From: Dental Institute of Experimental Research, and Institute of Pathological Anatomy, Rikshospitalet, University of Oslo, Norway.

A MICRORADIOGRAPHIC AND ELECTRON MICROSCOPIC STUDY OF THE CEMENTUM OF HUMAN DECIDUOUS TEETH

by

RANDI FURSETH

INTRODUCTION

Several investigations have been carried out on the cementum of permanent teeth, while only a few studies have been concerned with the cementum of deciduous teeth.

In a quantitative microradiographic study of the calcium content in the cementum, *Röckert* (1958) found that the amount of calcium in the cementum of deciduous teeth did not differ from that of the permanent teeth. *Keller* (1964) studied the cementum of deciduous teeth by means of polarized light and found cellular and acellular cementum as in the permanent teeth. The main difference between the cementum in the two dentitions was found in the cellular cementum of the deciduous teeth and consisted of "a very pronounced radiation of the Sharpey's fibers in a layer devoid of cells and similar to fibrous cementum". In a histochemical study of the cementum, *Haim* (1961) found that while the mineralized ground substance stained orthochromatic, the cementoid and the walls of the lacunae and canaliculi stained metachromatic. This was common for both the permanent and the deciduous teeth, but the staining reaction of the cementocytes

differed. Thus, the cytoplasm of the cementocytes in the permanent teeth stained metachromatic, while the reverse was found in the deciduous teeth.

On account of the limited information available on the cementum of deciduous teeth, is was found pertinent to investigate this tissue further to see if the cementum of the deciduous teeth differed from the cementum of the permanent teeth. Particular emphasis was placed on the study of the ultrastructure of the cementocytes and the adjacent cementum, as information on this subject is scarce.

MATERIALS AND METHODS

Thirty eight deciduous human teeth extracted in the Clinic of Oral Medicine and Oral Surgery, Dental Faculty, University of Oslo, and in various school dental clinics in Oslo were used in this study. The teeth had been extracted because of pulpitis, periapical pathological conditions or for orthodontic reasons. Teeth in which some of the soft tissue adhered, were preferred because the soft tissue gave a possibility to see if inflammation was present adjacent to the tooth area studied.

The teeth were fixed immediately after extraction in one of the following fixatives.

1. 2.5 % glutaraldehyde in Sörensen's phosphate buffer at pH 7.3.
2. 4 % formaldehyde buffered to pH 7.2 with Sörensen's phosphate buffer and 7.5 % sucrose (*Holt* and *Hicks*, 1961).
3. 4 % formaldehyde buffered to pH 7.2 with Sörensen's phosphate buffer.

The teeth were fixed at room temperature or at about 4°C where refrigerators were available.

Light microscopy

After fixation 15 teeth were decalcified for 24 hours in 5.2 % nitric acid, dehydrated in graded alcohols, embedded in paraffin, sectioned and stained with hematoxylin and eosin.

Microradiography

After fixation 16 teeth were cut on a Gillings-Hamco Thin Sectioning Machine and the thickness of the sections was reduced

by grinding on abrasive papers to 60—250 microns. Microradiographs were produced on Kodak Spectroscopic plates 649—0 with a Phillips X-ray diffraction unit type PW 1009, operated at 20 kV and 20 mA. Nickel-filtered copper radiation were used, and the unit was supplied with a fine focus tube. The target-film distance was 26 cm, and exposure time varied from ½ to 2 hours. This technique has been shown to demonstrate the distribution of mineral salts in bone and dental tissues (*Bergman* and *Engfeldt,* 1964).

Electron microscopy

a. Decalcified material

After fixation, small pieces of 4 teeth with the adjacent soft tissue were cut off from the tooth with a rotating diamond disc under water spray and decalcified for one week in 3 changes of 0.3M EDTA at pH 7.0. The specimens were then postfixed at 4°C in 1 % buffered OsO_4 at pH 7.3, dehydrated in graded solutions of acetone and embedded in Vestopal W (*Ryter* and *Kellenberger,* 1958). For the purpose of orientation, and in order to find out if inflammation was present in the adjacent soft tissue, thick sections (2—3 microns), cut on a Cambridge Ultramicrotome, Huxley Pattern, were taken at intervals and stained with 0.1 % toluidine blue in 0.067 M $NaHPO_4$. Thin sections were cut with glass knives on a LKB Ultrotome I, collected on formvar- and carbon-coated grids, and floated on a saturated solution of uranyl acetate in 30 % alcohol for 30 minutes and subsquently stained with lead citrate for 5 minutes (*Reynolds,* 1963). The sections were then examined in a Siemens Elmiskop I electron microscope operated at 80 kV.

b. Undecalcified material

After fixation small pieces of the teeth with adhering soft tissue were cut out and postfixed at 4° C in OsO_4 at pH 7.3. The specimens were then dehydrated in graded acetone solutions and embedded in Vestopal W. Sections were cut with a diamond knife on a LKB Ultrotome I. Some sections were examined unstained, while some were stained for 5 minutes with lead citrate, and 1 or 30 minutes in uranyl acetate. The subsequent procedures were identical with those described for the decalcified material.

FINDINGS

Cellular cementum

Light microscopic examination showed that the cementum in the coronal half of the root was mainly of the acellular type (Fig. 1). The cementum layer was rather thin close to the cemento-enamel junction, but increased in thickness towards the apex. The cementum stained heavier than the dentin (Fig. 1), and the cemento-dentinal junction and the surface of the cementum formed straight and smooth lines.

Microradiographs of the acellular cementum showed that the cementum was separated from the dentin by a radiodense line approximately 10 microns wide. On both sides of the cemento-dentinal junction, radiolucent areas were observed of which the granular layer of Tomes was the widest (Figs. 3, 4, 5). The remaining part of the cementum exhibited a relatively uniform mineral distribution. In a few instances incremental lines could be discerned (Fig. 5). In most specimens the mineral content of the cementum seemed less or fairly equal to than the mineral content of the dentin (Fig. 3), while two specimens showed a decidedly higher mineral content in the cementum (Fig. 4).

Ultrathin sections of the acellular cementum showed that Sharpey's fibers were oriented at approximately right angles to the cemento-dentinal junction (Figs. 9, 10). The characteristic cross-banding of collagen was seen in the periodontal space, but it was partly obscured as the fibers entered the cementum. The fibers could be followed into the cementum for varying lengths and the cementum surface appeared serrated (Fig. 9). Undecalcified sections showed that the cementum was relatively electron dense (Fig. 10). Immediately beneath the cemento-dentinal junction an electron lucent zone was observed but further into the dentin the mineral content seemed to increase again (Fig. 10). At higher magnification the individual crystals could be seen (Fig. 11), and they appeared as electron dense, needle-shaped structures with a width in the range of 65Å, and less electron dense plates with a length in the range of 600Å.

Cellular cementum

In the apical third of the root the cellular cementum dominated (Fig. 2). The cellular cementum did not stain as heavily as

the acellular type, and the exact location of the cemento-dentinal junction was often difficult to determine (Fig. 2). The surface was also more uneven than that of the acellular cementum. Cementum lacunae were frequently observed and several of the lacunae contained a cellular component (Fig. 2).

In microradiographs the cellular cementum appeared less mineralized than the acellular variety (Fig. 5). A radiodense line at the cemento-dentinal junction was sometimes present (Fig. 5) and sometimes absent (Fig. 6). No distinct incremental lines were seen. Cementum lacunae of a roundish or ovoid shape approximately 8 microns in diameter were regularly observed (Fig. 6, 7, 8), and in some areas large radiolucent caverns were noticed (Figs. 7, 8). Canals extended from these caverns and could be followed for some distance into the surrounding tissue. The walls of the caverns usually had the same mineral content as the rest of the tissue (Fig. 8), but in a few instances caverns with highly mineralized walls could be seen (Fig. 7).

