A qualitative microradiographic study of the enamel and the dentine in ground sections of impacted human permanent teeth

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52 totally or partially embedded teeth were studied in ground sections by soft microradiography to assess the quality of the enamel and the dentine. In 79 % the dentine was more or less globularly mineralized. In 50 % the dentine-enamel junction (D.E.J.) was more scalloped than normally and in three cases the border-forming globules were vacuolated. All kinds of hypoplasia were found, gross, minor, and tube. The enamel-cementum junction was irregular in 63 %, hypoplastic in 60 %, hypomineralized in 42 %, and provided with loose enamel globules in 27 %. Cementum or bone-like tissue covered the enamel lingually in two front teeth and occlusally in a third lower molar. The fissures could be extremely narrow and penetrate the enamel till near the dentine border. The distance between the fundus of the fissure and the D.E.J. was measured to 0.15—0.5 mm, is one case only 0.06 mm. In their basal parts the fissures could be invaginated or ampullar. T-hypoplasia could be found in the walls or the fundus of the fissure and the lingual aspect of the front teeth. The mineralization of the dental hard tissues in embedded teeth thus displays heavy disturbances especially in the fissures and the D.E.J.

Key-words: Dental enamel; dentin; tooth, impacted; microradiography; tooth, calcification

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The old concept that the strong caries susceptibility in molar and premolar pits and fissures might have some relation to the anatomical form and the mineralization of these areas was renewed by *Hodson* (1949) who stated that deep invaginations of the fissures, the T-hypoplasia, constitute areas of arrested amelogenesis, often associated with defective matrix formation. *Gillings & Buonocore* (1961) presented new evidence for this opinion by making graphic reconstructions of 40 molars and 12 bicuspids which had been prepared for ground sections. In all but one of the specimens the presence of deeply invaginated fissures were shown. These authors, however, stated that in spite of the fact that almost every molar and premolar in their material displayed deep fissures, they were all caries-free (by selection). Some teeth were from elderly persons and the authors therefore concluded that the presence of deeply invaginated enamel cannot be the sole

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Table I. *Distribution of teeth according to age, sex and location*

Age	M	F	3d molars Max.	3d molars Mand.	Premolars Max.	Premolars Mand.	Canines Max.	Canines Mand.	Incisors Max.	Incisors Mand.	Accessory Max.	Accessory Mand.	Total
9—14	7	13			9	1	3		2		5		20
15—19	3	8			2	3	4		2				11
20—24	3	7		6	3	1							10
25—29	2	1		1	1	1							3
30—35	1	4			1		4						5
43—50	2	1		2							1		3
Total	18	34		9	16	6	11		4		6		52

reason for the early decay which often is clinically observed in molar teeth, especially in the third permanent molar.

Predilection places for caries are further the enamel-cementum border and the foramina coeca in the incisors and canines. The objective of this study was to investigate by means of soft microradiography if the mineralization pattern of the enamel in the aforementioned places was different from the normal enamel morphology.

MATERIAL AND METHODS

In all, fifty-two surgically removed impacted teeth were used. Their distribution appears from Table I.

All teeth except four which were sectioned *in toto* were divided in two halves bucco-lingually. One half was embedded in methyl metacrylate according to a routine method and sectioned. All sectioning was performed in a water bath. The sections were ground and polished in usual way.

A Philips PW 1009 X-ray machine, provided with a copper anode and a nickel filter and operating at 20 kV and 20 mA, was used for soft microradiography. The photographs were recorded on Kodak MR spectroscopic plates.

The other half was demineralized in formic acid, embedded in paraffin wax and sectioned serially. This half was used for checking the mineralization pattern of the dentine. In evaluating the microradiographs, the interest was focused on the following characteristics:

(1) *The globular mineralization of the dentine.* The scoring index of dentine mineralization adopted by *Bergman, Göthe* and *Welander* (1961) for deciduous decalcified teeth and first permanent molars was used also for ground sections. A distinction was made between a fully homogenous dentine, a globular dentine and an interglobular dentine with free globules. In very severe cases the interglobular dentine was almost ubiquitous which was noted. Though the ground sections and the decalcified sections did not exactly correspond to each other (*Symons*, 1965), it appeared that the classification of the dentine mineralization of *Bergman et al.* (1961) for decalcified sections well could be used for comparing the ground sections *inter se.*

(2) *Incremental or other mineralization patterns of the dentine.* Measurements were performed with an eye-piece provided with an index graded in tenths of a millimeter.

(3) *The dentine-enamel junction (D.E..J.)*

The D.E.J. is ordinarily scalloped with the convexities facing the dentine. Distinction was made between (a) D.E.J. straight or almost straight or with small convexities, (b) more marked globular arrangement at the D.E.J., (c) D.E.J. very irregular and globulated, (d) the same as (c) but with an internal hypoplasia, giving the appearance of a lumen in the globules.

(4) *The enamel surface.* Globular structures and granular material were studied (a) in the fissures, (b) at the slope of the cusps, (c) at the other surfaces.

(5) *Enamel hypoplasia* was noted and classified g (gross) or m (minor) according to *Mellanby* (1934) and t (tube) consistent to *Hodson*'s (1949, 1950) classification.

(6) *The enamel-cementum junction (ECJ)* was observed with regard to irregular course, globular mineralization, hypoplasia and hypomineralization.

(7) *The occurrence of hard substances (cementum, bone)* amalgamated to the enamel surface was recorded.

(8) *Pericoronal inflammation* was noted in case the follicle was preserved.

(9) *The shape and depth of the fissures* were studied and the distance from the fundus of the fissure to the D.E.J. measured.

OBSERVATIONS

Deviations from »normal» mineralization of dentine and enamel in embedded teeth seemed to be extremely common.

(1) *Dentine.* The distribution of the material according to the classification of *Bergman et al.* (1961) is tabulated in Table II.

Table II. *Dentine mineralization patterns acc. to Bergman et al., loc. cit.*

Class	%
A	21.2
B	61.7
C	11.4
D	5.7

The globular areas were preferentially found in the cusp tips, beneath the fundus and the slopes of the fissure and along the buccal and lingual sides (Fig. 1). In class C and D the gross changes were found in these areas (Fig. 2). However, of the nine third molars in the material two showed heavy disturbances in the dentine mineralization (class D). This was substantially more than in the rest (one of forty-three).

