

The effect of calcium hydroxide and fluorides on human dentine

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With the aid of scanning electron microscopy and microradiography, 45 teeth including 20 contralateral tooth pairs were studied to assess the effect on human dentine of (1) a 1 minute treatment with 3 % NaF, (2) a dressing of Ca(OH)₂ and (3) a dressing of Ca(OH)₂ and CaPO₃F after follow-up periods of 2–8 weeks. After NaF treatment the SEM revealed no sign of obliteration of the dentinal tubules, and on microradiograms no indication of increased density could be registered compared to an untreated control area. Under the calcium dressing the SEM revealed in 13 cases out of 20 (5 cases of 11 intrapair comparisons) a varying degree of constriction of the dentinal tubules. Constrictions varied from one tubule to another and ceased approximately 0.1 mm in the dentine. On the microradiograms no significant difference could be registered between untreated dentine and dentine treated with the calcium dressings. Dressings of Ca(OH)₂, a combination of Ca(OH)₂ and CaPO₃F for 2 months, or a 1 minute treatment with a cavity cleaner containing 3 % NaF can thus not be considered to result in a reliable obliteration of the dentinal tubules.

Key-words: Dentine, calcium hydroxide; fluorides; microscopy, electron; microradiography

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Treatment of exposed dentine and prepared surfaces in such a way that a relatively rapid obliteration of the dentinal tubules occurs has long been clinically desirable. Such a blocking would not merely reduce the sensitivity of dentine associated with patent dentinal tubules (Brännström, 1966; Brännström & Åström, 1972; Johnson and Brännström, 1974). It would also provide protection from bacterial penetration and inhibit diffusion of toxins towards the pulp, which must be regarded as the main reason for pulpal damage under filling materials (Bränn-

ström & Nyborg, 1972; 1973; 1974. Vojinovic, Nyborg & Brännström, 1973) and exposed dentine (Lundy & Stanley, 1969; Mjör, 1974; Olgart, Brännström & Johnson, 1974). It has been suggested that treatment of dentine with fluorides and calcium hydroxide could aid in obliterating the dentinal tubules and thus provide protection for the pulp. These substances have also been tested with varying results for treatment of hypersensitive dentine (Lukomsky, 1941; Hoyt & Bibby, 1943; Kanause & Ashe, 1969; Shaefer, Bixler & Yu, 1971; Hiatt & Johansen, 1972; Jor-

kjend & Tronstad, 1972; Bhasker 1973; Levin, Yearwood & Carpenter, 1973), and are used in different combinations as a »conditioner» or dressing in cavities under temporary and permanent fillings (*Zander, 1959; Mjör, Finn & Quigley, 1961; Ripa, Guzman & Dilzell, 1972*).

The effect of calcium hydroxide in a suspension of methylcellulose has been studied by *Klein (1961)* who found in densitometric evaluations an increase in the degree of mineralization in the dentine between the dressing and the pulp. In a similar investigation *Mjör et al. (1961)* found on a relatively large area towards the pulp a markedly increased hardness in the dentine under calcium hydroxide dressings as early as 15 days after placement. This change did not increase during longer observation periods. In a more recent investigation *Mjör and Furseth (1968)* found on ground sections and microradiograms »some degree of increased mineralization in localized areas of the cavity tubules, i.e. those dentinal tubules exposed by cavity preparation and covered with calcium hydroxide, or corticosteroid compound». As pointed out by *Biven, Bapna & Heuer (1972)*, *Mjör's* result may be queried, as comparisons have been made with hardness measurements of different teeth, and from the opposite side of the same tooth.

One may also question the validity of interpreting increased hardness and density of ground surfaces — respectively microradiograms — as an indication of »intratubular obturation». A possible increased mineralization of dentine can be confined to the intertubular areas. *Mjör & Furseth (1968)* studied selected preparations from the abovementioned tooth material in a transmission electron microscope investigation and found »obturation of the tubules by a moderately electron

dense crystalline material in most cases». The same changes were noted also under dentine covered with a corticosteroid. To judge from the illustrations in the work mentioned above, which deals mainly with the pre-dentine — dentine region, it does not seem justified for us to conclude that calcium hydroxide or corticosteroid results in an obliteration of the dentinal tubules with mineral salts.

