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CHANGES IN THE MINERALIZATION OF REPLANTED HUMAN TEETH

by

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The possibilities of replanting extracted or luxated teeth or of filling a gap in a dental arch with the aid of a transplanting technique have been known since classical times. The replanting technique has also been used in other connections e.g. in the treatment of periapical diseases in which the tooth has been replanted after extraction. In an extensive literature many problems in this field have been discussed from different aspects. This literature is dominated by clinical and roentgenological studies of treated cases (*Schön* 1954). Many experimental and histological investigations on animals have been performed, but very few histological investigations have been made on human teeth after transplantation or replantation (*Heiss* 1944, *Pindborg & Hansen* 1951, *Miller* 1956). Therefore, most of our knowledge in this field is based upon histological information obtained from animal experiments.

In most of the previous investigations the main interest has been focused on the attachment of the replanted teeth and the development of periodontal tissue in the alveolar bone after an extended period of time. Thus *Axhausen,* 1937, and

Heiss, 1944, have proposed that the pulp of a totally luxated tooth is completely devitalized and has to be replaced by a root filling. Concerning the healing of the replanted teeth, *Axhausen* 1937, and *Hammer* 1937 & 1938, among others, on the basis of histological findings after animal experiments, stress the importance of a vital periodontal membrane covering the cementum of the root. The vital membrane is important for a good prognosis and makes direct fastening of the replanted tooth possible without any influence from the mineralized tissues in the root. The surface of the cementum, which has no vital membrane will be attacked by granulation tissue and a resorption of the cementum and the dentin will occur to a greater or lesser degree. The resulting lacunae will be filled by osseous tissue and the tooth will develop a stable but unphysiological attachment to the alveolar bone. Sooner or later new resorptions will begin. They will be followed by new osseous formation until the entire root is replaced by cancellous bone tissue. The role of the vital membrane as the only existing and determining factor for the prognosis of the replantation is not accepted by all authors. *Heiss,* 1944, stressed the importance of the age of the patient. His opinion is based on clinical experiments in which the resorption and the rebuilding processes in and around the root of the replanted tooth show a more rapid activity in young patients than in old. This rapid activity leads to a worse prognosis for the replanted teeth in young individuals — an opinion, however, which is not generally accepted.

Clinical experience has not substantiated the hypothesis that there is a lack of reparative possibilities in the pulp after replantation. Many years after replantation a tooth may contain vital pulp tissue (*Krepil* 1949). X-ray examinations of replanted teeth have shown how the pulp cavity may be filled by mineralized tissue (*Pålsson* 1944). Changes at the dentinal-pulp junction. studied in animal experiments, are dominated histologically by the development of osseous tissue. When similar tissues appear in the pulp in cases of scurvy, they are called osteodentin, osteoid or pulp bone (*Westin* 1931). The appearence of this bone-like tissue in teeth having been exposed to traumata is supposed to be the result of disturbances in the nutrition because blood vessels are torn. Whether this mineralized tissue is a product of

dedifferentiated odontoblasts or other cells in the pulp is not quite clear (*Santoné* 1937, *Flemming* 1953, *Agnew* et al. 1956, *Pafford* 1956).

In spite of the information obtained from animal experiments no systematic investigations have been performed regarding the histologic appearance in replanted human teeth. Therefore, the prognosis of replantation of human teeth is uncertain. According to our clinical experience one of the most important factors is the age of the patient. Replantation is, however, frequently most valuable as a temporary or permanent solution to problems met with in children involved in accidents. In clinical practice slight traumata will very often result in serious damage similar to that which is seen in replantation cases, although no total luxation of the tooth occurred. Similar problems regarding healing and prognosis of pathological processes in teeth are met with in surgical orthodontics. The direction of the migration of a tooth, which is not finally formed, or which is in a wrong position may be altered operatively. Surgical orthodontics and traumatic injuries of teeth have their highest occurrence in the young patient up to the age at which permanent bridges may be employed. A wide apical foramen is probably the prerequisite condition for the pulp to retain its vitality after the circulatory breakdown due to the trauma (*Apfel* 1954, *Holland* 1956, *Thoma* 1956, *Miller* 1956). For the above reasons the present investigation was made on patients aged 11—15 years.

X-ray microscopy was considered to be the best tool by which we could analyse changes in the mineralized tissues of the teeth without any decalcification. This method enables us to correlate semiquantitative changes in mineralization to the morphology of the tissue. Changes in the organic stroma of the pulp, especially the nerve regeneration, were studied separately by *Öhman* and will be described later.

MATERIAL AND METHODS

40 teeth, clinically intact, with one or several roots from patients of both sexes aged 11—15 years were investigated. The teeth were to be extracted for orthodontic reasons. Under local anesthesia the tooth in question was removed and then immediately replanted.

No fixation was applied, but grinding was made in cases of strong pressure in occlusion or articulation positions. The time of observation and control after replantation to final extraction (which was performed under local anesthesia) varied between three weeks and seven months. In some cases replantation was made of one of two contralateral teeth. When the replanted tooth was finally extracted, the contralateral tooth was removed as well and used as a control.

The extracted teeth were immediately placed in buffered 10 % neutral formalin. They were cut longitudinally according to the method described by *Engström & Öhman*, 1960.