The dentine mineralization pattern was checked with the decalcified sections in 37 of the specimens. It was found that the globular patterns in the undecalcified and the decalcified sections were of the same dignity.

(2) *Incremental lines* were measured in 7 cases to about 4 μm. In one case however, the mineralized lines were 8 μm and the intervening arrested lines 4 μm (Fig. 3).

(3) *The dentino-enamel junction* was in half of the cases more scalloped than normal. In seven of these cases the border was composed of more or less loose enamel globules which projected into the dentine (Fig. 4). These globules were in three cases vacuolized when studied in the microradiographs (Fig. 5). In one case this feature was dominating (Figs. 6A, B).

(4) *The enamel surface* was at least partly globular or granular in all cases except one. The globules were preferentially found in the fissures (Fig. 7), in invaginations (Fig. 8), at the slopes of the cusps, especially below the summit (Figs. 9A, B), or at the cervical buccal or lingual surfaces (Fig. 10). The granular

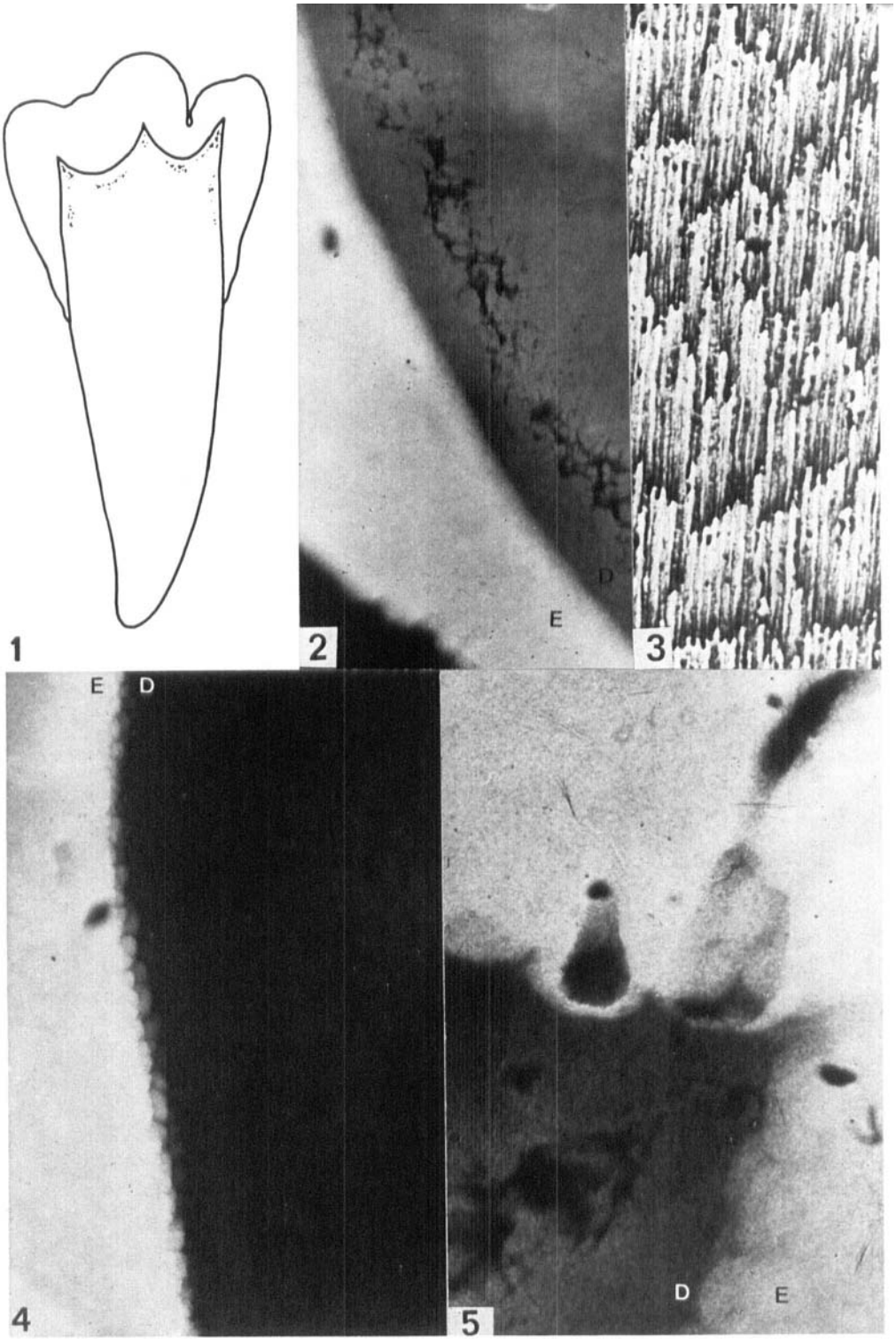

Fig. 1. Sketch showing the main sites of interglobular areas.
Fig. 2. Right upper canine, ♀ 13 yrs., globular dentine along the buccal D.E.J., mineralization pattern type C. Microradiograph. × 32.
Fig. 3. Right upper canine, ♀ 50 yrs., a staggered mineralization pattern of the dentine, decalcified section; Bock staining. × 320
Fig. 4. Left upper second premolar, ♀ 14 yrs., D.E.J. globular, type C. Microradiograph. × 32.
Fig. 5. Left lower third molar, ♀ 23 yrs., D.E.J. globular with radiolucent centre. × 125.

