separating the articular surface from the underlying bone. (Fig. 6-8).

Figure 6-7. Apex of the condyle x 300 (H and E).

A	-	Fibrous tissue
B	-	Fibroblast
C	-	Calcified cartilage
D	-	Cortical compacta
E	-	Haversian system

Figure 6-8. Articular surface of the posterior articular slope of the condyle x 300 (H and E).

A - Fibrous tissue

B - Undefined cells

C - Apparent defect

D - Cement lines

iv. Articular Eminence of the Temporal Bone.

The articular surface of the articular eminence was covered by a thick layer of tissue that was arranged in several layers (Figs. 6-1, 6-9 and 6-10).

The superficial layer of the articular eminence was covered by a thick layer of fibrous tissue with a number of flattened cells, orientated in an antero-posterior direction. This was in contact with a thick layer of fibrocartilage that appeared to be roughtly orientated at right angles to the surface of the eminence (Fig. 6-9). Chondrocytes were present within this fibrocartilage. Beneath the fibrocartilage was a cellular layer of chondrocytes (Fig. 6-10). Remnants of calcified cartilage, that were embedded in the connective tissue, separated the cellular layer from the subarticular bone (Fig. 6-10).

v. Roof of the Mandibular Fossa.

In contrast to the articular eminence the mandibular fossa was lined by a thin layer of connective tissue (Figs. 6-1 and 6-11).

The roof of the mandibular fossa was lined by tissue similar to that found over the rest of the fossa.

Figure 6-9. Surface of the articular eminence of the temporal bone x 300 (H and E).

A - Fibrous tissue

B - Fibrocartilage

C - Chondrocyte

Figure 6-10. Deep layer of the articular tissue of the articular eminence x 300 (H and E).

A - Fibrocartilage

B - Cellular layer

C - Calcified cartilage

D - Bone

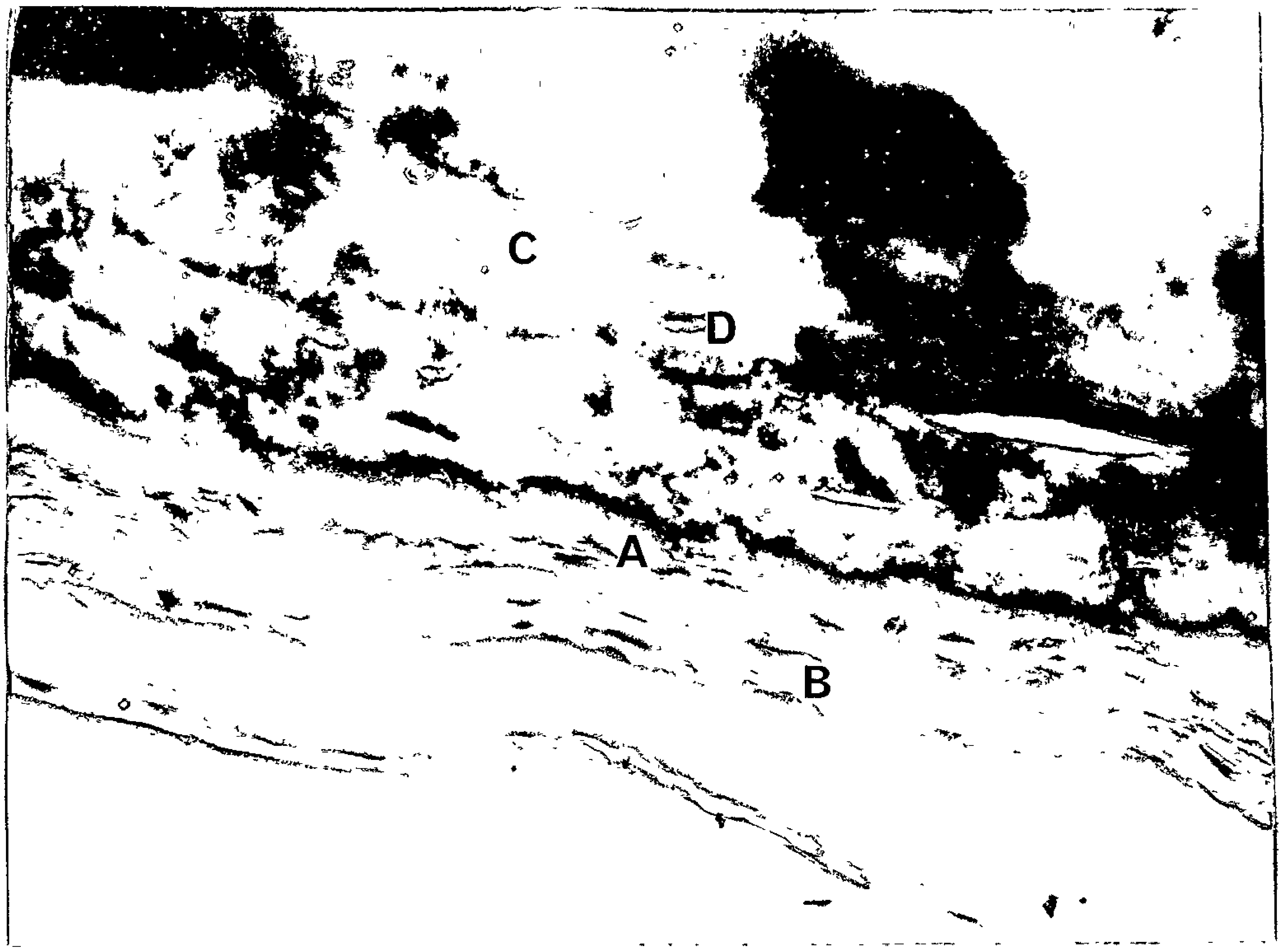

Figure 6-11. Articular surface of the roof of the mandibular fossa x 300 (H and E).

A - Fibrous tissue

B - Fibroblast

C - Cement line

D - Osteocyte

It consisted of a thin layer of fibrous tissue with a moderate number of fibroblast type cells, orientated in an antero-posterior direction. Cement lines were present in the underlying bone and a number of osteocytes were present in this bone.

B. Medial.

The articular surface of the condyle, in the medial sagittal section of joint 1, was different to that of the lateral section (Figs. 6-1 and 6-12).

i. Anterior Articular Slope of the Condyle.

The anterior extremity of the articular slope showed an outgrowth of bone (Fig. 6-13). The curvature of this outgrowth seemed to correspond to the haversian system with which it was associated. The tissue that covered the outgrowth appeared to be sparsely cellular fibrocartilage, orientated over the curvature of the bone. Some chondroid cells were present forming an indistinct layer in the middle of the fibrocartilage. A thin layer of calcified cartilage lined the bone.

In contrast, the articular tissue of the anterior articular slope of the condyle consisted of several layers (Fig. 6-14). The fibrocartilage, that was present in the anterior extremity covered the

Figure 6-12. Low power photomicrograph of joint 1, medial section x 4 (H and E).

A - Anterior articular slope of the condyle

B - Crest of the condyle

C - Posterior articular slope of the condyle

D - Roof of the mandibular fossa

E - Articular eminence

Figure 6-13. Anterior extremity of the anterior articular slope of the condyle x 300 (H and E).

A - Fibrocartilage

B - Chondroid cell

C - Calcified cartilage

D - Haversian system

Figure 6-14. Anterior articular slope of the condyle x 200 (H and E).

A - Fibrocartilage

B - Cellular layer

C - Calcified cartilage

D - Haversian system

surface. A prominent cellular layer of chondrocytes lay midway through the thickness of the articular tissue (Fig. 6-14). Below this was an irregular layer of fibrocartilage that contained very few chondrocytes. Intruding up into this fibrocartilage were remnants of calcified cartilage, that appeared to be devoid of cells. The calcified cartilage was in close proximity to the edge of an haversian system, the cement lines of which were easily recognised (Fig. 6-14.

ii. Crest of the Condyle.