After the pulp had been removed, the two halves of the tooth were put into alcohol. Approximately 48 hours later the specimens were embedded in methyl methacrylate. Absolute plane parallel ground sections about 75μ thick were then prepared according to the method described by *Hallén & Röckert*, 1960. Any section with a length of about 2 cm thus exhibited a variation in thickness, which normally takes the shape of a wedge, of less than 0.5μ; a condition which is important for the interpretation of the microradiograms. This type of preparation eliminated the possibility that the density variations were due to varying thicknesses of the specimen and not to irregular mineralization.

The sections obtained were placed in close contact with a film emulsion with very small grains (Kodak Spectroscopic Plate No. 649). They were exposed to soft x-rays within the wavelength ranage 0.6 — 4 Å, generated from a Machlett tube (OEG-50) with a tungsten anode, 1 mm beryllium filter and a focal spot size of 1.5 mm.

The total absorption of the *organic* material within the wavelength range used was negligable because of the minute absolute amount of material present and the small absorption of the atomic components of the material. The absorption of *calcium*, however, was high at these wavelengths primarily because the K-absorption jump occurs at 3.07 Å and because of the relatively large amount of calcium compared to organic material. In the microradiograms shown in this paper dark areas represent parts rich in organic material, and white areas parts rich in calcium.

RESULTS

Most of the changes observed appeared one month after replantation. In the *cementum* smaller defects in the mineralization were visible (Figs. 1 and 2). Most often such defects openly communicated with the periodontal membrane. Very seldom

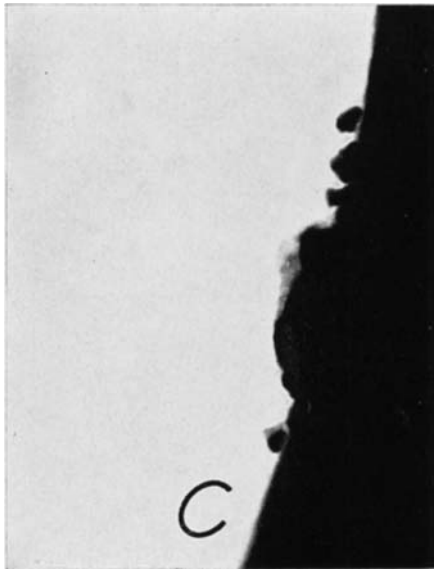

Fig. 1. Irregular demineralized edge of the cementum. White areas represent the mineralized parts. C=cementum. (Microradiogram. Orig. mag. × 40).

seemed the entire cementum to be intact (in this material in 3 cases in one of which the tooth had been extracted three months after replantation). Now and then demineralized areas without "contact" either with the periodontal membrane or the pulp were seen (Fig. 3). This phenomenon appeared most frequently at the bifurcation between branched roots where the cementum was comparatively thick. The entire cementum could disappear within a month after replantation but usually disappeared after 3—6 months. Then the dentinal tubules continued directly into the periodontal membrane and the calcium content gradually was decreasing towards the periphery of the root within a limited zone of about 75μ (Fig. 4).

In very few cases, the *dentin* seemed to be quite intact. The frequency of the occurrence and the size of areas of interglobular dentin were increased. In some cases a 20—30μ wide zone at

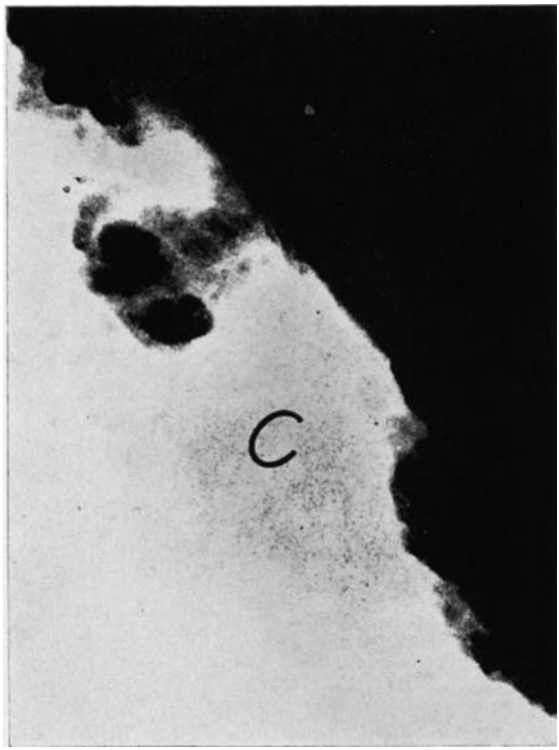

Fig. 2. Multicystic demineralized area in the cementum (C) in contact with the periodontal membrane. (Microradiogram. Orig.mag. × 100).

about a distance of 10μ from the dentino-enamel junction and running parallel to the latter turned into interglobular dentin (Fig. 5). In about 90 % of the cases studied a globular arrangement of the calcium was seen at the pulpo-dentinal junction. In the microradiograms of the sections one can easily see how the dentinal tubules are passing uninterrupted through the globules (Figs. 6, 7, and 8). The size of the globules is very variable, approximately 5—50μ. The amount of globules shows no correlation to the width of the pulp cavity or to the observed time after replantation. In two cases a globular arrangement of the entire dentin was observed (Fig. 9) and in those cases the amount of calcium varies greatly in different parts of the dentin. Usually