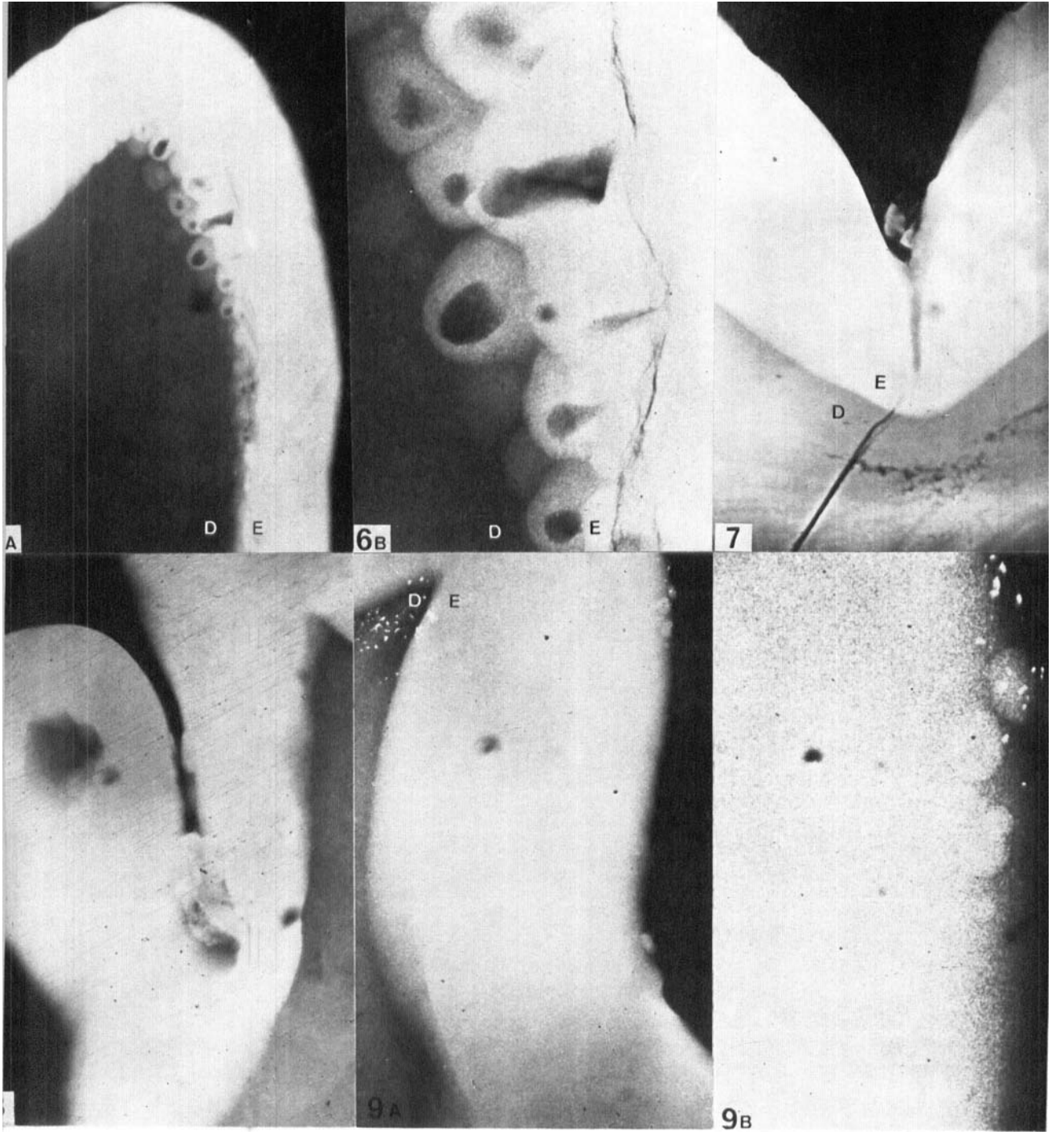

Fig. 6A. Mesiodens, ♂ 12 yrs., D.E.J. extremely globular, the globules vacuolated. Microradiograph. × 32.
Fig. 6B. Detail of Fig. 6A. Microradiograph. × 125.
Fig. 7. Left upper second premolar, ♀ 13 yrs., globular material in the fissure. Microradiograph. × 125.
Fig. 8. Mesiodens, ♂ 12 yrs., invagination with loose, globular tissue. Microradiograph. × 125.
Fig. 9A. Left upper second premolar, ♀ 13 yrs., enamel globules slightly below the summit of the cusp and at the cuspal slope. Microradiograph. × 32.
Fig. 9B. Magnification of Fig. 9A showing the globules at the cusp tip. Microradiograph. × 125.

material was found at the same places, but could be generally dispersed at the enamel surface, thereby giving the surface a loose texture.

(5) *Hypoplasia.* Gross (G) hypoplasia (Figs. 11A, B) was found in 13 cases (25 per cent). Minor (M) hypoplasia was much common (about 68 per cent) (Figs. 11A, B). Tube hypoplasia (T) was noted in seven cases (13 per cent) (Fig. 11B). Of the gross hypoplasia twelve were single and in three tooth surfaces multiple. Minor hypoplasia was generally multiple (in 53 tooth surfaces). Only occasionally (three surfaces) they were single.

Tube hypoplasia (Figs. 12A, B), was found single in three occlusal surfaces and in two lingual surfaces. Multiple tube hypoplasia was found in two occlusal and one lingual surface.

(6) *The enamel-cementum junction (ECJ).* The E.C.J. in the majority of cases (63 per cent) showed an irregular course (Fig. 13). Often (27 per cent) the enamel was partly globular in this region (Figs. 14A, B). Granular material could accompany the globules or exist separately. In the cervical region the enamel often appeared hypoplastic (60 per cent) (Figs. 10, 14A, B) or was hypomineralized (42 per cent). (Fig. 10). The cementum occasionally covered the enamel with a spur (Fig. 15).

(7) *Cementum or bone-like hard tissue* was noted in three cases covering the tooth surfaces, in two cases the lingual (Fig. 16) and in one case the occlusal (Fig. 17A). In a few other cases there was a thin lamellar covering of certain enamel surfaces (Fig. 17B).

(8) *Inflammation* was noted in the surrounding soft tissues in six of the twenty-

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Fig. 10. Right lower third molar, ♀ 24 yrs., partially embedded. Enamel globules at the cervical lingual surface. × 125.

Fig. 11A. Right upper canine, ♂ 13 yrs., gross and minor hypoplasia of the enamel. Photograph. × 4.

Fig. 11B. The lingual aspect of the tooth shown in Fig. 11A. Gross (G) and minor (M) hypoplasia as well as tube hypoplasia (T). Microradiograph. × 125.