The outer layer of the articular tissue of the crest of the condyle consisted of fibrocartilage and a moderate number of chondrocytes. A relatively acellular layer that contained only a few flattened chondrocytes, was present below the surface fibrocartilage (Fig. 6-15). A layer of calcified cartilage was not apparent.

iii. Posterior Articular Slope of the Condyle.

The surface of the articular tissue of the posterior articular slope consisted of fibrous tissue, which appeared to be acellular in the surface region (Figs. 6-16 and 6-17).

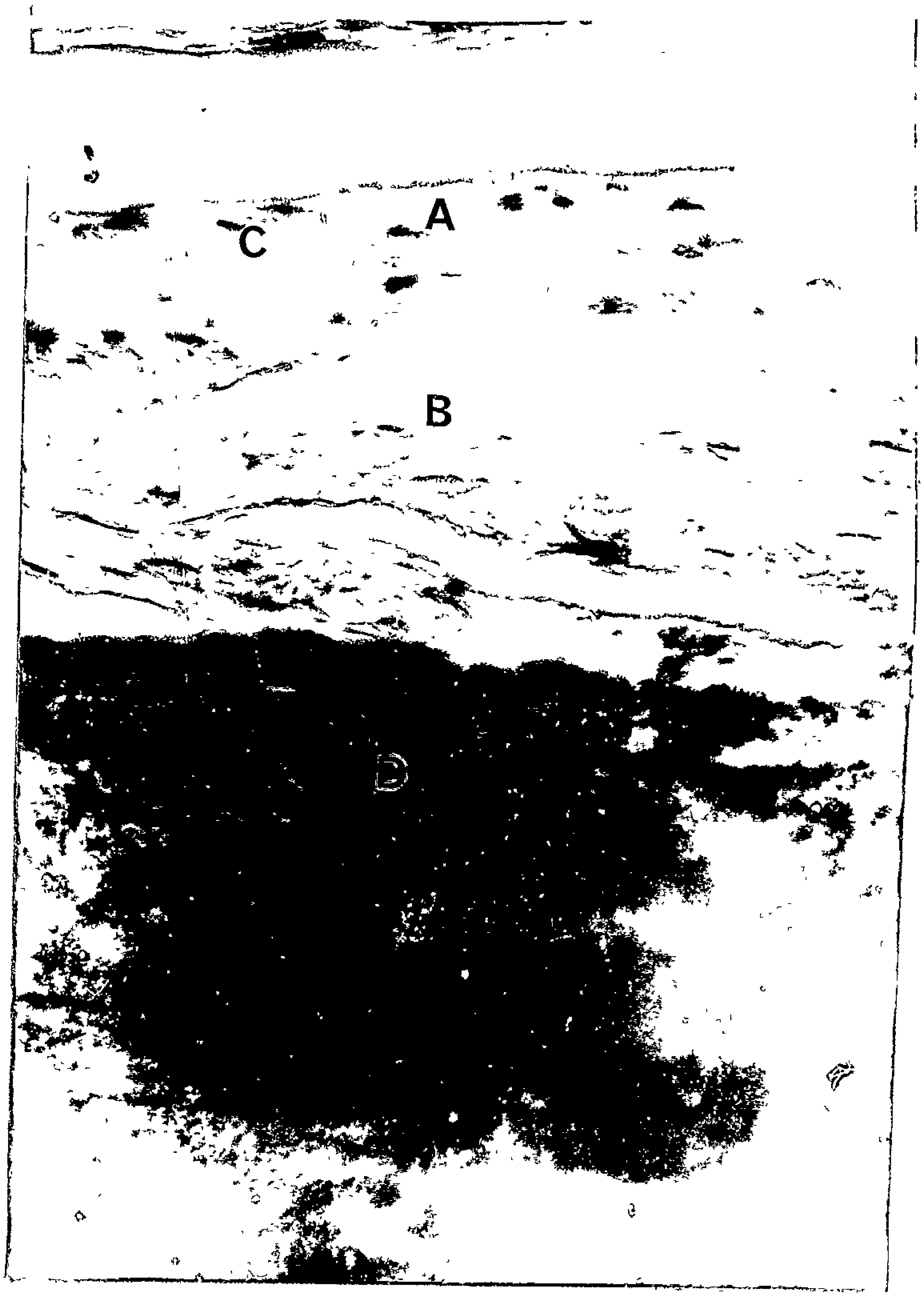

Figure 6-15. Crest of the condyle x 300 (H and E).

A - Surface fibrocartilage

B - Relatively acellular fibrocartilage

C - Chondrocyte

D - Cortical compacta

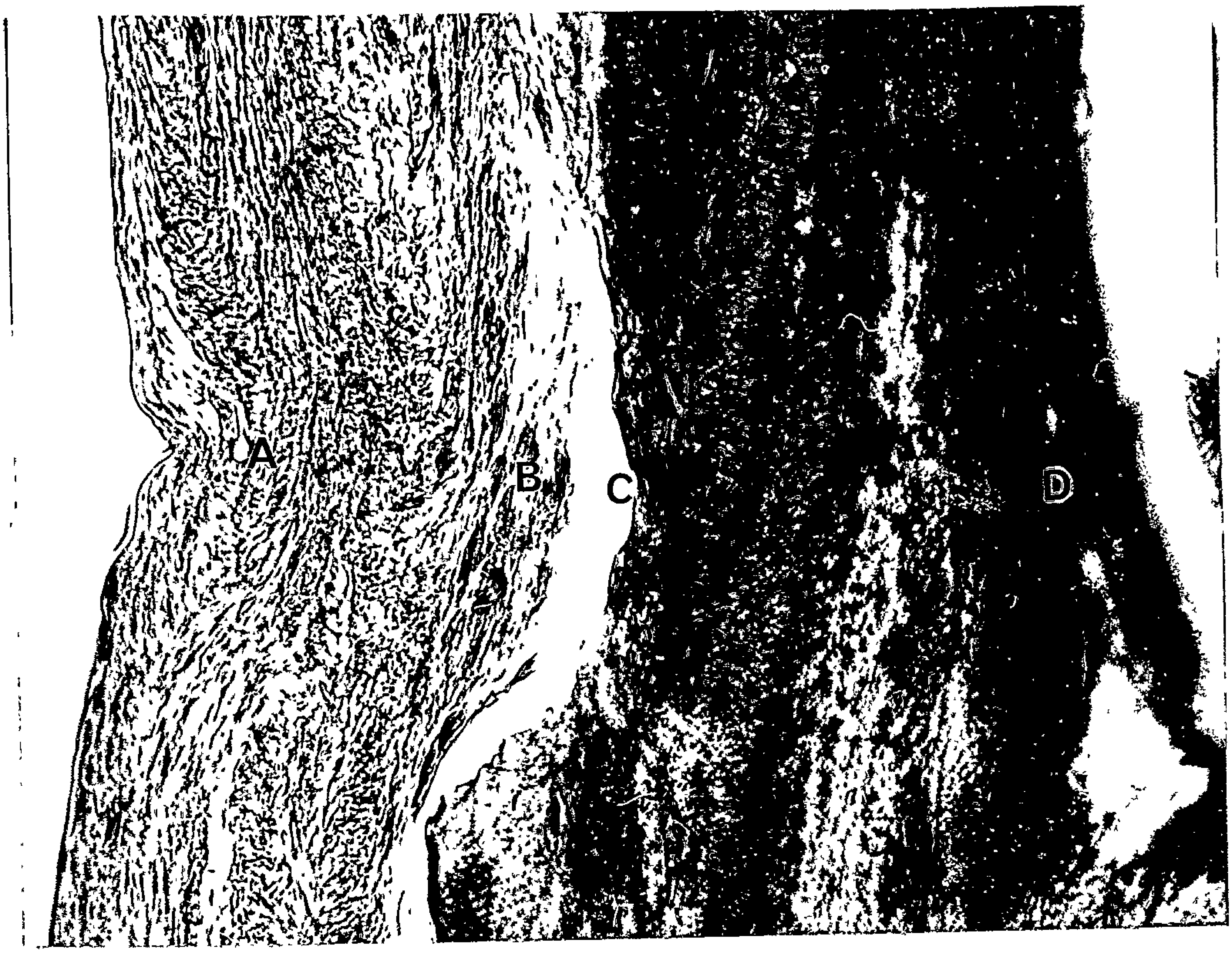

Figure 6-16. Posterior articular slope of the condyle x 300 (H and E).

