TISSUE CHANGES INCIDENT TO CAVITY PREPARATION

AN EVALUATION OF SOME DENTAL ENGINES

by

KAARE LANGELAND

INTRODUCTION

The increase in rotational speeds of dental cutting and grinding tools has again brought the biological aspect of tooth preparation to the fore. The problem has been dealt with by the present writer in several previous publications (*Langeland* 1956, 1957, 1958, 1959, 1960). In these studies the literature covering this problem up to the present has been considered and discussed and readers taking particular interest in this are referred to the papers mentioned, which include comprehensive reference lists. In the present study only recent literature dealing with the evaluation of the relevant histologic criteria will be quoted.

LITERATURE PERTINENT TO THE HISTOLOGIC ASPECT OF CAVITY PREPARATION

The author in his earlier publications (*Langeland* 1956, 1957) discussed the criteria commonly used for histologic evaluation of reactions due to cavity preparation *per se,* i.e. the immediate reactions, and concluded:

(1) that the presence of odontoblast nuclei and occasionally also erythrocytes in the pulpal ends of the cut dentinal tubules constitutes the only certain criterion of pulp injury when using histologic methods known today,

(2) that the absence of odontoblast nuclei and erythrocytes from the dentinal tubules shows that the methods of preparation in question are non-injurious,

(3) that the presence of erythrocytes in the dentinal tubules is a sure sign of a hemorrhage *in vivo*.

In his later articles referring to the use of ultra high speed, *Langeland* (1958, 1959, 1960) discussed the after-effects of cavity preparation methods and showed:

(1) that no reaction would occur in cases where the cavity preparation *per se* did not cause odontoblast nuclei or erythrocytes to migrate into the dentinal tubules,

(2) that an inflammatory reaction would occur in cases where this migration had initially taken place (*Langeland* 1958, 1959, 1960). The extent of the inflammatory reaction was dependent on the number of odontoblasts and/or erythrocytes which had initially migrated into the dentinal tubules. He also contended that hemorrhages, often associated with ultra high speed, must be considered a more serious reaction than migration of odontoblasts alone.

The findings of *Marsland & Shovelton* (1957) were principally the same although these authors were of the opinion that "vacuoles" were a criterion of a pulp reaction. With regard to migrated odontoblasts, they found that a preparation at 3,000 r.p.m. would cause such migration and that at 5,000 to 15,000 r.p.m. the migrated odontoblasts were more numerous, and in addition, also present at the outside of the area of the cut dentinal tubules. They were less numerous when the injury was more severe because of coagulation of the tissue. Like *Langeland* (1957, Fig. 18), they demonstrated that the phenomenon occurred also as a result of cavity preparation in freshly extracted teeth (*Marsland & Shovelton* 1959). In a later publication *Marsland & Shovelton* (1960) considered that the ultra high speed technique caused fairly mild reactions if suitable precautions were taken.

Swerdlow & Stanley (1958) considered the reaction as mild when the cell-rich zone beneath the zone of Weil was relatively intact and as severe "when the cell-rich zone was missing and not according to the number of infiltrating inflammatory cells, as other investigators have described". They also considered edematous changes, histologically evidenced by odontoblasts raised from the predentin or separated from each other, as a criterion of a pulp reaction. With regard to displaced cells in the cut dentinal tubules, they offered the theoretical explanation that this phenomenon was caused by an increase of the intrapulpal pressure which forced the cells into the dentinal tubules.

In a subsequent paper (1960) *Stanley & Swerdlow* maintained that a handpiece pressure of 8 ounces was injurious and concluded generally, from all their experimental experience to date, that pressure was the dangerous factor.

Bernier & Knapp (1958) introduced a new term, "*rebound response*", into the histologic vocabulary. In a definition they stated that "the rebound response, heretofore undescribed, consisted of changes in the odontoblasts and subodontoblastic tissue at some distance from the cavity site and in no way related to the cut dentine. It was generally found across the pulp from the cavity site. The rebound response was evidenced histologically in the dog by disorganization of odontoblasts, edema, inflammation, and a change in the ground substance. In the human teeth, this response was represented primarily by areas resembling degeneration." *Bernier & Knapp* (1959) also introduced another term, namely "varicosity". About varicosity they said, "The second unusual reaction noted in the experimental teeth, was the formation of large air-filled spaces in the pulpal tissue. These were devoid of any lining cells, suggesting that the response was immediate (Fig. 7). As in the rebound response, there are at least speculative reasons which would indicate that energy transmission and focalization could be responsible". Also in this paper they stated that the rebound response "is a change in the dental pulp never before described. The selection of this term to define the reaction in no way implies a factor of causation. Of particular significance is its location on the wall of the pulp chamber opposite, or at least at a distance from, the cavity preparation. While the biologic nature of the change is not yet clear, it appears to be a disturbance in the interstitial ground substance. No cellular infiltrate is noted, and vascular alterations are absent (Figs. 4, 5, and 6)".

In sections taken from teeth treated with ultra high speed *Shovelton* (1958) observed "collections of inflammatory cells, which had not been seen in any sections from the high speed range". He also found damage on the side of the pulp remote from the cavity preparation. *Marsland & Shovelton* (1959) concluded that displacement of the odontoblast nuclei into the dentinal tubules beneath cavities "can and does occur" at the time of cavity preparation. *James, Schour & Spence* (1959) as in an earlier paper (*James, Schour & Spence* 1954) explained the phenomenon as a result of the pressure in an unfilled part of the cavity being lower than that of the underlying pulp.

Rateitschak, König & Mühlemann (1959) in an experimental series comprising 32 teeth observed tissue changes in the odontoblast layer on the other side of the pulp remote from the cavity. These changes were evidenced by the presence of "vacuoles" in the odontoblast layer opposite cavities prepared at 20,000 r.p.m., a result which the authors termed "rebound response". However, they also used the term in cases where inflammatory cells could be observed centrally in the pulp, in spite of the fact that *Bernier & Knapp* had stated that "no cellular infiltrate is noted". The sections used by *Rateitschak et al.* were 15 microns thick. Further, they quoted the present author incorrectly as follows: "Bei Steigerung der Umdrehungszahl auf 50.000 Touren mit Spray ("Dentalair") konnte *Langeland* (25) Veränderungen beobachten, die denjenigen bei 20.000 Touren mit Spray ähnlich sind". ("Increasing the r.p.m. to 50,000 with spray ("Dentalair"), *Langeland* could observe changes similar to those occurring at 20,000 r.p.m."). Furthermore: "Er anerkennt als sicheres Kriterium einer Pulpaschädigung durch Bohr- und Schleifarbeiten nur die Verlagerung von Odontoblasten (Odontoblastenaspiration, "Displacement") in die Dentinkanälchen (20, 25, 28, 29)". ("He regards displacement of odontoblasts into the dentinal tubules as the only safe criterion of a pulp damage").

Marianne Weder (1960) has likewise misquoted the present author: "*Langeland* behauptete, dass einzig und allein die Anwesenheit von Odontoblastenkernen in den Dentinkanälchen als Antwort der Pulpa auf die Präparation anzusehen ist". ("*Langeland* maintained, that the presence of odontoblast nuclei in the dentinal tubules is the one and only response of the pulp to cavity preparation"). *Marianne Weder* could not state with certainty that she found a rebound response exactly like that described by *Bernier & Knapp*, but she observed a similarity which she assumed would corroborate their findings. In some of her sections from teeth prepared at 80,000 r.p.m., she found accumulations of inflammatory cells opposite to the cavity, and mostly situated over the bifurcation of the roots. In the consecutive sections, this area of infiltration developed into an empty space.

Seltzer & Bender (1959) in an experimental series concerning reactions to full crown preparations, in some instances found odontoblast nuclei in the dentinal tubules. With more severe damage the pulpo-dentinal membrane became disrupted by edema and the cells had degenerated.

Some authors, *Jarby* (1958), *Aplin, Cantwell & Manny* (1959) believed that pulp reactions would not occur provided an increase in the *pulp* temperature could be avoided and on this basis recommended certain clinical methods. On the other hand, *Kramer* (1960) and *Maeglin* (1960) demonstrated heat damage in the cavity walls of teeth cut with air rotors. This corroborates the findings of the present author (*Langeland* 1959, 1960), who showed the simultaneous occurrence of burns in the cavity bottom and odontoblast nuclei and erythrocytes in the pulpal ends of the burnt dentinal tubules.

THE AUTHOR'S INVESTIGATIONS

Statement of problems

The current literature reveals that opinions differ considerably with regard to what histologic criteria are valid in experiments of this kind and the conclusions drawn seem rather speculative and cannot always be considered conclusive. One of the reasons seems to be that the investigations are based on insufficient material. The purpose of this investigation is, therefore, to evaluate in a more comprehensive experimental series the criteria commonly used and thus clarify the problem of deciding what criteria can be considered valid for experiments on pulp structures. Such criteria will be of value in the process of testing new engines and advising manufacturers as to improvements of the engines.

It has been shown that, using air as a coolant, no temperature rise takes place in the pulp during preparation with a Borden®

air rotor. In spite of this a smell of burnt tooth structure still occurs. It was therefore considered important to record changes in the dentin where the drilling instrument contacted it.

Several investigators have discussed the effect on pulp reactions of the shape of the bur used and the type of bur (steel, T.C. and diamond) (*Swerdlow & Stanley, Marsland & Shovelton*). Therefore different shapes and makes of cutting and grinding instruments were included in the present investigation. In these experiments the following equipment was used:

Engines

(1) A Kavo® handpiece with reduction gear 10 : 1 (Fig. 9A).
(2) A Ritter® belt-driven engine running at 5—6,000 r.p.m.
(3) A Ritter belt-driven engine with a Kavo or Micro-Mega® speed increasing wristjoint giving about 40,000 r.p.m. and a Kavo automatic spray directing an air/water spray on to the field of operation (Fig. 9 B, C).
(4) A Micro-Mega geared contra-angle handpiece running at r.p.m. up to about 80,000 (Fig. 9 D).
(5) A Dentalair®, an air turbine engine running at 50,000 r.p.m. (Fig. 9 E).
(6) LDX®, an experimental vane motor running at about 135,000 r.p.m. (Fig. 9 F, G).
(7) Original and modified Borden air rotors, (Fig. 9 H, I, 10 G—I).
(8) A Midwest® air turbine, (Fig. 10 A—C).
(9) An Aero Turbex® air turbine, (Fig. 10 D—F).
(10) A Bien Air® air turbine running at about 250,000 r.p.m. (Fig. 10 J—L).

Material and methods

The teeth used for these experiments were mostly premolars from 10 to 16 year-old individuals. A smaller group of teeth from older individuals up to 65 years was included. In most of the teeth, a cavity was prepared in the gingival part of the buccal surface which was usually clinically intact. In some teeth, cavities were prepared on the lingual or occlusal surfaces as well. In other teeth full crown preparations were made. Some of the teeth belonging to the older group had fillings or carious defects. The cavity preparations were performed in these areas. In some cases local anesthesia was used before preparing the cavities.

The preparations were performed:

(a) without any special precautions

(b) under a constant jet of water

(c) under an air/water spray

(d) under a steady stream of tempered or cold air.

Sections taken from clinically intact teeth of the same kind as those used for this investigation, served as a "normal" control material (*Langeland* 1957). As an additional control comparisons were made between the area adjacent to the cavity tubules*) and the areas not directly influenced by the cavity preparation.

In another group, after cavity preparation under water, a steel instrument, about the size of a No. 3 rosehead bur, was heated to redness and pressed against the bottom of the cavity.

In experiments which aimed at recording the reaction to cavity preparation or burning *per se*, the teeth were extracted immediately or after observation periods of minutes only. In other cases, which aimed at recording the after-effect of preparation or heating, a zinc oxide-eugenol dressing was inserted into the cavity after washing with lukewarm water and drying with sterile cotton. The zinc oxide was chemically pure (analytic reagent). The dressing was left for varying observation periods before extraction.

Immediately after the extraction, which was performed under local anesthesia, a hole was drilled through the gingival part of the root to facilitate the penetration of the neutral formalin in which the tooth was then placed. The histologic method used for this material has been described previously (*Langeland* 1957). As usual the thickness of the sections was 4 to 5 microns.

Nygaard Östby and *Langeland* (unpublished study) carried out experiments on preparation with rotational speeds under 300 r.p.m. With the permission of *Nygaard Östby*, this series, comprising 80 teeth, is included in the present material. A further

*) In this paper the dentinal tubules cut and opened by cavity preparation will be termed *cavity tubules*.

series concerning cavity preparation at 10,000 r.p.m. under refrigeration anesthesia (Nondolor) (*Langeland* 1959), performed together with *Irene Sundvall-Hagland* and *Ingeborg Löfsted Stålhane*, will be mentioned.

Criteria for assessment of pulp reaction to cavity preparation

It seemed important to consider the particular histologic appearances that form a basis for conclusions made by other authors. It was also necessary to evaluate conditions under which their experiments were performed.

In the present investigation the following data were noted:

1. Age
2. Tooth
3. Duration of experiment
4. Cavity — pulp distance in mm
5. Engine used
6. Spray system
7. Filling material.

Histologic findings were recorded as follows:

1. Cavity formations ("vacuoles") in:
   (a) Odontoblast layer adjacent to cavity tubules
   (b) Odontoblast layer outside area of cavity tubules
   (c) Centrally in the pulp
2. Odontoblast nuclei in cavity tubules
3. Erythrocytes in cavity tubules
4. Hyperemia
5. Presence of inflammatory cells
   (a) In odontoblast layer
   (b) Centrally in the pulp
6. Irritation (secondary) dentin
7. Burning of dentin in cavity bottom.

Observations

In Table 1 a survey is presented of the experiments and the findings in 674 cases. It is condensed from tables in which all the details for each individual case are recorded. Table 1 shows that throughout the material some findings were general, regardless of which engine had been used and of the length of the observation period, the age of the patient and the experimental tooth, but other findings were associated with a particular speed or spray system, and in these cases the length of the observation period influenced the findings.

Findings generally observed

It is seen from Table 1 that cavity formations occurred in 610 out of 674 cases and tears in 111 cases. The cavity formations were found to the same extent in untreated control teeth as in experimental teeth. They appeared in the entire odontoblast layer, where they were classified as small (Fig. 1 A, high magnification B), medium (Fig. 1 C) or large (Fig. 1 E, high magnification F), and also centrally in the pulp (Fig. 1 C, high magnification D). When they occurred in experimental teeth they were not confined to the area where the cavity tubules terminated in the pulp but were as frequent in the odontoblast layer elsewhere in the coronal pulp (Fig. 1).

Separation of the pulp tissue from the predentin, referred to in Table 1 as "Tear", and folding of the thin sections were observed more often in the area subjacent to the cavity than elsewhere, but the occurrence was not influenced by the engine or cavity preparation method used.

