

Microscopic study of the pulps of human teeth following vital root resection

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The effects of vital root resection upon the remaining pulp were studied in twenty-six periodontally involved human molars. The pulp was extirpated 14 days after the intervention. Granulomatous tissue present in the pulp chamber protruded from the site of the exposure as a polyp in eleven cases. Mild chronic inflammatory changes were present in the coronalmost part of the radicular pulp. The apical pulp was not affected at this time interval.

Whenever a vital tooth is amputated by resection of a root, the pulp becomes exposed at the base of the resected root. The dentist is then confronted with a clinical problem that is usually solved in one of two ways: pulp capping (or pulpotomy) to conserve the vitality of the organ or pulpectomy and root canal filling. Vital pulp therapy has fewer proponents and it is considered today exceptional rather than routine treatment in adults.¹⁻³ Therefore, it is not surprising that only a small number of authors advocate conservation of pulp vitality after root resection.^{4, 5} It is, however, surprising that the whole procedure of root resection or hemisection was so widely accepted and used before its rationale and long-term effects were investigated. The recent publication of studies of larger series of root-resected teeth with longer follow-up periods^{6, 7} has shown the soundness of the procedure from the clinical point of view. One should note, however, that there has not yet been a study including similarly involved control teeth that have not undergone resection, so that the benefits of the operation could be objectively evaluated and compared in terms of tooth longevity, inflammatory changes of the investing tissues, etc.

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Table I. Distribution of teeth and resected roots in experimental material

<i>Tooth</i>	<i>Mesiobuccal</i>	<i>Distobuccal</i>	<i>Palatal</i>	<i>Mesial</i>	<i>Distal</i>	<i>Total</i>
Maxillary first molar	3	9	3			15
Maxillary second molar	2	4	—			6
Mandibular first molar				1	2	3
Mandibular second molar				1	1	2
Total	5	13	3	2	3	26

The recommendations concerning the treatment of the pulp in cases of vital root resection^{8, 9} seem to be mostly empirical or based on assumptions of possible pulpal reactions extrapolated from different situations. Only two experimental studies of vital pulp therapy after root resection included clinical follow-up of the pulpal reactions^{4, 5} and one of these was supplemented with histologic observations of two cases.^{10, 11} In order to evaluate the effect of any type of treatment, one should know the natural history of the condition, that is, the effect of root resection upon the remaining untreated exposed pulp. Although there is no record of a histologic study of such nature in human subjects, most clinicians seem to know the answer from their clinical experience or by inference from animal studies.¹²⁻¹⁴ The validity of the animal studies is not questioned, but there are some species differences and, still more important, studies in the animal give no indication on the problem of pain that is so closely associated with pulpal disease.

This investigation was undertaken to study the short-term effect of vital root amputation on the residual pulp. For practical reasons, the period of observation was limited to 2 weeks. The first part of the study¹⁵ dealt mostly with the clinical implications of delaying for this period the definitive endodontic therapy (pulp-ectomy and root canal filling). The present article reports the microscopic changes that occurred in the pulp.

MATERIALS AND METHODS

The study was carried out on twenty-six cases of vital root amputation performed in the course of routine periodontal practice (Table I). It involved nineteen patients 27 to 62 years of age (mean, 47.1), who were all in good physical health. The clinical diagnosis of normal pulp was established in all cases at the time of the first examination. It was based on careful examination of the teeth (including thermal tests with ice) and on a detailed history. The diagnosis was confirmed again just prior to surgery, and the resected root was recovered for histologic processing.

The same tests were performed on the resected teeth 2 weeks postoperatively, just prior to endodontic treatment. The patient's subjective symptoms were carefully recorded. An endodontic access cavity was prepared after anesthesia, and an attempt was made to remove the radicular pulp in toto. Barbed broaches were used after gentle probing of the canals with a small file. If a pulp polyp was present at the exposure site (Fig. 1), it was removed with a sharp spoon excavator. All pulpal tissue was immediately placed in 10 per cent formalin. The pulps were embedded in celloidin-paraffin after a short period of decalcification in 5 per cent formic acid. The resected roots were fully decalcified prior to embedding.



Fig. 1. Pulp polyp at base of resected mesiobuccal root in a 47-year-old woman.