In the electron microscope the surface of the cellular cementum appeared considerably more irregular than that of the acellular variety (Fig. 12) and the collagen fibers of the matrix also had a somewhat more irregular arrangement, especially in the neighbourhood of the lacunae. Thus, fibers running parallel to and at angles to the plane of section were observed (Figs. 18, 22). The cementum lacunae and canaliculi were surrounded by a narrow, electron dense zone (Figs. 13, 14, 15, 20, 22). The contents of the canaliculi were difficult to make out, but seemed to consist of a granular or fine fibrillar material (Fig. 15). The cementocytes close to the cementum surface (3—6 microns) resembled the cementoblasts, but the amount of cytoplasm was less, and they contained less mitochondria and endoplasmic reticulum (Figs. 13, 14). The mitochondria had a granular appearance and did not exhibit the typical cristae mitochondrales. The endoplasmic reticulum appeared dilated, and cytoplasmic ribosomes were abundant (Fig. 13). The shape of the nucleus varied and the nuclear chromatin was most abundant at the periphery of the nucleus (Figs. 13, 14). In the cells close to the surface of the cementum, the cytoplasm was immediately adjacent to the lacunar wall in most instances, but in some areas a narrow zone, 100–150Å

wide, could be seen between the cytoplasm and the lacunar wall (Fig. 13).

The cementocytes situated at some distance from the surface appeared different from those close to the surface. Fig. 18 shows a cell approximately 65 microns from the cementum surface where the nucleus appeared normal, while the cytoplasm had a fine reticulated appearance with few identifiable organelles. Fig. 15 shows a cementocyte which exhibited even more marked changes. The central part of the nucleus had a peculiar honeycomb appearance. In one area of the cytoplasm a dense material was observed which was thought to be accumulated metabolites. Remnants of mitochondria could still be seen, and the cytoplasm had partly shrunk away from the lacunar wall, and filaments were observed in the resulting space. Different nuclear changes were also observed. Clumped nuclear material (Fig. 16) and cells where the nuclear material seemed to have almost disappeared (Fig. 17) were noticed. The amount of cytoplasm was also markedly reduced in both instances. Fig. 19 shows a lacuna with collagen fibers and a fine fibrillar material in the periphery, while the center of the lacuna contains a material which might be nuclear debris. In some instances lacunae which were almost empty in the plane of the section were seen (Figs. 20, 21) while other lacunae contained a considerable amount of collagen fibers (Fig. 22). Fibers were also observed close to the lacunar wall where the cell still occupied a major part of the lacunae (Figs. 14, 16). The two lacunae shown in Figs. 21 and 22 were found approximately 75 microns away from the cementum surface, and the total thickness of the cementum in this area was 100 microns.

DISCUSSION

The cementum of the deciduous teeth appeared to be similar to the cementum of the permanent teeth in most respects.

The radiodense line found to border cementum and dentin in deciduous teeth, corresponds to that demonstrated in permanent teeth (*Soni et al.*, 1962; *Yamamoto et al.*, 1962; *Furseth*, 1965, *Anneroth et al.*, 1966). The fact that incremental lines could only be seen in the middle portion of the root where the cementum was relatively thick (Fig. 5) while they were absent in the coronal areas, suggests that the lines are situated so close together that

they are not resolved with microradiography when comparatively thick sections were used. The finding in two instances of a higher mineral content in the cementum than in the dentin (Fig. 4) is interesting, since both qualitative microradiography (*Dreyfuss* and *Frank*, 1964; *Furseth*, 1965) and chemical analysis of permanent teeth (*Sicher*, 1962) showed that the cementum has a lower mineral contant (46 %) than the dentin (69 %). A high mineral content in the cementum in the specimens were a consistent finding from the coronal part of the root towards the apex, and thus it is not at result of exposure to the oral environment. Microradiographs of cellular cementum showed that this variety was less mineralized than the acellular one, and this corresponds to findings in permanent teeth (*Soni et al.*, 1962; *Furseth*, 1965). This phenomenon however, might be due to a summation effect of lacunae in the cellular cementum. The absence or presence of a radiodense line on the cemento-dentinal junction also was in accordance with findings in permanent teeth (*Furseth*, 1965).

While the cellular cementum in permanent teeth usually exhibits incremental lines with high mineral content, the cellular cementum in the deciduous teeth seemed to have a more uniform mineral distribution, and distinct incremental lines were not seen. The caverns observed in the cellular cementum corresponded to those described by *Dreyfuss* and *Frank* (1964) in the cementum of permanent teeth.

The electron microscopic picture of acellular and cellular cementum was very similar to that described for permanent teeth (*Herting*, 1963; *Selvig*, 1965). The electron dense needle-shaped crystals and the less electron dense plates were similar to the ones observed in dentin and bone (*Johansen* and *Parks*, 1960). These authors, using stereoscopic techniques, concluded that the crystals were plate formed. The crystals were oriented with their long axis parallel to the long axis of the collagen fibers.

The cementocytes appeared to be similar to the cementoblasts (*Stern*, 1964; *Selvig*, 1964), but with less organelles. Similar observations have been made in relation to osteocytes and osteoblasts (*Dudley* and *Spiro*, 1961; *Baud*, 1962; *Cameron*, 1963; *Cooper et al.*, 1966). The endoplasmic reticulum appeared dilated, which might be a sign of poor fixation, but it may also be a normal state, since this phenomenon is nearly always seen in cemen-

toblasts (*Stern,* 1964) as well as in fibroblasts (*Ross* and *Benditt,* 1961; *Movat* and *Fernando,* 1962). The fact that the dilatations were filled with a fine granular material, might indicate the latter possibility.

The cementocytes situated close to the cementum surface seemed to fill the whole lacuna, with the exception of a few areas where a narrow zone was observed between the cytoplasm and the lacunar wall. In bone the relationship of the osteocyte to the lacunar wall seems to be a matter of dispute. *Baud* (1962) found a limiting membrane, 0.17 to 0.67 microns wide between the osteocyte and the lacunar wall, and *Dudley* and *Spiro* (1961) observed a layer of non-fibrillar material separating the cell surface from the mineralized lacunar wall. *Cooper et al. (1966)* also report the finding of a zone between the cell and the lacunar wall, but states that it contains a fibrillar material which neither had the diameter nor the crossbanding of collagen. *Cameron* (1963) however, did not observe the amorphous zone reported by *Dudley* and *Spiro,* but found parts of the cell in contact with the mineralized bone. The latter concept seems to agree with what was found in cementum in the present study.

In sections demineralized with phosphotungstic acid, *Cooper et al.* (1966) observed an electron dense zone 325 Å wide around the matrix and the unmineralized matrix. This zone corresponded to the electrondense zone observed around the cementum lacunae (Figs. 13—16). The nature of the bone matrix adjacent to lacunae and canaliculi is also a matter in which there is not general agreement. *Pritchard* (1956) and *Maximow* and *Bloom* (1957) describe a non-fibrillar material in this location, while *Robinson* and *Watson* (1952) and *Mjør* (1962) found that the bone matrix adjacent to lacunae and canaliculi had a fiber component. The findings in the present investigation agree with the findings of the latter authors. With the exception of an extremely thin electrondense zone, collagen fibers with the typical 640Å cross banding was observed in the cementum matrix adjacent to the lacunae. Even in the electrondense zone there might be a fiber component wich was obscured by the density of the material.

In some instances the fibers seemed to extend through the electron dense zone and into the lacunae (Fig. 18); while other

lacunae contained varying amounts of collagen fibers. These fibers might have been mineralized prior to EDTA-decalcification. If that was the case, it would agree with microradiographic findings in bone (*Jowsey*, 1960; *Mjør*, 1962) where hypermineralized plugged lacunae were observed. The microradiographs of cementum did not show hypermineralized, plugged lacunae, but this might be due to the fact that the sections used in this study were relatively thick (60—250 microns) while Mjør e. g. used sections in the range of 30—40 microns. This increase in thickness might obscure possible plugged lacunae. The finding of fibers in the lacunae is interesting. Naturally, one cannot say when they were deposited there, but it is tempting to speculate that they have been produced by the cementocytes prior to their deterioration.