A - Fibrous tissue

B - Flattened cells

C - Defect

D - Cement line

Figure 6-17. Posterior articular slope of the condyle, adjacent to Figure 6-16 x 150 (H and E).

A - Fibrous tissue

B - Flattened cell

C - New bone

D - Osteoblast

E - Haversian system

In the deeper parts several areas of flattened cells were associated with defects (Fig. 6-16), while others were associated with new bone (Fig. 6-17).

Although this defect formation resembled a cleft produced by osteoclastic activity, no osteoclasts were observed. However, in each case where resorption was evident, there were cells in the overlying tissue (Fig. 6-16).

In areas adjacent to these areas of apparent resorption, were areas that appeared to be the formation of new haversian systems (Figs. 6-17 and 6-18). These areas consisted of a groove in the cortical compacta. In this groove was vascular mesenchyme. New bone formation was evident forming a lip over the groove, preparatory to the closing over of the groove to form a haversian system. In the adjoining bone was what appeared to be a new haversian system (Fig. 6-17).

In other areas there were cells, in contact with the bone, that were reminiscent of osteoblasts (Fig. 6-17).

Figure 6-18. Posterior articular surface of the condyle x 300 (H and E).

A - Fibrous tissue

B - New bone

C - Blood vessel

iv. Articular Eminence of the Temporal Bone.

The tissue that lined the articular eminence was made up of several indistinct layers.

The surface was provided by a fairly thin layer of fibrocartilage which rested upon fibrocartilage, in which there were wavy orientated fibres (Fig. 6-19). Below this layer was fibrocartilage in which the fibres were obliquely orientated. Throughout this entire thickness of fibrocartilage were a moderate number of chondroid type cells. In the deep part of the articular tissue was an area that gave the appearance of being the remnants of the cellular layer (Fig. 6-20) that was apparent in the lateral section (Fig. 6-10). Below this cellular zone was more fibrocartilage, in which remnants of calcified cartilage were evident. In the cortical compacta the cement lines ran parallel to the articular surface, but an area of erosion was present in the cortical compacta close to the junction of bone and calcified cartilage (Fig. 6-20).

v. Roof of the Mandibular Fossa.

The articular tissue of the roof of the mandibular fossa resembled periosteum and consisted of a fibrous layer, and a cellular layer that was in contact with the calcified cartilage above the cortical compacta (Fig. 6-21).

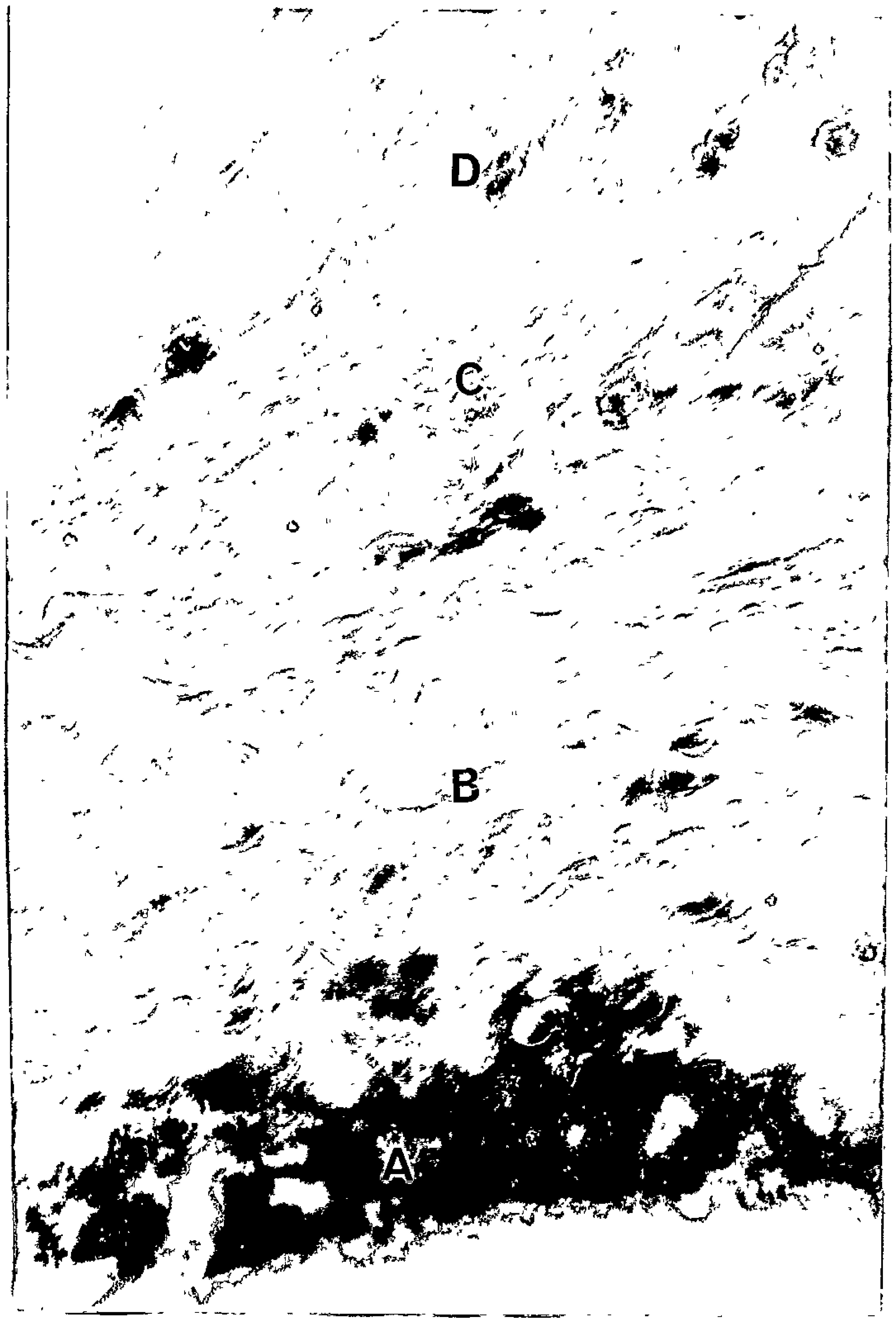

Figure 6-19. Surface articular tissue of the articular eminence x 300 (H and E).

A - Surface fibrocartilage

B - Fibrocartilage

C - Oblique fibres

D - Chondroid cell

Figure 6-20. Deep tissue of the articular eminence x 300 (H and E).

A - Oblique fibrocartilage

B - Remnants of cellular layer

C - Calcified cartilage

D - Cortical compacta

E - Erosion

Figure 6-21. Articular tissue of the roof of the mandibular fossa x 30 0 (H and E).