In a relatively large number of cases small concentrations of inflammatory cells were observed centrally in the pulp over the bifurcation and distinctly separate from the area subjacent to the cavity tubules (Fig. 2). Similar concentrations of cells were also observed in clinically intact teeth, even in embedded teeth. They were not related to any specific method of cavity preparation or engine or observation period.

On inspection of the teeth prior to or after extraction, a discolored fissure might be found occlusally, or a decalcification buccally or distally. In the dentin usually no alterations could be observed after sectioning and neither odontoblast layer nor the tissue between this and the concentration of cells seemed influenced by any pathologic reaction. Some of the cells in the concentration were typical plasma cells, lymphocytes and macrophages (Fig. 2 B p, l, m) whereas others were atypical cell forms usually occurring in the pulp tissue in inflamed areas (Fig. 2 C).

The use of an air jet during preparation or drying the cavity with air after the preparation regularly caused odontoblasts and occasionally erythrocytes to migrate into the cavity tubules (Fig. 8 A; Plate 12 D, E; Table 1, Ritter belt-driven + air spray, Dentalair + air spray, Borden + air spray). This migration was not avoided even if the temperature of the air was reduced from +37°C to +1°C (Plate 12 F, G; Table 1, belt-driven + Nondolor).

Like in earlier investigations, it was found that the dentinal tubules in older individuals were narrower than in young ones. In the present material the ages of the patients varied from 10 to 65 years. In spite of this, no significant difference in the pattern of reaction could be observed between the various age groups. Thus, the pulp reacted in the same way to dry cavity preparation in old and in young individuals. It made no difference which teeth were used, or which tooth surface or whether cavities were prepared in carious or in non-carious areas (Plate 12 B, C from 57 year old individual).

A peculiarity frequently observed was that the strongest reaction often occurred under the part of the cavity most remote from the pulp, i.e., under the gingival part of the cavity, but, generally, deep cavities produced a stronger reaction than shallow cavities and wider cavities a stronger reaction than narrow ones.

Findings varying with speed and spray

It was also a general observation that neither odontoblasts nor erythrocytes migrated into the cavity tubules when a water jet or an air/water spray was continuously directed to the field of preparation during the whole operation. However, there were exceptions to this rule, namely, that the need of and the efficiency of the spray was influenced by the engine used and by the rotational speeds. Thus, usually no reaction, or only a slight reaction, occurred when infra low speed was used (Fig. 9 A) in spite of the fact that no spray at all had been applied. At rotational speeds of 5,000, 10,000, 40,000 (Fig. 9 B, C), 50,000 (Fig. 9 E), and 135,000 r.p.m. (Fig. 9 F, G) no reactions occurred as long as the water jet or air/water spray of the engine had been used whereas a marked migration into the cavity tubules took place when the original Borden was used with its water jet at maximum (Plate 12 K). When, however, the nurse applied extra water from the air/water spray of the dental unit, no reaction occurred (Fig. 5 A, B).

A certain decrease in the intensity of the reaction was seen as the result of the new spray of the Kavo Borden (Fig. 9 H, I), whereas this was not the case when the new S.S. White® was used (Figs. 10 G—I and 5 D; Plate 12 L, M).

In experiments where the extraction had taken place immediately after the preparation or after observation periods of a few minutes, hyperemia very seldom developed, except when ultra high speed turbines were used. In such cases, however, hyperemia and circulatory disturbances could be seen after days' and weeks' observation periods (Fig. 6 A, B; Fig. 8 D, E).

The observation of migrated cells in the cavity tubules also varied with the observation period. In teeth which had been extracted immediately after, or up to four weeks after the operation, migrated cells could be observed if the preparation method in question had caused them to migrate initially (Table 1, 0 days). After four weeks, however, remnants of the migrated cells were usually no longer observed in the cavity tubules, but irregularity of dentin and predentin formation was usually seen (Fig. 6 C—F; Plate 12 N, O, Q, R). At observation periods of 1 to 30 days when odontoblasts or erythrocytes were still seen in the tubules (Fig. 5 C), leukocytes were regularly observed along the predentin where the cavity tubules terminated in the pulp (Plate 12 D, E, F, G, K).

Preparation and filling methods which did not cause migration of cells initially, did regularly not cause any reaction in dentin, predentin or pulp (Fig. 3 A, B; Fig. 4 A, B) after long observation periods. In some of these cases, however, irritation dentin was found in a small restricted area. The predentin was bordered by an odontoblast layer in which the number of cells was reduced (Fig. 3 C, D; Fig. 4 C, D).

On the other hand, a significant difference in reaction could be seen after long observation periods in cases in which the preparation method had initially caused migration (Table 1, 0 days).

Rather broad and wide layers of irritation dentin were formed and they were bordered by a layer of odontoblasts mostly reduced to one row (Fig. 6 C, E; Plate 12 N, O). Between the odontoblast nuclei and the predentin a fibrous tissue appeared. It was formed at the place where normally the odontoblast processes are seen, but this fibrous tissue was considerably broader than the cytoplasm of the odontoblasts (Fig. 6 D, F).

In cases in which the cavity bottom was heated after preparation under air/water spray, large numbers of odontoblasts and often erythrocytes migrated into the burnt tubules (Table 1, heating of cavity bottom). At observation periods varying from one to 79 days the reactions were in quality the same, in quantity even stronger than when preparation had taken place under an air jet at 50,000 r.p.m. (Plate 12 D), or when Borden had been used with air jet (Plate 12 E). The odontoblast layer was reduced, and inflammatory cells had gathered in the subjacent pulp tissue (Fig. 7 B; Plate 12 P). The odontoblast layer was considerably reduced and the predentin irregular (Fig. 7 C; Plate 12 P, R). The cells in the adjacent tissue were lymphocytes and macrophages (Fig. 7 D).

At the place where the hot steel instrument had been pressed against the cavity bottom, a strong discoloration was observed. In hematoxylin-eosin a marked darkening was seen (Fig. 7 A; Plate 12 J). Stained according to *Masson,* the same area appeared bright red. A similar discoloration was observed in the cavity bottom and margins in many teeth in which the cavity preparation had been performed with airotors (Plate 12 I, J, L), whereas this staining reaction seldom occurred when the teeth had been prepared with ultra low speed without water (Plate 12 A) or with other engines having rotational speeds up to 135,000 r.p.m. when their air/water spray had been used (Plate 12 H). Exceptions to this rule occurred, but Table 1 shows that whereas the staining reaction was termed slight in most cases of the latter group, it was termed moderate or strong in the airotor groups. This discoloration was also seen when zinc oxide-eugenol had been in the cavity for varying observation periods whether air (Fig. 8 B) or water (Fig. 6 B, E) had been used as a "coolant".

Observations of instruments in action

As previously reported, a smell of burnt tooth substance was often observed during cavity preparation under varying conditions. It did not occur when cavities were prepared at infra low speed (Fig. 9 A), or when belt-driven engines of rotational speeds up to 80,000 r.p.m. were used in such a way that the spray, even when coming from the single outlet, was not prevented from reaching the area of preparation. A smell of burnt tooth substance was also avoided when Dentalair and LDX were used. The outlets for the air/water spray of the latter came from three directions and seemed to reach the area of cavity preparation in all instances. However, a smell of burnt tooth structure occurred now and then when using a new Kavo Borden in spite of the double spray which seemed to cover the full surface of a bur (Fig. 9 I). A similar reaction occurred when using the Midwest Air Drive even if the water jet, delivering large amounts of water, was not deflected from the bur running at about 250,000 r.p.m. (Fig. 10 B). Even when used at full spray Aero Turbex and S.S. White having double water jets created a smell of burnt dentin and Table 1 shows that at the same time discoloration of the cavity bottom occurred (Fig. 10 D—I; Fig. 6 C, E; Plate 12 J, L). The same observations were made when the Bien Air with a spray outlet far away from the bur was used (Fig. 10 J—L; Plate 12 I).

The drilling instruments used

No variation in the reactions of the pulp could be seen after cavity preparation with steel burs, tungsten carbide burs, fine and coarse diamonds. Even vibrations caused by instruments which were not balanced and true running caused no reactions which could be recorded in the sections. However, they could cause damage in other ways. For instance, a diamond having a shaft with a too weak core might bend and injure the soft tissues of the mouth (Fig. 11 A). It might also, as the diamond demonstrated in Fig. 11 A, be thrown out of the plastic chuck. If the shaft is too hard, the diamond will break, fall down in the mouth and cause harm where it hits (Fig. 11 B).

DISCUSSION

Interpretation of Table 1

The advantage of condensing all observations in one table is that the general trends will be more obvious than in tables giving all details of each case. The disadvantage is, however, that small variations — still important for the evaluation — will not appear. When, for instance, cavity - pulp distance influences the reaction the condensed table does not reveal if this factor has influenced the result more in one group than in another. Theoretically it might, therefore, be possible that most of the cavities in one series were shallow whereas in another they were deep, while the outer limits were the same. In a comparison of the influence of two different engines, therefore, the cavity - pulp distance might influence the result more than would the engines in question. Knowing this from earlier experiments the author has endeavored to have a comparable range of cavity depths in each experimental series.

The summary of Table 1 gives for each particular finding the ratio of cases affected to the total number of cases in the group. However, it is not sufficient to judge by the number of cases showing the finding, but the extent of the finding must be determined from the full table. For example, out of 130 teeth treated with Dentalair, 7 showed discoloration of the cavity bottom, and 38 out of 52 showed the same when prepared with the original Borden. This difference in such a large series appears convincing but, in view of the fact that in the first group 4 of the 7 showed only slight discoloration and 3 a strong one, whereas in the second group the discoloration was moderate in 19 and strong in 12, the difference becomes even more distinct.

The occurrence of odontoblast nuclei and erythrocytes in the dentinal tubules must be assessed in the same way. Even in this respect, however, Table 1 does not differentiate directly. Only the range of observation periods is given and not a detailed breakdown. Since it is known that migrated odontoblasts disintegrate after 3—4 weeks, a lower number of cases with migrated odontoblasts does not necessarily indicate lack of reaction. One has to find out from the table if the cavity preparation method in question caused migration of odontoblasts in immediate extraction cases (0 days). However, a further breakdown of the observation periods can be deduced. The cases showing migrated odontoblasts must have an observation period of less than 30 days, and those showing irritation dentin without migrated odontoblasts must have observation periods over 30 days.

Thus, even the table presented here is suitable for statistical treatment, but the summary of the table must be used only to obtain an over - all picture.

Discussion of histologic criteria

Many of the phenomena used as criteria of pulp reaction appear also in sections taken from clinically intact teeth. Therefore it seems important to arrive at distinct criteria for evaluation of pulp reactions.

Empty spaces and cavity formations

Empty spaces in sections taken from experimental teeth have often been regarded and recorded as criteria of pulp reactions to the treatment in question. The unreliability of this criterion is established by the large variety of names — (vacuoles, reticular atrophy, blister, cystic cavities, varicosity and rebound response) — used to denote these empty spaces. When followed in consecutive serial sections it is obvious that they formed cavities in the specimens before sectioning (*Langeland* 1957).

It may be that the very first reaction in the pulp is an accumulation of tissue fluid along the pulpo-dentinal membrane, but since these fluids — using present histologic methods — would be washed out one cannot in the sections determine if they have been there *in vivo*. Introduction of a freezing technique for fixation gave certain additional information, but because of loss of adaption to the cavity tubules in this technique, it cannot be used for determining reactions to operative encroachments (*Langeland* 1957).

The cases which give a basis for assuming that a fluid accumulation is the possible first reaction to cavity preparation are some of the cases from the experiments in which Nondolor has been used and in which a fibrous material has been demonstrated (*Langeland* 1959).

In areas in which inflammatory cells are deteriorating it is known that the enzymes released are able to dissolve ground substance and fibres. On this basis a liquefaction occurs and where the liquids are washed out cavity formations will result, but they cannot be distinguished from artifacts as long as they are empty. From the presence of inflammatory cells in the region one may conclude, however, that they are only partly artifacts.

It has been shown by the present author, in this material as in all previous control and experimental material, that the empty spaces are not related to any particular cavity preparation or filling method.

There is, however, one factor which is the same in all these control and experimental teeth, namely the histologic method. The reagents to which the extracted tooth is exposed, influence the pulp tissue in such a way that cavity formations frequently develop. The fixative, 10 % formalin, produces a certain degree of shrinkage, the decalcifying agents some swelling, and the alcohols, from 70 to 100 %, a marked shrinkage. Since the odontoblast processes are fixed to the rigid dentin walls which do not shrink to the same extent as the pulp tissue, cavities are formed. Accordingly, it is the histologic method and not the cavity preparation method which causes these empty spaces, and terms as "vakuoläre Degeneration der Odontoblastenschicht", "retikuläre Atrophie", "blisters", "cystic cavities", "varicosity" and "rebound response" are terms based upon the result of the histologic method and, accordingly, various names for one and the same artifact.

A study of the illustrations of *Bernier & Knapp* indicates that the phenomena they describe as signs of pathologic reactions are also seen in the author's material. However, *Bernier* defines the term varicosity — "formation of large air-filled spaces" and this cannot be right. An air-filling of the pulp tissue could not occur in the closed pulp chamber *in vivo*. It is the obligation of *Bernier & Knapp* to demonstrate how the air entered the pulp tissue. The Grosset Webster dictionary, however, defines varicose = swollen.

Swelling of the pulp tissue could not take place within the closed pulp chamber, and the result of swelling would be compression of the tissue and give no possibility of formation of empty spaces. Thus, even the term "varicosity" is misleading.

The term "rebound response" is no more descriptive and no more evident than varicosity.

Even though the findings of *Bernier & Knapp* are corroborated by *Rateitschak, König & Mühlemann* and partly by *Marianne Weder*, it does not alter the fact that they are all describing the same artifact, and the terms mentioned should never be used because they bring confusion into the histologic evaluation of any preparation or filling method.

Occurrence of "tears" and "blisters"

"Tears" and well formed "blisters" appear more often in treated cases under the cavity tubules than elsewhere, but the difference is not significant. They are generally not confined to the cavity tubules but continue into the adjacent areas. One reason why they may appear more often under the cavity tubules is related to the histologic method. When the sections are cut at 4 microns they will easily fold even if stretched. The folds naturally often occur where the section is weakest, namely in the region of the prepared cavity.

In experiments in which odontoblasts have migrated into the cavity tubules the odontoblast processes may be torn and this will allow fluid-filled tissue spaces to form *in vivo*. When the effect of the histologic reagents is added to this, "tears" and "blisters" will more easily be formed in the cavity region than elsewhere in the pulp. However, the cavity formations cannot have been as large and extended *in vivo* as they appear in the sections.

One way of deciding whether the pulpo-dentinal membrane, separated from the predentin in the sections, has been separated from the predentin *in vivo*, is to observe the formation of the predentin after days and months. If, after the extraction of the tooth, the cavity tubules can be followed without interruption through dentin and predentin the "tear" is an artifact. If the tear had occurred at the time of operation an irregular predentin and dentin formation would have resulted.