The fact that only the cementocytes of the outer cementum layer demonstrated normal cellular details, disagrees with some of the findings at the light microscopic level (*Paynter* and *Pudy*, 1958; *Haim*, 1961), but agrees with observations made by other investigators *Kronfeld*, 1939; *Nygaard Østby*, 1939; *Held*, 1951; *Hattyasy*, 1967; *Sicher*, 1962). In the deeper layers of the cementum *Kronfeld* found small nuclei and shrunken cell bodies, further in remnants of the nuclei and fat granules, and in the deepest layers dustlike debris. This has a parallel in bone. *Frost* (1960) found that with increasing age an increasing percentage of bone cells dies. At 70 years of age 45 % of Harversian bone and 75 % of extrahaversian bone have empty lacunae. In the present study cementocytes found in the depth of the tissue (60 microns or more) did not demonstrate normal cellular detail. In some instances the nucleus seemed relatively normal, while great changes were observed in the cytoplasm (Fig. 16). Other lacunae exhibited nuclear changes in addition to the cytoplasmic changes, and some lacunae contained only cellular debris. This might be a parallel to the changes observed in the light microscope by *Kronfeld*. The question of cellular changes due to the decalcification procedures arises. Studies by *Moe* and *Kurahashi* (1966) however, showed good cellular details after 10 days of decalcification in 2.5—5 % EDTA at pH 7.4. Thus there seems to be no damaging effect of the decalcifying agent.

Another factor that has to be taken into consideration is the

question of artifacts due to delayed fixation. A recent study by *Sorenson* and *Gatewood* (1966) using radioactive formalin showed a very rapid penetration (less than ten minutes) of the entire pulp chamber when the liquid had easy access. The penetration of the cementum varied, but during the first few minutes the concentration built up more rapidly in the cementum than in the dentin.

Even if the occurrence of fixation artifacts cannot be entirely excluded, it seems reasonable to presume, on the basis of *Sorenson* and *Gatewood's* study, that the cellular changes observed in the deeper layers of the cementum are a result of poor nutritional conditions (*Provenza,* 1964) and/or ageing of the cementocytes.

SUMMARY

The structure of the cementum of 38 human deciduous teeth was studied by means of light microscopy, microradiography and electron microscopy. The ultrastructure of the cementocytes and the cementum lacunae received particular attention.

In most respects the cementum of the deciduous teeth appeared similar to the cementum of permanent teeth. In the coronal part of the root acellular cementum dominated while the cementum in the apical part was mostly of the cellular type. In most instances a radiodense line, 10 microns wide, was found on the cementodentinal junction and radiolucent caverns of varying size similar to those in permanent teeth were observed. The crystals were platelike and oriented with their long axis parallel to the long axis of the collagen fibers. However, a few dissimilarities to cementum in permanent teeth were noted. Distinct incremental lines with a high mineral content were not found in the cellular cementum of the deciduous teeth, and the cellular cementum was thinner than that in the permanent teeth. In a couple of instances the acellular cementum was observed to have a higher mineral content than the dentin.

Electron microscopy showed that the cementocytes close to the cementum surface resembled the cementoblasts, but the amount of cytoplasm was reduced, and they contained less endoplasmic reticulum and mitochondria. The cementum lacunae and canaliculi were surrounded by a thin electron dense zone.

In the cementocytes some distance from the surface several

changes were noted. Some of the lacunae contained cementocytes where the nucleus appeared normal while the cytoplasm had a fine reticulated appearance with few identifiable organelles. Cementocytes in other lacunae exhibited nuclear changes as well as cytoplasmic changes. In other lacunae varying amounts of fibers and fibrillar material were observed.

The present study seems to support the concept that only the cementocytes in the superficial layers of the cementum are vital.

RÉSUMÉ

ETUDE DU CÉMENT DES DENTS TEMPORAIRES HUMAINES PAR MICRORADIOGRAPHIE ET A L'AIDE DU MICROSCOPE ÉLECTRONIQUE.

La structure du cément de 38 dents temporaires humaines a été étudiée à l'aide du microscope optique, par microradiographie et à l'aide du microscope électronique. Une attention particulière a été portée à l'étude de l'ultrastructure des cémentocytes et des lacunes du cément.

Dans l'ensemble, le cément des dents temporaires a paru semblable à celui des dents permanentes. Dans la partie coronaire de la racine, le cément acellulaire dominait, tandis que le cément de la partie apicale était surtout du type cellulaire. Dans la plupart des cas, une ligne radio-opaque d'une largeur de 10 microns a été trouvée à la jonction cément-dentinaire, et des cavités radioclaires de diverses grandeurs, semblables à celles des dents permanentes, ont été observées. Les cristaux étaient aplatis et orientés de telle manière que leur axe longitudinal était parallèle à l'axe longitudinal des fibres collagènes. Cependant, quelques traits distinctifs ont été notés par rapport au cément des dents permanentes. On ne trouvait par dans le cément cellulaire des dents temporaires de lignes d'accroissement distinctes ayant une teneur élevée en substances minérales, et le cément cellulaire était plus mince que celui des dents permanentes. Dans quelques cas, le cément acellulaire précentait une teneur plus élevée en substances minérales que la dentine.

L'examen au microscope électronique a montré que les cémentocytes placés près de la surface du cément ressemblaient à des cémentoblastes, mais la quantité de cytoplasme était diminuée, ainsi que le réticulum endoplasmique et les mitochondries.

Les lacunes cémentaires et les canalicules étaint entourés d'une mince zone opaque.

Dans les cémentocytes placés à une certaine distance de la surface, on a noté plusieurs modifications. Quelques unes des lacunes contenaient des cémentocytes dont le noyau avait un aspect normal, tandis que le cytoplasme présentait une apparence finement réticulée et peu d'organites identifiables. Dans d'autres lacunes, les cémentocytes précentaient des altérations du noyau et du cytoplasme. Dans d'autres lacunes, on observait des fibres et des substance fibrillaires en quantité variable.

Le présente étude semble confirmer que seuls les cémentocytes des couches superficielles du cément sont vivants.

ZUSAMMENFASSUNG

EINE MIKRORADIOGRAPHISCHE UND ELEKTRONENMIKROSKOPISCHE UNTERSUCHUNG ÜBER DAS ZEMENT DER MENSCHLICHEN MILCHZÄHNE

Die Struktur des Zementes von 38 menschlichen Milchzähnen wurde mittels Lichtmikroskop, Mikroradiographie und Elektronenmikroskop studiert. Der Ultrastruktur der Zemontozyten und der Zementlakunen wurde besondere Aufmerksamkeit gewidmet.

In den meisten Beziehungen ergab es sich, dass das Zement der Milchzähne ähnlich dem Zement der permanenten Zähne war. Im koronalen Teil der Wurzel wurde hauptsächlich zellfreies Zement gefunden, während das Zement im apikalen Teil vom zellhaltigen Typus war. In den meisten Fällen wurde eine röntgendichte Linie, 10 Mikron breit, an der Zement-Dentin Grenze observiert, und auch röntgentransparente Kavernen von verschiedener Grösse ähnlich derjenigen des Zementes der permanenten Zähne. Die Kristallen waren plattenförmig und in der Weise orientiert, dass ihre lange Axe parallel mit derjenigen der Kollagenfibern verlief. Jedoch wurden einige Unterschiede zwischen Milchzahnzement und demjenigen der permanenten Zähne gefunden. Deutliche Wachstumslinien mit hohem Mineralgehalt konnten im zellhaltigen Zement der Milchzähne nicht observiert werden, und das zellhaltige Zement war dünner als dasjenige der permanenten Zähne. In ein paar Fällen hatte das zellfreie Zement einen grösseren Mineralgehalt als das Dentin.

Es hat sich elektronenmikroskopisch gezeigt, dass die Zementozyten nahe der Oberfläche des Zementes den Zementoblasten

ähnlich waren. Die Menge von Zytoplasma war aber reduziert, und enthielt weniger endoplasmatisches Reticulum und Mitochondrien. Die Zementhöhlen und Kanälchen wurden von einer dünnen elektronen dichten Zone umgeben. Tiefer im Zement wurden mehrere Unterschiede in den Zementozyten gefunden. Einige Zementlakunen enthielten Zementozyten mit normalen Kernen, das Zytoplasma aber hatte ein feines, retikuläres Aussehen und wenige identifizierbaren Organellen. Zementozyten in anderen Zementlakunen zeigten Veränderungen sowohl in den Kernen als auch im Zytoplasma. Noch andere Zementlakunen enthielten variierende Mengen von Fibern und fibrillärem Material.

Diese Untersuchung unterstützt die Ansicht, dass nur die Zementozyten in den oberflächlichen Schichten des Zementes vital sind.

REFERENCES

Anneroth, G., G. Bergman and *E. Welander,* 1966: Microradiographic study of dental tissues using soft and ultrasoft x-rays. Odont. Revy. *17:* 131—148.

Baud, C. A., 1962: Morphologie et structure inframicroscopique des ostéocytes. Acta anat. *51:* 209—225.