A - Fibrous layer of periosteum

B - Cellular layer of periosteum

C - Calcified cartilage

D - Haversian system

The fibrous layer contained a small number of flattened cells, while the cellular layer contained many small cells (Fig. 6-21). Calcified cartilage separated the articular tissue from the underlying cortical compacta in which haversian systems were present (Fig. 6-22).

2. Joint Two.

The head of the condyle of the second joint differed greatly from that of the first (Fig. 6-23).

A. Lateral.

i. The Anterior Articular Slope of the Condyle.

A thin layer of chondrific tissue lined the articular surface of the condyle on its anterior articular slope (Fig. 6-24). Beneath this was a very thin layer of fibrous tissue in which were a few flattened cells orientated strictly in an antero-posterior direction. This fibrous tissue rested upon a thick layer of fibrocartilage that was randomly orientated and contained several chondrocytes (Fig. 6-24), below which was a cellular layer of flattened chondrocytes. A relatively thin layer of fibrocartilage lay beneath the cellular layer. This fibrocartilage was continuous with a layer of calcified cartilage (Figs. 6-24 and 6-25). The edge of a relatively new haversian system intruded into this calcified cartilage (Fig. 6-25).

Figure 6-22. Subarticular bone of the roof of the mandibular fossa x 300 (H and E).

A - Haversian system.

Figure 6-23. Low power photomicrograph of joint 2, Lateral section x 8 (H and E).

A	-	Anterior articular slope of condyle
B	-	Crest of condyle
C	-	Posterior articular slope of condyle
D	-	Roof of mandibular fossa
E	-	Articular eminence

Figure 6-24. Anterior articular slope of the condyle x 300 (H and E).

A - Chondrific tissue

B - Fibrous tissue

C - Fibrocartilage

D - Cellular layer

E - Calcified cartilage

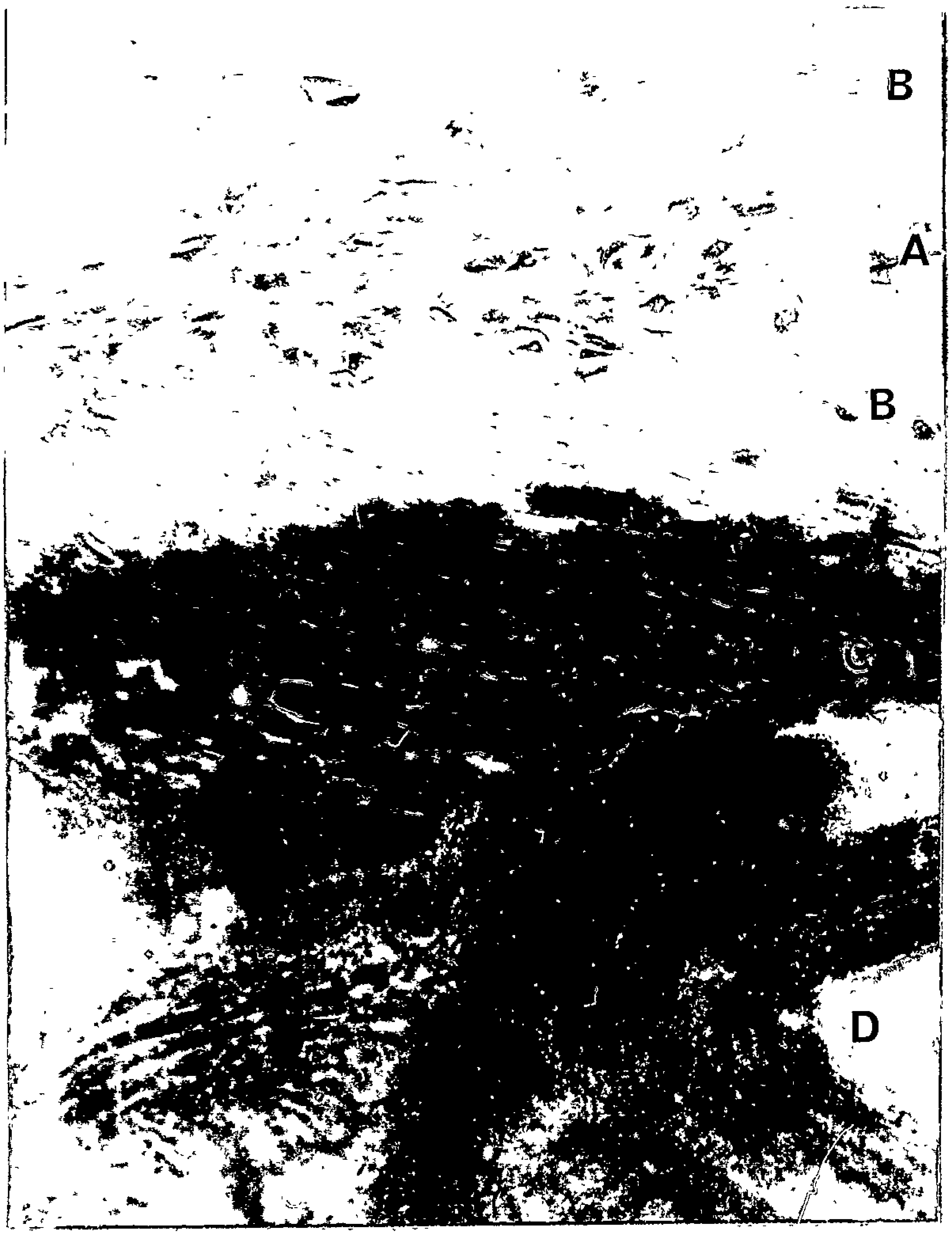

Figure 6-25. Deep layer of the anterior articular slope of the condyle x 300 (H and E).

A - Cellular layer

B - Fibrocartilage

C - Calcified cartilage

D - Haversian system

ii. Articular Surface of the Crest of the Condyle.

The articular surface of the crest of the condyle, in the second joint, was vastly different to that found in the first joint.

The articular tissue of the second joint was exceedingly thick. The surface was made up by a layer of fibrous tissue, below which was a thicker layer of fibrocartilage (Fig. 6-26). A layer of young and resting chondrocytes was evident below this fibrocartilage. Beneath the cellular layer was a region of hypertrophic chondrocytes (Figs. 6-26 and 6-27). Remnants of calcified cartilage were present around the hypertrophic chondrocytes and some small chondrocytes were also present (Fig. 6-27). Bone was in contact with this tissue.

iii. Posterior Articular Surface of the Condyle.

The posterior articular surface was covered by a layer of fibrous tissue that contained a few fibroblasts (Fig. 6-28). This tissue was in contact with a thin layer of calcified cartilage that rested upon cortical compacta, in which there were irregular cement lines.

Figure 6-26. Surface of the articular surface of the crest of the condyle x 300 (H and E).

A - Fibrous tissue

B - Fibrocartilage

C - Cellular layer

D - Hypertrophic chondrocyte

Figure 6-27. Deep layer of the articular tissue of the crest of the condyle x 300 (H and E).

A - Young and resting chondrocyte

B - Hypertrophic chondrocyte

C - Calcified cartilage

D - Small chondrocyte

Figure 6-28. Posterior articular slope of the condyle x 300 (H and E).

A - Fibroblast

B - Calcified cartilage

C - Cement line

iv. Articular Eminence of the Temporal Bone.

Fibrous tissue formed the surface layer, however, the bulk of the tissue of the eminence was fibrocartilage (Fig. 6-29). Although the fibrocartilaginous layer contained many chondrocytes of varying degrees of maturity, a distinct cellular layer was not evident. Hypertrophic chondrocytes were present in the deeper layers of the tissue (Figs. 6-29 and 6-30), especially near the junction with the calcified cartilage (Fig. 6-30). Remnants of calcified cartilage were present in the deepest part of the fibrocartilage (Fig. 6-30).

v. Roof of the Mandibular Fossa.