Stuart & Richardson (1968) studied the effect of calcium hydroxide applied to dentine, using densitometric »readings». They found that this dressing »had no special merit as a lining material as compared with zinc-oxide-eugenol, in terms of capacity to promote sclerosis in sound primary dentine». *Stuart & Richardson's* observations are an interesting comparison to those of *Rothberg & de Shazer (1966)* who found chemically and histologically that eugenol removes calcium from dentine. Other authors such as *Biven et al. (1972)* and *Mjör (1962)* found however, that dentine treated with zinc-oxide-eugenol showed an increased mineralization. Of interest in this context are also the observations of *Kato & Fusayama (1970)* in studies of recalcification of artificially decalcified dentine *in vivo*. The investigation showed that calcium hydroxide paste did not increase the recalcification which occurred in partially decalcified dentine, as a vital reaction.

Undoubtedly conflicting opinions and results exist as to what extent calcium hydroxide can contribute to an increased hardness of dentine. If a sclerosis occurs it is also doubtful if this can be attributed to obliteration of the dentinal tubules or to a higher mineral content of the intertubular dentine.

The significance of fluoride for solubility of the dental hard tissues has long been established. The majority of fluoride in-

vestigations have been carried out on dental enamel, but there are also reports of investigations carried out on dentine. Thus several studies have shown that dentine as well as enamel has a reduced acid solubility after treatment with fluorides (*Selvig*, 1968; *Sandoval & Shannon*, 1969; *Söremark, Hedén & Röjmyr*, 1969; *Shannon, Urbie & Wightman*, 1973). *Wolf et al.* (1973) found that dentine treated with a zinc oxide-eugenol liner containing CaPO_3F had a greater hardness, which the authors describe as »a hardening effect of the calcium ions liberated from the dissolved CaPO_3F by the water and tissue fluid of the dentine». *Tsuchitani* (1965) found that there was complete obliteration of the dentinal tubules after treatment with sodium fluoride. The author assumes that this results in a slower penetration of caries.

Saumara-Wickrama, Silverstone & Johnson (1972) found in an electron microscope investigation that dentine treated with 0.05 mM fluoride at a pH of 7.4 had an increased radiopacity. Submicroscopically, mineral stratifications were found extending into the lumen of the tubule from the peritubular dentine. From these investigations it can be concluded that fluoride in different forms aids in mineralization and accelerates the process of mineralization.

Recent investigations of dentine have shown that the scanning electron microscope affords an opportunity to study the dentinal tubules and possible changes in the form of dense obliterations, and filling of the lumen with an amorphous substance, or calciospherites (*Brännström & Garberoglio*, 1972; *Tronstad*, 1973; *Brännström, Johnson & Garberoglio*, 1974).

The purpose of the present work was to study by means of SEM and densitometric investigation of microradiograms the effect

of treatment of dentine with sodium fluoride, calcium hydroxide, and a mixture of calcium hydroxide and calcium monofluorophosphate.

MATERIAL AND METHODS

The material consisted of 45 young permanent, intact premolars, of which 40 represented 20 contralateral tooth pairs. With water coolant, buccal cavities were prepared to a depth of 1.5 to 2.0 mm. After the cavities in a tooth pair were prepared, one cavity was selected by lot to be covered with either a layer of calcium hydroxide, $\text{Ca}(\text{OH})_2$ (Calacept)* or with a mixture equal parts calcium hydroxide, $\text{Ca}(\text{OH})_2$ and calcium monofluorophosphate, CaPO_3F ; or to be treated for 1 minute with a cavity cleaner containing 3 % NaF.**

In 13 tooth pairs the cavity in one contralateral pair comprised an untreated control and was cleaned with water only. In the other 7 pairs of teeth comparisons were made of the above-mentioned treatment of dentine. The 20 pairs of teeth were extracted after a follow-up period from 2 to 8 weeks, (Table I). Further, in 5 separate teeth buccal cavities were prepared and lined with $\text{Ca}(\text{OH})_2$. These teeth were extracted after 2—3 weeks.