Bergman, G. and *B. Engfeldt,* 1954: Studies on mineralized dental tissues. II. Microradiography as a method for studying dental tissues and its application to the study of caries. Acta odont. scand. *12:* 99—132.

Cameron, D. A., 1963: The fine structure of bone and calcified cartilage. Clin. Orthop. *26:* 199—228.

Cooper, R. R., J. W. Milgram and *R. A. Robinson,* 1966: Morphology of the osteon. An electron misroscopic study. J. Bone Jt. Surg. *48-A:* 1239—1271.

Dreyfuss, F. and *R. Frank,* 1964: Microradiographie et microscopie électronique du cément humain. Bull. Grp. int. Rech. sci. Stomat. *7:* 167—181.

Dudley, H. R. and *D. Spiro,* 1961: The fine structure of bone cells. J. biophys. biochem. Cytol. *11:* 627—649.

Frost, H. M., 1960: In vivo ostecyte death. J. Bone Jt Surg. *42-A:* 138—143.

Furseth, R., 1965: A microradiographic and ultrastructural study on the mineral phase of sound and carious human dental cementum. M. S. Thesis, Univ. of Rochester.

Haim, G. von, 1961: Histochemische Untersuchungen des Zementgewebes. Dtsch. zahnärztl. Z. *16:* 71—81.

Hattyasy, D., 1957: Ein Beitrag zur Struktur der Zahnwurzel. Öst. Z. Stomat. *54:* 505—514.

Held, A. J., 1951: Cementogenesis and the normal and pathologic structure of cementum. Oral Surg. *4:* 53—67.

Herting, H. C., 1963: Elektronenmikroskopische Untersuchungen über das Zahnwurzelzement des Menschen. Proceedings of the 9th ORCA Congress, pp. 303—312. Pergamon Press, Oxford.

Holt, S. J. and *R. M. Hicks*, 1961: Studies on formalin fixation for electron microscopy and cytochemical staining purposes. J. biophys. biochem. Cytol. *11:* 31—45.

Johansen, E. and *H. F. Parks*, 1960: Electron microscopic observations on the three-dimensional morphology of apatite crystallites of human dentine and bone. J. biophys. biochem. Cytol. *7:* 743—746.

Jowsey, J., 1960: Age changes in human bone. Clin. Orthop. *17:* 210—218.

Keller, H., 1964: Polarisationsoptische Untersuchung der Faserstruktur im Zement entkalkter menschlicher Milchzähne. Acta anat. *57:* 326—337.

Kronfeld, R., 1939: Histopathology of the Teeth and their surrounding Structures. 2. ed. Lea & Febiger, Philadelphia. pp. 247—255.

Maximow, A. A. and *W. Bloom*, 1957: A Textbook of Histology. 7. ed. W. B. Saunders Co., Philadelphia and London. p. 129.

Mjör, I. A., 1962: The bone matrix adjacent to lacunae and canaliculi. Anat. Rec. *144:* 327—339.

Moe, H. and *Y. Kurahashi*, 1966: Perfusion fixation of teeth in situ for electron microscopy. J. Ultrastruct. Res. *14:* 417.

Movat, H. Z. and *N. V. P. Fernando*, 1962: The fine structure of connective tissue. I. The fibroblast. Exp. molec. Path. *1:* 509—534.

Nygaard Östby, B., 1939: Über die Gewebsänderungen im apikalen Paradentiums des Menschen nach verschiedenartigen Eingriffen in den Wurzelkanälen. Dissertation. Det Norske Videnskaps-Akademi i Oslo. I. Mat.—Nat. Klasse. No. 4. p. 107 and p. 166

Paynter, K. J. and *G. Pudy*, 1958: A study of the structure, chemical nature, and development of cementum in the rat. Anat. Rec. *131:* 233—251.

Pritchard, J. J., 1956: General anatomy and histology of bone. In: The Biochemistry and Physiology of Bone. G. H. Bourne, ed. Acad. Press. Inc., New York, pp. 1—25.

Provenza, V. D., 1964: Oral Histology. Pitman Medical Publ. Co. p. 289—307.

Reynolds, E. S., 1963: The use of lead citrate at high pH as an electronopaque stain in electron microscopy. J. Cell Biol. *17:* 208—212.

Robinson, A. A. and *M. L. Watson*, 1952: The collagen-crystal relationships in bone as seen in the electron microscope. Anat. Rec. *114:* 383—409.

Röckert, H., 1958: A quantitative x-ray microscopical study of calcium in the cementum of teeth. Acta odont. scand. *16:* Suppl. 25 pp. 55—57.

Ross, R. and *E. P. Benditt*, 1961: Wound healing and collagen formation. I. Sequential changes in components of guinea pig skin wounds observed in the electron microscope. J. biophys. biochem. Cytol. *11:* 677—700.

Ryter, A. et *E. Kellenberger*, 1958: L'inclusion au polyester pour l'ultramicrotomie. J. Ultrastruct. Res. *2:* 200—214.

Selvig, K. A., 1964: An ultrastructural study of cementum formation. Acta odont. scand. *22:* 105—120.

— » — 1965: The fine structure of human cementum. Acta odont. scand. *23:* 423—441.

Sicher, H., 1962: Orban's oral Histology and Embryology. H. Sicher, ed. 5. ed. C. V. Mosby., St. Louis, p. 53 and p. 172.

Soni, N. N., G. Van Huysen and *H. M. Swenson*, 1962: A microradiographic and X-ray densitometric study of cementum. J. Periodont. *33:* 372—378.

Stern, I. B., 1964: An electron microscopic study of the cementum, Sharpey's fibers and periodontal ligament in the rat incisor. Amer. J. Anat. *115:* 377—409.

Sorenson, F. M. and *D. C. Gatewood*, 1966: Formalin penetration of extracted teeth. J. dent. Res. *45:* 1413—1418.

Yamamoto, H., M. Masuda, K. Toeda, and *K. Suzuki*, 1962: Microradiographic and histopathological study of the cementum. Bull. Tokyo med. dent. Univ. *9:* 139—150.

Address: *Dental Institute of Experimental Research,*
University of Oslo,
Blindern, Oslo 3, Norway.

Fig. 1. Micrograph of acellular cementum (C) with adjacent dentin (D) and periodontal membrane (PM). Hematoxylin/etosin. × 260.

Fig. 2. Micrograph of cellular cementum (C) with adjacent dentin (D) and periodontal membrane (PM). Hematoxylin/eosin. × 105.

Fig. 3. Microradiograph of section from the cervical area of the root showing acellular cementum. Cementum (C), cemento-dentinal junction (CDJ), the granular layer of Tomes (G). × 105.

Fig. 4. Microradiograph of section from the cervical area of the root showing highly mineralized cementum (C). Cemento-dentinal juction (CDJ). × 105.