The roof of the mandibular fossa was lined by a relatively thin layer of fibrous periosteum that contained a few flattened cells (Fig. 6-31). This tissue appeared to be in contact with the cortical compacta below, in which several cement lines were present.

B. Medial.

i. Anterior Articular Slope of the Condyle.

The articular tissue of the anterior articular surface consisted of a thickened layer of fibrocartilage, in which remnants of calcified cartilage were evident in close proximity to the cortical compacta (Fig. 6-32).

Figure 6-29. Articular eminence of the temporal bone x 150 (H and E).

A	-	Fibrous tissue
B	-	Fibrocartilage
C	-	Chondrocyte
D	-	Calcified cartilage

Figure 6-30. Deep layer of the articular tissue of the articular eminence x 300 (H and E).

A - Hypertrophic chondrocyte

B - Calcified cartilage

C - Cortical compacta

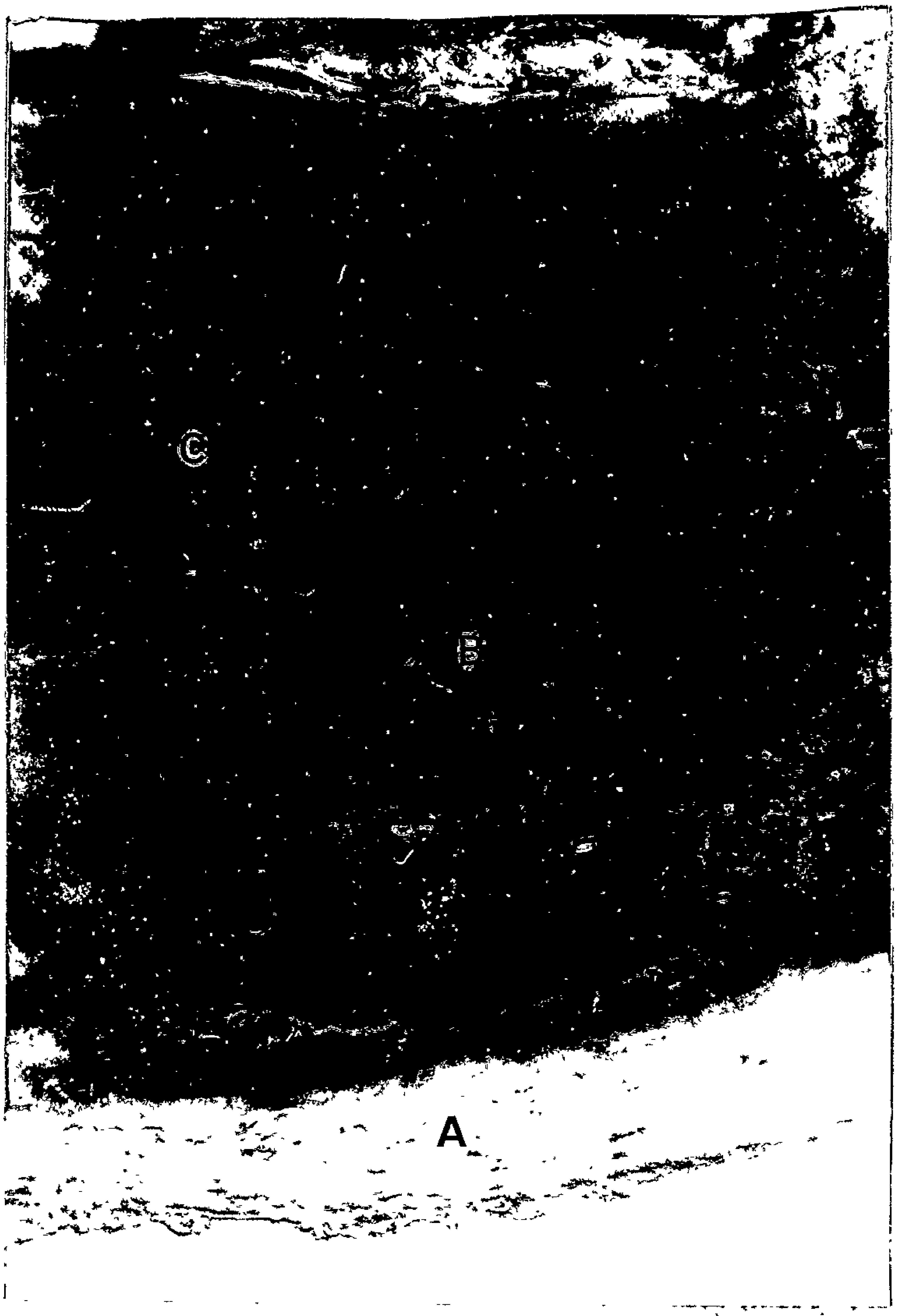

Figure 6-31. Roof of the mandibular fossa x 150 (H and E).