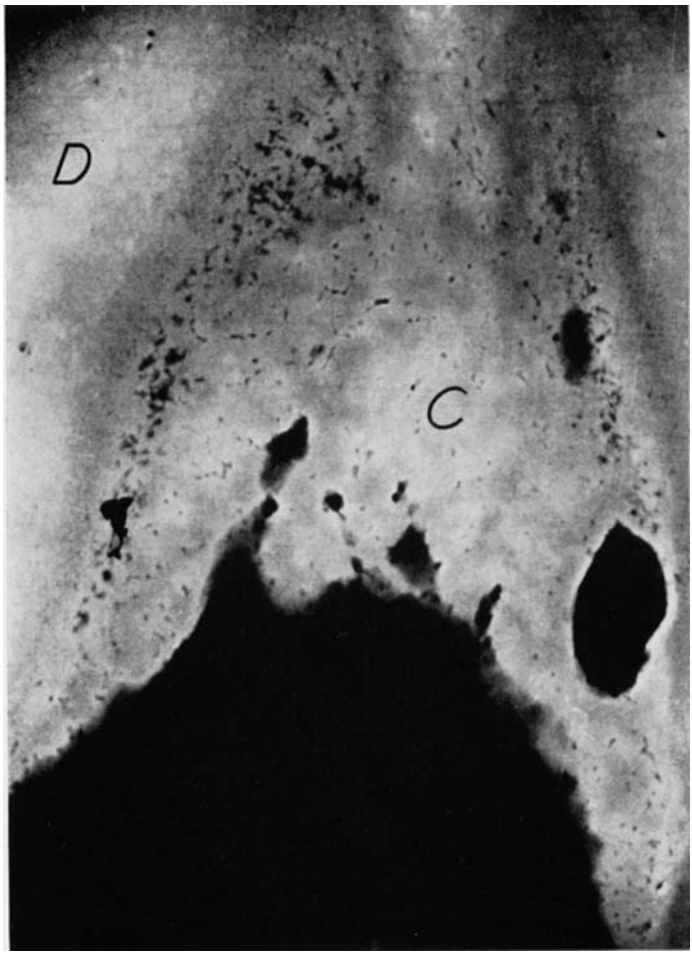

Fig. 3. The mineralization of the cementum (C) at the bifurcation of a branched root. D=dentin. (Microradiogram. Orig.mag. × 100).

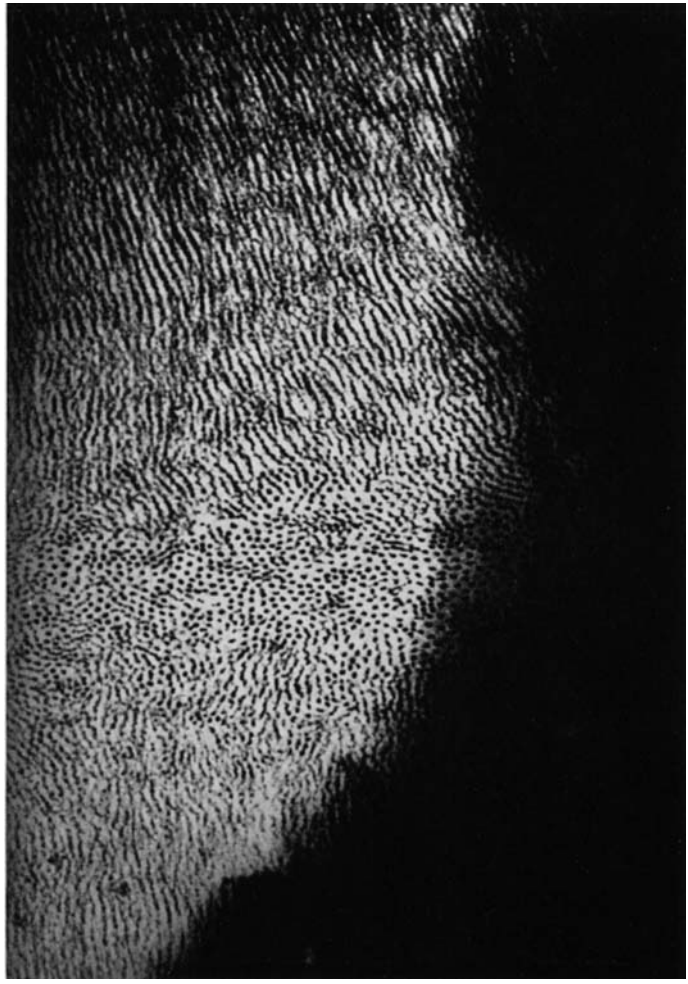

Fig. 4. Total disapperance of the cementum and a diffuse demineralization of the dentin towards the periodontal membrane to the right. (Microradiogram. Orig.mag. × 500).

