The Histopathogenesis of Vertical Root Fractures

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Fractured roots were examined histologically, using different stains, to study the morphological fracture patterns and to identify potential irritants. Fractures were usually, but not always, complete and extended from a surface to include the root canal. The potential irritants identified in both the fracture space and communicating canal were bacteria, necrotic tissue, food debris, and unidentifiable amorphous substances. Soft tissues on the root surface adjacent to the fracture were inflamed with occasional ingrowth into the fracture space. The nature of the fractures and irritants demonstrated why vertical root fractures often cause marked tissue destruction.

A vertical root fracture is a devastating occurrence. Once diagnosed, the fractured root or tooth usually has an unfavorable prognosis (1-3) and requires removal.

The published information on vertical root fractures is a series of case reports (4-6) and a clinical study (7). Meister et al. (7) described the signs, symptoms, and radiographic findings present in a series of clinical cases. Although there were reported variations in diagnostic findings, they concluded that the problem was usually severe because of significant damage to the periodontium. The outcome of the majority of the cases was extraction of the affected tooth or removal of the fractured root in molars.

The clinician and investigator alike are impressed with the profound effect that the vertical root fracture has on the periodontium adjacent to the tooth. Bone loss is often rapid and soft tissues may manifest swelling or suppuration. Probing usually reveals a deep periodontal defect (4, 7-9).

Several causes of vertical root fractures have been proposed; such as wedging of endodontic posts (6), expansion of posts or pins from corrosion (10, 11), or excessive force during lateral condensation (7). However, the precise etiology or etiologies of the accompanying tissue destruction have not been clarified. There are no published reports pertaining to histological or bacterial findings which might clarify the source and location of the irritants which lead to the associated pathogenesis.

OBJECTIVES

The purpose of this study was to histologically examine roots and adherent tissues that were removed after the diagnosis of vertical fracture. Specifically, the specimens were studied to ascertain the pattern of the fractures and the nature and location of potential irritants. The resultant findings might then be used to explain the marked tissue response that occurs adjacent to the fracture line.

MATERIALS AND METHODS

The specimens utilized in the study were fractured roots obtained following the diagnosis and determination that their prognosis was hopeless because of significant tissue damage. A total of 36 roots were available for subsequent sectioning, staining, and microscopic analysis.

Immediately upon extraction, the roots or teeth were immersed in 10% neutral buffered formalin. The specimens were then decalcified in 10% formic acid and infiltrated and embedded in paraffin. Step serial sections were cut with the blocks oriented two ways. The majority of the roots were cut in cross-section at the cervical, middle, and apical thirds while the remaining roots were oriented so that longitudinal sections could be cut in order to study the fracture from the cervix to the apex.

From each area, adjacent sections were subjected to three different types of stains: (a) hematoxylin and eosin, to study general soft and hard tissue morphology and changes; (b) bacterial stains (Brown and Brenn or McCallum’s), to identify bacteria; and (c) Wilder’s reticulum, to characterize granulation (reparative) tissue.

All sections were examined, and photomicrographs were made with a Zeiss Il photomicroscope. The specimens were examined for the following: extent and location of fracture lines; location, concentration, and nature of bacteria in canals, fracture spaces, and adjacent periodontal tissues; nature of the contents of the canal adjacent to the fracture; evidence of and identification of foreign debris in the fracture space; and presence of obturating materials in the fracture space and adjacent periodontal tissues.
For this report, no attempt was made to correlate the associated clinical and radiographic findings with the histopathology.

RESULTS

All of the specimens demonstrated marked changes in both the hard and soft tissues. Furthermore, most histological sections demonstrated irritants in the fracture spaces, which could potentially have contributed to the inflammatory response observed clinically and histologically in the adjacent periodontium.

Fracture Characteristics

The fractures were readily visible on all sections. The majority (90%) of the fractures observed in the roots cut in cross-section were complete; meaning that the fracture passed completely through the root to include opposite surfaces (Fig. 1). The remaining 10% of the fractures were incomplete; the fracture extended only to one surface of the root (Fig. 2). Of the longitudinally sectioned roots, the majority showed complete fractures that extended from the cervix to the apex. When the fracture was confined to the root or appeared to have initiated apically, the fracture was in a facial-lingual direction. In contrast, the fracture was mesial-distal when molar and premolar teeth had crown-root fractures which appeared to have initiated from the crown.