Central sections through the tissues made at a setting of 7 micrometers were mounted in groups of four or five to a carrying glass. Every sixth slide was stained with hematoxylin and eosin. Additional slides were stained by van Gieson's method or with Gram's stain for tissues.¹⁶

RESULTS

The pulp biopsies of twenty teeth were suitable for evaluation. The remaining six specimens were either too crushed or insufficient in quantity for a reliable diagnosis. Even though in some of the twenty, there was tissue available from parts only of the remaining pulp, it was possible to establish that all the examined pulps were vital and without acute inflammatory infiltrate. Calcification in varying degrees was present in twelve of the biopsy specimens. Some pulps showed small, discrete denticles in the cervical portion of the radicular pulp, but the more apical calcifications were of the dystrophic type. Van Gieson's stain showed that some pulp fragments were more fibrous than others.

Changes in cellularity were the most reliable sign for this investigation. The apical portion of the pulp was not affected at all by the operation. It was usually similar to the corresponding part in the resected roots. Neutrophilic leukocytes were present within the blood vessels of three specimens but not in the tissue. In the middle and coronal thirds of the radicular pulp, changes could be observed in some of the specimens. In the pulps that were not too calcified, an increase in cellularity characterized by "small round cells" could be noted. Very seldom were neutrophilic leukocytes present.

The most notable changes occurred in the coronal pulp, and they extended to some distance into the radicular pulp. There was a marked increase in cellularity, part of the effect being due to the large swollen nuclei of the endothelial cells of the capillaries. Lymphocytes and plasma cells, together with fibroblasts, macrophages, and other connective tissue cells completed the picture (Fig. 6). Scattered neutrophilic leukocytes were present in five specimens, accompanied in two of them by eosinophilic leukocytes. In two of the biopsies, the edge of the pulp blended with the granulation tissue which formed the polyps (Fig. 5). This area

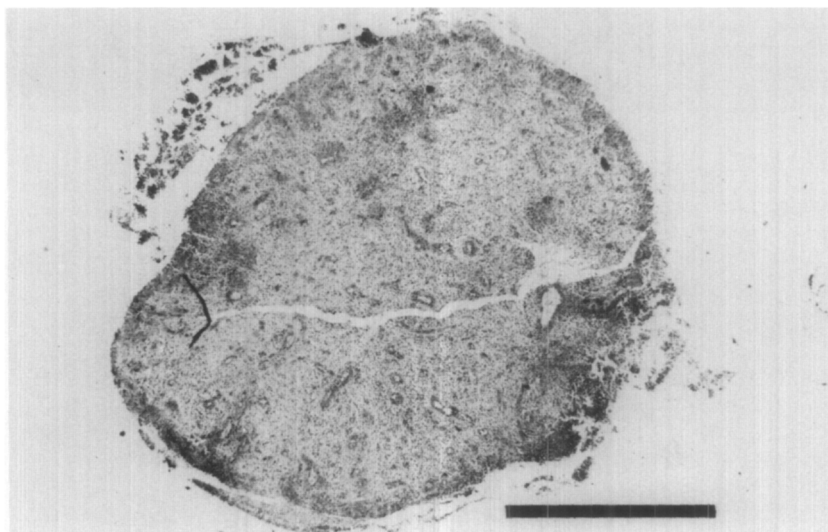


Fig. 2. Pulp polyp consisting of granulation tissue. (Hematoxylin and eosin stain. Bar represents 1 mm.)

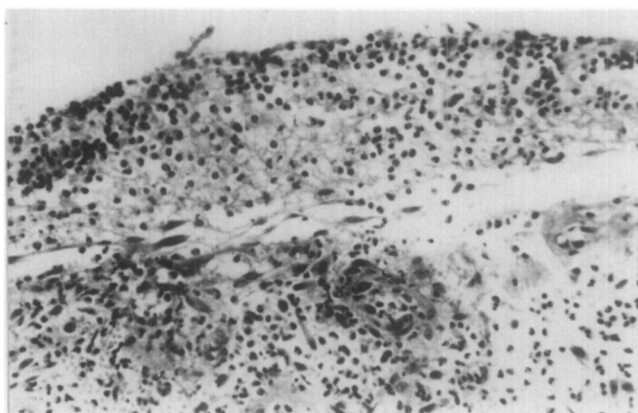


Fig. 3. Edge of polyp showing neutrophilic leukocytes and erythrocytes in a fibrinous network. No evidence of epithelium. (Hematoxylin and eosin stain. Magnification, $\times 160$.)

usually contained some chips or even larger fragments of dentin and, occasionally, amalgam filings.