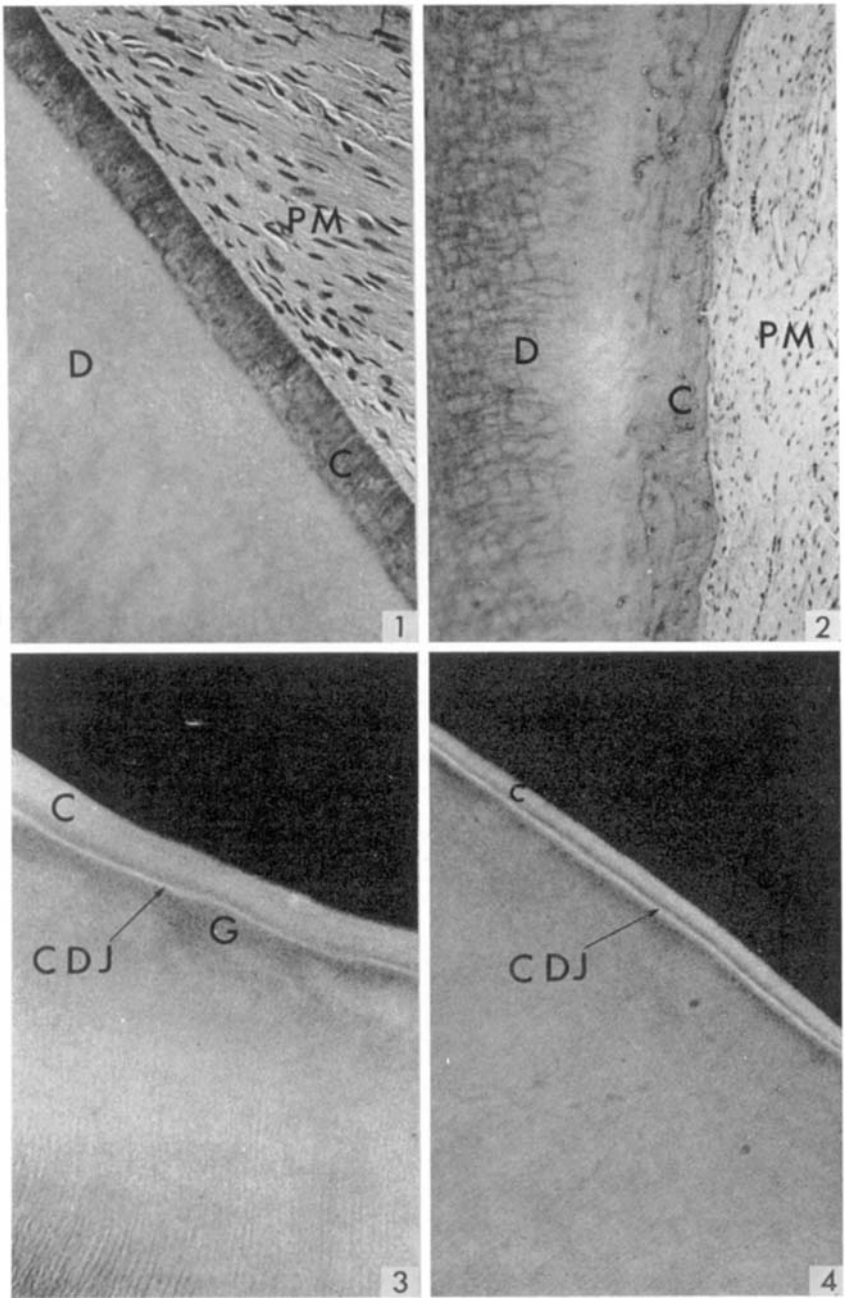
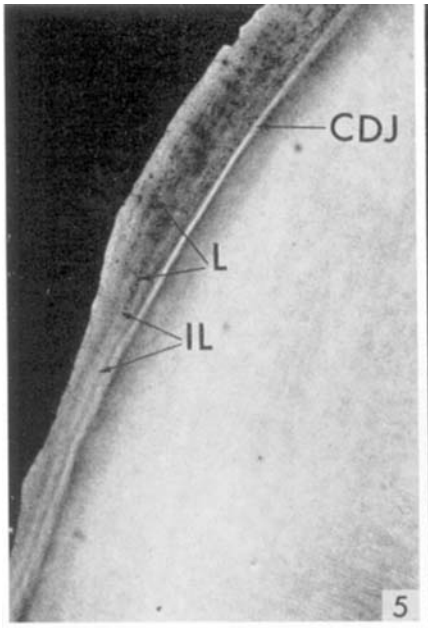

PM
D
C
1
D
C
PM
2
C
G
CDJ
3
C
CDJ
4

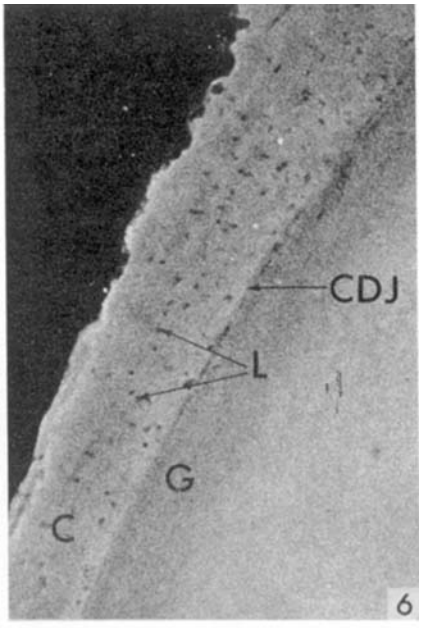
Fig. 5. Microradiograph from the middle third of the root showing the transition between acellular and cellular cementum. Cemento-dentinal junction (CDJ) cementum lacunae (L), incremental lines (IL). × 35.

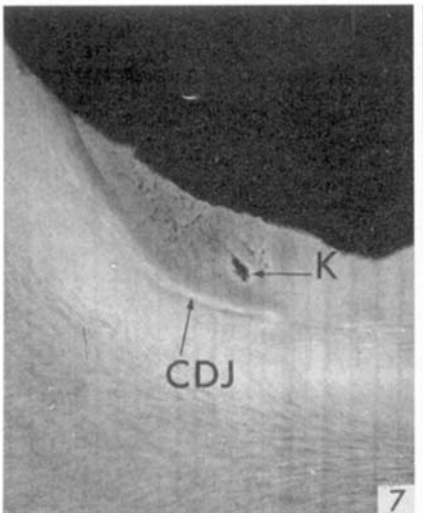
Fig. 6. Microradiograph of cellular cementum (C). Cementodentinal junction (CDJ), cementum lacunae (L), granular layer of Tomes (G). × 105.

Fig. 7. Microradiograph of cementum from the bifurcation showing cavern with highly mineralized wall (K). Cemento-dentinal junction (CDJ). × 35.

Fig. 8. Microradiograph of section from the apical third of the root showing caverns in the cementum (K). Cemento-dentinal junction (CDJ). × 105.


CDJ
L
IL
5


CDJ
L
G
C
6


K
CDJ
7

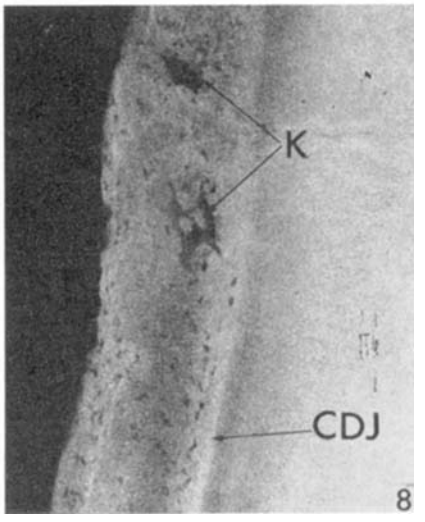
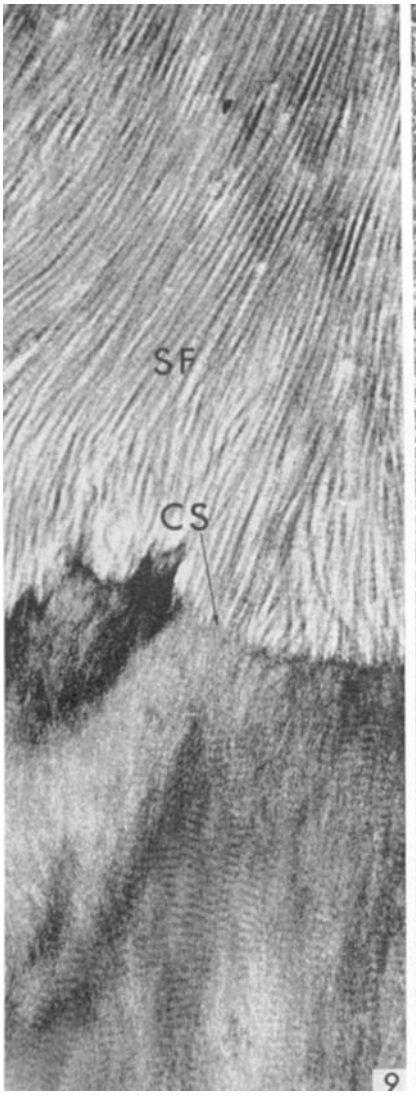

K
CDJ
8

Fig. 9. Electron micrograph of decalcified section showing periodontal fibers (SF) entering the acellular cementum as Sharpey's fibers. Cementum surface (CS). × 15 000.

Fig. 10. Electron micrograph of undecalcified section of acellular cementum (C) and the granular layer of Tomes (G). Cemento-dentinal junction (CDJ). × 8 000.