Fig. 12A. Right upper second premolar, ♂ 35 yrs. Tube hypoplasia on the occlusal surface and an opposing dentine projection. The intervening enamel has a thickness of 0.12 mm. Microradiograph. × 32.

Fig. 12B. Magnification of Fig. 12A showing a hypomineralized zone connecting the T-hypoplasia and the dentine. Presumably there is an extension of the T-hypoplasia in dentinal direction in another plane as indicated by the radiolucency. Microradiograph. × 125.

Fig. 13. Left upper second premolar, ♀ 12 yrs., partially embedded. The enamel-cementum junction irregular and hypoplastic. Microradiograph. × 32.

Fig. 14A. Right upper central incisor, ♀ 12 yrs. The buccal E.C.J. with marked enamel globules. E = enamel, C = cementum. Microradiograph. × 125.

Fig. 14B. Right upper central incisor, ♂ 10 yrs., follicular cyst. The buccal E.C.J. with hypoplasia and globular spaces. E = enamel, C = cementum. Microradiograph. × 125.

Fig. 15. Left lower third molar, ♂ 49 yrs., follicular cyst. Cementum spur covering the enamel at the C.E.J. Microradiograph. × 125.

Fig. 16. Right upper canine, ♀ 13 yrs., lingual aspect with a rough surface, partly discoloured. Photograph. × 4.

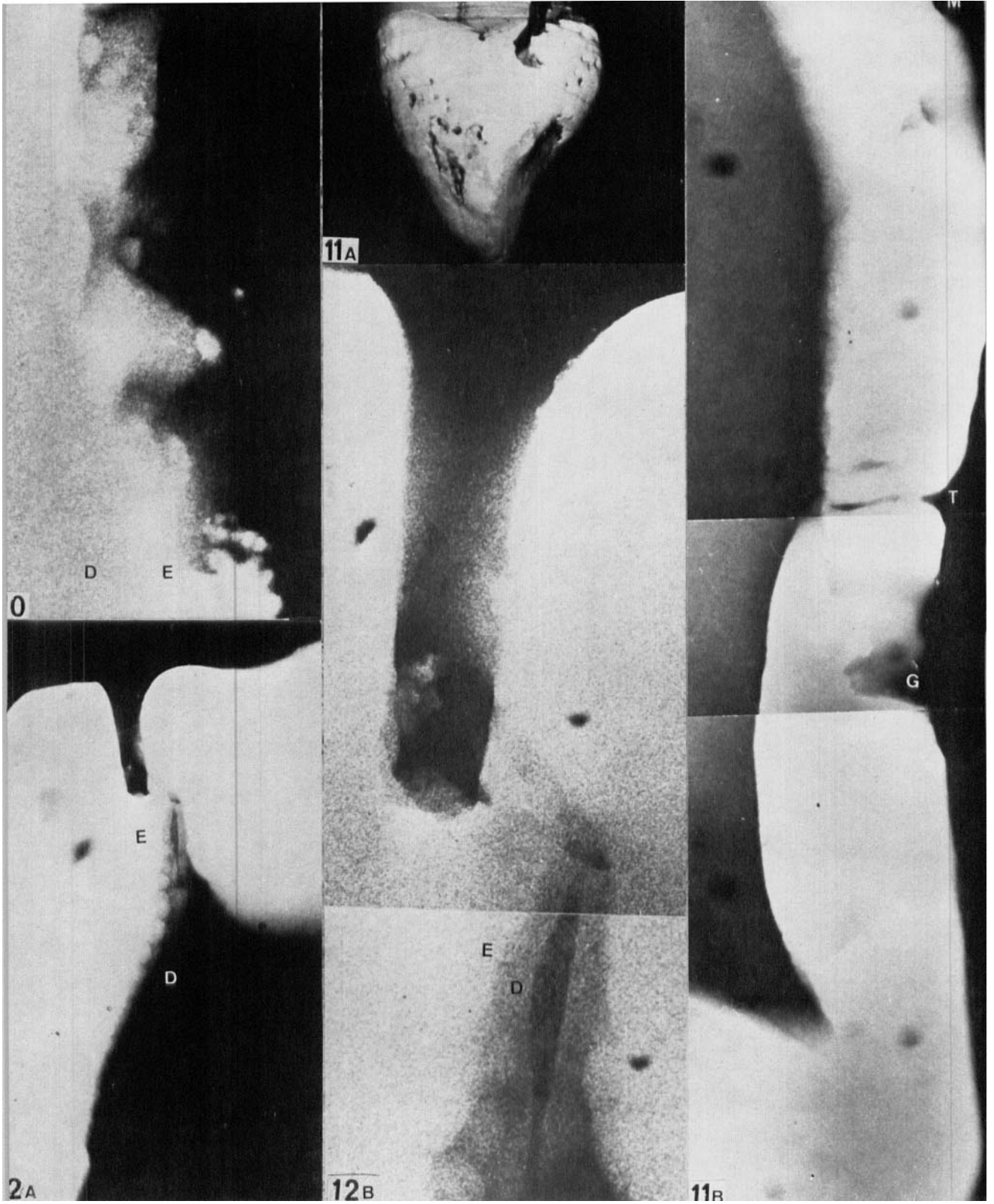
Fig. 17A. Right lower third molar, ♀ 50 yrs., apposition of bone-like hard tissue (B) on the occlusal surface. (E). Microradiograph. × 125.

Fig. 17B. Left lower third molar, ♂ 49 yrs., follicular cyst. Thin, lamellar covering of the buccal surface. Microradiograph. × 125.

Fig. 18A. Left upper second premolar, ♀ 14 yrs., the fissure to the left penetrates the enamel to a distance of 0.06 mm from the dentine. To the right of this fissure there can be seen a T-hypoplasia. Microradiograph. × 32.

Fig. 18B. Ibidem, ♀ 14 yrs., magnification of Fig. 18A showing the tubelike projections from the deeply invaginated fissure. Basal ampullalike widening. Microradiograph. × 125.