The pulp polyps measured from 1 to almost 3 mm. in diameter. The sections, parallel to the excised surface, consisted of granulation tissue only (Fig. 2). Parts of the periphery showed leukocytes and erythrocytes embedded in a fibrinous network, but there were no recognizable epithelial cells (Fig. 3).

Gram's method was used on sections from all three types of biopsy specimens—extirpated pulps, pulp polyps, and resected roots. The stain showed no microorganisms in the tissues. Bacteria were detected only in a carious lesion present on one root and in adjacent dentinal tubuli.

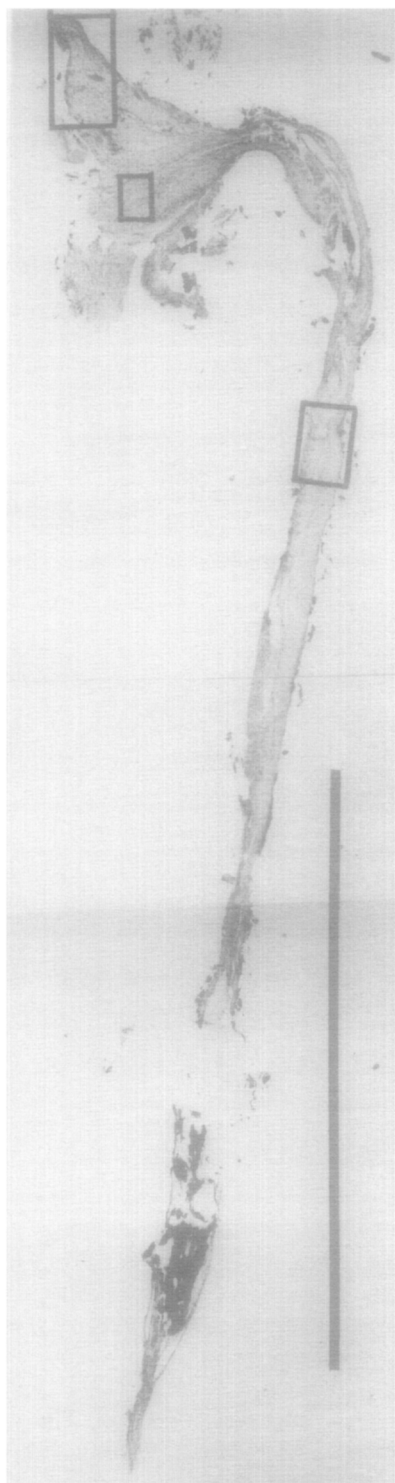


Fig. 4. Composite photomicrograph of entire section of pulp indicating the areas from which the following higher magnifications are taken.
(Hematoxylin and eosin stain. Bar represents 5 mm.)

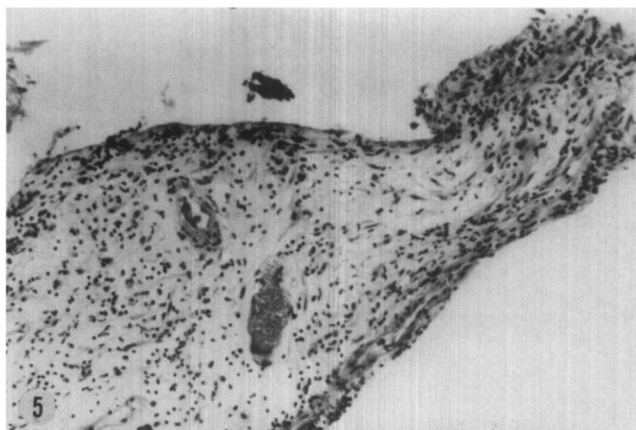


Fig. 5. Granulation tissue in pulp chamber. (Magnification, $\times 100$.)