SF
CS
9

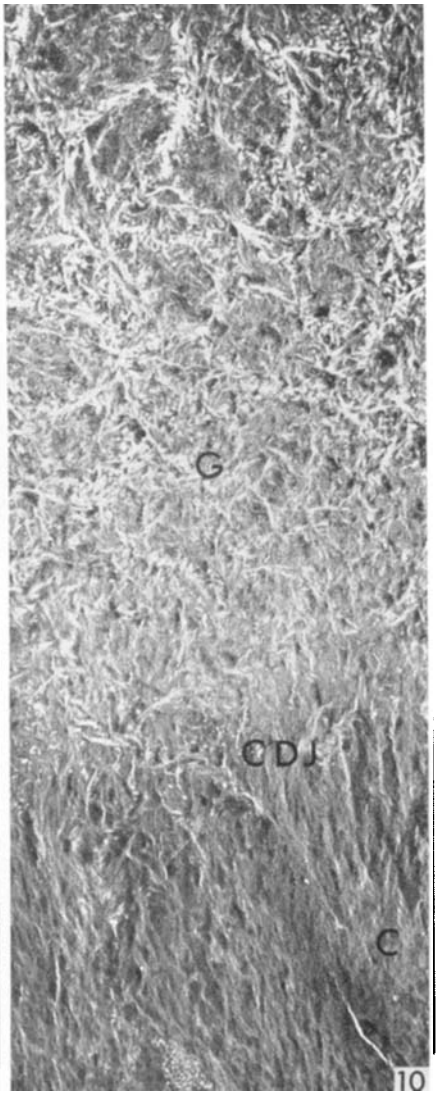
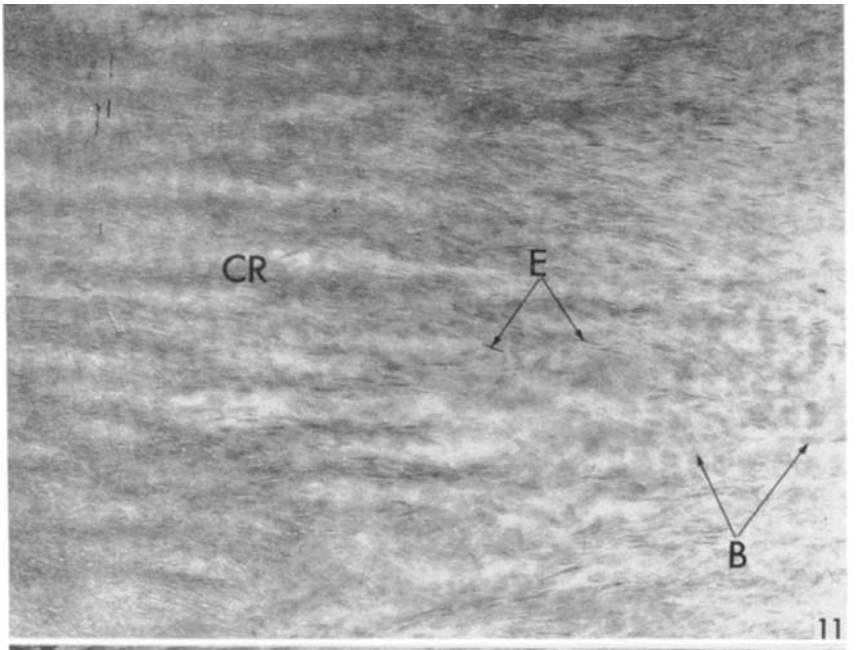
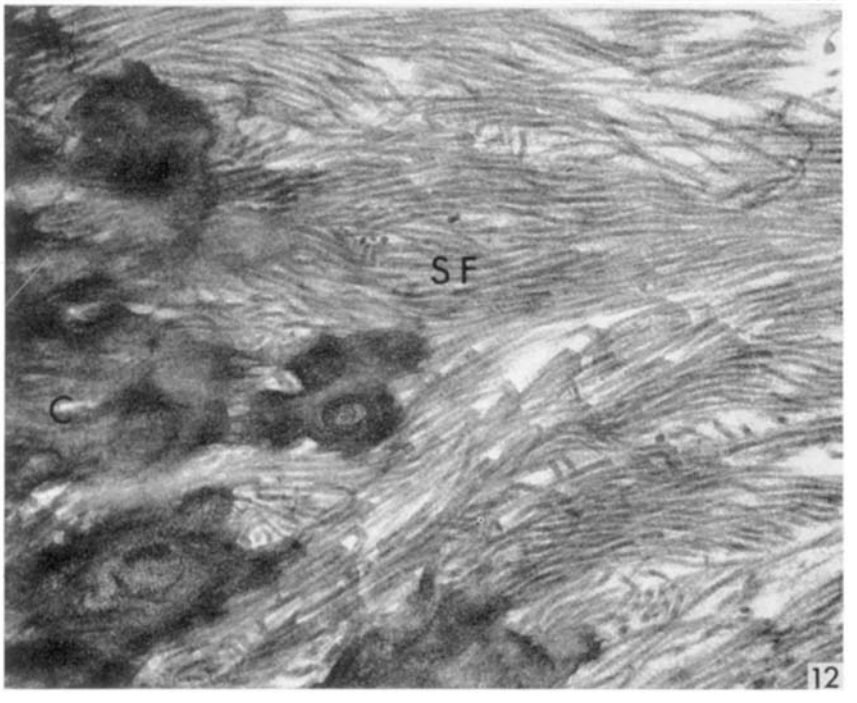

G
CDJ
C
10

Fig. 11. Electron micrograph showing the individual apatite crystals at the cementum surface. Edgeviews of the crystals (E), broad surface views (B), crossbanding of mineralized collagen fibers (CR). × 55 000.

Fig. 12. Electron micrograph of decalcified section showing periodontal fibers (SF) entering the cellular cementum (C) as Sharpey's fibers. × 16 500.



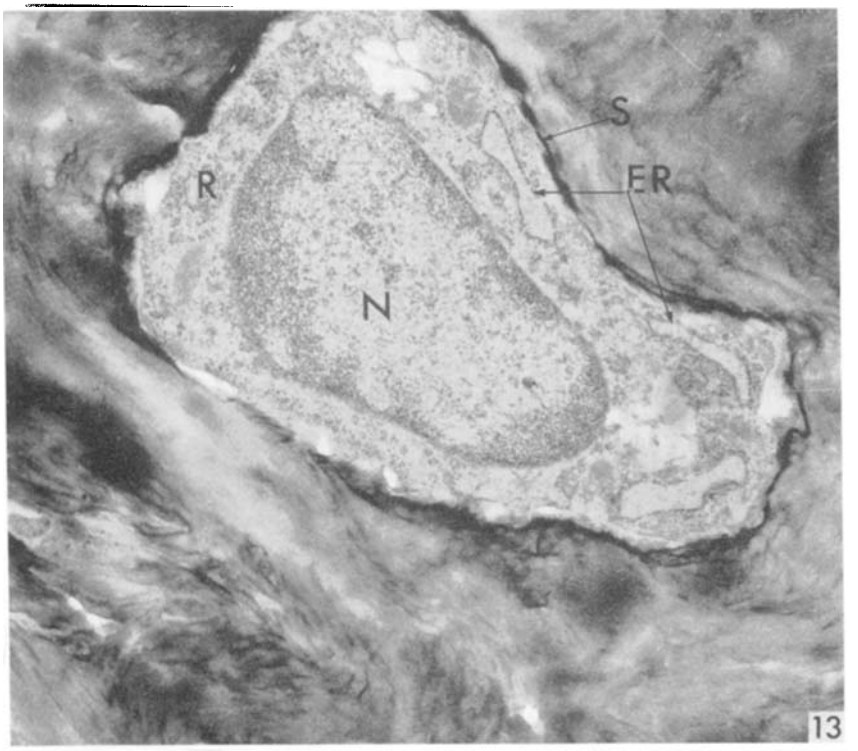
11



12

Fig. 13. Electron micrograph of cementocyte located 3 microns from the cementum surface. Decalcified section. Nucleus (N), endoplasmic reticulum (ER), cytoplasmic ribosomes (R), electron dense zone surrounding the lacuna (S). × 12 000.

Fig. 14. Electron micrograph of decalcified section showing cementocyte close to the cementum surface (CS). Electron dense zone surrounding the lacuna (S), nucleus (N). × 5 500.