Calcium hydroxide covering of the cavity floor and adjacent walls was done on a total of 20 of the 45 teeth. After the application of the calcium hydroxide dressing excess fluid from the dressing was removed and the covering compressed firmly against the cavity floor with a dry pellet. After careful blasting with air the dressing and the whole cavity were covered with polyurethane lacquer and then filled

* Calacept®, Scania Dental AB, Knivsta, Sweden.

** Tubulicid® red label, Dental Therapeutics AB, Nacka, Sweden.

Table 1. *Cavity treatments and observation periods in terms of tooth pairs*

Treatment	Observation period (weeks)			Total
	2	4—5	8	
3 % NaF vs no dressing	3	2	2	7
Ca(OH) ₂ » no dressing	2	2	2	6
Ca(OH) ₂ » —3 % NaF	2	3	—	5
Ca(OH) ₂ + CaPO ₃ F* » Ca(OH) ₂ *	—	—	2	2
Total	7	7	6	20

*) The cavities were first treated with 3 % NaF (Tubulicid-red label) for one minute.

with composite resin. The other cavities, i.e. the NaF treated cavities, and the control cavities, were blasted with air and filled as above.

Immediately after extraction, the apical half of each tooth was cut off and the tooth placed in neutrally buffered formalin. After two to four days fixing, a thin diamond disc was used to cut a groove longitudinally buccolingually through the outer part of the filling and the buccal enamel. This cut was made deeper occlusally and lingually. The teeth were placed in nitrogen-chilled propane for several minutes, after which they were easy to fracture along the indicating groove. By this method two similar halves of the tooth were obtained with a fracture surface running through the centre of the cavity and the underlying dentine. One fractured half was freeze-dried in a modified Glick-Malmström apparatus (*Moberger, Lindström & Andersson, 1954*) for 20 hours. The fracture was produced to allow a study of the dentinal tubules running longitudinally under the treated dentine.

The preparations were covered with 200 Å thick layer of gold in vacuum and studied in a Cambridge scanning electron microscope. Intrapair comparison was

done, the examiner not being aware of the method of treatment of a given specimen. Photographs were taken of the dentine immediately under the cavity floor and at the cervical corner of the cavity and also of tubules some distance from the cavity and close to the pulp. Control pictures were also taken of intact dentine immediately above the tubules coming from the cavity.

After the SEM-studies, the two halves of each tooth were available for further investigations of ground sections. Based on the observations made in the SEM and the quality of the fractured surface, 17 specimens were selected for further treatment. Ten specimens represented calcium hydroxide treated cavities. 2 NaF-treated and 5 control cavities. These specimens were dehydrated in absolute alcohol and embedded in methylacrylate. Plane parallel 80—120 µm sections were ground as near the fractured surface as possible. The ground sections were micro-radiographed for study of the distribution of the inorganic component on a cellular level. The specimens were then placed in close contact with an extremely fine grained photographic emulsion (Kodak high resolution plate) which was exposed to Cu-K α -radiation ($\lambda = 1.54 \text{ \AA}$) emitted from an X-ray tube. The size of the focal spot was 1 × 1 mm and the focus-image distance was 25 cm. The voltage supplied was 20 kV and the resulting X-radiation was filtered through 20 µm thick Ni-filter to ensure sufficient monochromatization. This technique and its applications have earlier been described by *Wallgren (1957)* and *Holmstrand (1957)*.