Regardless of whether the fractures were complete or incomplete, all extended into the root canal. When the root contained two canals, the fracture included both canals (Fig. 1). In addition to the major fracture (or primary fracture) lines that extended from the surface of the root to the canal, there frequently were secondary fractures. These did not extend to the root surface but emanated from the canal or primary fracture to form a blind-ending within the dentin.

Bacterial Characteristics

A frequent finding in the fracture spaces was bacteria (Figs. 3 and 4). Brown and Brenn, and McCallum stained sections showed both gram-positive and gram-negative bacteria, with a predominance of gram-positive, within the canals of 32 of the 36 specimens studied. Frequently, the bacteria were seen in defects, secondary fractures, or dentinal tubules that communicated with the fracture (Figs. 5 and 6). Generally, the bacteria were in low concentrations. However, there were occasionally dense accumulations of bacteria in a pattern resembling plaque.

Canal Contents

Frequently, necrotic tissue, bacteria, and amorphous debris were observed in the canal space adjacent to the communicating fracture line or lines (Fig. 7). Occasionally, these would be seen to extend into the primary and secondary fracture spaces.
Fracture Contents

Foreign materials of various types were frequently observed in the fracture spaces. In two specimens, which showed fractures extending into the crown, the spaces were filled with food debris mixed with bacteria (Figs. 8 and 9). Gutta-percha and sealer (as identified by polarized light) often appeared in the primary and secondary fracture spaces and in communicating tubules (Figs. 10 and 11). Occasionally, an unidentified amorphous material was found in the fracture spaces.

Tissue Reaction

In many specimens, tissue was adherent to the root surface adjacent to the fracture (Fig. 12). Examination...
of the hematoxylin and eosin sections showed that, invariably, this soft tissue was inflamed. Principally, the inflammation was chronic and this granulomatous tissue was often seen extending into the fracture space.

Wilder's reticulum stain, specific for reticulum fibers, showed areas of granulation (reparative) tissue in the fracture space. This ingrowth would occasionally extend through the fracture into the canal or canals.

Scattered areas of resorption were often visible along the fracture line. Many of these areas showed reversal lines overlayed by cementum-like tissue which apparently formed after the resorption (Fig. 1). The reticulum stain also showed fibers inserted into this cementum-like tissue that had formed on the raw dentin surface within the fracture (Fig. 13).

**DISCUSSION**

This study identified several probable and potential irritants at the fracture site. However, the precise etiol-
logical agent or agents that cause the periodontal inflammation was not definitely determined. The agents which were associated with the fracture and which, in other studies, have demonstrated irritating properties were bacteria and their metabolites (12, 13), necrotic pulpal tissue (14), sealer components (15, 16), and food debris forced into the fracture during mastication. Another possibly significant irritant is the disintegration products of percolating tissue fluids (17).

The number of bacteria in the fracture were small, but this may not represent the true picture. Histological stains are nonspecific and are not quantitative. Generally, numbers of bacteria are many times greater than those shown by the actual staining.

There are several potential sources for the bacteria seen in the fracture. One is anachoresis. However, this is unlikely, as bacteria could not be introduced into empty pulp spaces (18), or even into pulp canals con-
taining necrotic tissue (13). Another source may be
directly from the oral cavity when the fracture com-
municates with the gingival sulcus. The most interesting
Possibility is from the canal space itself. Often bacteria
are not totally removed during canal preparation (19,
20). Following obturation, some of these microorga-
nisms may survive in an inactive state. However, with
a subsequent fracture, substrates may enter the pulp
canal, allowing the microorganisms to proliferate and
to produce virulence factors. It is readily accepted that
bacteria are an important etiological factor for periapical
inflammation (21). The same principle should apply to
the fracture, with the exception that a greater area of
exposure is provided by the fracture.
Significantly, these bacteria were never observed in
vital tissue. This demonstrated either their low patho-
genicity or high host resistance.
It was significant that necrotic debris was frequently
found in the canal space adjacent to the fracture. It could not be ascertained whether this debris was originally in the canal, or had seeped in via the fracture from the oral cavity or surrounding periodontium. It is likely, however, that this necrotic tissue represented remnants which are frequently found in the canal system after debridement (22-25). Normally, this debris would be sealed in the canal and inaccessible to the periodontal tissues. A fracture, however, would provide easy access to the periodontium.