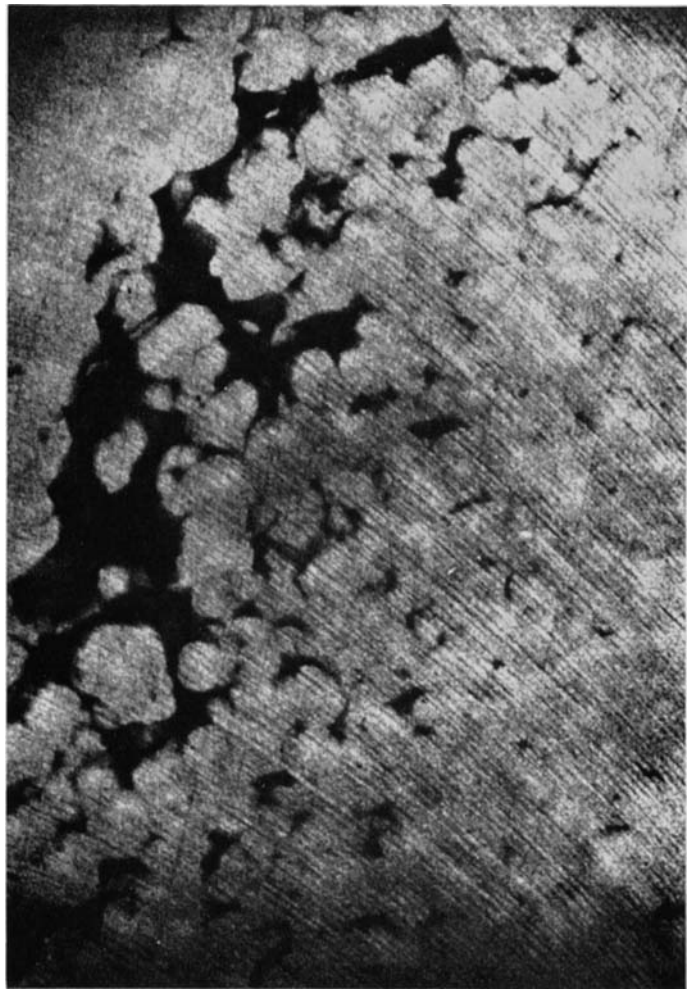

Fig. 5. Microradiogram showing interglobular dentin. (Orig.mag. × 400).

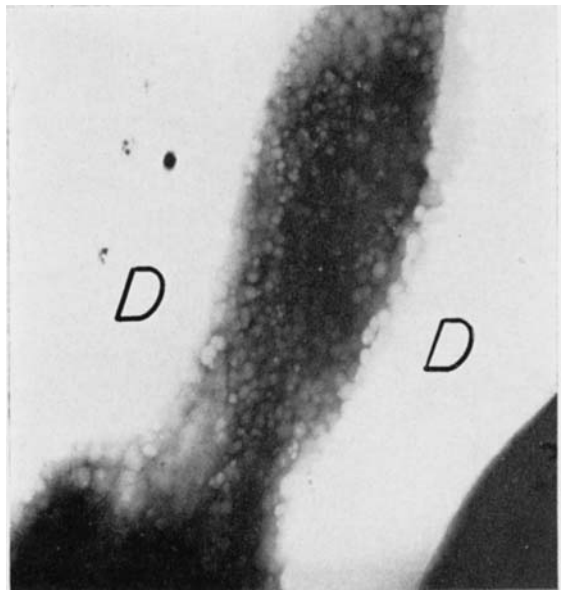

Fig. 6. Microradiogram showing calcium-rich globules at the pulpo-dentinal junction. D=dentin. (Orig.mag. × 100).

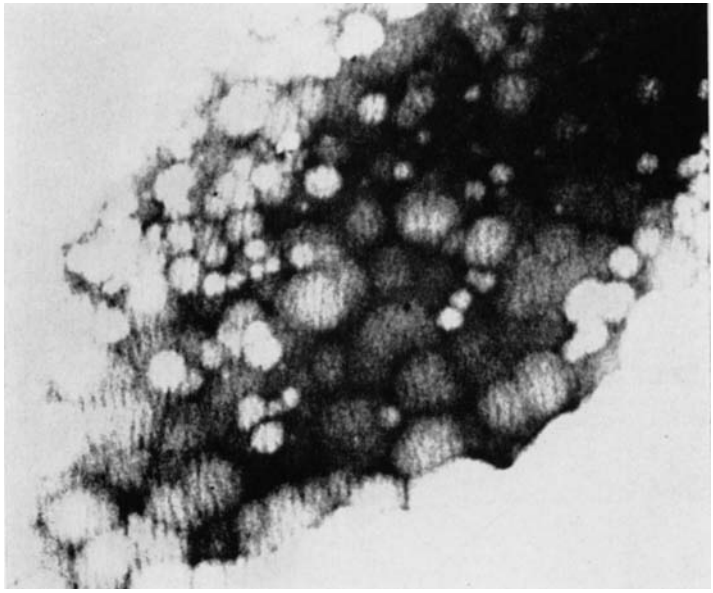

Fig. 7. Longitudinal section of dentinal tubules passing through the globules at the pulpo-dentinal junction. (Microradiogram. Orig.mag. × 500).