A densitometric investigation of the microradiogram was made on a Leitz photometer equipped with a displayer unit, which allows a wellcontrolled movement and orientation of the microradiogram in

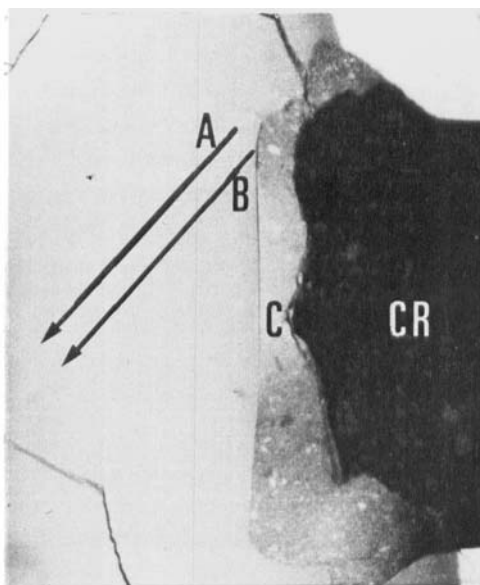


Fig. 1. Microradiogram of a cross-sectioned tooth with a layer of Ca(OH)_2 (C) covering the bottom of a cavity. The remaining cavity is filled with composite resin (CR). Following-up period 4 weeks. In order to study the relative mineral content in the dentine beneath the cavity a photometric evaluation was made along a measuring line (B) which follows the direction of the dentinal tubules. Coronally to the cavity, 130 μm and parallel with line B, another measuring line (A) was laid following dentinal tubules extending from untreated dentine. Further descriptions are to be found in the text.

a two-dimensional co-ordinate system (Lindström & Philipsson, 1966). A measuring line was placed under the treated cavity where the direction agreed with that of the dentinal tubules. The distance between the measuring points was 40 μm . Parallel to this line and at a distance of ca 130 μm from it another measuring line was placed as a control, with measuring points at the same level as the first line. The control line was placed occlusally to the dentinal tubules running from the cavity (Figs. 1 & 2), and represented an untreated area of dentine. To determine if any difference existed in X-ray absorption between the first and second measurement, a t-test for paired observations was performed.

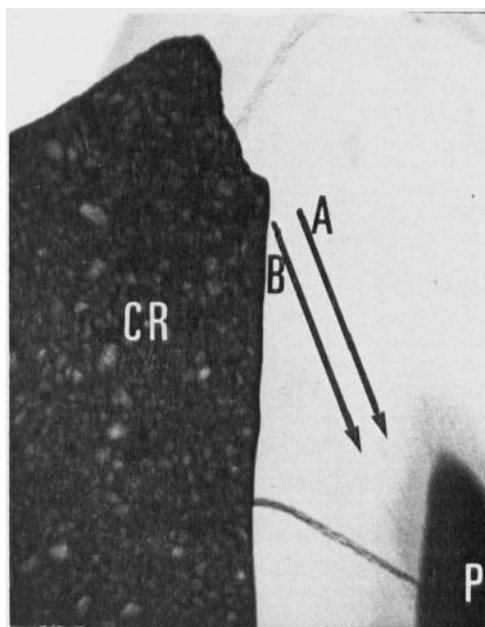


Fig. 2. Microradiogram of a cross-sectioned tooth with an untreated cavity filled with composite resin (CR). A photometric evaluation was made along the A and B lines towards the pulp (P). Notice the lack of difference in density of the dentine beneath the cavity compared with that more coronally.

RESULTS

SEM investigation

Under NaF treated cavities no indications of obliteration of the dentinal tubules could be detected. The picture was the same as under the control cavities regardless of observation time. As a rule the tubules were empty and had the same dimensions as the tubules in the intact area occlusal to the cavity. Only in a few of the tubules were calciospherites observed on the walls of the tubules.