S
ER
R
N
13

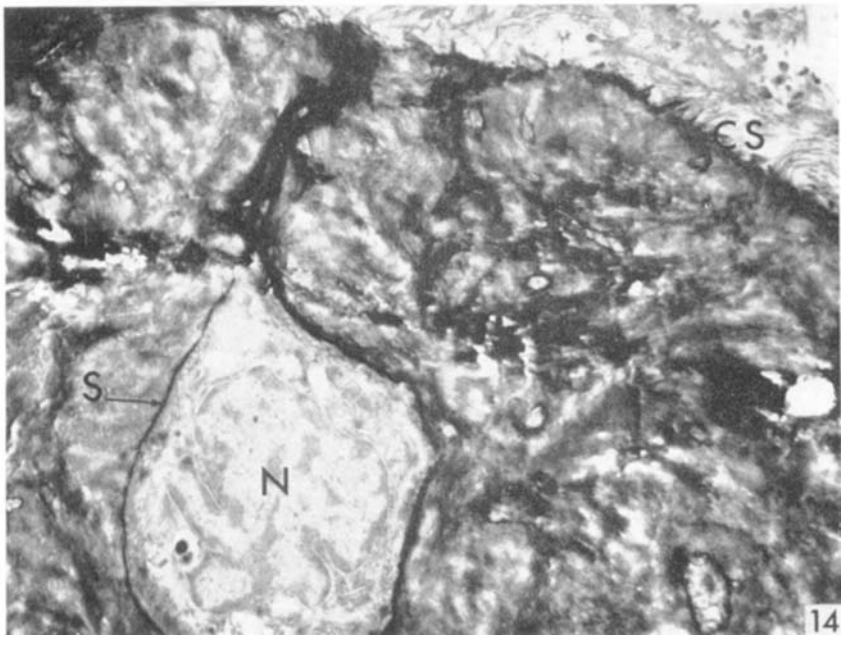

CS
S
N
14

Fig. 15. Electron micrograph of decalcified section showing cementocyte. Nucleus (N), accumulated material in the cytoplasm (AM), remnants of mitochondria (M), canaliculi (CA). × 15.500.

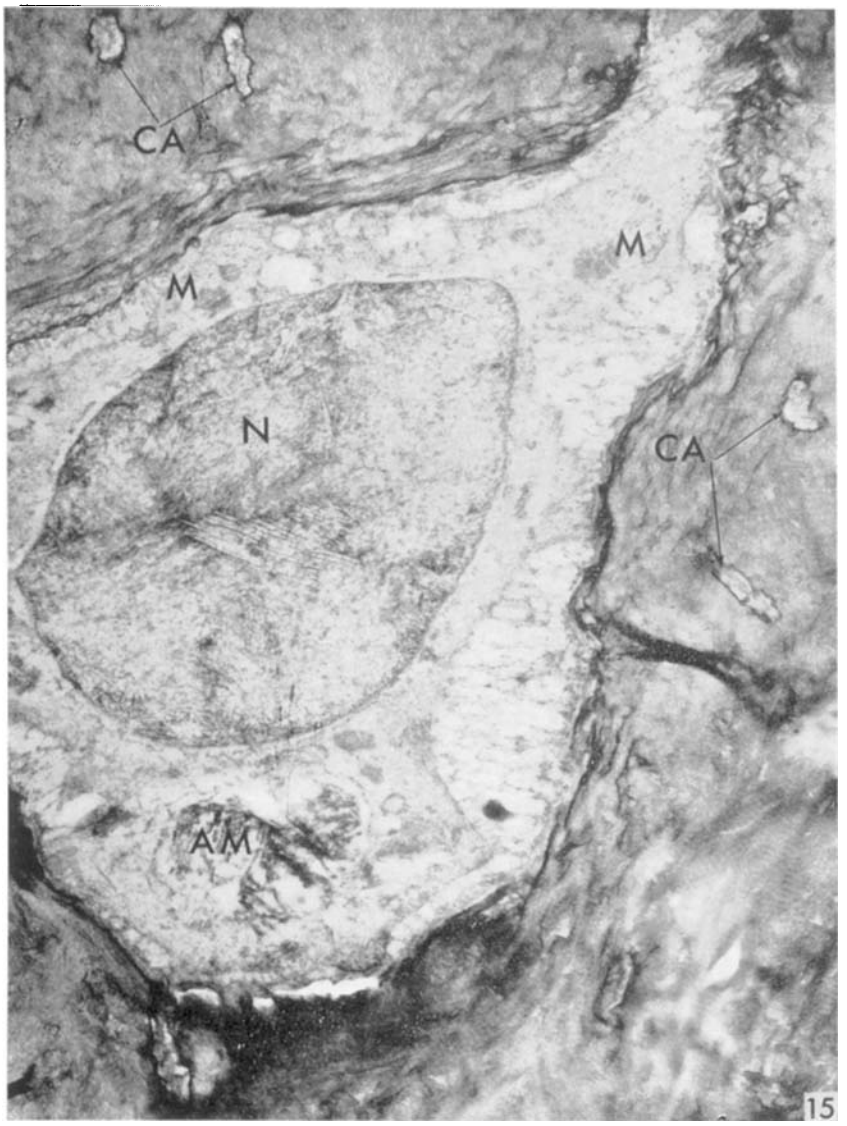

CA
M
M
N
CA
AM
15

Fig. 16. Electron micrograph of decalcified section showing cementocyte with nuclear and cytoplasmic changes. The cell is surrounded by fibrillar material. Nucleus (N), cytoplasm (P). × 16 500.

Fig. 17. Electron micrograph of decalcified section showing cementum lacuna located 70 microns from the cementum surface. Nuclear remnants (N), cytoplasm (P). × 20 500.


N
P
16

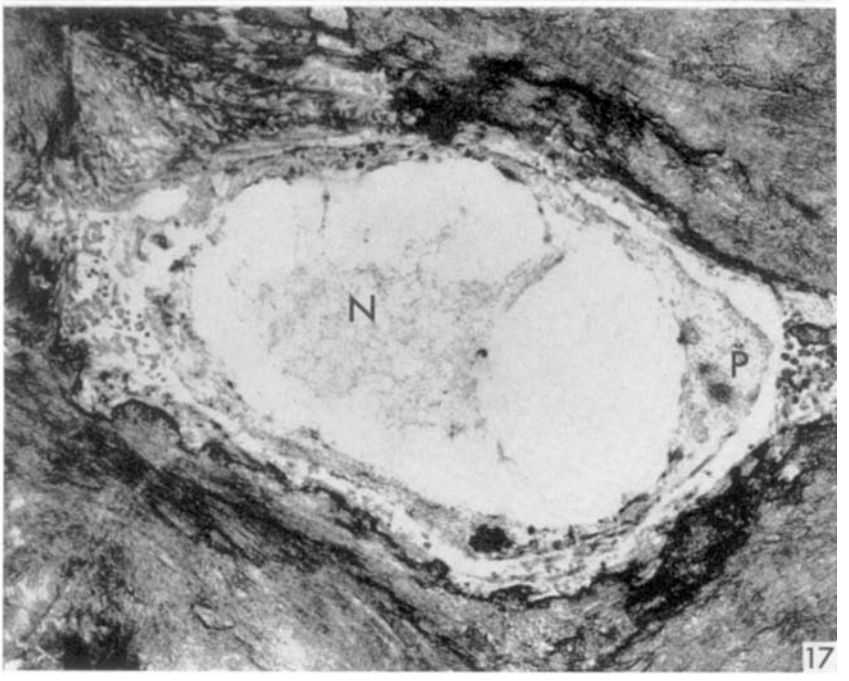
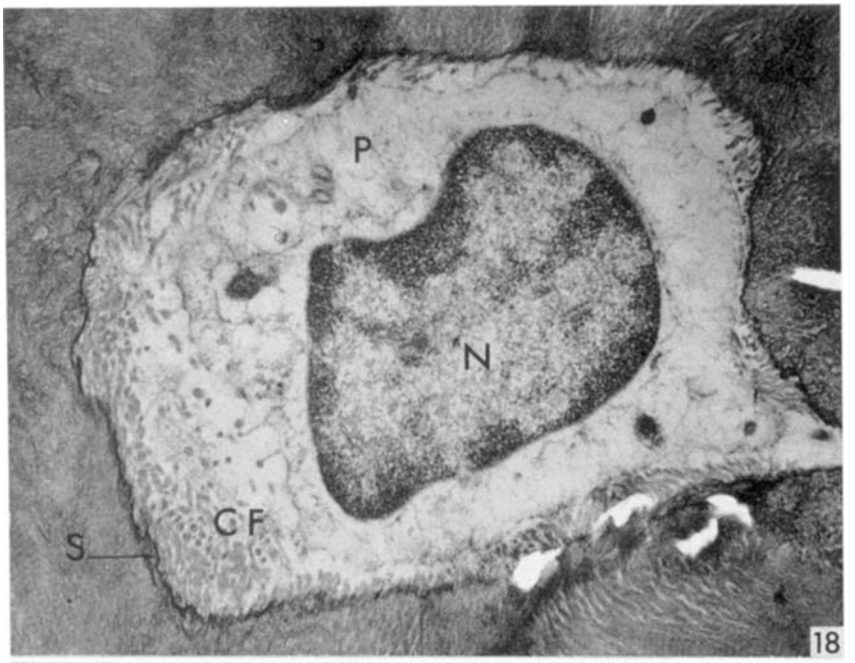
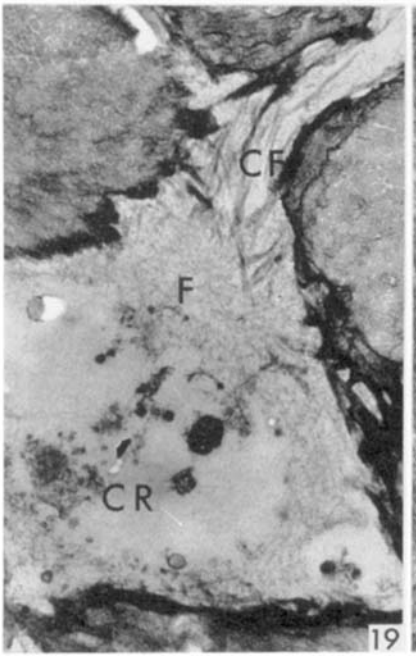