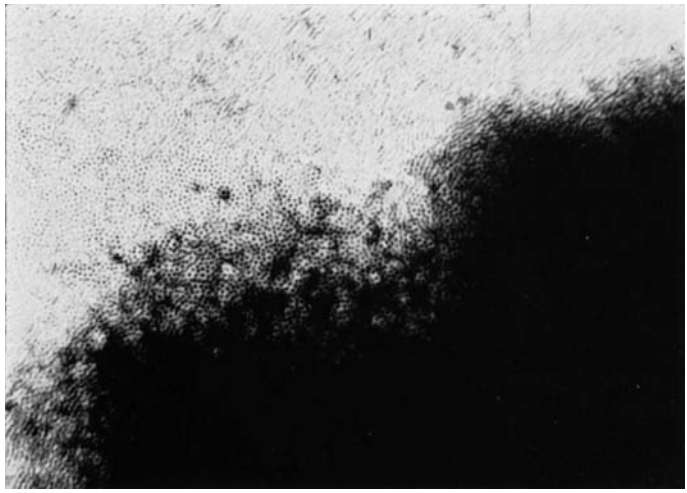

Fig. 8. Transverse section of the dentinal tubules passing through the juxtapulpal dentinal globules. (Microradiogram. Orig.mag. × 100).

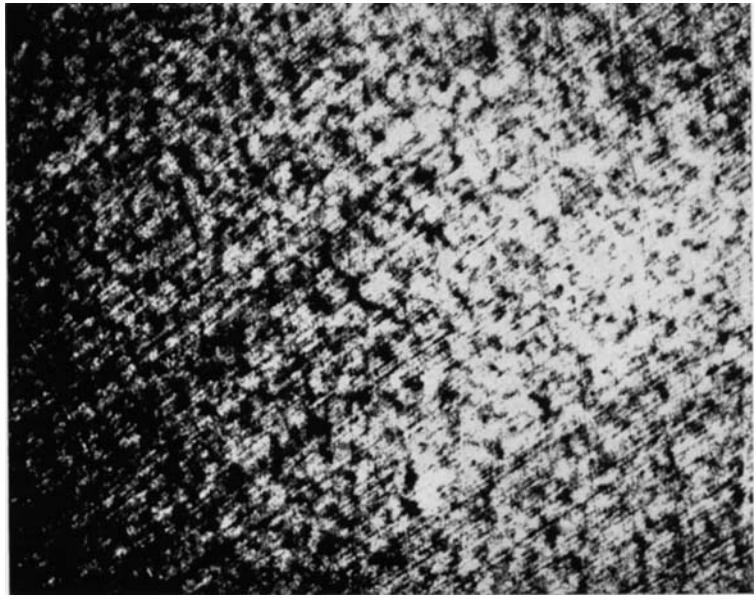

Fig. 9. Microradiogram showing varying mineral distribution within a section and showing globular mineralization of the entire dentin. (Orig.mag. × 300).

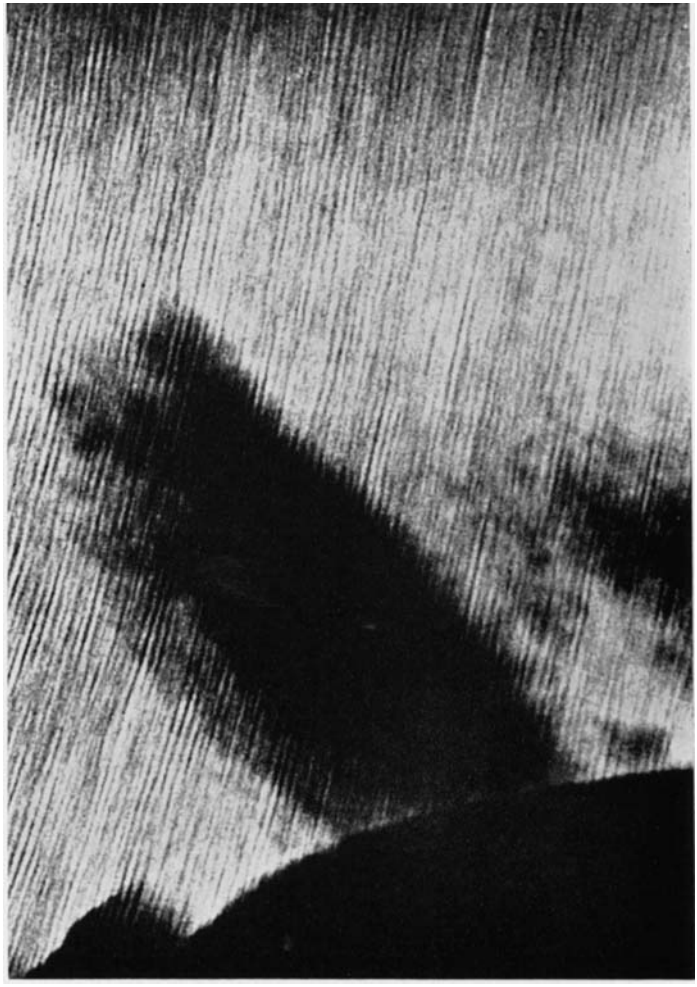

Fig. 10. Demineralized area in the dentin in contact with the pulp. (Microradiogram. Orig.mag. × 500).