Intra-pair comparison of the dentine under cavities with Ca(OH)_2 dressings and control cavities or NaF treated cavities showed differences in 5 of 11 pairs of teeth. Certain dentinal tubules directly under 5 Ca(OH)_2 treated cavities showed a varying degree of constriction. This change consisted in places of net-like structures

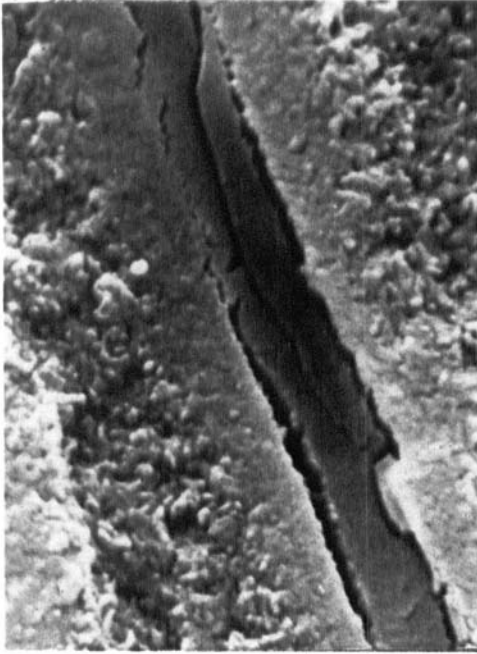
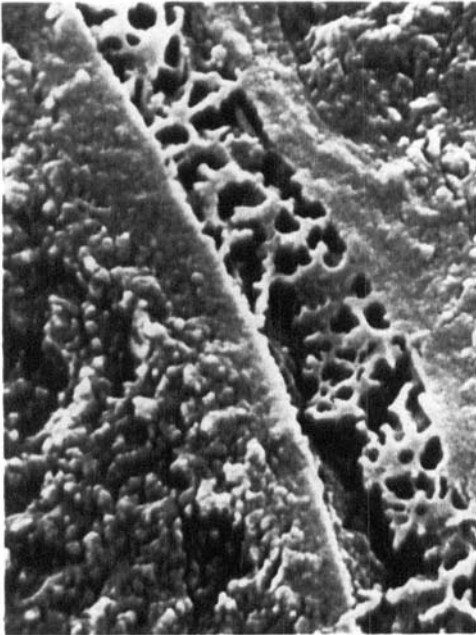


Fig. 3. Longitudinally fractured dentinal tubules under cavity covered with $\text{Ca}(\text{OH})_2$ for 5 weeks
 a) tubule immediately beneath the cavity floor. Lumen filled with an amorphous, loose substance. Note small cracks in the contents of the tubules due to dehydration of the preparation. SEM $\times 11,300$.



b) 0.3 mm in the dentine. The lumen of the tubule contains a sparse net-shaped structure. SEM $\times 11,300$.

or an amorphous substance. In certain tubules an increased number of calcospherites occurred on the walls of the tubules (Figs. 3—4). These changes varied appreciably from one tubule to another, and decreased in extent, ceasing completely at approximately 0.1 mm from the floor of the cavity. No tubules showed complete obliteration.

Of the remaining 9 cavities with $\text{Ca}(\text{OH})_2$ dressing there was a tendency towards similar accumulations on the walls of a few dentinal tubules nearest the dressing. No difference occurred between the dentine under cavities with $\text{Ca}(\text{OH})_2$ and those with a mixture of $\text{Ca}(\text{OH})_2$ and CaPO_3F .

Microradiography

In 3 out of 10 microradiograms where the dentine under the $\text{Ca}(\text{OH})_2$ dressings was compared with a control area occlusally, a systematic evaluation showed an increased x-ray absorption. In 5 cases the conditions were the opposite and in 2 cases no difference occurred. In 6 of these 10 cases an insignificantly increased X-ray absorption was registered immediately beneath the cavity itself. Under the 5 control cavities the dentine showed increased density in 2 cases; no difference could be seen in 3 cases. Nor could any difference be observed in the 2 microradiograms where NaF treated dentine was compared with the control area.

DISCUSSION

This investigation would suggest that only in certain cases can $\text{Ca}(\text{OH})_2$ contribute to some constriction of the dentinal tubules. Individual variations possibly occurred because certain substances must be transported from the dentine and/or

the pulp to enable the building of an organic matrix, for the formation of an amorphous deposit in the tubules, and for a precipitation of salts to occur. The SEM investigation also showed that great variations could exist from one dentinal tubule to another and that this change was confined to an area immediately beneath the cavity.