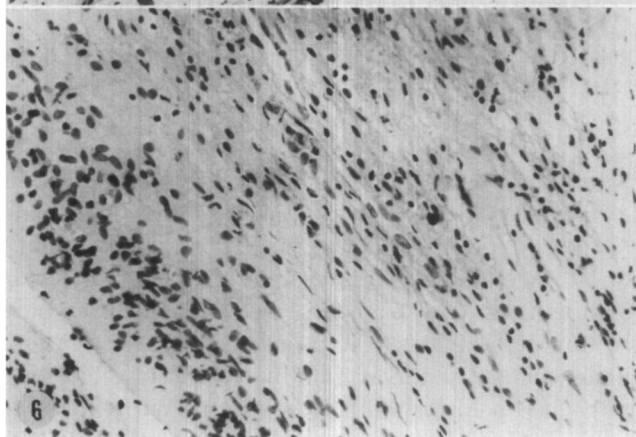


Fig. 6. Note parallel orientation of structural elements and prominence of endothelial cells. (Magnification, $\times 250$.)

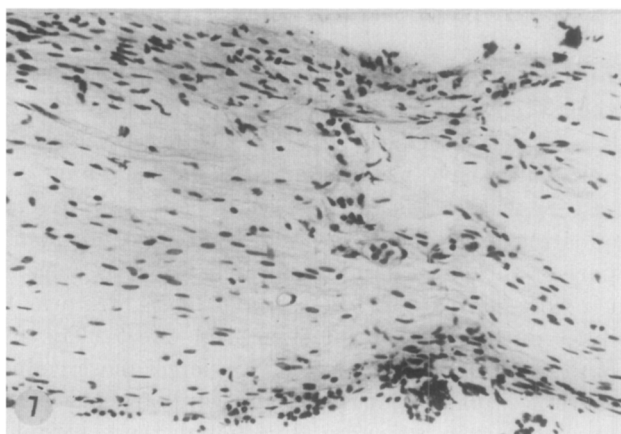


Fig. 7. Neutrophilic leukocytes present within blood vessels only. (Magnification, $\times 160$.)

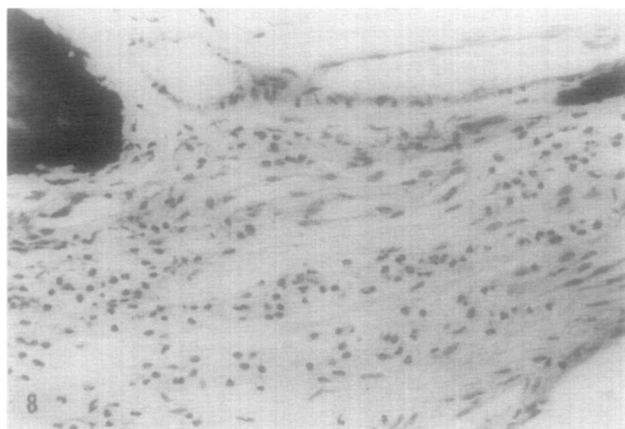


Fig. 8. Acute inflammation in pulp extirpated 2 weeks after root resection. Previous condition of pulp unknown. This section is from the Department's collection and not from the present investigation. (Hematoxylin and eosin stain. Magnification, $\times 160$.)

DISCUSSION

Before the beginning of this study, we believed that the pulp could be studied reliably only if it were sectioned together with the root. An investigation had been started in which the resected root was left in situ to be extracted for histologic study of its pulp at various postoperative intervals.¹⁷ The incidental removal of entire radicular pulps from vital teeth that were treated in preparation for pre-planned root resection prompted us to start our present investigation. An improvement upon the older method is the availability of the resected root to serve as a control showing the preoperative state of the pulp. We realized from the start that this is not an ideal control because the resected root is usually the most severely involved one from the periodontal point of view. If we accept the claim that advanced periodontal disease affects the pulp,¹⁸ this root should also contain the most affected pulp. In our study, however, none of the pulps of the resected roots showed any changes of an inflammatory nature. Therefore, all inflammatory changes in the extirpated pulps could be attributed to the experimental procedure.

The pattern of pulp reactions can be reconstructed primarily with the help of the biopsies in which the radicular pulp was removed in toto—a string that sometimes reached 10 to 12 mm. in length (Fig. 4). The process can best be described as a state of chronic ulcerative pulpitis, starting at the wound area and slowly progressing toward the root canals. When a polyp is present, it consists of granulation tissue originating from the pulp and coated with fibrinous exudate. The granulomatous part of the pulp at the root canal orifice is more fibrous and all the elements, such as engorged blood vessels and fibers, are oriented in parallel bundles, probably a purely mechanical structural effect (Fig. 6). The deeper layer, although still resembling pulpal tissue, is much more cellular because of the presence of chronic inflammatory cells and capillary proliferation. Finally, the apical portion of the pulp is unaltered, although the neutrophilic leukocytes passing in the blood vessels toward the coronal area are sometimes fixed in situ.