Migration of odontoblasts and other cells into the cavity tubules, and its influence on dentin formation

Criteria of reaction to injury, however, is the appearance of odontoblast nuclei and erythrocytes in the dentinal tubules. *Stanley & Swerdlow* (1960) believe that this phenomenon occurs because of increased pressure in an inflamed area subjacent to the cavity tubules. That such an assumption is dubious is seen from the fact that migration occurs as an immediate reaction when there has been no time for development of an inflammation. In addition, migration occurs as a result of cavity preparation in extracted teeth (*Langeland* 1957). A theoretical consideration also indicates that their explanation cannot be correct. If an increase of the pressure took place, the pressure would spread equally strong in all directions since the pulp tissue *in vivo* can be compared with a fluid. Therefore, if their speculation were right, one would find odontoblast nuclei in all the pulp walls and not only confined to the cavity tubules. The migration can be more satisfactorily explained by alteration in the osmotic pressure occurring when cell tissue is damaged (*Langeland* 1957). This finding is corroborated in *Brännström's* experiments (1960). However, in the experiments of *Brännström* (1960) migration of odontoblasts occurred both in test and control cavities. The fact that it occurred under control cavities as well means that the reaction under the test cavities was not due entirely to the factors which the experiments were designed to test.

In the present material accumulation of leukocytes consistently followed migration of odontoblasts. *Brännström* refuses to accept that the appearance of leukocytes is due to degeneration of these odontoblasts and prefers to consider unspecified changes in unspecified structures as the cause. *Brännström* (1960) like *Langeland* (1957) found that the strongest reaction was often observed where the gingival cavity tubules ended in the pulp. *Brännström* believed that this was due to leakage along the cavity margin. As long as he has not demonstrated that this takes place in the whole area in which the peripheral cavity tubules terminate in the pulp, his statement is not valid. In the present material the stronger reaction is restricted to the area in which the gingival cavity tubules terminate. It is therefore more probable that the stronger reaction derives from a larger amount of degenerative products coming from the long gingival cavity tubules than from the shorter central ones, as long as the filling material does not include free harmful chemicals. *Brännström's* speculations resemble those of *Swerdlow & Stanley* (1958) who coded the lesions as severe if the cell-rich zone beneath the zone of Weil "was missing and not according to the number of infiltrating inflammatory cells, as other investigators have described". Since the usual reaction to degeneration in connective tissue is chemotaxis causing accumulation of leukocytes, which is generally seen in the present material, it is the responsibility of *Swerdlow & Stanley* to demonstrate that their criterion of a reaction which is not accepted in general pathology is valid.

Stanley & Swerdlow speculated upon the effect of the pressure applied to burs and thought that a pressure of 8 ounces was injurious. The lack of reaction in experiments with infra low speed (term introduced by *Nygaard Östby* to designate speeds under 300 r.p.m.) in which such a pressure, or stronger, has been regularly applied, indicates that their opinion is not well founded.

Formation of irritation dentin

The dentin laid down in the region of the cavity tubules will in all cases where odontoblasts have migrated into the tubules show irregularity, because the influenced tubule terminates at the place it had reached at the time of migration of the odontoblast, the process of which was included in that particular tubule. The degree of irregularity depends upon the number of migrated odontoblasts. In cases of some days' observation period only, the irregularity of the predentin occurs simultaneously with appearance of migrated odontoblasts. After increasing observation periods, when odontoblast nuclei are no longer seen in the tubules, the irregularity of the dentin is more obvious and the odontoblast layer is still reduced. Regeneration of the odontoblast layer by formation of pre-odontoblasts — young odontoblasts — mature odontoblasts as believed in by *James et al.* has never been found in the author's material. The final result in cases where odontoblasts have degenerated has always been irregular dentin and predentin with reduction in number of the adjacent odontoblasts.

This concerns experiments in which *no perforation* to the pulp has taken place.

On the other hand, the amount of predentin and dentin laid down is not dependent on the number of odontoblasts, but on the distance of the remaining odontoblasts from the pulpo-dentinal membrane. Usually the odontoblasts situated nearest to the predentin migrate first. Thus, the greater the number of migrated odontoblasts the broader the irritation dentin. This stresses the fact that odontoblasts do not form dentin, but they regulate the formation of dentin in that a dentinal tubule is formed around each odontoblast process. When an odontoblast degenerates, for instance after migration, the tubule which had previously been formed around its process will end at the place corresponding to the time of the injury. This is the reason why irritation dentin contains fewer tubules than the dentin formed before the injury. The tubules in the irritation dentin are formed around the processes of the surviving odontoblasts. The tissue between the tubules is irregular and varying from case to case. Part of it may be calcified to a high degree whereas the tissue inbetween is a degenerative fibrous, usually cell-free tissue. The irregularity implies that it is no dependable barrier against injury.

If regeneration of odontoblasts occurred one would expect an increase in the number of tubules. This was never found in the present material. Thus, the whole area of irritation dentin must be considered a scar tissue.

The significance of the spray systems

Based upon their measurements of temperature variations in the pulp, *Aplin et al.* suggested the use of air as a coolant during cavity preparation. Since it is demonstrated in all cases in the present material in which air has been used as a "coolant" that migration of odontoblasts occurs, it is obvious that such a method cannot be used. In addition, it implies that the problem of avoiding reactions is not only a question of temperature control, but as much a question of avoiding drying and desiccation of the tissue.

It is unimportant whether the air blast takes place during or after cavity preparation. When testing the effect on the pulp of an engine or filling material the use of an air stream in any form must be avoided, otherwise the reaction to desiccation will be recorded together with a possible reaction to the engine or filling material. Similarly, when testing the effect of a filling material one must make sure that neither the preparation method nor the cavity toilet produces any reaction.

It may generally be concluded that lack of increase of the temperature measured in the pulp chamber is no evidence of innocuousness of a filling method as *Jarby* (1958) believes.

Temperature of the spray

When the first Borden types were introduced their spray systems were connected directly to the cold water supply. This was critisized in the first publication on ultra high speed (*Nygaard Östby* 1958) and pre-heating of the spray was subsequently introduced. If, however, the thermostat is set at 40°C as, for instance, in the Siemens air turbine, the cooling effect of the spray will be considerably reduced. *Brännström* used a spray temperature of 37°C and this may be one of the reasons why odontoblasts migrated into the cavity tubules of his control and test material.

The temperature of the spray should be as low as possible without hurting the patient. Usually that implies a temperature of about 23°—26°C measured at the place where it hits the bur. As *Peyton* (1955) has shown that the cooling effect of an air/water spray is as efficient as a jet of water, an air/water spray is preferable because, delivering less water, it gives better visibility and the evacuation of water is easier. This is important because the evacuation system of dental units has not been developed to meet the increased requirement of the new technique.

The need for spray at various speeds

Careful preparation at infra low speed did not produce any pathologic reaction. At speeds from about 5,000 r.p.m. up to 50,000 r.p.m. a single spray of Kavo type or the spray system attached to Dentalair was sufficient if the spray reached the bur all the time. At 80,000 r.p.m. Kavo automatic spray covered the whole working surface of even a long bur on one side, but left the other side dry.

In addition, the single jet will always have the disadvantage that it may be prevented from reaching the working place by a cusp or a cavity wall. Particularly at increasing speeds, where the need of spray is greater, it is important that the spray comes from at least three sides as in the LDX.

The increasing need of spray is demonstrated in the Borden engines. Severe reactions occurred in the pulp when cavities were prepared with these engines with their maximum spray. After introduction of the double spray engines, the reactions are reduced but still present (Table 1, New Kavo Borden). Even though the Aero Turbex delivers considerably more water, the reactions caused by that engine are stronger than the reactions caused by the new Kavo Borden. The new spray of the S.S. White Borden is no improvement on the old one. The amount of water delivered is doubled, but the reactions are in general the same as with the original one, because of the inadequate placement of the second jet. Accordingly, the second jet is, as a whole, a disadvantage.

Biological evaluation of drilling instruments

The statement that any instrument used at any particular speed (r.p.m.) should cause stronger reactions than others is not corroborated by the findings in the present experimental material. When *Rateitschak et al.* maintain that the present author found the same reaction to drilling at 20,000 r.p.m. as at 50,000 r.p.m. this is a misunderstanding. First and foremost, the present author has never published results from drilling at 20,000 r.p.m. In addition, if other researchers' results, e.g., *Swerdlow & Stanley's* at 20,000, should be compared with mine at 50,000 it is still wrong, because in the present material no reaction was reported from the 50,000 r.p.m. region when preparing with a sufficient spray for the instrument used, whereas *Swerdlow & Stanley* reported a pathologic reaction.

It is always difficult to compare the results of one researcher with those of another. One factor, however, is important and that is the number of experimental cases. If the number is small, general conclusions can seldom be drawn. This relates particularly to the experimental series of *Marianne Weder* (1960) comprising 22 experimental and 4 control teeth and that of *Rateitschak et al.* (1959) comprising no more than 27 experimental and 5 control teeth. When these small series are divided into groups the conclusions drawn are not significant.

Marsland & Shovelton's observation that steel burs produced a stronger reaction than T.C. burs, is not corroborated in the present material. In this large series no correlation has been observed between the bur or diamond used and the reaction in the pulp. This implies that steel burs, T.C. burs and coarse or fine grain diamonds did not influence the pulp reaction differently. When *Swerdlow & Stanley* maintained that a certain stone, No. 37 diamond stone, produced a stronger reaction at 20,000 r.p.m. than other instruments even when these were used at higher speeds, the reaction should rather be related to the invert cone shape of the diamond, preventing the water to penetrate between the diamond and the tooth, than to the speed. Thus, the problem is again related to the spray system.

Vibrations, caused by belts of belt-driven engines or by acentric handpieces, have not caused pulp reactions in the present material. However, vibration must be considered of importance for the comfort of the patient and for the maintenance of the handpieces, in particular for the ball bearings. Therefore, drills and diamonds should be centric and balanced and the handpiece true running.

Another factor which is of importance for the safety of the patient is the shaft of the bur.

If this is too soft, being hardened on the surface only, it may bend and if this happens while it is working there is a risk of cutting the soft tissue. If it is too hard it may break and fall straight down or be thrown away by centrifugal forces, if it comes out of center the moment before it breaks. For prevention of such a risk when using friction grip instruments, a gadget which ensures placement and removal of the instruments without bending, should be used (Fig. 11 D—F).

The importance of the tissue changes due to cavity preparation and desiccation

On the basis of the present experiments it is concluded that the harmfulness of a preparation method can be evaluated on the basis of the occurrence of migrated odontoblasts and erythrocytes in the cavity tubules. Thus, the testing of engines can be made in experiments of immediate extraction and of short duration.

If a preparation method causes migration of moderate numbers of odontoblasts the method is considered clinically harmless.

If a preparation method causes migration of numerous odontoblasts, the tissue damage is more extended, but the method may after all be considered a calculated risk if it is advantageous — all conditions taken into consideration.

If a preparation method causes migration of numerous odontoblasts and some erythrocytes, it is considered more harmful and clinically inacceptable.

This does not imply that pulpitis or necrosis would occur as a result of the preparation method alone if no harmful filling material were inserted into the cavity. The result of the harmful preparation method *per se* is a scar tissue and a certain amount of chronical inflammatory cells. If, however, as in crown preparation a large amount of dentinal tubules is opened, the reaction will be more severe. Possible pulp reactions due to caries will be added to the reaction to preparation.

If the cavity or abutment is subsequently thoroughly desiccated, the migration will increase.

If at last a chemically irritating material is brought in contact with the dentin treated this way, the tissue fluids thus removed from the peripheral ends of the dentinal tubules will be replaced by, for instance, acids or other irritating elements of the filling material in question. The cumulative effect on the pulp of all the factors mentioned is responsible for the pulpitis and necrosis we find clinically.

This implies that each of these steps should be considered and the reaction to each of them reduced as much as possible. This means that a sufficient air/water or water spray should be used during cavity and crown preparation. If the water spray of the engine in question is insufficient, additional spray should be used.

When drying the cavity or abutment before filling, the *surface* of the cavity or abutment should be dried to meet the requirements of the filling material, but a desiccation into the tubules should be avoided.

The burnt cavity margins will be of importance for secondary or recurrent caries. It is therefore imperative that the engines used have a sufficient spray reaching all cavity surfaces and that margin trimmers are used for finishing.

CONCLUSIONS

I Valid criteria for testing the effect of engines on the pulp were:

(1) After immediate extraction:
- (a) odontoblast nuclei in the cavity tubules,
- (b) erythrocytes in the cavity tubules,
- (c) discoloration of cavity bottom and margin.

If none of these phenomena were seen in experiments of immediate extraction, the method was considered harmless.

(2) After 1—30 days:
- (a) odontoblast nuclei in the cavity tubules,
- (b) erythrocytes in the cavity tubules,
- (c) simultaneously leukocytes in the odontoblast layer where the cavity tubules terminate in the pulp,
- (d) capillaries confined to this area, filled with blood, a criterion of hyperemia,
- (e) leukocytes inside and outside the circulatory vessels of the area involved.

If none of these phenomena were seen, the method was considered harmless.

(3) After more than 30 days:
- (a) usually no more odontoblast nuclei or erythrocytes in the dentinal tubules,
- (b) irregular irritation dentin adjacent to cavity tubules,
- (c) reduced number of odontoblasts adjacent to cavity tubules,
- (d) regular dentinal tubules running without interruption from dentin to pulpo-dentinal membrane, a criterion of *no reaction,*
- (e) no reduction in number of odontoblasts under cavity tubules compared to those under adjacent surrounding tubules, a criterion of *no reaction.*

(f) lymphocytes, plasma cells and macrophages confined to the area subjacent to the cavity tubules but usually not in the odontoblast layer,

(g) lack of inflammatory cells simultaneously with irritation dentin indicates that there has been an acute inflammatory reaction which has been resolved.

II The following phenomena are no criteria of pulp reactions:

(A) Concentration of inflammatory cells centrally in the pulp separate from the area where the cavity tubules terminate in the pulp.

(B) Empty spaces in the odontoblast layer.

(C) Empty spaces centrally in the pulp.

Accordingly, terms as rebound response, varicosity, vacuoles, reticular atrophy, blisters are not valid.

III Lack of temperature increase in the pulp chamber as a result of a preparation or a filling method is no criterion of harmlessness of the method in question.

IV Small cavity formations around the pulpo-dentinal membrane may be the first reaction of the pulp to injury, but the histologic method used in the studies published till today gives no possibility to ascertain whether these cavities were formed *in vivo,* or which fluids they possibly contained. This may be examined in histochemical investigations, but the orientation to the cavity tubules will be a difficulty.