Although the first measuring points on the microradiogram as a rule showed a greater density nearest the cavity, this does not necessarily mean an increased mineral content. This effect can be due to Fresnel-diffraction, which causes an increased radiographic density at the edges of the preparation (Hobdel & Braden, 1971).

The results presented agrees with those of Ripa *et al.*, (1972). They found in an *in vitro* investigation no difference between eugenol and calcium hydroxide-treated dentine. They proposed that »vital response of the tooth to the medicating agent or to the residual caries is necessary for reported clinical change to occur«. The present results cannot confirm the observations of Mjör *et al.*, (1961) Mjör & Furseth (1968) and Mazetti & Toledo (1971). They claimed to have found a definite increase in density and intra-tubular condensation under $\text{Ca}(\text{OH})_2$ dressings, which after a relatively short time has even been demonstrated near to the pulp.

Undoubtedly a $\text{Ca}(\text{OH})_2$ dressing applied for a period of 2 months cannot be considered to give a reliable obliteration of the dentinal tubules. This applies also to a combination of CaPO_3F and $\text{Ca}(\text{OH})_2$ and to a single treatment of dentine with 3 % NaF. This should be kept in mind when taking into account the fact that such treatment is considered to contribute to an obliteration of the dentinal tubules and thus give pulpal protection, good

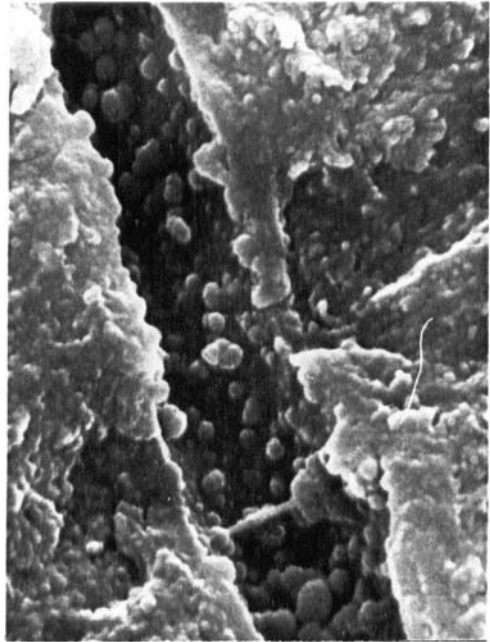
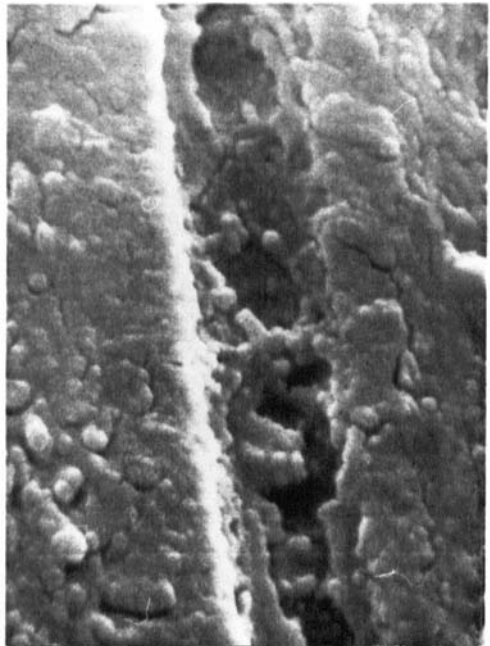


Fig. 4. Longitudinally fractured dentinal tubules 5—10 μm from the floor of cavity covered with $\text{Ca}(\text{OH})_2$ for 4 weeks.

a) Calcospherites on the walls of the tubules. SEM $\times 11,000$.



b) Calcospherites covered by an amorphous substance. SEM $\times 11,500$.

insulation, and reduction of the sensitivity of the dentine.