A - Fibrous periosteum

B - Cortical compacta

C - Cement line

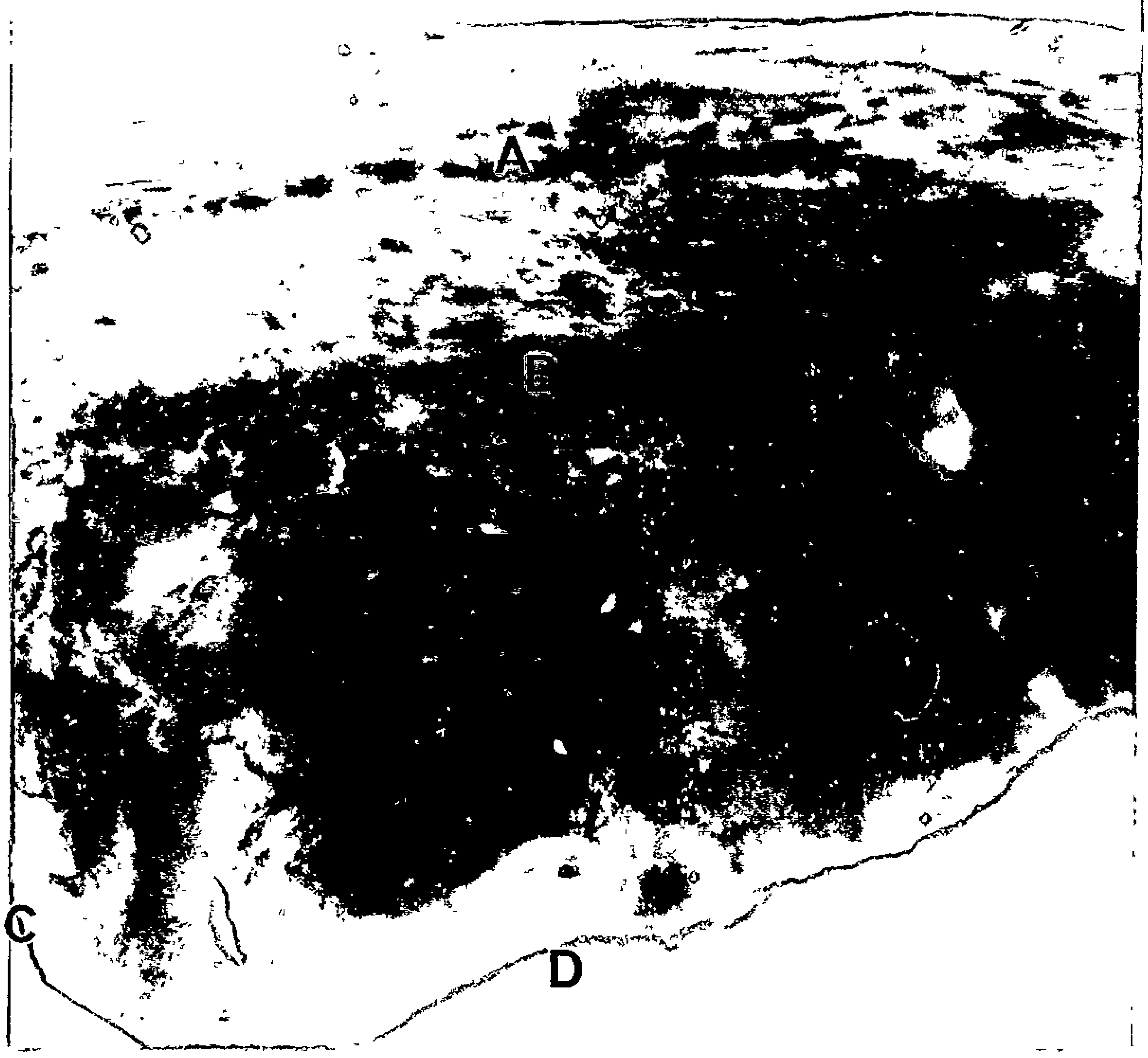

Figure 6-32. Anterior articular slope of the condyle of joint 2, medial section x 150 (H and E).

A - Fibrocartilage

B - Calcified cartilage

C - Haversian system

D - Medullary space

A small number of chondrocytes were present throughout the layer of fibrocartilage. Several haversian systems, that were in contact with the medullary space, were in close proximity to the calcified cartilage.

ii. Crest of the condyle.

The crest of the condyle was covered by a thick layer of fibrocartilage (Figs. 6-33 and 6-34). The surface fibrocartilage rested upon an indiscreet cellular layer of small flattened chondrocytes (Figs. 6-33 and 6-34). A thick layer of fibrocartilage with a few chondrocytes lay below the cellular layer. In the base of this tissue were remnants of calcified cartilage. Haversian systems were not well defined in the cortical compacta, but several areas of erosion were present (Figs. 6-33 and 6-35).

iii. Posterior Articular Slope of the Condyle.

A relatively thin layer of fibrocartilage lined the posterior articular slope of the condyle (Fig. 6-36). This tissue was directly in contact with the cortical compacta without any evidence of calcified cartilage. Cement lines were present in the cortical compacta adjacent to the medullary space, but disorganised bone with lacunae was present, adjacent to the fibro-cartilage.

Figure 6-33. Articular surface of the crest of the condyle x 150 (H and E).

A - Fibrocartilage

B - Cellular layer

C - Calcified cartilage

D - Area of erosion

Figure 6-34. Surface articular tissue of the crest of the condyle x 300 (H and E).

A - Fibrocartilage

B - Cellular layer

Figure 6-35. Deep layer of the articular tissue of the crest of the condyle x 300 (H and E).

A - Fibrocartilage

B - Calcified cartilage

C - Cortical compacta

D - Area of erosion

Figure 6-36. Posterior articular slope of the condyle x 300 (H and E).

A	-	Fibrocartilage
B	-	Chondrocyte
C	-	Cement line
D	-	Medullary space

iv. Articular Eminence of the Temporal Bone.

The articular eminence was covered by a thin layer of fibrous tissue over a thick layer of fibrocartilage that contained a cellular layer of flattened chondrocytes (Fig. 6-37). The cells deep to this layer were hypertrophic chondrocytes (Fig. 6-38). Remnants of calcified cartilage were present in the deep layers of the fibrocartilage which was in contact with the cortical compacta.

v. Roof of the Mandibular Fossa.

The roof of the mandibular fossa was lined by a thin layer of fibrous tissue that was in contact with the cortical compacta below. This tissue was identical to that in Figure 6-31.

3. Joint Three.

A. Lateral.

The remodelling in the third joint was similar to that seen in the first joint. Only the articular eminence of the temporal bone will be described here.

The articular eminence was lined by a layer of fibrous tissue orientated over the curvature of the eminence (Fig. 6-39). The rest of the tissue of the articular eminence was made up of fibrocartilage,

Figure 6-37. Surface of the articular eminence of the temporal bone x 300 (H and E).

A - Fibrous tissue

B - Fibrocartilage

C - Young and resting chondrocyte

Figure 6-38. Deep layer of the articular tissue of the articular eminence x 300 (H andE).

A - Hypertrophic chondrocyte

B - Calcified cartilage

C - Cortical compacta

Figure 6-39. Surface layer of the articular tissue of the articular eminenc of joint 3. x 300 (H and E).

A - Fibrous tissue

B - Fibrocartilage

C - Chondrocyte

Figure 6-40. Deep layer of the articular tissue of the articular eminence of joint 3 x 300 (H and E).

A - Fibrocartilage

B - Calcified cartilage

C - Cortical compacta

D - Cement line

throughout which were many chondrocytes. These cells were found throughout most of the thickness of the fibrocartilage and thus did not form a discreet layer. Below the fibrocartilage were remnants of calcified cartilage which were in contact with the underlying cortical compacta (Fig. 6-40). Even cement lines were noted in the cortical compacta.

IV. Discussion.

Remodelling of the articular surfaces of joints has been recognised for many years (OGSTON, 1875, 1878). OGSTON (1875, 1878) described three zones in the articular tissue of the joint surfaces. He described a zone of 'central growth' that was found in the more superficial half of the articular tissue. This cellular layer was made up by a proliferation of new cartilage cells and was later referred to as the proliferative zone by BLACKWOOD (1959; 1966 a,b; 1969). The presence of this proliferative zone has been confirmed by the H3-thymidine studies of MANKIN, (1962 a,b) TONNA and CRONKITE (1964) and BLACKWOOD (1966b). In these studies it was found that the H3-thymidine accumulated in the proliferative zone in the short, term, but was also found in the deeper tissue after some time.

OGSTON (1875, 1878) described a zone, deep to the proliferative zone, where the cartilage cells formed into columns to form a pattern similar to an epiphyseal growth plate. This zone was referred to as the hypertrophic zone by BLACKWOOD (1959; 1966 a,b; 1969). This zone was produced from the proliferative zone, as was indicated by the H3-thymidine study of BLACKWOOD (1966 b). In this study it was found that the H3-thymidine, that had been initially found in the proliferative zone, was also found in the hypertrophic zone, after 1 day in the rat.

A superficial layer was described by OGSTON (1875, 1878) where the removal of disintergrated cells and cartilage was accomplished by articular movement. This area was defined as the articular layer by BLACKWOOD (1959; 1966 a,b; 1969). The H3-thymidine study of BLACKWOOD (1966 b), indicated that this zone was not derived from the proliferative zone but was maintained from its own cells.

HEINE (1926) studied 1000 gross specimens of joints and correlated the changes that occurred with age. He found that normal articular cartilage grew throughout life, but with increased age this growth potential lost much of its vigour. PUTSCHAR (1931) and SHARPE et al (1965) reported similar conclusions, but SHARPE et al (1965) indicated that there was always a growth potential in the human condyle.

The articular cartilage contributes to growth in bones (JOHNSON, 1959), but it is also of vital importance in the remodelling of the articular surfaces, in response to functional requirements (WEISS, 1940). WEISS (1940) drew particular attention to the presence of incremental lines which indicated intermittent periods of growth. These incremental lines generally developed in the non-weight bearing parts of a joint. In weight-bearing areas a thick subchondral plate is found instead of the incremental lines (JOHNSON, 1959).

JOHNSON (1959, 1962) described three types of remodelling that occurred in the articular surfaces of joints. He referred to these as progressive, regressive and circumferential. This description of remodelling was discussed in connection with the temporomandibular joint by MOFFETT et al (1964) and BLACKWOOD (1959; 1966 a,b; 1969).