Fig. 18C. Left lower third molar, ♀ 23 yrs., tubelike projection from the fissure. Microradiograph. × 32.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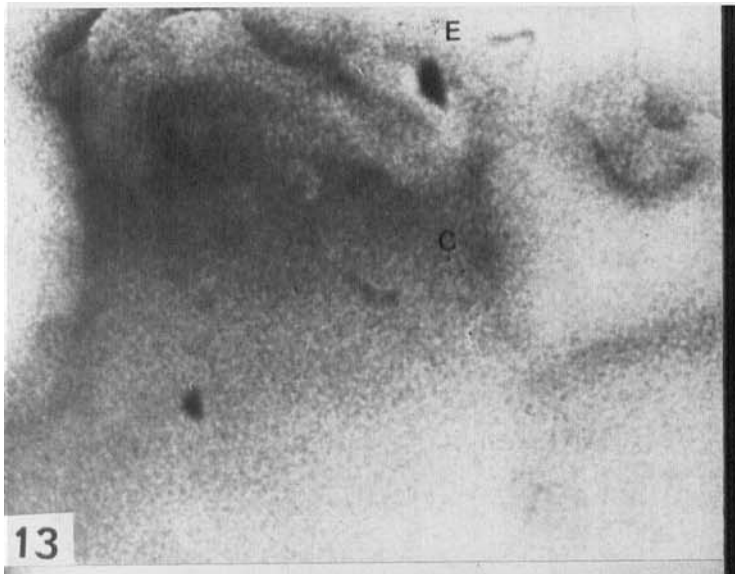

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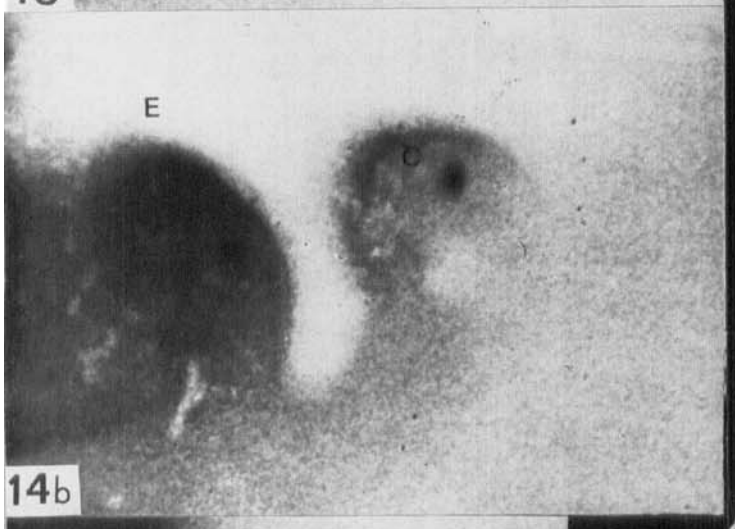

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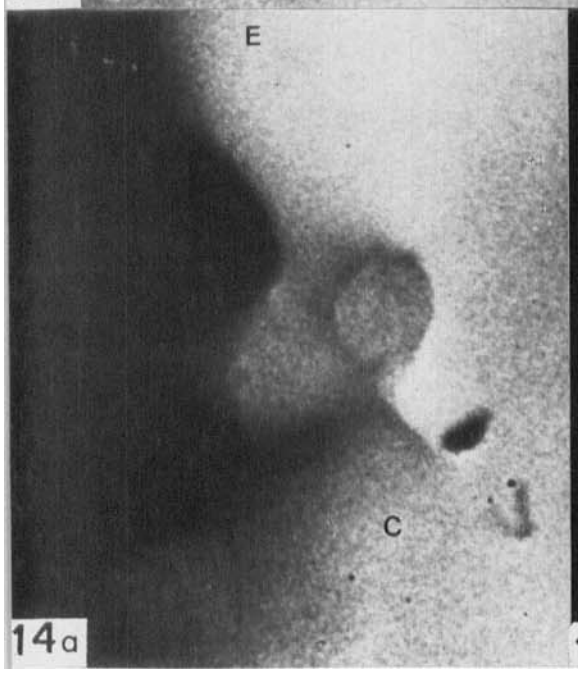

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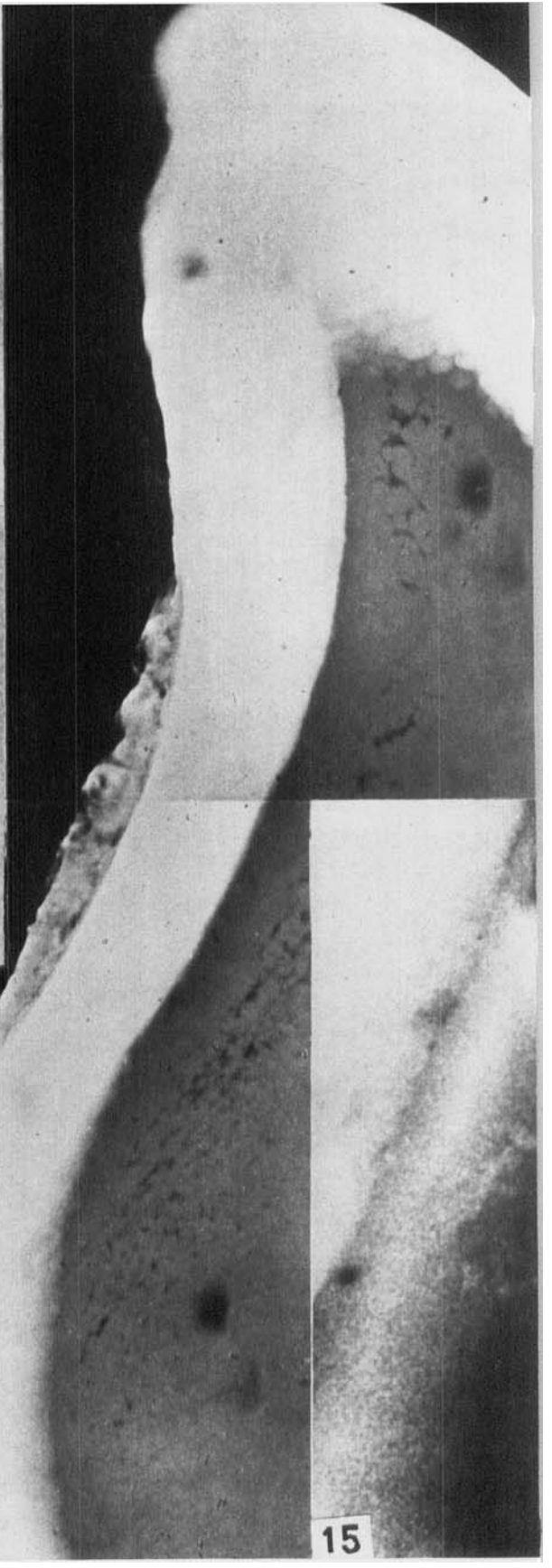