V Based upon these criteria, it was found that:

(1) Engines with r.p.m. up to 300 could be used for preparation in the dentin without spray.

(2) The engines tested (Ritter, Kavo, Micro-Mega belt-driven, Dentalair, LDX) with r.p.m. from 5,000 to 135,000 should be used with an air/water spray to be harmless.

(3) The original Borden airotors caused degeneration of odontoblasts, hemorrhages and an inflammatory reaction.

(4) The new Kavo Borden double spray engine caused less reaction than the original one, in that hemorrhages usually did not occur.
(5) New S.S. White Borden double spray engine was no considerable improvement on the original one, because the water jets came from the same side of the bur.
(6) The Aero Turbex caused essentially the same reactions as the new S.S. White Borden.
(7) The Bien Air single jet engine had an inadequate spray.
(8) The Midwest Air Drive caused reactions similar to those created by the new Kavo Borden, or perhaps a little less.

VI The spray should be sufficiently forceful and directed in such a way that it always remains like a lubricant between tooth and drilling instrument.

VII The reactions to harmful drilling methods and to burns in the dentin were in principle similar, but the reactions to burns from a red-hot steel instrument were stronger.

VIII The effect on the pulp of steel burs, T.C. burs, fine and coarse grained diamonds was similar.

IX No specific influence on the pulp could be seen as a result of the vibration deriving from the drilling instruments used.

SUGGESTIONS FOR RECONSTRUCTION OF AIR-DRIVEN DENTAL ENGINES

The air turbines were received with enthusiasm by the profession when they were introduced, but if they shall be more than an additional equipment meant for special purposes and fully replace the belt-driven engines, rather important new constructions must be introduced.

(1) *Speed - torque*

It is up to the dental surgeon to choose the preferable speed and torque for the operation in question. Certain claims are related to this particular problem:

(A) The speed range of the engine should be from the lowest up to about 250,000 r.p.m. during operation.
(B) At low speed the torque should be high.

(C) At higher speeds the torque should decrease, but — for most operations — not be so low that tactile sense is lost.

(D) Only by perforation of artificial crowns and enamel in tender teeth tactile sense is not wanted. This implies a working speed at about 250,000 r.p.m.

(E) One air engine is hardly sufficient to fulfil all these claims, therefore air motors and handpieces including r.p.m. from 1 to 250,000 should be connected in one unit.

(F) The engines should stop immediately when the air pressure is released.

(2) *Spray*

The spray systems of most of the engines are insufficient, and should be altered to comply with the following claims: It should

(a) come from at least three sides of the bur,

(b) have a sufficient force not to be deflected by the air turbulence around the bur,

(c) always, as a lubricant, penetrate between the tooth substance and the bur, no matter the shape or size of the bur,

(d) prevent smell of burnt tooth structure,

(e) preferably be an air/water spray,

(f) have a thermostat controlled temperature as low as possible without hurting the patient (23—26°C).

(3) The exhaust air should be let out of the mouth or spread to avoid the inconvenience of a forceful jet of air streaming from the rear side of the head of the turbine.

(4) The intensity of the sound should be reduced.

(5) The handpieces should be as free of vibrations as possible.

(6) The bur chuck should secure a firm and centric grip of the bur.

(7) The equipment for insertion and removal of friction grip burs should be constructed in such a way that burs are inserted without the risk of being bent, and removed without the risk of disturbing the chuck or ball bearings.

(8) The engines should be tested biologically prior to commercial introduction.

SUMMARY

In order to investigate the biologic aspects of some modern dental engines, a series of experiments on cavity preparation was carried out. The rotational speed of the engines ranged from about 300 r.p.m. to 250,000 r.p.m. For the preparation were employed various rotating instruments, such as steel burs, tungsten carbide burs, and diamond points with different grain size.

After observation periods varying from three minutes to 620 days, during which the cavities were sealed with zinc oxide-eugenol, the teeth were extracted and submitted to a histologic examination. As a basis for the evaluation of the findings the criteria worked out in the writer's earlier investigations were used.

According to this evaluation, some of the new engines caused pathologic pulp reactions which could be ascribed to an inadequate spray system.

Based upon these investigations, the writer proposes some changes in the construction of dental air-driven engines.

RÉSUMÉ

CHANGEMENTS TISSULAIRES RÉSULTANT DE LA PRÉPARATION DES CAVITÉS

ESTIMATION DE LA VALEUR DE QUELQUES TOURS DENTAIRES

Dans le but d'étudier les aspects biologiques de quelques tours dentaires modernes, il a été procédé à une série d'expériences sur la préparation des cavités. La vitesse de rotation des tours allait d'environ 300 t/min à 250.000 t/min. Divers instruments rotatifs ont été utilisés pour la préparation, fraises en acier, fraises en carbure de tungstène, et pointes de diamant de différents grains.

Après des périodes d'observation variant de trois minutes à 620 jours, pendant lesquelles les cavités étaient obturées à la pâte eugénol-oxyde de zinc, les dents ont été extraites et soumises à un examen histologique. Pour l'évaluation des résultats, l'auteur s'est basé sur les critères établis dans ses recherches antérieures.

Cette évaluation montre que les nouveaux tours ont déterminé des réactions pulpaires pathologiques qu'on peut mettre sur le compte d'un système de refroidissement inadéquat.

Se basant sur ces études, l'auteur propose quelques modification à apporter à la construction des tours dentaires à turbine à air.

ZUSAMMENFASSUNG

GEWEBEVERÄNDERUNGEN ALS FOLGE VON KAVITÄTENPRÄPARATION

EINE UNTERSUCHUNG EINIGER ZAHNÄRZTLICHER TURBINEN

Um die Möglichkeit biologischer Schädigungen bei der Präparation mit einigen modernen zahnärztlichen Turbinen zu ermitteln, wurden an Zähnen mit vitaler Pulpa Kavitäten präpariert und hierbei Rotationsgeschwindigkeiten zwischen 300 und 250.000 Umdrehungen pro Minute gewählt. Es wurden hierzu Stahl- und Hartmetallbohrer sowie Diamanten mit verschiedener Splittergrösser benutzt.

Die Beobachtungsdauer variierte zwischen drei Minuten und 620 Tagen. In dieser Zeit wurden die Kavitäten mit Zinkoxyd-Eugenol verschlossen. Die Zähne wurden extrahiert und der histologischen Untersuchung zugeführt und bei der Auswertung Richtlinien aus früheren Veröffentlichungen des Verfassers berücksichtigt. Es wurde festgestellt, dass bei Verwendung einiger Turbinen pathologische Veränderungen der Pulpa auftreten. Sie müssen einer unzweckmässigen Spraykühlung zugeschrieben werden.

Aufgrund der festgestellten Ergebnisse schlägt der Verfasser einige Änderungen für die Konstruktion der Luftturbine vor.

RESUMEN

CAMBIOS TISULARES DEBIDOS A LA PREPARACIÓN DE CAVIDADES

EVALUACIÓN DE ALGUNOS TORNÓS DENTALES

A fin de investigar los aspectos biológicos de algunos tornos dentales modernos, se efectuaron series experimentales de preparación de cavidades. La velocidad de rotación de los tornos varió desde 300 r.p.m. hasta 250.000 r.p.m. aproximadamente. Para realizar la preparación cavitaria se emplearon distintos instrumentos de rotación, tales como fresas de acero, fresas de carburo de tungsteno y puntas de diamante con diferente tamaño de grano.

Transcurridos períodos de observación que variaron desde tres minutos hasta 620 días, tiempo durante el cual las cavidades fueron selladas con óxido de cinc-eugenol, se extrajeron los dientes y se sometieron a un examen histológico. Como base para la evaluación de las observaciones se utilizó el criterio desarrollado en investigaciones anteriores del autor.

De acuerdo con esta evaluación, algunos de los nuevos tornos produjeron reacciones pulpares patológicas que podían ser atribuidas a un sistema de refrigeración inadecuado.

Basado en estas investigaciones el autor propone algunos cambios en la construcción de los tornos dentales "air-driven".

REFERENCES

1. *Aplin, A. W., K. R. Cantwell and V. R. Manny*, 1959: Effect of coolants on temperature rise resulting from cavity preparation. J. dent. Res. *38:* 761.
2. *Bernier, J. L. and M. J. Knapp*, 1958: A new pulpal response to high-speed dental instruments. Oral Surg. *11:* 167.
3. —»— 1959: Methods used in evaluation of high-speed dental instruments and some results. Oral Surg. *12:* 234.
4. *Brännström, M.*, 1960: Dentinal and pulpal response. I. Application of reduced pressure to exposed dentine. Acta odont. scand. *18:* 1.
5. —»— 1960: Dentinal and pulpal response. II. Application of an air stream to exposed dentine. Short observation period. Acta odont. scand. *18:* 17.
6. —»— 1960: Dentinal and pulpal response. III. Application of an air stream to exposed dentine. Long observation periods. Acta odont. scand. *18:* 235.
7. *James, V. E., I. Schour and J. M. Spence*, 1954: Response of human pulp to guttapercha and cavity preparation. J. Amer. dent. Ass. *49:* 639.
8. —»— 1959: Biology of the pulp and its defense. J. Amer. dent. Ass. *59:* 903.
9. *Jarby, S.*, 1958: On temperature measurements in teeth in vitro and in vivo. Odont. T. *66:* 421.
10. *Kramer, I. R. H.*, 1960: Changes in dentine during cavity preparation using turbine handpieces. Brit. dent. J. *109:* 59.
11. *Langeland, K.*, 1956: En sammenligning av pulpareaksjoner på low og high speed preparering, og om pulpareaksjoner på fyllingsmaterialet Cavinyl. (Autoreferat). Norske Tannlægefor. Tid. *66:* 528.
12. —»— 1957: Tissue changes in the dental pulp. An experimental histologic study. Odont. T. *65:* 239.
13. —»— 1958: Pulpareaksjoner ved high speed preparering. Norske Tannlægefor. Tid. *68:* 127.

14. *Langeland, K.*, 1958: Pulp reactions to high speed instrumentation. Norske lægefor. Tid. *68:* 137.

15. —»— 1959: Histologic evaluation of pulp reactions to operative procedures. I & II. Oral Surg. *12:* 1235 & *12:* 1357.

16. —»— 1959: High speed instrumentation. A histologic and clinical evaluation. Rev. belge Sci. Dent. *14:* 139. (Autoreferat)

17. —»— 1960: Pulpareaktioner vid kavitetspreparation. Sverig. Tandläk. Förb. Tidn. *52:* 215.

18. —»— 1960: Pulp reactions to cavity preparation and to burns in the dentin. A preliminary report. Odont. T. *68:* 463.

19. *Maeglin, B.*, 1960: Auswirkungen der Kavitätenpräparation mit höchsten Geschwindigkeiten in histologischen Untersuchungen. Schweiz. Mschr. Zahnheilk. *70:* 877.

20. *Marsland, E. A. and D. S. Shovelton*, 1957: The effect of cavity preparation on the human dental pulp. Brit. dent. J. *102:* 213.

21. —»— 1959: Displacement of odontoblasts associated with cavity preparation. J. Amer. dent. Ass. *59:* 1257.

22. —»— 1960: The response of the human dental pulp to cavity preparation with an air turbine handpiece. Brit. dent. J. *109:* 225.

23. *Nygaard Östby, B.*, 1958: Clinical and experimental experience with Borden Airotor. Norske Tannlægefor. Tid. *68:* 135.

24. *Peyton, F. A.*, 1955: Temperature rise in teeth developed by rotating instruments. J. Amer. dent. Ass. *50:* 629.

25. *Rateitschak, K. H., K. G. König and H. R. Mühlemann*, 1959: Histologische Pulpareaktionen auf hoch- und höchsttourige Kavitätenpräparation. Schweiz. Mschr. Zahnheilk. *69:* 477.

26. *Seltzer, S. and I. B. Bender*, 1959: Early human pulp reactions to full crown preparations. J. Amer. dent. Ass. *59:* 915.

27. *Shovelton, D. S.*, 1958: Symposium: The use of high rotational speeds in conservative dentistry. Brit. dent. J. *105:* 441.

28. *Stanley, H. R. and H. Swerdlow*, 1960: Biological effects of various cutting methods in cavity preparation: the part pressure plays in pulpal response. J. Amer. dent. Ass. *61:* 450.

29. *Swerdlow, H. and H. R. Stanley*, 1958: Reaction of the human dental pulp to cavity preparation. I. Effect of water spary at 20.000 rpm. J. Amer. dent. Ass. *56:* 317.

30. *Weder, Marianne*, 1960: Ueber die Veränderungen der Pulpa des menschlichen Zahnes nach Beschleifen mit hohen Geschwindigkeiten. Dtsch. zahnärztl. Z. *15:* 104.

PLATES

Plate 1.

Fig. 1. (Nygaard Östby – Langeland's material).

Sections from three teeth in which cavities were prepared into the dentin with a Dentalair ® (Fig. 9E) and a coarse grained Dentatus ® diamond 129 under water spray, and in the dentin with a No. 2 or 3 inverted cone or round steel bur running at 150–300 r.p.m., in a Kavo ® reduction handpiece (Fig. 9A) without a water spray. The teeth were extracted immediately afterwards.

A. Cavity – pulp distance 1.6 mm.
Pulp tissue underlying cavity tubules.* Small cavity formations in the odontoblast layer.

B. High magnification of A.
Dentinal tubules pass without interruption from mineralized dentin through predentin to pulpo-dentinal membrane.
Odontoblast nuclei with nucleoli and spread chromatin. Vacuoles in the cytoplasm of the odontoblasts.

C. Cavity – pulp distance 2 mm.
Left side: Pulp tissue underlying cavity tubules. Medium cavity formations which are also present in the entire odontoblast layer of the coronal pulp. Centrally in the pulp horn disorganized ground substance and cells.

D. High magnification of this area.

E. Cavity – pulp distance 1.8 mm.
Left side: Pulp tissue underlying cavity tubules. Large cavity formations among odontoblasts. Similar appearance on untreated side.

F. High magnification of cut dentinal tubules. Dentinal tubules uninterrupted, ending in pulpo-dentinal membrane. Large cavity formations and »shrunken« odontoblasts.