Sealers are subject to the same principles. Their irritating components are largely confined to the canal space after obturation. A fracture line would provide extensive contact between the sealer and the periodontium, resulting in a source of continual irritation.

Food debris, saliva, and their myriad components may certainly be important irritants. These substances from the oral cavity may also supply the substrates for plaque formation when forced by mastication into a communicating fracture. This may result in the periodontal breakdown and the deep probing defects usually associated with vertical root fractures (7).
Percolation and breakdown of tissue fluids within the fracture may be an important irritant. Although the "hollow tube theory" (17) is disputed (26, 27), the fracture represents a considerable area of exposure to the canal space for substances to enter, deteriorate, and then exit as irritants. Again, the critical factor is that the tissue area exposed to a vertical fracture is much larger than that afforded by an apical foramen.

The fracture patterns and their contents gave an indication of the time of the occurrence of the fracture. If sealer was not present in the fracture space in the histological section, the fracture may have occurred at some time following obturation or post placement. The possibility of a delayed fracture is plausible. Meister et al. (7) presumed that many of the root fractures occurred at varying periods of time after obturation or post placement. Stresses created in the root at the time of treatment may manifest themselves as strains (fractures) at a later date.

The presence of sealer in the fracture space, however, would not guarantee that the fracture occurred at the time of obturation. Being that substances do migrate (28), it is possible that sealer moved into the space after the actual fracture. Another consideration is that the sealer present in the fracture site is an artifact resulting from its solubilization during histological processing. However, when sealer was found in the tubules communicating with the fracture (Figs. 10 and 11) or in the small secondary fractures, it could be assumed that this was the result of condensation forces.

The incomplete fracture is interesting both from a morphological and from a diagnostic standpoint. This phenomenon demonstrates that the dentin has suffi-
cient elasticity to permit separation of root segments without a through-and-through, or complete, fracture. This could present difficulties in visualizing the fracture clinically. If the fracture is only on the lingual and does not extend to the facial, it could not be observed during a surgical procedure if only a facial flap is reflected. This obviously would complicate the diagnosis of a vertical root fracture.

The inflammation present in the adjacent periodontium was not surprising considering the variety of potential irritants already discussed. What was surprising was how far the inflamed tissue extended into the fracture site from the root surface. In some specimens, tissue filled the entire fracture space. Why this tissue demonstrated considerably less inflammation than that on the adjoining root surface cannot be explained.

Also significant was the capability of this tissue to supply cells to form hard tissue on the walls of the fracture. However, in no section was there an attempt to “bridge” or heal the fracture as may occur in horizontal root fractures (29). This hard tissue formation presumably was only a reactive phenomenon which is induced when connective tissues contact dentin.

SUMMARY AND CONCLUSIONS

Extracted roots with vertical root fractures were examined histologically. Hematoxylin and eosin, bacterial stains, and reticulum Stain were used to study morphological patterns of the fracture, the status of associated soft tissues, and to identify potential irritants. The sample included 36 roots. The following observations and conclusions were made:

1. The majority of fractures were complete in that they extended from a peripheral surface to the opposite surface and included at least a canal or canals. A few specimens showed incomplete fractures.

2. Bacteria were demonstrated in most fracture spaces, occasionally in communicating canals, and often in secondary fractures and/or tubules.

3. Canals that were continuous with the fractures often contained potential irritants such as food debris, sealer, necrotic tissue, bacteria, and undentifiable amorphous substances.

4. Soft tissue on the root surface adjacent to the fracture always demonstrated inflammation. Tissue ingrowth was frequently observed in the fracture space and would often be seen along its entire length. Exposed dentin in the fracture spaces was occasionally overlayed by cementum-like hard tissue.

The fracture line appears to form an open pathway for irritants from the oral cavity and from the canal space to adjacent tissues. Because the fracture is extensive, the irritants have easy and extensive access to the reactive periodontium.

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References