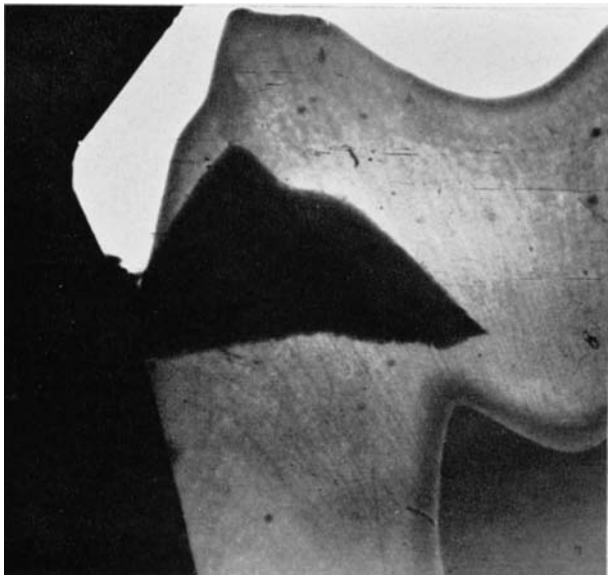

Fig. 11

Fig. 12

Fig. 11 and 12. Microradiograms showing large demineralized areas in the dentin. (Orig.mag. × 40).

Fig. 13. Osteodentin at the pulpal edge of the section. The pulp is to the right. The deposits show similarities to dentin. (Microradiogram. Orig.mag. × 100).

it decreases gradually towards the pulp. In cases without the globular demineralization, one very often saw a diffuse demineralization of the dentin next to the pulp and sometimes smaller areas near the periodontal membrane, from which the cementum had disappeared. Frequently the demineralization widened the pulp cavity. Large demineralized areas with or without visible "contact" with the pulp (Figs. 10, 11, and 12) appeared as early as one month after replantation but were more frequent after 2.5 months. After that time some irregular structures appeared which look like secondarily deposited material. In the pulp it has similarities with dentin and bone (Figs. 13 and 14) and at the tip of the root there are similarities with cementum and bone (Figs. 15 and 16).

Not until 2.5 months after the replantation did changes in the mineralization of the *enamel* appear. Demineralization round a foramen caecum appeared even in unimplanted teeth due to incipient caries (Fig. 17). In the present material, however, such

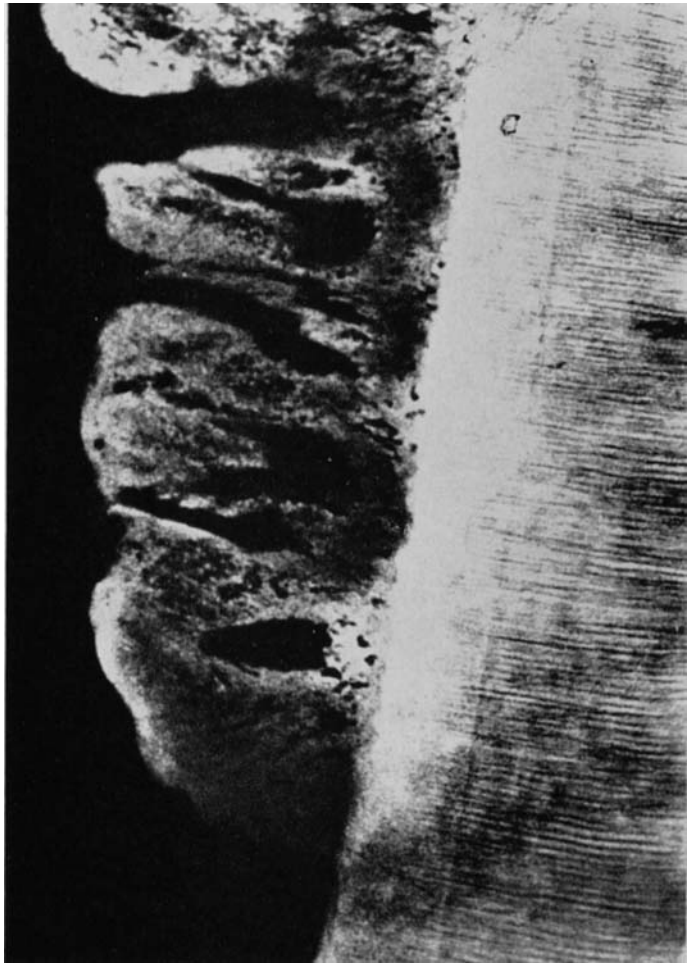

Fig. 14. Irregular osteoid deposits at the pulpo-dentinal junction. Pulp cavity to the left. (Microradiogram. Orig.mag. × 500).