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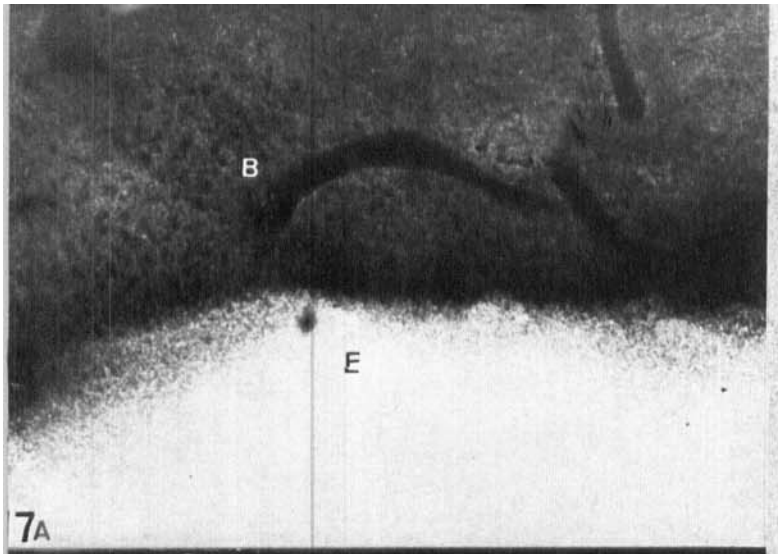

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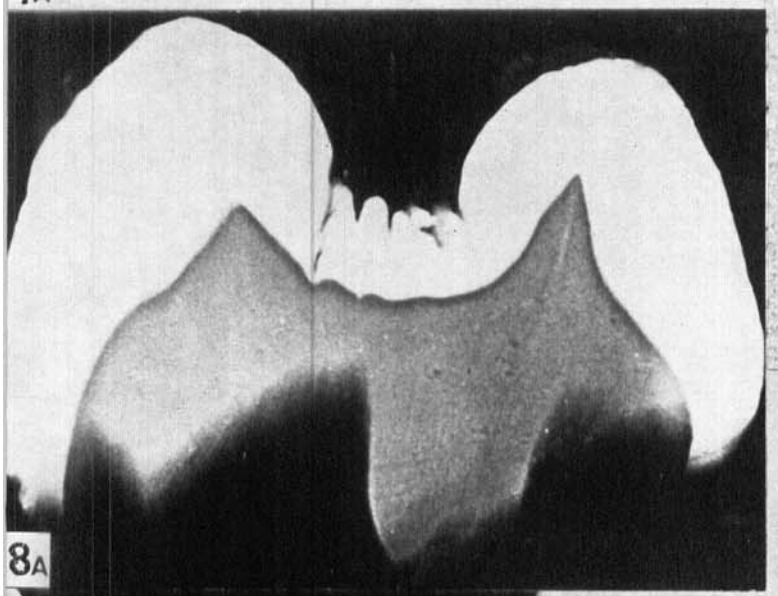

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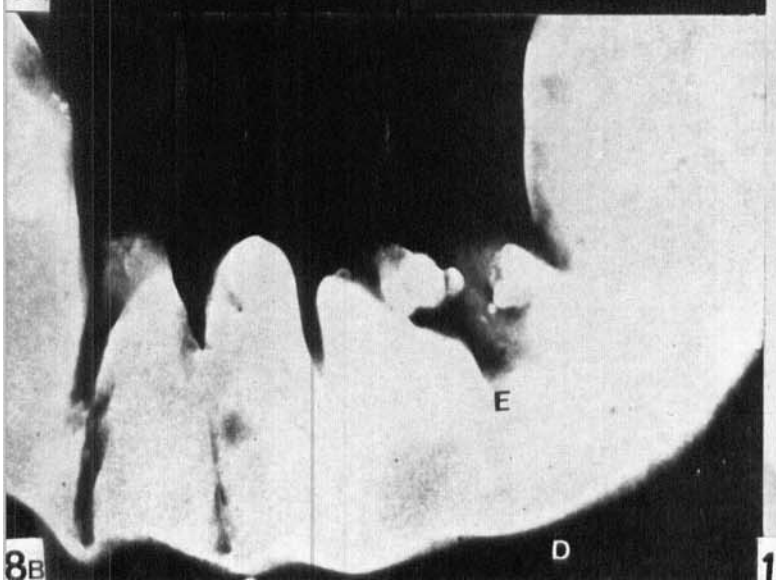

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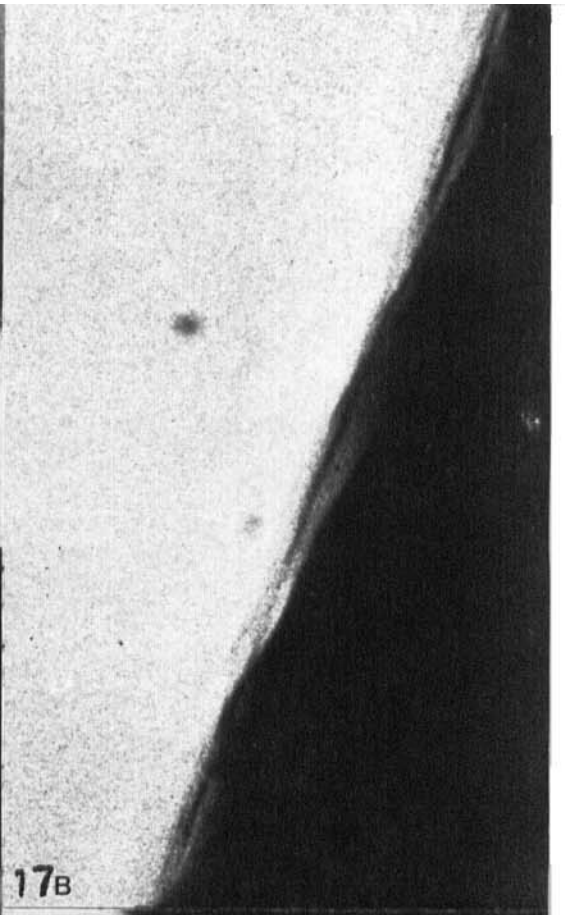