* In this paper the dentinal tubules cut and opened by cavity preparation will be termed *cavity tubules.*

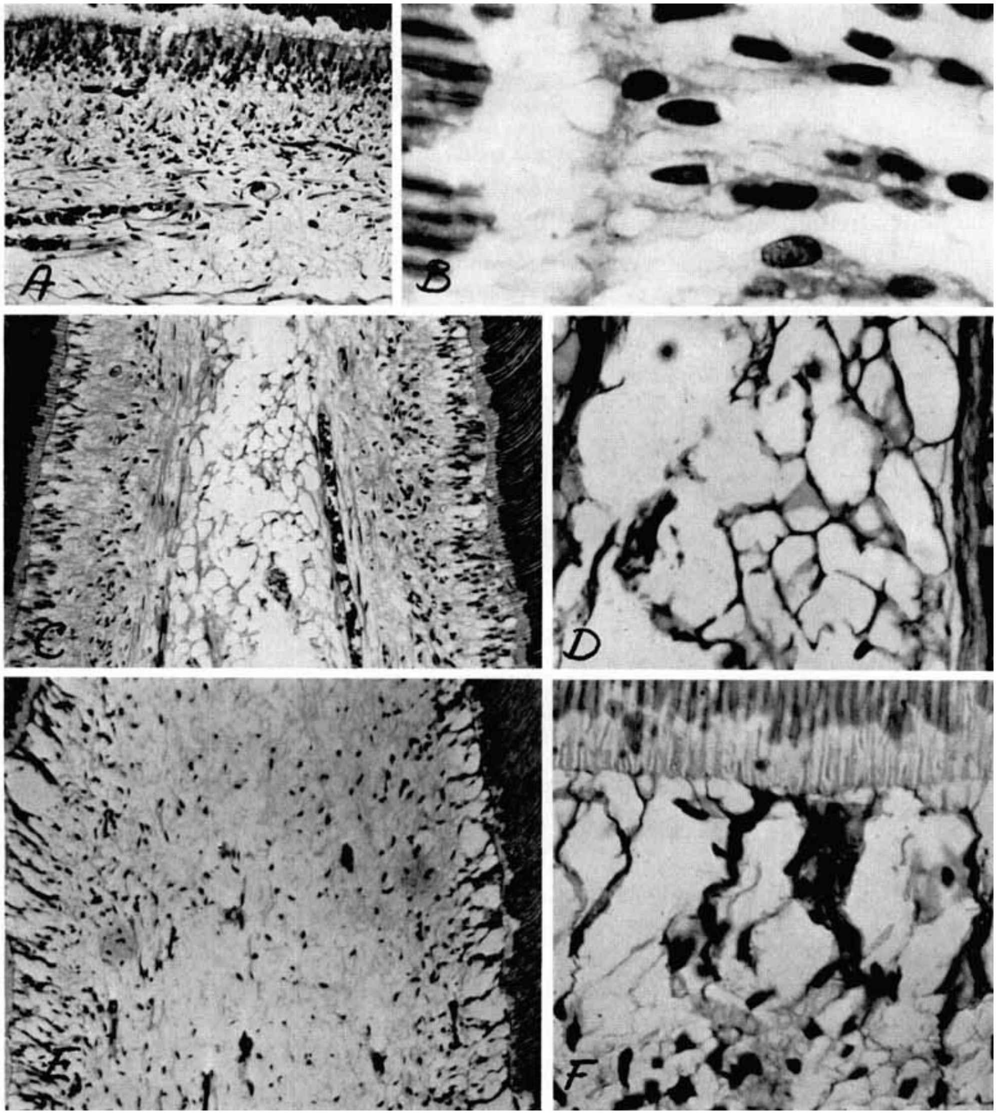


Fig. 1.

Plate 2.

Fig. 2. Untreated tooth. Discoloration of occlusal fissure without involvement of dentin.

A. Dentin and pulp tissue underlying fissure.
Between arrows, concentration of cells centrally in the pulp.

B. High magnification from concentration shows different types of inflammatory cells present, p) plasma cell, l) lymphocyte, m) macrophage.

C. Transition shapes of cells occurring in inflamed region.

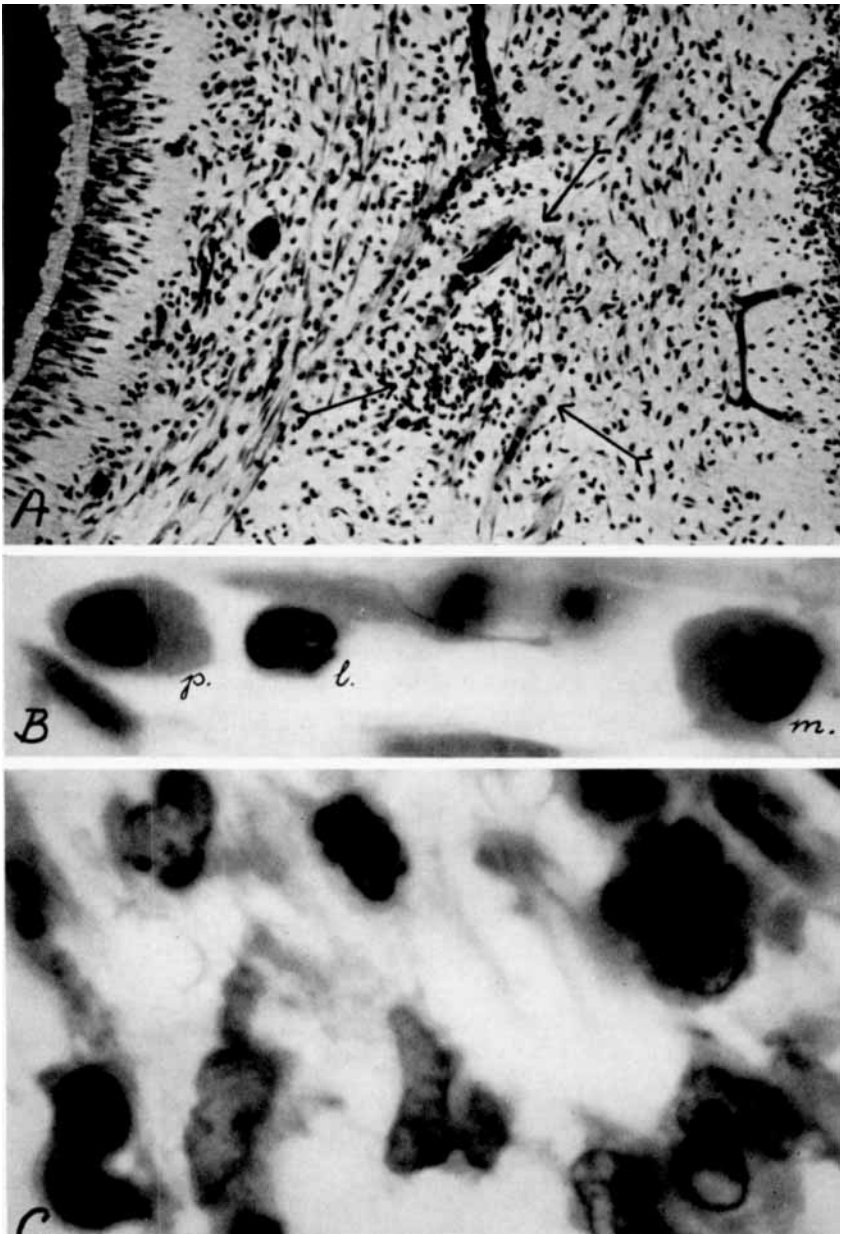


Fig. 2.

Plate 3.

Fig. 3.

A & B. Cavity preparation method as under Fig. 1.
Subsequently cavity washed with lukewarm water, dried with cotton wool and filled with zinc oxide-eugenol. Observation period 47 days. Cavity – pulp distance 2 mm.

A. Pulp tissue underlying cavity tubules and intact tubules. No difference between the two areas.

B. High magnification. Dentinal tubules run without interruption to pulpo-dentinal membrane. Small cavity formations separate pulpo-dentinal membrane from predentin. Medium cavity formations among odontoblasts.

C & D. Ritter ® belt-driven engine, about 5,000 r.p.m. Air/water spray throughout operation, performed with Viking ® diamond 586 into dentin, steel bur in the dentin. Cavity toilet and filling as in A & B.

C. Pulp tissue underlying cavity tubules and intact tubules. Slight reduction in number of odontoblasts in restricted region under cavity. No inflammatory cells.

D. In this region the predentin is irregular and there is no pulpo-dentinal membrane.

E & F. Micro-Mega ® handpiece (Fig. 9C) and wrist joint (35–40,000 r.p.m.). Kavo automatic spray, Dentatus coarse grained diamond 129 into dentin, steel bur in dentin. Immediate extraction. Cavity – pulp distance 0.8 mm.

E. Cavity tubules on part of right side of picture, untreated tubules on left. No difference in appearance of two sides.

F. High magnification of treated tubules. Tubules run without interruption to pulpo-dentinal membrane, which is separated from predentin by small cavity formations. Medium cavity formations in odontoblast layer like those seen under untreated tubules.

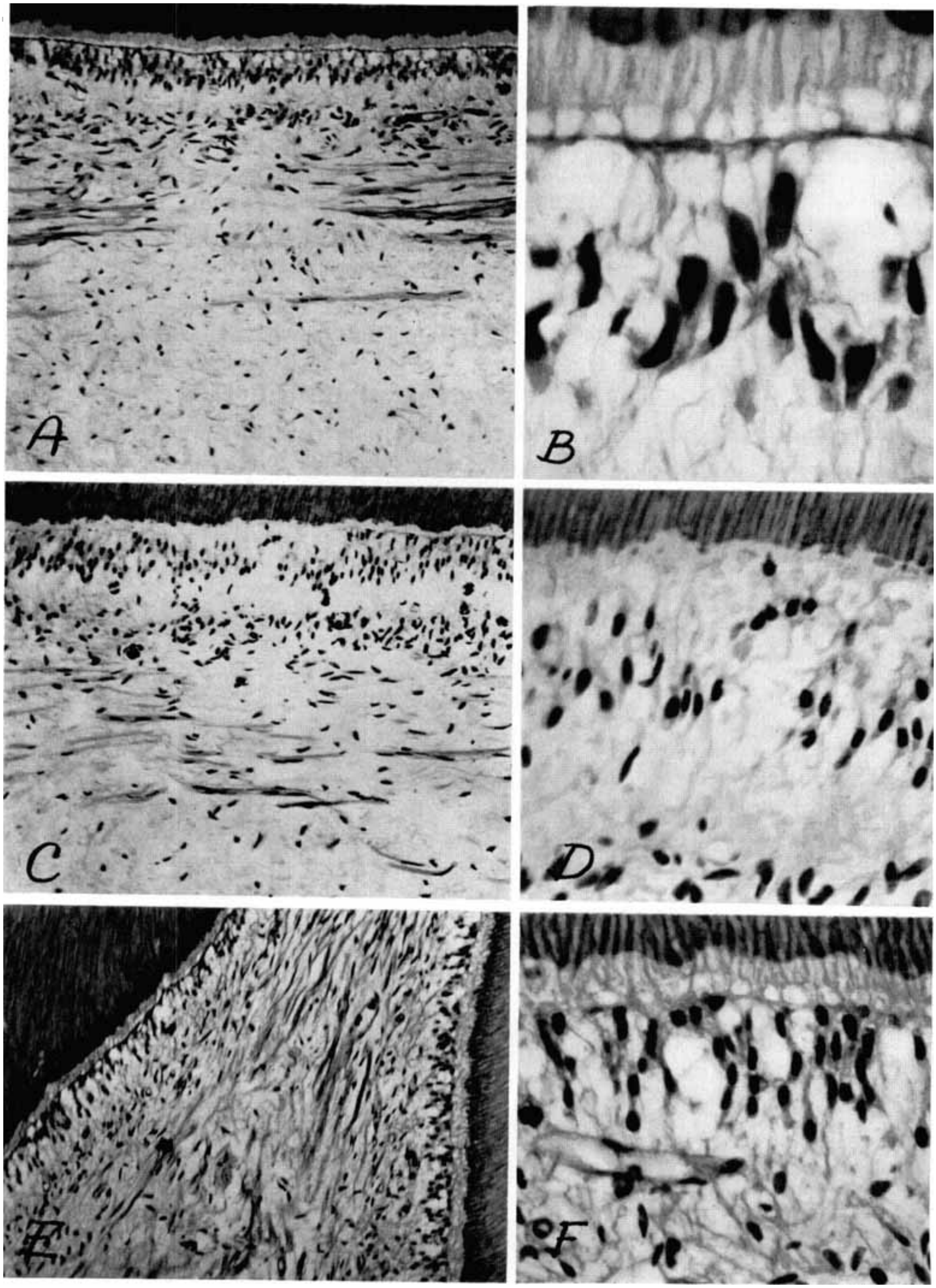


Fig. 3.

Plate 4.

Fig. 4.

A & B. Dentalair with air/water spray (Fig. 9 E), Dentatus diamond 129 into dentin, tungsten carbide (T. C.) bur No. 1 in dentin, cavity toilet and filling as before. Observation period 215 days. Cavity – pulp distance 1.1 mm.

A. Pulp tissue underlying cavity tubules and untreated tubules. Pulpo-dentinal membrane separated from predentin. No inflammatory cells.

B. High magnification. Dentinal tubules run without interruption through dentin and predentin. Medium cavity formations among odontoblasts.

C & D. Dentalair with air/water spray, Dentatus diamond 129 into dentin, T. C. bur No. 1 in dentin. Cavity toilet and filling as before. Observation period 294 days.

C. Irritation dentin under small part of cavity tubules. No inflammatory cells.

D. High magnification. Tubules in irritation dentin irregular and reduced in number. Underlying odontoblast layer reduced in width.