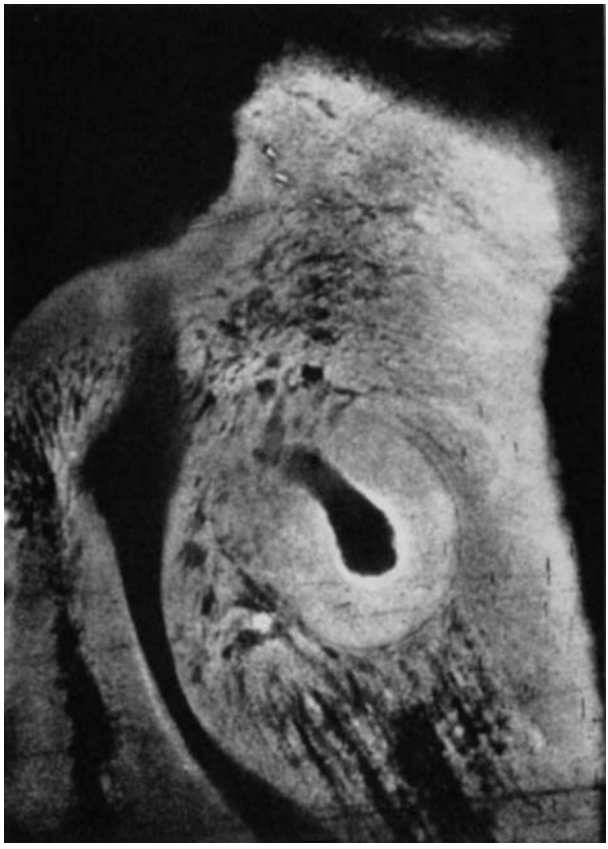

Fig. 15

Fig. 15 and 16. Osteoid deposits in the apical region (Microradiogram. Orig.mag. × 100).

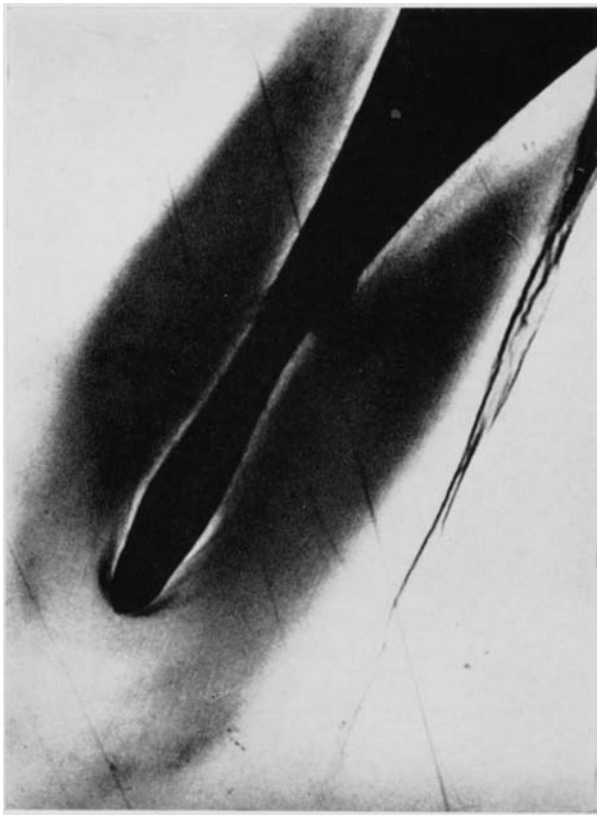

Fig. 17. Demineralized zone around a foramen caecum. (Microradiogram. Orig.mag. × 100).

changes were visible in one hundred per cent of cases with a foramen caecum. Demineralization and degeneration in the enamel elsewhere (Fig. 18) were in most cases correlated to a corresponding degeneration of the underlying dentin. In a few cases demineralized areas in the enamel appeared without any visible changes in the dentin of the same specimen.

DISCUSSION

The technical as well as the biological conditions of these replantations were optimal because the replantation in most of the cases was made a few seconds after extraction. The low age of

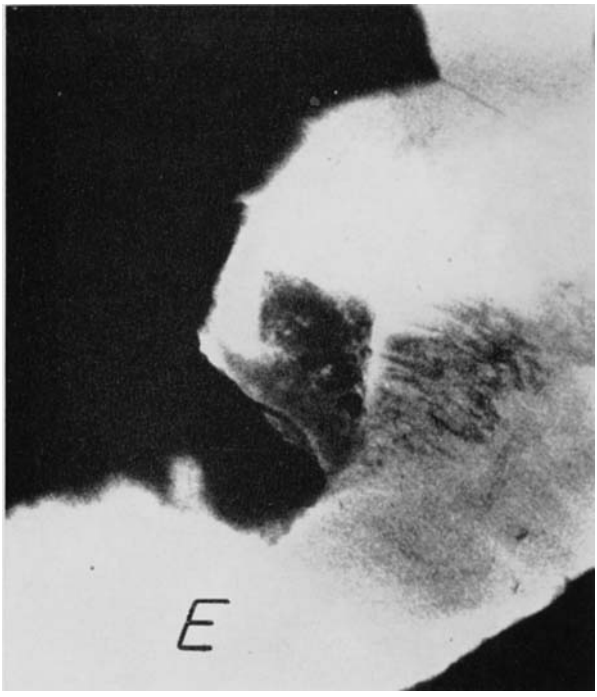

Fig. 18. Irregular demineralization of the enamel (E) not far from the dentino-enamel junction at the bottom of the picture. (Microradiogram. Orig.mag. × 100).

the patients contributed both to a minimum of trauma at the time of extraction and to a maximum of healing potentiality. In spite of these advantageous conditions, extensive demineralized zones in the cementum and dentin could be seen in most of the cases. It is impossible to say that these defects in the mineralization are due to lack of the membrane covering the cementum, a theory presented by *Axhausen* and *Hammer*. The dentinal changes are probably partly due to the sudden circulatory disorder in the pulp. In any case one gets the impression that the reattachment between the cementum and the alveolar bone is a more complicated process than has been previously assumed in some of the literature concerning the treatment of periodontal diseases. In spite of the optimal conditions for a reattachment

and a deposition of secondary cementum in cases where the covering membrane might not be intact, it is impossible to observe any changes of that type during the time of the present investigation.