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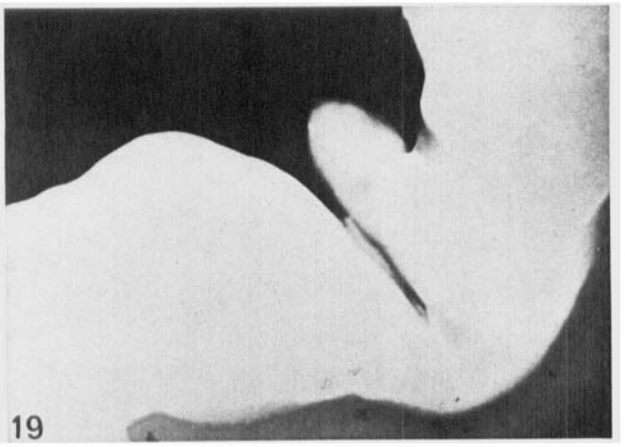

Fig. 19. Left lower third molar, ♂ 49 yrs., follicular cyst. Distance between the fundus of the fissure and the dentine is 0.2 mm.

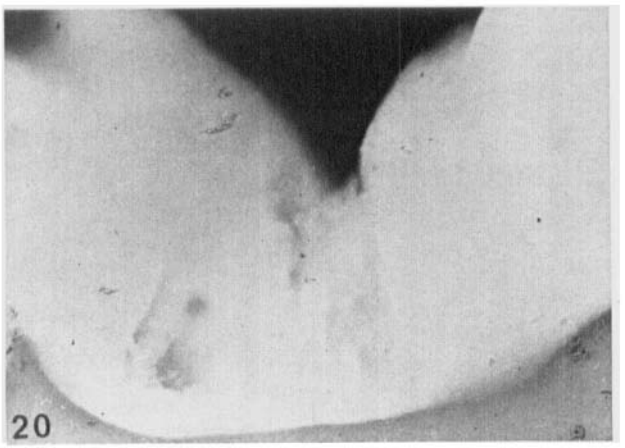

Fig. 20. Right upper second premolar, ♀ 12 yrs., partially embedded. A cavern-like widening of the fissural system. Microradiograph. × 125.

one cases where the follicle was preserved, i.e. an incidence of 29 per cent.

(9) *The fissures*. Though the sectioning of the teeth not always was performed in such a way that the deepest part of the fissure was preserved in the ground section it was obvious that in both the second premolar and the third molar the fissures often were deeply penetrating the enamel (Figs. 18A, B). Frequently the fissures formed a mild type of invagination with a narrow opening and an ampulla-like widening basally (Figs. 18B, C). The distance between the fissural fundus and the dentine was in many cases 0.15—0.5 mm (Fig. 19). and in one case where the fissure system was rather complicated, the distance was as short as 0.06 mm (Figs. 18A, B). From the walls and the fundus of the fissure tubelike projections could penetrate the enamel further in dentinal direction (Fig. 19). In one case the fissure was widened to a veritable cavern with great extension (Fig. 20). In two lower third molars an enamel pearl in the bifurcation was found.

All ground sections were viewed in the fluorescence microscope. In one case, a 14 year old boy, a fluorescent, probably tetracycline line was observed corresponding to an age of about 3.5 years.

DISCUSSION

The globules in the enamel, the globular pattern of dentine, and certain other structural features will be particularly discussed in the following.

The enamel globules are of different kind at the D.E.J. and at the surface. The scalloped D.E.J. might be produced by globules, fused in their inner parts. Their convexity against the dentine suggests that they have developed from the enamel side. By disturbed enamel formation they may be vacuolized (Figs. 5, 6A and B) and eventually filled with an organic, radiolucent substance. They were found in teeth with gross formative disturbances, including in one case a deeply invaginated fissure, in another enamel pearl formation at the bifurcation and class D interglobular dentine, and in a third supernumerarity and gross hypoplasia.

Ameloblasts are said to lay down their secretion in globular form, 4 μm in diameter (*Schour* 1953; *Gustafson, A.G.* 1959). Globules have also been described by *Symons* (1962) in the rat ameloblast layer and stratum intermedium. They are of small dimensions and probably represent degenerated mitochondria or other cell organelles. The globules now observed are twenty-five times larger than the former and a hundred times larger than the latter, and might represent an aggregation of mineral precursors just before starting of the mineralization.

The globules at the enamel surface are in structure and position very similar to the globular material in *amelogenesis imperfecta* (*Bergman et al.*, 1964) and *epidermolysis bullosa* (*Delaire et al.*, 1960; *Arwill et al.*, 1965) which material has been called »tissue amélóïde» by *Delaire* and his co-workers.

These globules, in epidermolysis bullosa, have been shown to consist of partly vacuolized, partly homogenous, apparently »keratinized» or/and mineralized epithelial pearls, caused by a metaplasia of the enamel epithelium to squamous stratified epithelium before the enamel had been fully formed (*Arwill et al.*, 1965). As in the epidermolysis bullosa cases the mineralized globules in the impacted teeth were trapped in the outer enamel epithelium shell and thus attached to the enamel surface and rather loosely kept in place during eruption. It is probable that the globules in the fissures at the cuspal slopes, in invaginations, and at the C.E.J. are caused in a similar way. In the erupted tooth the globules can readily be worn off except in places where they are hidden, i.e. fissures and invaginations. Of course, they might also be more intimately »glued» to the enamel during the mineralization (Fig. 9B). In such case the enamel surface will be irregular and rough. The fact that the globules mostly are found in the fissures, at the cusps and at the E.C.J. points to the hypothesis that the enamel epithelium in these places behaves differently than in other locations. *Kraus* and *Jordan* (1965) showed that, in deciduous molars, the fissures are the last areas to be mineralized. It is probable, that this is the case also in permanent teeth. If the enamel epithelium in the fundus of the fissure is prematurely reduced it may become metaplastic, thereby producing epithelial pearls which are subject to easy mineralization. These globules can fuse and form aggregates (Fig. 10) with each other or with the enamel (Figs. 10, 13A, 14B, C). The E.C.J. in 63 % formed an irregular line which may play a certain role as starting point for food impaction and plaque formation after the eruption. There are still other possibilities for enamel globule

formation which will be discussed in a forthcoming paper (*Arwill*, 1974).