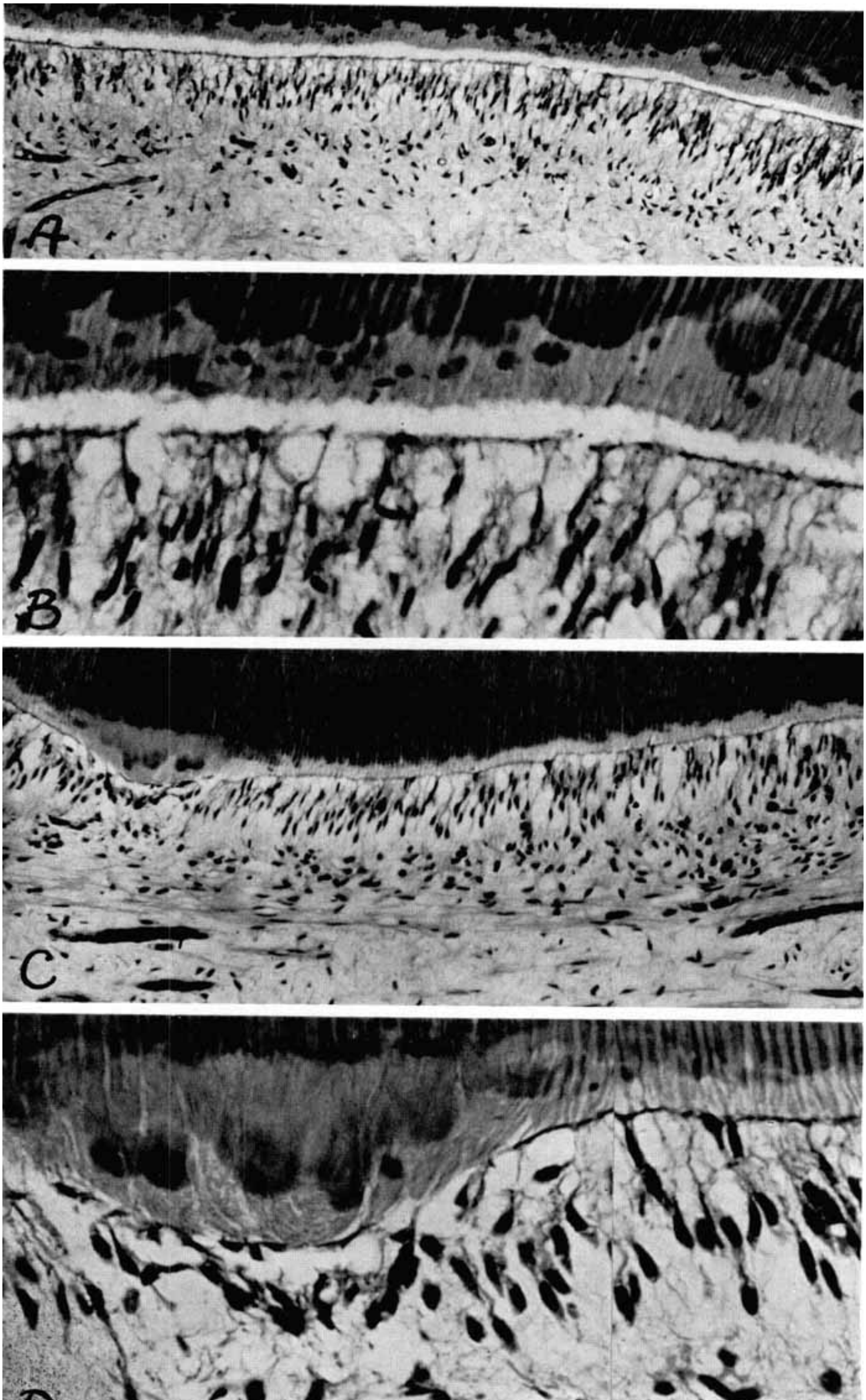


Fig. 4.

Plate 5.

Fig. 5.

A & B. Original Borden ® with maximum spray plus extra air/water spray from unit, Horico ® round diamond bur throughout. Light brushing technique. Immediate extraction. Cavity – pulp distance 1.9 mm.

A. Pulp tissue underlying cavity tubules and untreated tubules. No difference between the two areas.

B. High magnification under cavity tubules. Separation of pulpo-dentinal membrane from predentin.

C. Original Borden with maximum spray. Horico round diamond into dentin, Meisinger ® T.C. No. 2/0 in dentin. Brushing technique. Cavity toilet and filling as before. Observation period 2 days. Cavity – pulp distance 1.3 mm. Cavity tubules, predentin on right. Elongated odontoblast nucleus and erythrocytes in tubules, erythrocytes as far as 0.5 mm from pulp. (Plate 12, K).

D. S.S. White ® Borden with new type jets (Fig. 10G, H, I), T.C. No. 2. Immediate extraction. Cavity – pulp distance 2.2 mm. Cavity tubules including few odontoblast nuclei and numerous erythrocytes. (Plate 12, M).

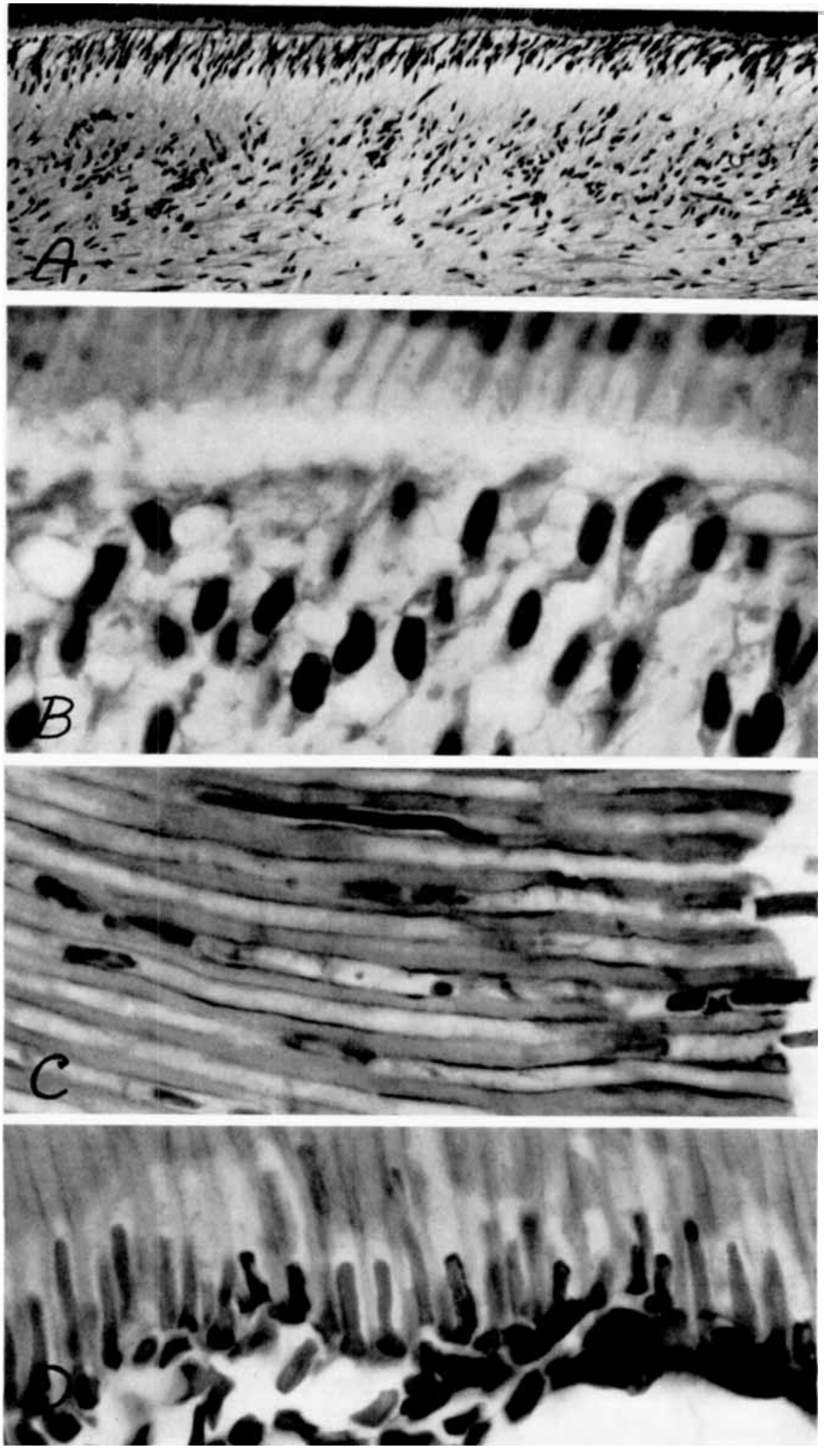


Fig. 5.

Plate 6.

Fig. 6.

A & B. Midwest ® Air Drive with maximum spray (Fig. 10B), S.S. White T.C. round No. 1. Brushing technique, cavity toilet and filling as before. Observation period 4 days. Cavity – pulp distance 1.8 mm.

A. Pulp tissue underlying cavity tubules. Some odontoblast nuclei in tubules, strong hyperemia and presence of inflammatory cells.

B. Extravasated erythrocytes and leukocytes in odontoblast layer and in layer of Weil.

C & D. Aero Turbex ® with maximum spray (Fig. 10E). Meisinger T.C. round bur No. 1. Brushing technique. Even so smell of burnt dentin. Cavity toilet and filling as before. Observation period 69 days. Cavity – pulp distance 1.4 mm.

C. Part of cavity (top right), underlying tubules and pulp tissue. Darkly stained zone in cavity bottom. (Two vertical lines due to folding of section). Broad layer of irritation dentin bordered by one row of odontoblasts. Some inflammatory cells in subjacent pulp tissue.

D. Predentin and adjacent remaining odontoblasts. Area between odontoblast nuclei and predentin contains fibrous tissue. Large cavity formations in odontoblast layer, also in odontoblast layer opposite cavity (C bottom right).

E & F. Technique as in C & D. Observation period 105 days. Part of cavity (top right) underlying tubules and pulp tissue. Darkly stained cavity bottom (vertical line due to folding of section). Broad layer of irritation dentin bordered by one row of odontoblasts. Some inflammatory cells in pulp tissue. Large cavity formation centrally in pulp horn.

F. High magnification. Predentin and odontoblasts. Fibrous tissue between predentin and odontoblast nuclei.

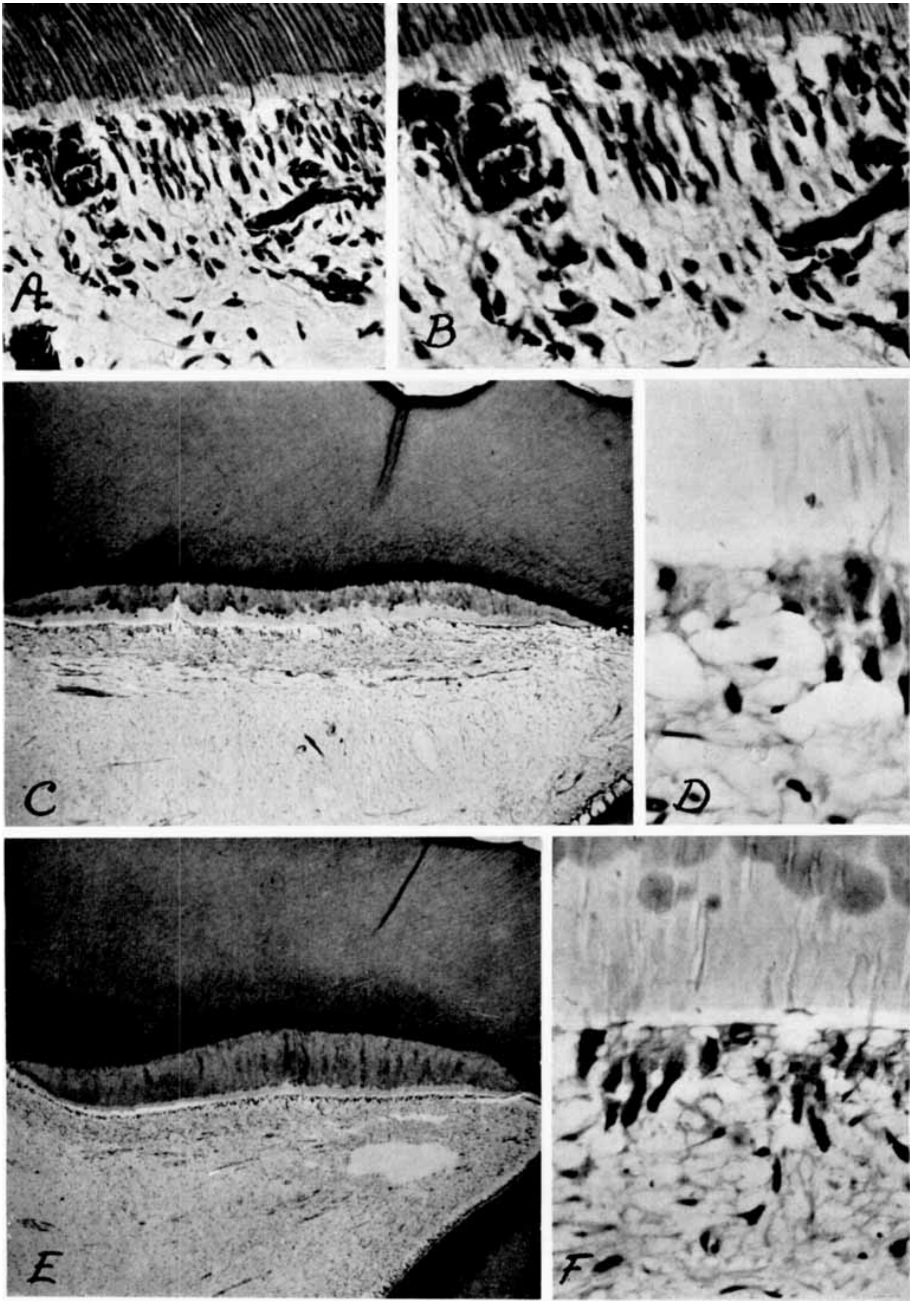


Fig. 6

Plate 7.

Fig. 7. Dentalair with air/water spray. Dentatus diamond 96. Subsequent to cavity preparation a round steel instrument of size of a No. 4 round bur heated to red-hot over spirit flame and pressed against cavity bottom. Cavity filled with zinc oxide-eugenol. Observation period 38 days. Cavity – pulp distance 1 mm.

A. Dentin touched by hot instrument. Dark stained zone on surface layer (Plate 12, P).

B. Cavity tubules. Numerous odontoblast nuclei in tubules. Marked reduction in number of odontoblasts. Numerous inflammatory cells in subjacent tissue.

C. High magnification of cavity tubules. Predentin irregular consisting of fibrous tissue without tubules but including cavity formations. Cavity formations in subjacent tissue.