The striking extensive demineralized areas in the dentin and in the enamel appear relatively soon after replantation. The deposition of osteoid material agrees well with what has been found in animal experiments and at roentgenological control examinations of clinical cases. A tendency for the osteoid tissue to resemble the adjacent mineralized tissue seems to exist.

Interglobular dentin may be a degenerative phenomenon which possibly is accentuated into the globular arrangement near the pulp in the replanted teeth.

All the demineralized areas seem to be the sites of degenerative changes. The only reparative signs are seen at the pulpo-dentinal junction and at the apex.

SUMMARY

Permanent teeth from 40 patients were extracted and immediately replanted. Changes in the mineralization were studied with the aid of x-ray microscopy at different lengths of time up to 7 months after the replantation. The following observations were made:

Cementum:

1. Mineralization intact.
2. Demineralized areas in direct contact with the periodontal membrane.
3. Isolated demineralized areas in the cementum.
4. Total demineralization and disappearance of the cementum.
5. Deposits of osseous tissue in the apical region.

Dentin:

1. Mineralization intact.
2. Increased appearance of interglobular dentin.
3. Globular demineralization of the entire dentin.
4. Globular demineralization of the zone next to the pulp.
5. Large totally demineralized areas.
6. Diffuse demineralization at the pulpo-dentinal junction.

7. Widened pulp cavity.
8. Deposits of osteoid material (osteodentin).

Enamel:

1. Mineralization intact.
2. Demineralization around foramen caecum.
3. Demineralized irregular areas with a corresponding demineralized area in the dentin underneath.
4. Demineralized irregular areas without any visible changes in the dentin.

RÉSUMÉ

MODIFICATIONS DANS LA MINÉRALISATION DES DENTS HUMAINES APRÈS RÉIMPLANTATION

Sur 40 patients, des dents permanentes ont été extraites et réimplantées immédiatement. Les modifications dans la minéralisation ont été étudiées pendant des durées variables et jusqu'à 7 mois après la réimplantation, en recourant à la radiographie microscopique. Les observations suivantes ont été faites:

Cément:

1. Minéralisation intacte.
2. Surfaces déminéralisées en contact direct avec le desmodonte.
3. Zones isolées de déminéralisation dans le cément.
4. Déminéralisation totale et disparition du cément.
5. Dépôts de tissu osseux dans la région apicale.

Dentine:

1. Minéralisation intacte.
2. Augmentation de la fréquence des espaces interglobulaires.
3. Déminéralisation globulaire de toute la dentine.
4. Déminéralisation globulaire de la zone proche de la pulpe.
5. Vastes zones entièrement déminéralisées.
6. Déminéralisation diffuse de la jonction pulpe-dentine.
7. Elargissement de la cavité pulpaire.
8. Dépôts de matière ostéoïde (ostéodentine).

Émail:

1. Minéralisation intacte.
2. Déminéralisation autour du foramen caecum.
3. Zones déminéralisées irrégulières avec zone correspondante déminéralisée dans la dentine sous-jacente.
4. Zones déminéralisées irrégulières sans changements visibles dans la dentine.

ZUSAMMENFASSUNG

MINERALISIERUNGSVERÄNDERUNGEN BEI REIMPLANTIERTEN MENSCHLICHEN ZÄHNEN

Permanente Zähne von 40 Patienten wurden extrahiert und sofort wieder reimplantiert. Die Veränderungen in der Mineralisierung nach verschiedenen Zeitabständen bis zu sieben Monaten wurden mit Hilfe der Röntgenmikroskopie studiert. Folgende Beobachtungen wurden gemacht:

Zement:

1. Mineralisierung intakt.
2. Demineralisierte Gebiete in direktem Kontakt mit der periodontalen Membran.
3. Isolierte demineralisierte Gebiete im Zement.
4. Völlige Demineralisierung und Verschwinden des Zements.
5. Ablagerung von knöchernem Gewebe in der apikalen Region.

Dentin:

1. Mineralisierung intakt.
2. Vermehrtes Vorkommen von Interglobulardentin.
3. Globulare Mineralisierung des gesamten Dentins.
4. Globulare Mineralisierung der pulpanahen Zone.
5. Grosse, völlig demineralisierte Gebiete.
6. Diffuse Demineralisierung an der Pulpa-Dentingrenze.
7. Vergrösserte Pulpahöhle.
8. Ablagerung von osteoidem Material (Osteodentin).

Schmelz:

1. Mineralisierung intakt.
2. Demineralisierung um Foramen caecum herum.

3. Unregelmässige demineralisierte Gebiete mit entsprechenden demineralisierten Stellen in dem unterliegenden Dentin.
4. Unregelmässige demineralisierte Gebiete ohne sichtbare Veränderungen im Dentin.

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