MOFFETT et al (1964) referred to the bone underlying the articular connective tissue as subchondral bone because it was usually covered by a thin layer of calcified cartilage (Fig. 6-3). However, in some areas no calcified cartilage was apparent (Fig. 6-16 and 6-17). It seems likely therefore that the term subchondral bone could only be used in cases where calcified cartilage was present.

Progressive remodelling, as described by MOFFETT et al (1964) depended upon invasion of the calcified cartilage by vascular channels from the underlying subchondral bone. In contrast, regressive remodelling was dependent upon the resorption of bone occuring at the junction of the calcified cartilage and the subchondral bone.

BLACKWOOD (1959; 1966 a,b; 1969) described three cell zones in the mature mandibular condyle. These were the articular zone, the proliferative zone and the hypertrophic zone. He also reported mineralisation of the deeper layers of the fibrocartilage, which was indicated by the deeper basophilic staining of this material (Fig. 6-40). He noted that the chondrocyte lacunae, in general, were much smaller than those in growing cartilage (Fig. 6-40). On this basis BLACKWOOD (1966a) defined progressive remodelling as being indicated by hypertrophy of the cells of the proliferative zone (Fig. 6-26 and 6-27). Proliferation in the proliferative zone resulted in thickening of the fibrocartilage layer with subsequent mineralisation of the fibrocartilage (Fig. 6-38).

BLACKWOOD (1966a) stated that the mineralisation front, at all times, remained approximately parallel to the articular surface (Fig. 6-38).

He emphasised that these changes occurred with no apparent changes in the articular layer (Fig. 6-37). When activity ceased, the proliferative zone returned to its normal width. BLACKWOOD (1966a) suggested that the significant feature was the absorption of the mineralised cartilage by osteoclastic activity, and its replacement by haversian bone. He found progressive remodelling to occur on the condyle and the articular eminence of the temporal bone.

BLACKWOOD (1966a) found that regressive remodelling was associated with osteoclastic resorption of the subarticular bone and the adjacent layer of calcified cartilage. This resorption cavity was filled by vascular mesenchymal tissue, and rapid proliferation of the articular tissue in that area. Proliferation of the articular tissues appeared to involve the proliferative zone. He indicated that any mineralised cartilage would have previously been removed during the resorptive phase. When repair of the area commenced there appeared to be differentiation of the mesenchymal tissue to produce bone, or cartilage, or both. He also noted that the surface articular zone remained intact and appeared to conform passively to changes occuring below it. BLACKWOOD (1966a) observed that regressive remodelling was most common on the posterior articular slope of the condyle.

It is difficult to correlate completely the observations of MOFFETT et al (1964) and BLACKWOOD (1959, 1966 a, 1969) with the present material. The normal appearance of the condyle, as described by BLACKWOOD (1966a), may be seen in Figures 6-2, 6-3, 6-24, 6-25, 6-34 and 6-35. Here a surface articular zone, a proliferative zone, a zone of fibrocartilage and some calcified cartilage could be observed. Similar zones were present covering the articular eminence (Figs.6-9, 6-10, 6-37 and 6-38).

The earliest indications of progressive remodelling , as described by BLACKWOOD (1966a) were seen to be hypertrophy of the cells in the proliferative zone,with increased matrix production. This was followed by an advancement of the mineralisation into the fibrocartilage (Figs. 6-37, 6-38, 6-26 and 6-27).

The third phase, resorption of the mineralised cartilage by osteoclastic activity, was not observed. However, replacement of the calcified cartilage by haversian bone was occasionally seen (Figs. 6-13 and 6-14).

Regressive remodelling was mainly seen on the posterior articular slope of the condyle. Osteoclastic activity could not be positively identified, however resorption cavities filled with vascular mesenchyme were noted (Figs. 6-17 and 6-18). It has been suggested that osteoclasts were difficult to identify because of the fixation and preparation of these tissues (MOFFAT, 1975). The embalming fixation of the cadavers could not be expected to provide good histological material, and the decalcification of this tissue by 5% nitric acid has also been indicated to damage the tissues (CLAYDEN, 1962).

The resorption cavities that were noted along the posterior articular slope of the condyle resembled periosteal remodelling. In many cases it was not possible to determine whether the resorptive cavities would progress to form new haversian canals, or whether they would resorb the subarticular bone, thereby causing regressive remodelling. The articular tissue of the posterior articular slope of the condyle did not possess the same components that were found in the other areas of the articular surfaces of the temporomandibular joint; instead it resembled periosteum. It is impossible to postulate as to whether this tissue could regain a structure similar to that found in the other articular surfaces, following adequate stimulus. However such an arrangement did not appear to be necessary for the production or removal, of bone from the posterior articular surface of the condyle.

Table 6-1. Remodelling of the articular surfaces of the temporomandibular joint in aged humans.

	J1L	J1M	J2L	J2M	J3L
Ant. condyle	-	P	-	-	-
Ant. art. condyle	P	P	P	P	P
Crest condyle	-	-	P	P	-
Post. art. condyle	R	P+R	-	-	R
Art. eminence	P	P	P	P	P
Mand. fossa	-P	-P	-P	-P	-P

- \- No active remodelling present

R - Regressive remodelling

P - Progressive remodelling

J1 - Joint 1

M - Medial section

L - Lateral section

It is suggested that there may be two different mechanisms responsible for remodelling in the temporomandibular joint. Remodelling of the progressive type was observed in association with a thick articular tissue in which the basis of a proliferative zone existed. Although MOFFETT et al (1964) and BLACKWOOD (1966a) claimed that regressive remodelling was also possible by this mechanism, the present writer did not observe such a situation due perhaps to the relatively small number of joints examined.

MOFFETT et al (1964) examined 34 joints and BLACKWOOD (1966a) examined 45 joints. MOFFET et al (1964) observed active regressive remodelling in the condyle of 12 of these joints. BLACKWOOD (1966a) did not indicate the frequency with which he noted regressive remodelling. From the report of MOFFETT et al (1964) it may be suggested that active regressive remodelling occurs in approximately 30% of temporomandibular condyles in adults 45 years of age or older.

The pattern of remodelling observed by the present writer was similar to that found by MOFFETT et al (1964) and BLACKWOOD (1966a, 1969).

The observations made were sumarised in Table 6-1 and may be sumarised thus:

Progressive remodelling occurred in the anterior articular slope and crest of the condyle, and also in the roof of the mandibular fossa and the articular eminence. Regressive and progressive periosteal remodelling were evident of the posterior articular slope of the condyle, with the regressive remodelling appearing to be more common.

The remodelling of the articular surfaces of the temporomandibular joint represent a functional analysis of the articulation. Different functional stimuli result in different remodelling patterns, as was evident in joints one and two. RAMFJORD and ASH (1966) claimed that occlusal disharmony stimulated remodelling, while orthodontic treatment has also been claimed to cause remodelling (THILANDER, 1963, 1965). Experimentally this stimulus-remodelling relationship has been demonstrated in monkeys by several authors (BREITNER, 1941; JANZEN and BLUHER, 1965 ; MEIKLE, 1970).

Chapter 7.

Conclusions.

Several conclusions may be drawn from the previous descriptions and discussions.

It is apparent that the cellular content of the elements of the temporomandibular joint change considerably with increase in age, and functional stress. These changes are apparent in all tissues of the joint.

The meniscus of the 16 week foetus was a highly cellular structure that was composed primarily of fibroblasts, with a small number of fine collagen fibres. The different areas of the meniscus, the pes menisci, the pars gracilis menisci and the pars posterior menisci were all similar in strucutre.