D. Lymphocytes, plasma cells and macrophages in tissue, nearly free from normal pulp cells and fibres.

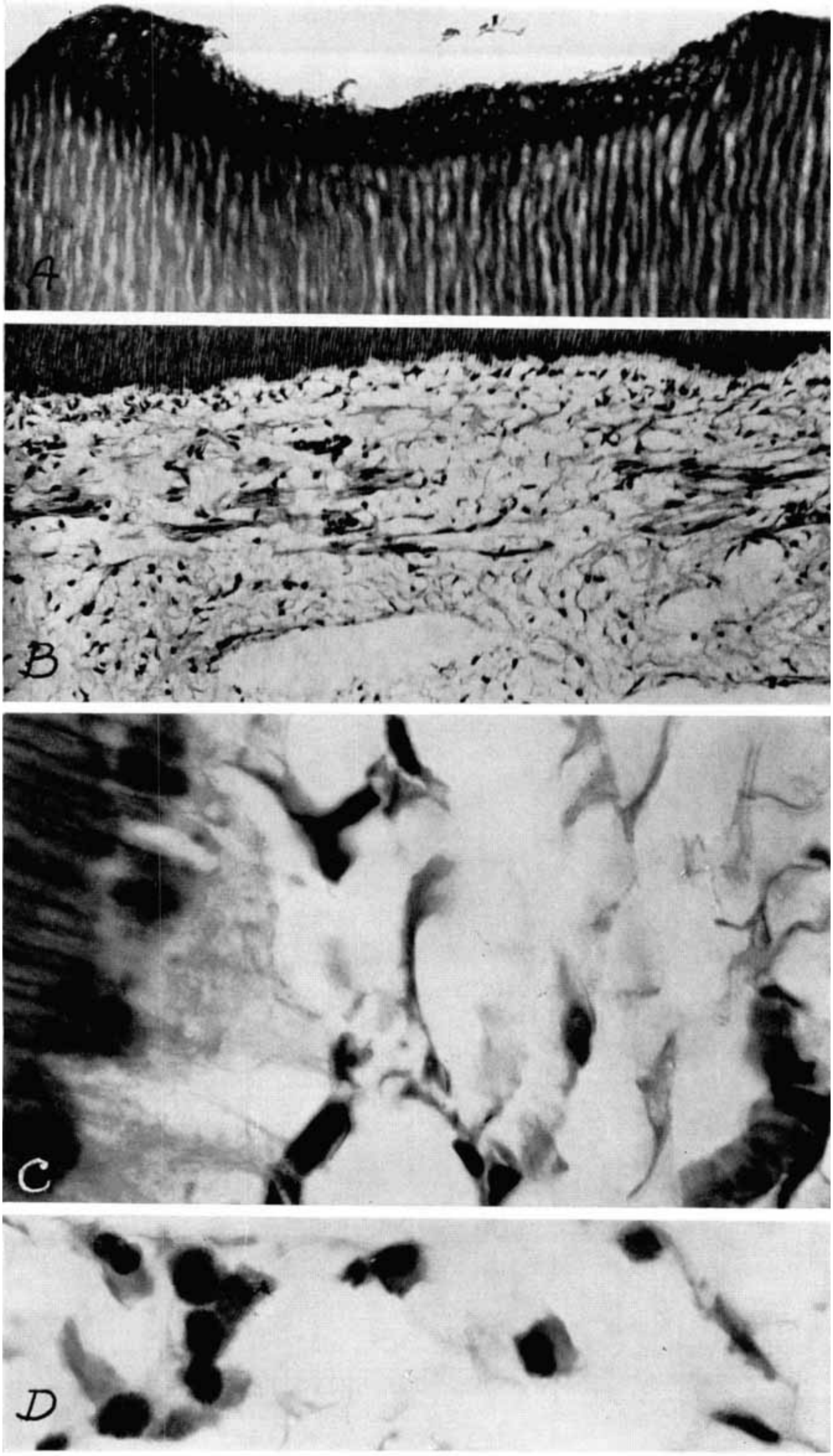


Fig. 7.

Plate 8.

Fig. 8.

A. Dentalair, air blown to cavity during preparation. Dentatus diamond 129. Cavity filled with zinc oxide-eugenol. Observation period 2 days. Cavity – pulp distance 1.5 mm.
Pulp tissue underlying cavity tubules. Numerous odontoblast nuclei in cavity tubules. Numerous neutrophilic leukocytes in subjacent pulp tissue.

B. & C. Kavo Borden, *air* spray only. S.S. White T.C. bur No. 557. Cavity filled with zinc oxide-eugenol. Observation period 14 days.

B. Darkly stained cavity bottom (right).

C. Pulp tissue underlying cavity tubules (black line, due to folding of section). Broad predentin zone bordered by reduced odontoblast layer. Accumulation of inflammatory cells.

D. Capillaries included in predentin zone.

E. Reduced odontoblast layer with blood-filled capillaries.

F. Remaining odontoblasts bordering irregular predentin with included cells.

G. Lymphocytes in subjacent pulp tissue.

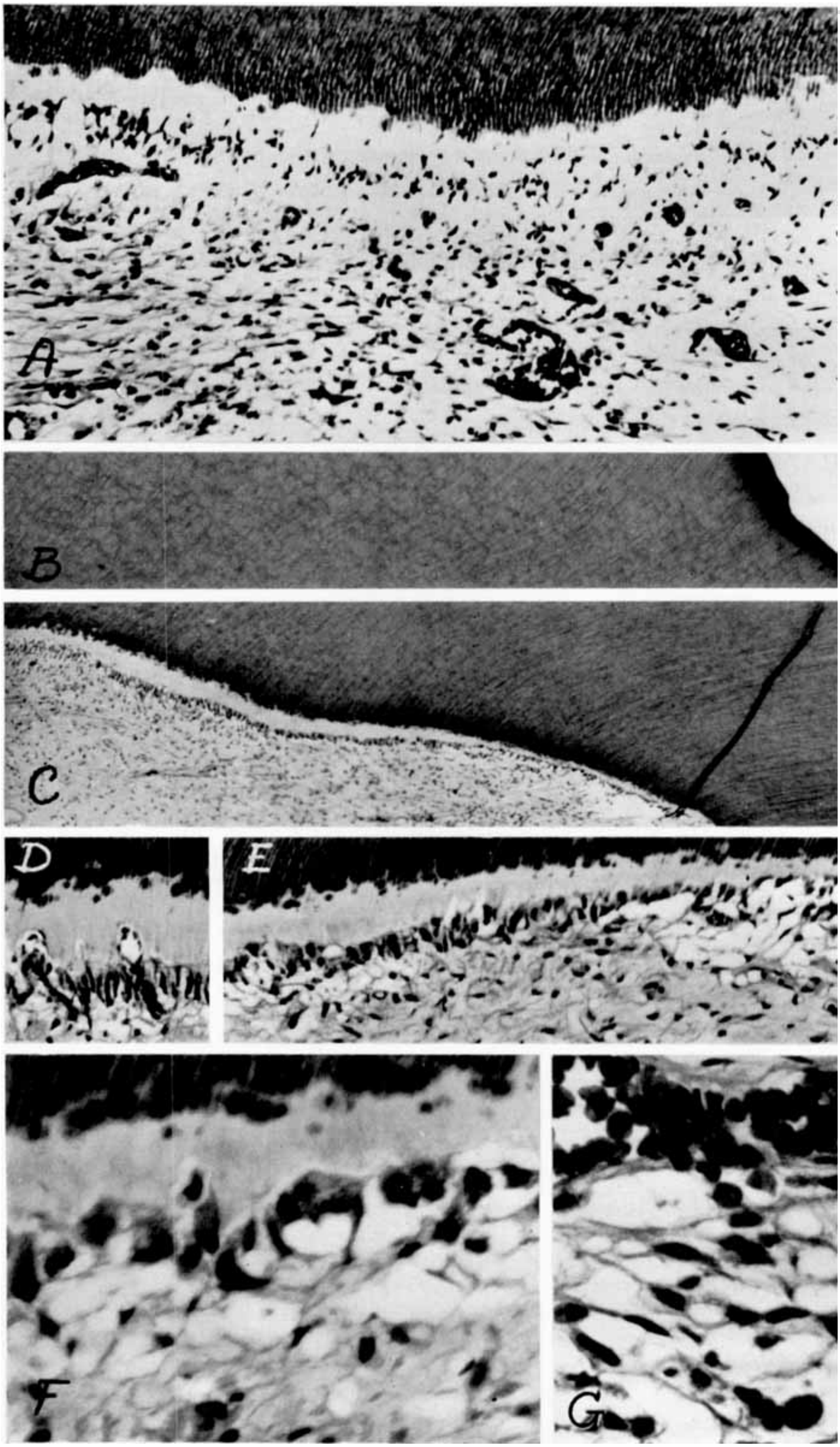


Fig. 8.

Plate 9.

Fig. 9. Handpieces tested.

A. Kavo reduction-geared handpiece, reducing speed in ratio 10:1.

B. Kavo ball bearing contra-angle, rotating at about 40,000 r.p.m. with Kavo automatic spray.

C. Micro-Mega tungsten carbide bearing contra-angle, rotating at about 40,000 r.p.m. with Kavo automatic spray.

D. Micro-Mega geared contra-angle, rotating at about 80,000 r.p.m. with Kavo automatic air/water spray. Observe spray tube round contra-angle head.

E. Dentalair with air/water spray rotating at about 50,000 r.p.m.

F. L D X ® (Air driven experimental vane motor).
Three holes in head, outlets for air/water spray, hole on shaft, outlet for chip blower.

G. L D X rotating at about 135,000 r.p.m. with its air/water spray completely covering long diamond.

H. New contra-angle for Kavo Borden. Two holes outlets for air/water spray.

I. New Kavo Borden rotating at about 250,000 r.p.m. with air/water spray. Fine mist completely covering the working part of bur.
Holes under screw on top of head outlets for exhaust air.

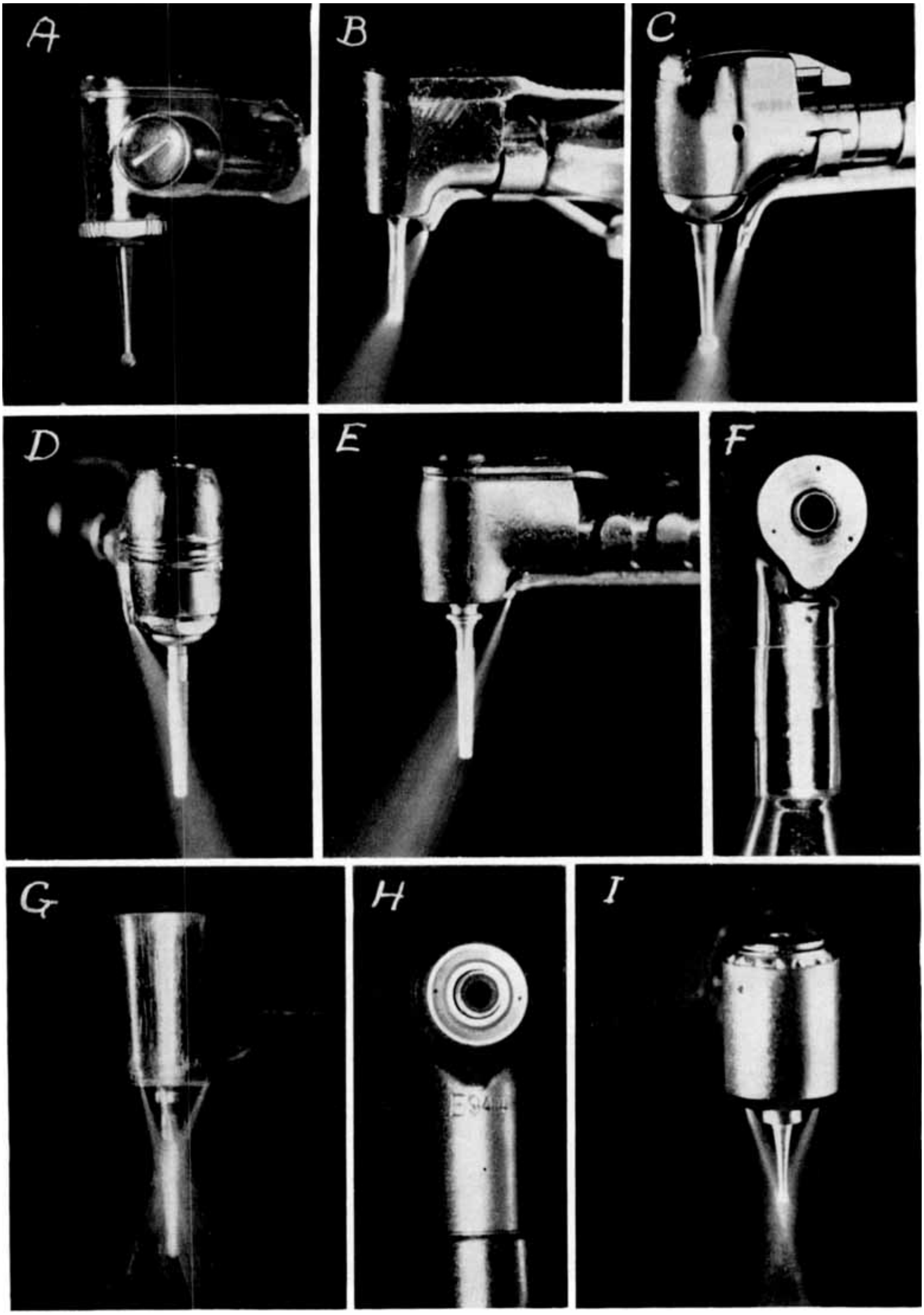


Fig. 9.

Plate 10.

Fig. 10.

A, B & C. – Midwest Air Drive.

A. One outlet for chip blower, the other for jet of water.

B. Air Drive rotating at about 250,000 r.p.m. with spray in action. Water covering the drill from one side whereas the other side of bur is left dry.

C. When spray pressure is reduced, air turbulence around the bur deflects spray from bur.

D. Fairfax ® Aero Turbex. Two outlets for water jets.

E. Aero Turbex running at about 250,000 r.p.m. with maximum spray hitting head of bur.

F. As in E with reduced water jets deflected from bur.

G. New S.S. White Borden. Two lower outlets for water jets. Three upper for part of exhaust air.

H. S.S. White Borden running at about 250,000 r.p.m. with maximum spray. Front jet hitting shaft of bur, rear jet upper part of working surface leaving part of bur uncovered.

I. As in H with reduced water jets deflected from bur.

J. Bien Air ®, air turbine with single outlet for air/water spray protruding from neck.
Metal chuck for burs with conventional shafts.