The globular pattern of dentine mineralization is referred to the calcospherite formation (*Schmidt & Keil*, 1958). It is generally assumed that the interglobular areas are filled with organic material which has not been mineralized. At the predentine border the odontoblasts form a cellular syncytium with tight junctions at the contact areas (*Frank*, 1966; *Arwill*, 1967). There is ordinarily no intercellular space at the matrix-forming line. If a break in the cellular border sheet is produced, a real hole in the dentine matrix would be the result. The interglobular area could thus be of differing origin, (1) hypocalcified but matrixcontaining area, (2) a real dentine hypoplasia without matrix, but containing fluid. *Schmidt* (1961) has maintained that the interglobular areas represent real spaces.

The localization of the interglobular areas was preferably found in the cusp tips, beneath the fissural slopes and fundus, and along the buccal and lingual aspects (Figs. 1A and B). There seemed to be a frequent localization beneath the foramen coecum of incisors and canines, (Fig. 2B). These disturbances could hardly be related to defined chronologic events such as the neonatal period as they were found in teeth with different mineralizing times but still in the same position. A delay in the odontoblastic activity therefore seems probable at the times when these parts of the dentine are formed.

The T-hypoplasia of *Hodson* (1949, 1950) was found rather frequently (Figs. 11C, 12B). They occasionally almost penetrated the enamel to the D.E.J. (Fig. 12B). They were found not only at the occlusal surfaces of the premolars and molars but also at the lingual surfaces of incisors and canines (Fig. 11C). Obviously they must be kept in mind when considering the caries susceptibility of these areas, as *Hodson* has stressed.

The hard tissue deposit which was lingually superimposed in two cases (Figs. 16A, B) might be an overdevelopment of the afibrillar cementum which in cases of defects in the reduced ameloblastic sheet can cover the enamel (*Listgarten*, 1966). In one case there was a thin but general covering of a radiopaque tissue which indicates a generally distributed disturbance in the activity of the reduced ameloblasts (Fig. 17B). The totally embedded lower third molar in Fig. 17A was occlusally covered with ordinary bone.

The most striking feature in the present, supposedly »normal» though impacted tooth material is the great variability in gross tooth anatomy as well as in microscopic structure. It thus seems questionable whether impacted teeth in any way could be considered as "normal".

REFERENCES

Arwill, T., Bergenholtz, A. & Olsson, O., 1965. Epidermolysis bullosa hereditaria. III. A histologic study of changes in teeth in the polydysplastic dystrophic and lethal forms. Oral Surg. 19, 723—744

Arwill, T., 1967. Studies on the ultrastructure of dental tissues. II. The predentine-pulpal border zone. Odont. Revy, 18, nr 2

Arwill, T., 1974. Hyaline bodies and odontogenic epithelium in the follicles of unerupted human permanent teeth. Acta Odont. Scand., 32, 15—28

Bergman, G., Göthe, Gertrud & Welander, E., 1961. Studies on mineralized dental tissue. XV. Mineral pattern of dentine. Arch. Oral. Biol. 4, 6—23

Bergman, G., Arwill, T., Welander, E. & Wennström, A., 1964. Observations on enamel and ectodermal lesions in some cases of amelogenesis imperfecta. Odont. Revy. 15, 1—9

Delaire, J., Kérébel, B. & Billet, J., 1960. Manifestations bucco-dentaires des epidermolysis bulleuses. Rev. Stomat. 61, 189—200

Frank, R., 1966. Etude au microscope electronique de l'odontoblaste et du canalicule dentaire humain. Arch. Oral. Biol. 11, 179—199

Gillings, B. & Buonocore, M., 1961. Thickness of enamel at the base of pits and fissures in human molars and bicuspids. J. Dent. Res. 40, 119—133

Gustafson, Anna-Greta, 1959. A morphologic investigation of certain variations in the structure and mineralization of human dental enamel. O.T. 67, 361—472

Hodson, J. J. 1949. Tubular investigations of the enamel capsule. T-hypoplasia, a new factor in the pathology of human enamel caries. B. Dent. J. 88, 167—180

Hodson, J. J. 1950. A study of some of the developmental, structural and pathological aspects of tubular hypoplasia in human enamel. I and II. B. Dent. J., 89, 63—13 and 34—38

Kraus, B. S. & Jordan, R. E. 1965. *The Human Dentition before Birth.* p. 65 Lea & Febiger, Philadelphia

Mellanby, M. 1934. Diet and the teeth (An experimental study). Part III. The effect of diet on dental structure and disease in man. Spec. Rep. Ser. No 191, Med. Res. Coun., London

Schmidt, H. 1961. Ein Beitrag zur Morphologie der Interglobularraume in verkalkten Dentin und ihr Nachweis nach der Entkalkung. Arch. Oral. Biol. 4, 63—66

Schmidt, W. J. & Keil, A. 1968. *Die gesunden un die erkrankten Zahngewebe des Menschen und der Wirbeltiere im Polarisationsmikroskop.* Carl Hanser Verlag, München

Schour, I., 1953. *Oral Histology and Embryology*, 7th Ed. Lea & Febiger, Philadelphia

Symons, N. B. B. 1962. Globular structures associated with the completion of the enamel matrix in the rat. J. Dent. Res. 41, 55—60

Symons, N. B. B., 1965. Interglobular dentine and the calcospherite pattern. Arch. Oral Biol. 10, 1009—1010