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REFERENCES

- Bhaskar, S. N.* 1973. A comparative evaluation of topical application and ionophoresis of sodium fluoride for desensitization of hypersensitive dentin. *Oral Surg.* 36, 448-458
- Biven, G., Bapna, M. & Heuer, M.* 1972. Effect of eugenol and eugenol-containing root canal sealers on the microhardness of human dentin. *J. Dent. Res.* 51, 1602-1609
- Brännström, M.* 1966. Sensitivity of dentin. *Oral Surg.* 21, 517-526
- Brännström, M. & Garberoglio, R.* 1972. The dentinal tubules and the odontoblast processes. *Acta Odont. Scand.* 30, 192-311
- Brännström, M. & Nyborg, H.* 1972. Pulpal reaction to composite resin restoration. *J. Prosthet. Dent.* 27, 181-189
- Brännström, M. & Åström, A.* 1972. The hydrodynamics of the dentine; its possible relationship to dentinal pain. *Int. Dent. J.* 22, 219-227
- Brännström, M. & Nyborg, H.* 1973. Cavity treatment with a microbicidal fluoride solution. Growth of bacteria and effect on the pulp. *J. Prosthet. Dent.* 30, 303-310
- Brännström, M., Johnson, G. & Garberoglio, R.* 1974. Ulteriori osservazioni sulle strutture fibro membranose dei tubuli dentinali e della paste pulpale. Estratto da *Mondo Odont. stom. gen.-feb.* 3-18
- Brännström, M. & Nyborg, H.* 1974. Bacterial growth and pulpal changes under inlays cemented with zinc phosphate cement and expoxylite CBA 9080. *J. Prosthet. Dent.* 31, 556-565
- Hiatt, W. & Johansen, E.* 1972. Root preparation I. Observation of dentinal tubules in treatment of root hypersensitivity. *J. Periodont.* 43, 373-380
- Hobdell, M. H. & Braden, M.* 1971. An investigation into some diffraction effects observed in microradiographic images of bone sections. *Calc. Tiss. Res.* 7, 1-11
- Holmstrand, K.* 1957. Biophysical investigations of bone transplants and bone implants. *Acta orthopaed. scand. Suppl.* 26.
- Hoyt, W. & Bibby, B.* 1943. Use of sodium fluoride for desensitizing dentin. *J. Am. Dent. Ass.* 30, 1372-1376
- Johnson, G. & Brännström, M.* 1974. The sensitivity of dentin. Changes in relation to conditions at exposed tubule apertures. *Acta Odont. Scand.* 32, 29-38
- Jorkjend, L. & Tronstad, L.* 1972. Treatment of hypersensitive root surfaces by calcium hydroxide. *Scand. J. Dent. Res.* 80, 264-266
- Kanouse, M. C. & Ash, M. M.* 1969. The effectiveness of sodium monofluorophosphate dentifrice on dental hypersensitivity. *J. Periodont.* 40, 38-40
- Klein, A. I.* 1961. Association between deciduous dentin sclerosis and calcium hydroxide-methylcellulose base material. *J. Am. Dent. Ass.* 63, 76-84
- Kato, S. & Fusayama, T.* 1970. Recalcification of artificially decalcified dentin in vivo. *J. Dent. Res.* 49, 1060-1067
- Levin, M., Yearwood, L. & Carpenter, W.* 1973. The desensitizing effect of calcium hydroxide on hypersensitive dentin. *Oral Surg.* 35, 741-746
- Lindström, B. & Philipson, B.* 1969. Microdensitometer system for microradiography. *Histochemie* 17, 187-193
- Lukomsky, E. H.* 1941. Fluorine therapy for exposed dentin and alveolar atrophy. *J. Dent. Res.* 20, 649-659
- Lundy, T. & Stanley, H.* 1969. Correlation of pulpal histopathology and clinical symptoms in human teeth subjected to experimental irritation. *Oral Surg.* 27, 187-201
- Mazetti, D. & Toledo, O.* 1971. Secondary mineralization of rat molar healthy dentin by means of calcium hydroxide: a fluorescence study. *J. dent. Child.* 38, 247-251
- Mjör, I. A.* 1962. The effect of zinc oxide and eugenol on dentin evaluated by microhardness testing. *Archs Oral Biol.* 7, 333-336
- Mjör, I. A., Finn, S. B. & Quigley, M. B.* 1961. The effect of calcium hydroxide and amalgam on non-carious, vital dentin. *Archs Oral Biol.* 3, 283-291
- Mjör, I. A. & Furseth, R.* 1968. The inorganic phase of calcium hydroxide and corticosteroid-covered dentin studied by electron microscopy. *Archs Oral Biol.* 13, 755-763
- Mjör, I.* 1974. The penetration of bacteria into experimentally exposed human coronal dentin. *Scand. J. Dent. Res.* 82, 191-196
- Moberger, G., Lindström, G. & Andersson, L.* 1954. Freeze-drying with modified Glick-Malmström apparatus. *Exp. Cell. Res.* 6, 228-237
- Olgart, L., Brännström, M. & Johnson, G.* 1974. Invasion of bacteria into dentinal tubules. Experiments *in vivo* and *in vitro*. *Acta Odont. Scand.* 32, 61-70
- Owen, D.* 1962. *Handbook of statistical tables.* Pergamon Press. London, Paris.
- Ripa, L., Guzman, C. & Dilzell, W.* 1972. The effect of calcium hydroxide and zinc oxide-eugenol on dentine in extracted human teeth. *Oral Surg.* 34, 531-537
- Rothberg, S. & de Shazer, D.* 1966. The complexing action of eugenol on sound dentin. *J. Dent. Res.* 45, 307-310
- Saumara-Wickrama, D., Silverstone, L. & Johnson, N.* 1972. Effect of calcifying fluids on human dentin *in vitro*. *J. Dent. Res.* 51, 1268-1269