The immature meniscus of the 4 month Bonnet monkey was quite different to the foetus, in that there was a reduction in the cellular content of the meniscus and an increase in the fibrous content. Different structural organisation of the different parts of the meniscus could be discerned.

The cellular content of the aged meniscus showed gross changes. Again there was a decrease in the cellularity, but perhaps more importantly there was a change in the cell type from fibroblastic, in the young and immature meniscus, to a chondroid type cell in the aged. However, a large population of cells remained of the fibroblastic type. The metaplasia of the fibroblasts to chondroid type cells was more apparent in the pars gracilis menisci and the pars posterior menisci than in the pes menisci.

As with the meniscus degeneration of the synovial membrane was noted. In the 16 week foetus a prominent synovial membrane was present in intimate contact with the joint compartment spaces. In the 4 month monkey a very distinct synovial membrane was also apparent, but the cells of the synovial membrane were covered by a thin fibrous tissue layer. In the aged joints there was a considerable reduction in the cellularity of the synovial membrane of the menisucs. The degeneration of the synovial membrane of the meniscus with age was not as evident at the reflections of the meniscus onto the bony elements of the joint. At the reflections a cellular synovial membrane was present in intimate contact with the synovial cavity throughout life.

The articular tissues of the condyle and the temporal bone exhibited profound changes with increased age.

The articular tissue of the roof of the mandibular fossa was seen to change from a thickish perichondrium in the 16 week foetus and 4 month monkey, into a thin periosteum in the aged human. Incremental lines in the underlying bone indicated that progressive remodelling had previously occurred in that area.

The articular tissue of the articular eminence of the temporal bone began as a perichondrium similar to that of the roof of the mandibular fossa in the young monkey. With increased function and age this tissue thickened and became fibrocartilaginous. However, it retained a cellular arrangement similar to that found in the immature joint, but in which activity appeared to be reduced. This resulted in the appearance of a cellular layer in the mid-region of the tissue. This layer resembled the layer of young and resting chondrocytes that was so apparent in the foetus and young monkey.

The condylar articular tissue retained its basic structure during all stages of development and aging. In the foetus and young monkey the condyle was covered by a perichondrium, and a condylar growth centre, similar to that of an epiphyseal plate, was also present. However, in the aged condyles this tissue changed in the different areas of the condyle, in response to forces that were generated in function. The anterior articular slope of the condyle developed a thickened articular tissue layer, whereas the posterior articular slope was covered by a thin layer of tissue that resembled periosteum. The tissue of the crest of the condyle was seen to be thinned in some instances, while in others it was thickened by a proliferation of cartilage. This proliferation originated from the proliferative zone that was apparent as the zone of young and resting chondrocytes in the immature condyles.

It was found that there was remodelling of the articular surfaces of all parts of the bony elements of the temporomandibular joint. This remodelling was initiated by stress on particular areas of the joint resulting from the functional activity of the joint.

The writer agrees with BLACKWOOD (1959; 1966 a,b; 1969) that a proliferation of the proliferative zone is the first histological indication of active remodelling in the articular surfaces of the temporomandibular joint. This proliferative zone produces fibrocartilage, which may be converted to bone, in the case of progressive remodelling, or to connective tissue, in the case of regressive remodelling. With progressive remodelling the articular surface of the bone moves towards the joint compartment by the process of bone deposition. In regressive remodelling the height of the articular surface is reduced by a bony resorptive process.

In areas where the articular tissue resembles periosteum progressive or regressive periosteal remodelling is possible.

In conclusion it may be suggested that increased age leads to a reduction in the activity of the tissues of the temporomandibular joint, but the basic structure of the fully formed embryonic joint remain throughout life.

Appendix 1. Staining Technique for Lillie/Mayer Haemotoxylin and Eosin.

1. Sections to 70% alcohol
2. Stain with haematoxylin (Lillie/Mayer) for 10 minutes
3. Wash in running water for 5 minutes
4. Differentiate
5. Blue in running water for 5 minutes
6. Stain with eosin for 5 minutes
7. Rinse in running water
8. Dehydrate, clear and mount

Appendix 2. Staining Technique for van Gieson

1. Sections to water
2. Stain with Weigert's hamatoxylin for 10 minutes
3. Wash with tap water
4. Rinse in distilled water
5. Stain with van Gieson for 4 minutes
6. Rinse in distilled water, then 95% alcohol
7. Dehydrate, clear and mount

Appendix 3.

Gomori's Aldehyde Fuchsin Stain.

1. Bring sections to water

2. a) Deparaffinise in Xylol - 10 minutes

   b) Rinse in two changes in 100% alcohol (1 min. each)

   c) Rinse in 70% alcohol (1 min)

   d) Wash in tap water

   e) Rinse in distilled water

2. Wash in running tap water for 2 minutes

3. Rinse in distilled water

4. Rinse in 70% alcohol

5. Stain in Gomori's Aldehyde Fuchsin Stain for up to 2 hours (Lillie ed 3p 556 - store 0-5°C - make fresh weekly

6. Wash in several changes of 95% alcohol until all excess stain is removed.

7. Counterstain in 0.5% light green stain for few seconds

8. Rinse in 95% alcohol. Dehydrate in 100% alcohol (at least 2 changes)

9. Clear sections in Xylol.

10. Mount

Appendix 4. Formulation of Eosin used.

The following Eosin was used as a 25% Working Solution.

Eosin	1gm	1gm
Potassium dichromate		0.5gm
Saturated aqueous picric acid		10 mg
95% alcohol		10mls
Distilled water		80mls

To make 100 mls of solution

Appendix 5.

Sequence of Development Observed by SYMONS (1952).

Approximate Gestation Age - weeks	Development
7	First evidence of the condylar process Attachment of lateral pterygoid.
8	Ossification of the temporal elements Evidence of the articular fibrous tissue Membranous bone from the ramus invades the condylar process.
10	Secondary cartilage evident on the condyle Formation of the inferior joint cavity
12	Superior joint cavity formed Strands of tissue connect the articular disc to the articular elements.

Appendix 6.

Sequence of Development Observed by FURSTMAN (1963)

Approximate Gestation Age - weeks	Development
6	Ossification of the anterior 1/3 mandible.
8	Ossification of the temporal elements of the joint.
	Attachment of external pterygoid muscle.
10	Condensation of mesenchyme at the superior end of the bony core of membranous bone - future condyle.
12	Inferior joint cavity evident
	Attachment of internal pterygoid muscle
14	Superior joint cavity formed.
22	Intramembranous bone formation in the temporal region
	Glenoid fossa well formed
	Articular disc well formed.

Appendix 7.

Sequence of Development Observed by YUODELIS (1966).

Approximate Gestation Age - weeks	Development
6	Slight condensation of mesenchyme in the temporal region (zygomatic process) Ossification of anterior 1/3 of mandible.
7	Analage of condylar process recognised. Attachment of external pterygoid to condyle.
8	Membranous bond from the mandible penetrates the condylar process. Ossification of the temporal region of joint.
10	First evidence of inferior joint cavity. Highly condensed fibrous tissue covering anterior surface of condyle.
12	Superior joint cavity evident. Condylar and temporal elements come into correct relationship.
14	Endochondral bone evident in the condyle. Fibrous strands connect the meniscus to the articular surface.

Appendix 8.

Age and Length of embryos and foetuses.

Adapted from PATTEN (1948)

Age (weeks)	Crown-rump length (mm)
6	12 -13
7	19-20
8	28-39
9	39-41
10	51-53
11	64-66
12	77-79
13	91-93
14	105-107
15	119-121
16	132-134
18	± 160
20	± 185
22	± 208
24	± 230
28	± 270
32	± 310

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