K. Bien Air running at about 250,000 r.p.m. with maximum spray, from one side covering the bur.

L. As in K. Spray hitting side of cusp, completely preventing it from reaching field of operation.

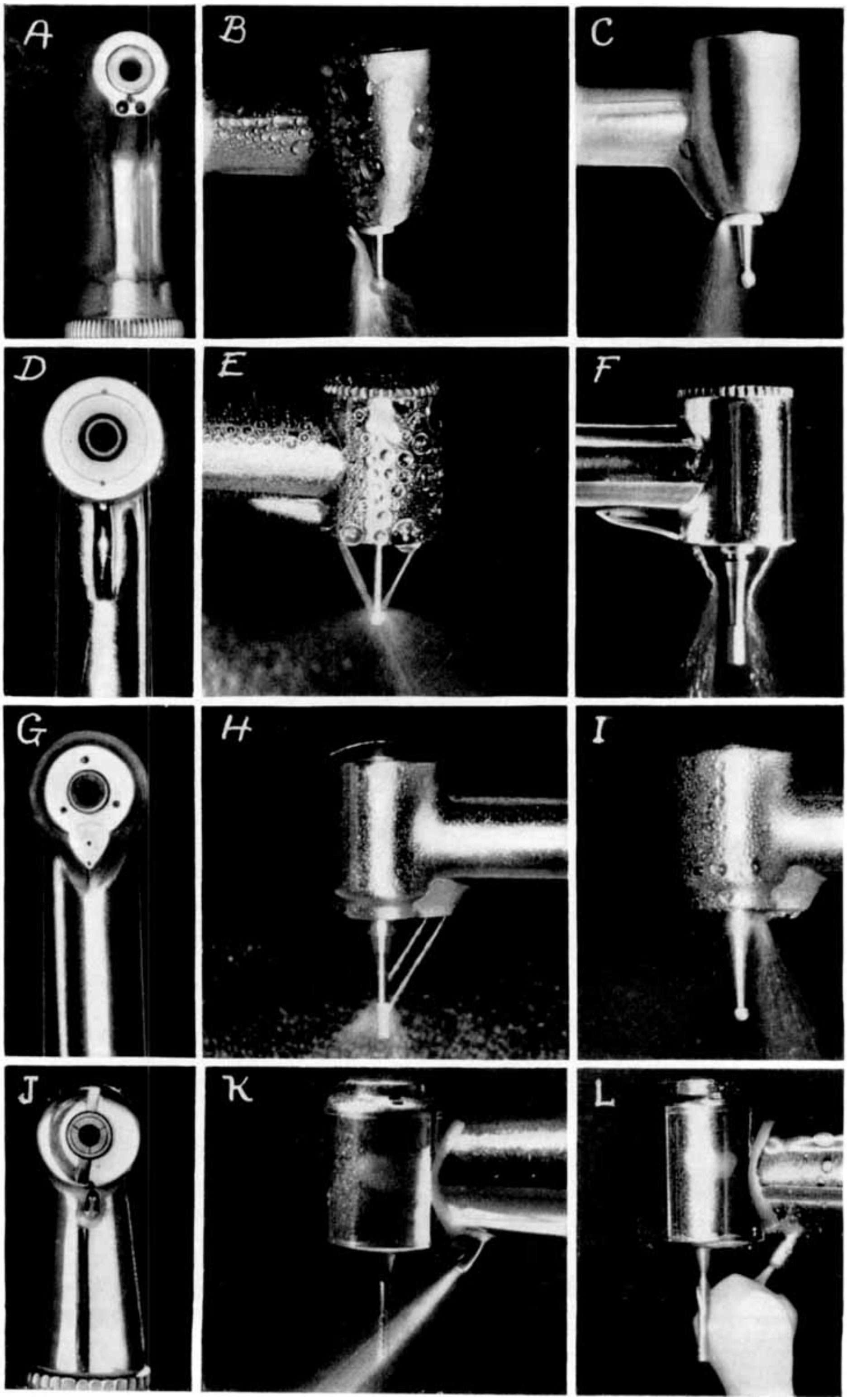


Fig. 10.

Plate 11.

Fig. 11.

A. Plastic chuck and diamond bent during drilling and thrown out of chuck.

B. Diamond broken during drilling. It was slightly bent the moment before breaking and the head was therefore thrown off by centrifugal force.

C. Slightly bent diamond running at about 250,000 r.p.m.

D. (Left): Same diamond as in C in air turbine placed in a gadget for precise removal of burs.

D. (Right): Gadget for insertion of bur into chuck preventing the possibility of tilting or bending.

E. Left part of gadget in D seen from the side. In middle, pin which presses bur out.

F. Right part of gadget in D seen from the side.

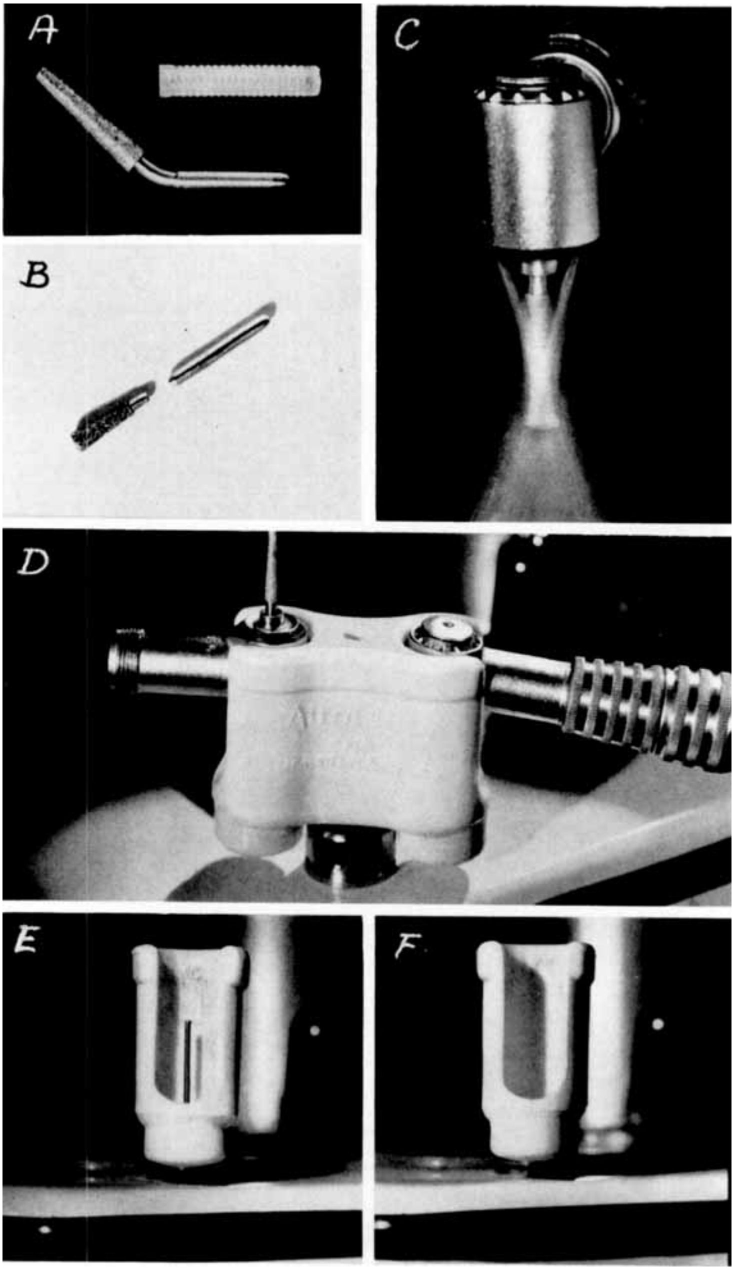


Fig. 11.

Plate 12.

A. Dentalair with air/water spray, Dentatus diamond 129 into dentin. Kavo reduction-geared handpiece, without spray, rotating an inverted cone bur No. 2 in dentin. Immediate extraction. Cavity – pulp distance 1.5 mm. Section stained according to *Masson* (trichrome stain). Cavity walls stained as deeper parts of dentin.

B. Ritter belt-driven engine and Horico diamond into dentin, a steel bur in dentin under continuous air blast. Cavity prepared in carious region. Immediate extraction. Cavity – pulp distance 0.8 mm. Irritation dentin due to caries. Predentin bordered by one chain of odontoblasts, some of which have migrated into tubules.

C. As in B. Cavity tubules adjacent to those in B. Numerous odontoblast nuclei in cavity tubules.

D. Dentalair and Viking diamond 586 into dentin, T.C. bur in dentin under continuous air blast. Cavity filled with zinc oxide-eugenol. Observation period 2 days. Cavity – pulp distance 1.5 mm. Pulp tissue underlying cavity tubules. Odontoblast nuclei in tubules, numerous neutrophilic leukocytes in pulp tissue.

E. New Kavo Borden with Horico diamond into dentin, Meisinger T.C. bur 2/0 in dentin under continuous air blast. Cavity toilet and filling as before. Observation period 7 days. Cavity -- pulp distance 1.5 mm. Dentin and pulp tissue underlying cavity. Odontoblast nuclei in cavity tubules, reduced odontoblast layer, and neutrophilic leukocytes along predentin.

F. Cavity prepared with belt-driven engine at 10,000 r.p.m. under a continuous blast of air, the temperature of which is reduced from $+37°$ to $+1°C$. (Non-dolor). Cavity filled with zinc oxide-eugenol 16 days. Cavity – pulp distance 1.6 mm. Dentin and pulp tissue underlying cavity. Darkly stained area in dentin, due to folding of thin section. Marked hyperemia, hemorrhage and accumulation of numerous neutrophilic leukocytes and lymphocytes in odontoblast layer and centrally in the pulp.

G. High magnification of F. Erythrocytes in cavity tubules evidence of hemorrhage. Neutrophilic leukocytes along predentin and in entire odontoblast layer.

H. Dentalair with air/water spray, Dentatus diamond 129 into dentin, Meisinger round No. 2 in dentin. Cavity toilet and filling technique as in Fig. 1. Observation period 43 days. Cavity – pulp distance 1.5 mm. Section stained according to *Masson* (trichrome stain). Cavity bottom stained as deeper parts of dentin.

I. Bien Air with Dentatus diamond 129 into dentin, with Meisinger T.C. inverted cone in dentin. Maximum spray. Spray was prevented from reaching cavity by hitting the cusp of the tooth. Immediate extraction. Cavity – pulp distance 1.8 mm. Section stained according to *Masson*. Heavily stained cavity bottom and margin.

J. Original Borden with water jet, Horico diamond into dentin, Meisinger T.C. bur No. 2/0 in dentin. Cavity toilet and filling as before. Observation period 2 days. Red stain of cavity bottom and margin evidence of overheating because of insufficient spray.

K. As in J. Cavity tubules and adjacent odontoblast layer. Odontoblast nuclei and erythrocytes in tubules; erythrocytes as far as 0.5 mm from pulp (Fig. 5 C). Hemorrhage in odontoblast layer.

L. New S.S. White Borden airotor, 2 water jets (Fig. 10, G, H, I). S.S. White T.C. bur round No. 2. Maximum spray. Immediate extraction. Cavity – pulp distance 2.2 mm. Red stain of cavity bottom evidence of overheating because of insufficient spray.

M. As in L. Cavity tubules and subjacent odontoblast layer. Numerous erythrocytes and few odontoblasts in tubules. Extravasated erythrocytes in odontoblast layer. Empty space partly an artifact (Fig. 5 D).

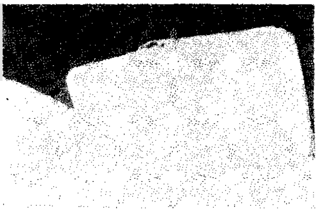
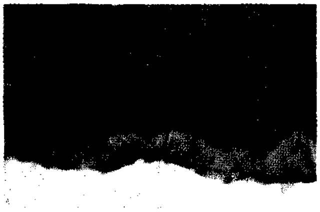
N. New S.S. White Borden, S.S. White T.C. bur No. 557. Maximum spray. Cavity toilet and filling as before. Observation period 26 days. Cavity – pulp distance 1.3 mm. Cavity tubules and subjacent pulp tissue. Irregular irritation dentin bordered by reduced odontoblast layer.

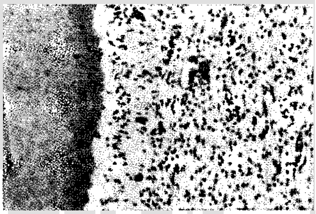
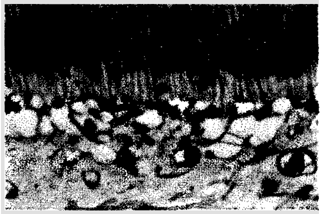
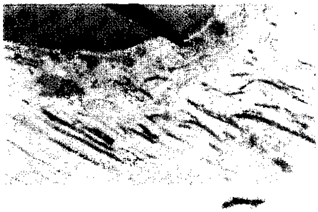
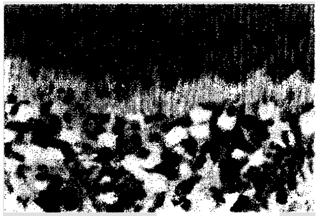
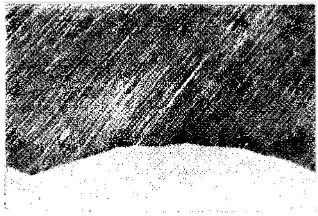
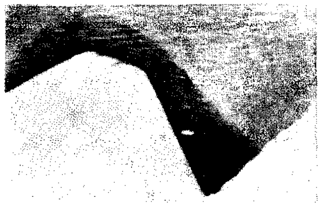
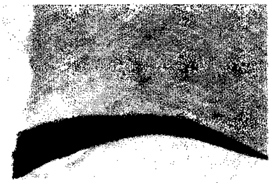
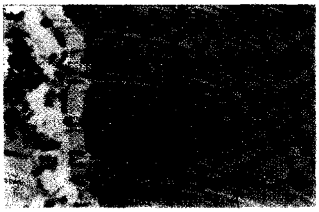
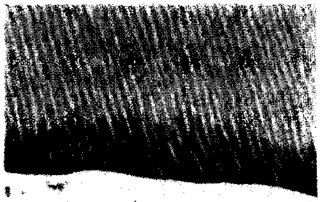
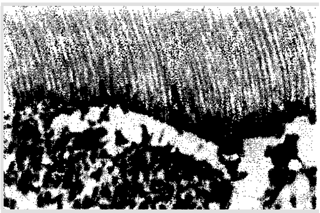
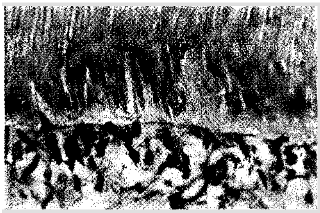
O. Aero Turbex, Meisinger T.C. bur round No. 2. Maximum spray. Cavity toilet as before. Zinc oxide-eugenol and amalgam. Observation period 73 days. Cavity – pulp distance 2 mm. Irregular irritation dentin containing fewer dentinal tubules than dentin formed before experiment. Odontoblast layer considerably reduced. Empty space partly an artifact.

P. Dentalair and Dentatus round diamond 96 into dentin, Meisinger T.C. round No. 1 in dentin. Air/water spray. Subsequently cavity bottom was burnt with a steel instrument of size similar to round bur No. 4. Zinc oxide-eugenol 38 days. Cavity – pulp distance 1 mm. Cavity and subjacent tissues. Bluish stain of part of cavity bottom. Inflammation in pulp (Fig. 7 A).

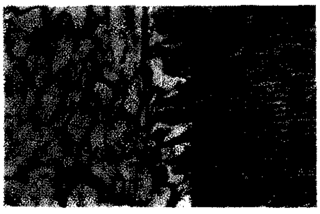
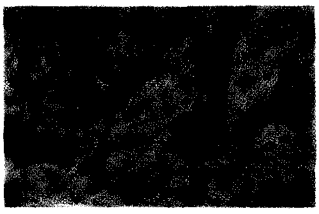
Q. As in P. Cavity tubules with subjacent irritation dentin bordered by one row of odontoblasts. Start of experiment demonstrated in stop of regular dentinal tubules. Irritation dentin formed during 38 days consists of loose fibrous tissue including empty spaces.

R. As in P. High magnification from Q. Cavity tubules and subjacent predentin with remaining odontoblasts. Predentin a loosely formed fibrous tissue bordered by one row of remaining odontoblasts.


A

B

C

D

E

F

G

H

I

J

K

L

M

N

O

P

Q

R