N
P
17

Fig. 18. Electron micrograph of decalcified section showing cementocyte 65 microns from the cementum surface with cytoplasmic changes and fibers within the lacuna. Nucleus (N), cytoplasm (P), collagen fibers (CF), electron dense zone surrounding the lacuna (S). × 16 000.

Fig. 19. Electron micrograph of decalcified section of cementum lacuna with cellular remnants (CR), fibrillar material (F), and collagen fibers (CF). × 185 000.

Fig. 20. Electron micrograph of decalcified section showing parts of cementum lacuna with collagen fibers (CF) and fibrillar material (F). Electron dense zone surrounding the lacuna (S), collagen fibers in the surrounding matrix (CF). × 40 000.


P
N
CF
S
18


CF
F
CR
19

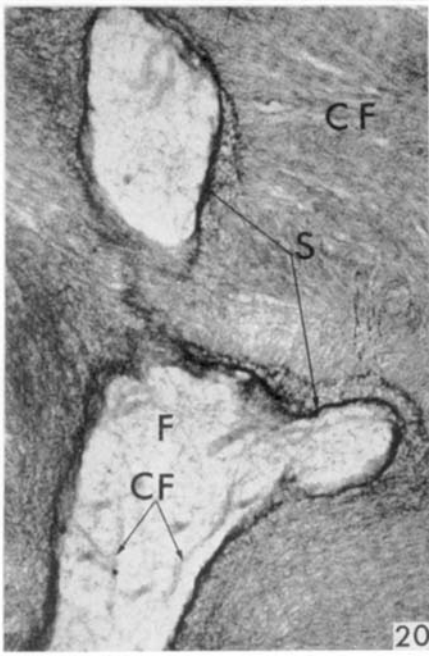
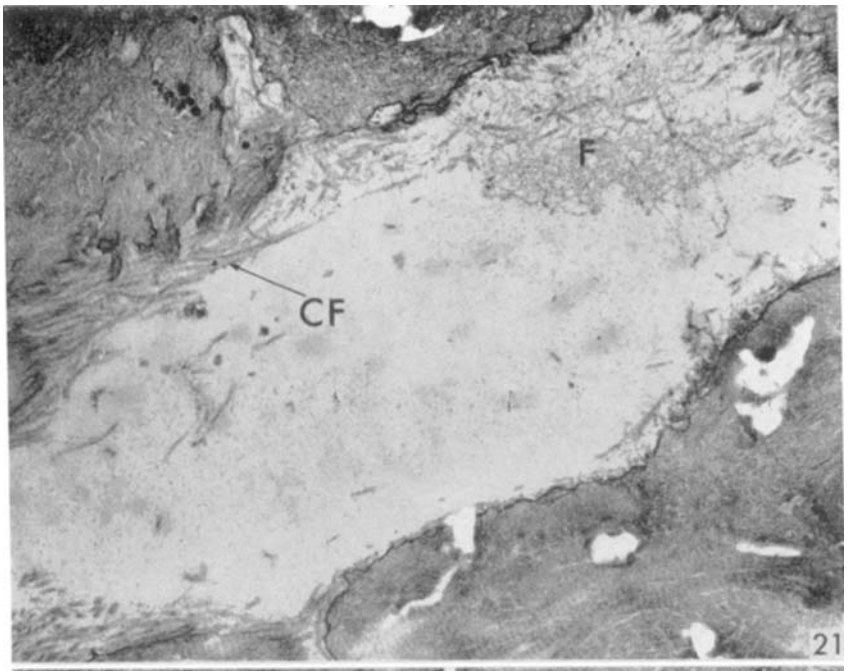
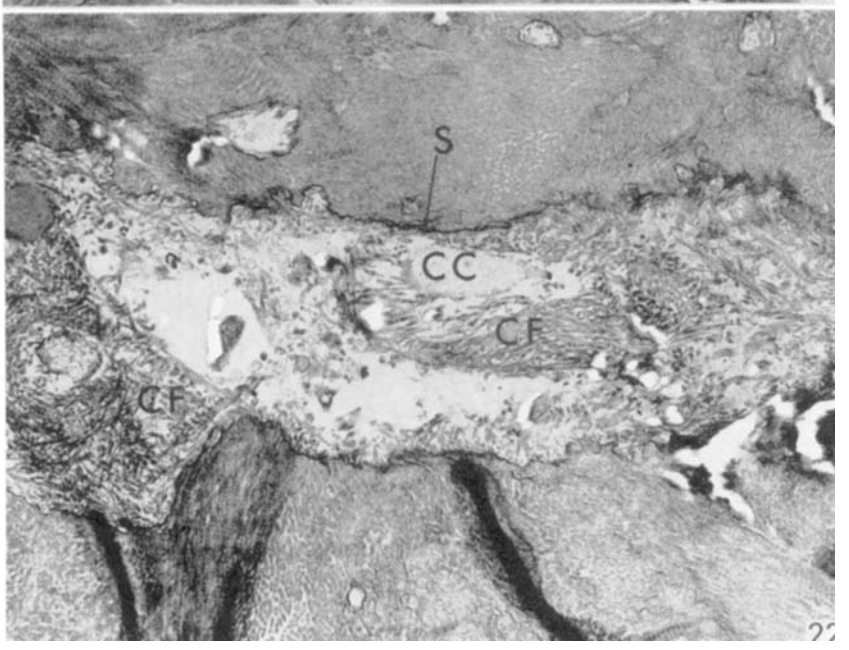

CF
S
F
CF
20

Fig. 21. Electron micrograph of decalcified section showing cementum lacuna 70 microns from the cementum surface. Collagen fibers (CF), fibrillar material (F). × 16 000.

Fig. 22. Electron micrograph of decalcified section showing cementum lacuna 75 microns from the cementum surface. Collagen fibers (CF), parts of cementocyte (CC), electron dense zone surrounding the lacuna (S). × 12 000.


F
CF
21


S
CC
CF
CF
22

THE PATTERN OF CRANIOFACIAL ASSOCIATIONS

A morphological and methodological correlation and factor analysis study on young male adults

BENI SOLOW

NEW SUPPLEMENT

No. 46

ACTA ODONTOLOGICA SCANDINAVICA

Copenhagen 1966

174 pages

Price $10:—. Sw. cr. 50:—

You can order these monographs by writing to:

Acta Odontologica Scandinavica
53, Nybrogatan
Stockholm Ö
Sweden