Perivascular tissue and nerve bundles represent all that has been spared from the dystrophic calcifications in some of the cases.

One of the pulps in the series was extirpated one month after the operation because the patient could not come in time and the tooth had remained asymptomatic. The finding that all the tissue was granulomatous confirms the trend of progressive transformation of the entire pulp into granulomatous tissue. In due time, chronic pulpitis leads to necrosis of the pulp and periapical involvement.¹⁹ Whether these changes are preceded by a stage of acute pulpitis is not known. Since practically all pulps were removed at the same time interval, it is possible to assume that there may have been a transitory stage of acute pulpitis, at least a partial one near the wound, shortly after resection of the root. However, histologically diagnosed acute pulpitis is not synonymous with the clinical term of acute pulpitis, that is, painful pulpitis.²⁰ Therefore, such an event may have passed unnoticed by the patient. Furthermore, there is no need to assume that chronic inflammation must be preceded by an acute stage.¹⁹ Pulps extirpated from teeth after root resection are now routinely collected for histologic examination. Since the whole series of tests and controls has not been run on them, they are not included in the study but they furnish additional material that expands and supplements our observations. Most biopsies seem to fall within the same pattern, but occasional pulps show different findings. In one of the cases in which the postoperative interval was just 2 weeks and the patient felt no spontaneous pain, the pulp was completely infiltrated with neutrophilic leukocytes (Fig. 8). Examination of the extracted roots showed that in the included sample the resection itself was quite atraumatic.¹⁵ It is possible, however, that the initial trauma of the operation may be severe and influence the reaction of the pulp, thus accounting for the variance of results. Comparison of our findings with those of animal studies is interesting. Exposure of the pulps of rats^{12, 14} and of monkeys¹³ resulted in acute inflammatory infiltrate in all stages, and pulp polyps were not present.

Fibrosis and calcifications were not considered reliable elements for evaluation of the results under the present set of conditions. The degree of fibrosis varies with the anatomic level of the pulp, increasing apically. One could not assess whether the fibers present were normal for the specimen, considering the anatomic level and the patient's age, or abnormal, affected by the experiment. Calcifications, likewise, are said to be present in up to 90 per cent of the pulps.¹⁹ No signs of newly calcifying foci were observed in the pulps, but it seems unlikely that significant calcification may have occurred in 2 weeks as a result of the experimental procedure.

Capping of the pulp after vital root resection raises several questions. The fact that we are dealing with a previously intact pulp and the lack of caries at the exposure site seem to increase the chances of success of the procedure. On the other hand, however, the pulp may be suffering from degenerative changes as a result of the periodontal condition, and the retention and seal of the filling placed over the capping material may be less adequate than in a normal deep cavity. In addition, an interesting academic point seems to have been overlooked until now: The procedure may be defined as "retrograde" or reverse pulp capping. In pulp

capping and in pulpotomy, the wound and, therefore, the area of healing lies distal to its main blood supply. During root resection, on the contrary, the main blood supply to the base of the root is cut off and only the collateral circulation from vessels of the other roots (through the pulp chamber) remains available. The importance of a good blood supply for the success of pulp capping has frequently been stressed; indeed, many authors recommend this procedure only for teeth with wide-open apices for precisely this reason.¹⁻³ Therefore, capping of the pulpal wound at the base of the root transgresses all the rules: mature apex, possibly atrophic pulp, and main route of blood supply cut off! However, if an area of tissue necrosis is necessary for the initial formation of a calcified barrier in the injured pulp,²¹ the conditions of limited blood supply that prevail in retrograde pulp capping may be ideal. The answers to these questions will not be found by inference from analogous situations but only from investigations carried out in the proper context.

Our investigation was not designed to offer any alternative clinical solution to the problem of the pulp exposed by vital root resection. It only proved the possibility of safely postponing the definitive endodontic treatment for 2 weeks, and it indicated that the pulpal changes occurring within this period are quite mild.

CONCLUSIONS

The healthy vital pulpal tissue is quite resistant to infection through the exposure site at the base of the root. The inflammatory changes present in the pulp 2 weeks after root resection caused no spontaneous pain and were of a chronic nature.

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