- Sandoval, E. & Shannon, I.* 1969. Stannous fluoride and dentin solubility. *Texas Rep. Biol. & Mod.* 27, 111—116
- Schaeffer, M., Bixler, D. & Yu, P.* 1971. The effectiveness of iontophoresis in reducing cervical hypersensitivity. *J. Periodont.* 42, 695—700
- Selvig, K. A.* 1968. Effect of fluoride on acid solubility of human dentin. *Archs Oral Biol.* 13, 1297—1310
- Shannon, I. L., Urbie, T. & Wightman, J.* 1973. Topical treatment of prepared cavities. *Texas Dent. J.* 91, 6—8
- Stewart, D. J. & Richardson, A.* 1968. Effect of calcium hydroxide and zinc oxide-eugenol on young, noncarious dentin. *J. Dent. Res.* Abstr. no 40, 47, 978
- Söremark, R., Hedin, M. & Røjmyr, R.* 1969. Studies on incorporation of fluoride in cavity liner (varnish). *Odont. Revy* 20, 189—199
- Tronstad, L.* 1973. Scanning electron microscopy of attrited dentinal surfaces and subjacent dentin in human teeth. *Scand. J. Dent. Res.* 81, 112—122
- Tsuchitani, Y.* 1965. Study on partial restoration within the cavity. *Jap. J. Conserv. Dent.* 8, 78—97
- Wallgren, G.* 1957. Biophysical analyses of the formation and structure of human fetal bone. *Acta Paediat. Suppl.* 113
- Vojinovic, O., Nyborg, H. & Brännström, M.* 1973. The acid treatment of cavities under resin fillings. The bacterial growth in the dentinal tubules and the pulpal reaction. *J. Dent. Res.* 52, 1189—1193
- Wolf, O., Gedalia, I., Reissstein, I., Goldman, J. & Stieglitz, H.* 1973. Effect of addition of CaFPO₃ to a zinc oxide-eugenol base liner on the microhardness and fluoride content of dentin. *J. Dent. Res.* 52, 467—471
- Zander, H. A.* 1959. Pulp response to restorative materials. *J. Am. Dent. Ass.* 59, 911—915