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Relationship of Radiologic and Histologic Signs of Inflammation in Human Root-filled Teeth

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The aim of this study was to determine the relationship between histologic and radiologic signs of inflammation in human root-filled teeth. In addition, other factors with possible importance for apical inflammation were assessed. Fifty-three block sections of root-filled teeth were gathered from human cadavers. The blocks were radiographically exposed, sectioned, and stained with hematoxylin and eosin. Histologic sections were categorized as inflamed or uninflamed. Radiographically, the roots were assigned as apical lucency, widened periodontal ligament (PDL), or no lucency. Presence and contents of accessory canals were recorded (empty, tissue, or filling material). Statistical analysis was performed with the Chi-square test. All roots had accessory canals; 12 showed tissue remnants, and the others were empty. Of the cases, 49% were histologically uninflamed at the apex, and 52% appeared radiographically intact. The odds ratio of finding a histologically inflamed apex with radiologic lucency versus a radiographically intact apex was 9.2 ($p = 0.002$). The odds ratio of finding a histologically uninflamed apex with a radiologically tight coronal seal versus an unacceptable seal was 3.7 ($p = 0.053$).

It may be concluded that there are relationships between radiologic and histologic signs of inflammation in human root canal-treated teeth. There appears to be a tendency that the radiologically determined quality of the coronal seal has an impact on the histologic state of the root-filled tooth. No relationship was detected between unfilled lateral or accessory canals and the status of inflammation at the periapex (51% inflamed, 49% uninflamed).

The presence or absence of apical inflammation in endodontically treated teeth in humans is evaluated by clinical symptoms and the radiologic status of the periapical area. However, root-filled teeth often appear clinically without symptoms, and apical pathology may be detected solely by radiographic evaluation. Radiographic evaluation has its own limitations. Bender and Seltzer (1) showed that even considerable loss of the spongious bone may be radiographically invisible, depending on the density or thickness of the overlying compact bone.

Brynolf (2) has shown that only 6% of root filled teeth could be considered histologically healthy. This finding was confirmed in a study by Seltzer (3). However, several animal studies showed histologically much higher percentages of apical healing in endodontically treated teeth (4–6).

It has been speculated that the presence of lateral or accessory canals that are not properly filled may have a negative impact on the outcome of root-filled teeth. However, this hypothesis could never be confirmed for ethical reasons.

The aim of this study was to determine relationships between histologic and radiographic signs of inflammation in humans using material from human bodies. A secondary intention was to record the presence and status of accessory canals in relation to apical health status. Other factors with potential impact on the apical status of root filled teeth were also evaluated.

MATERIAL AND METHODS

In the Department of Anatomy, Free University Berlin, Berlin, Germany, the oral cavities of human cadavers were searched for the presence of teeth. The bodies had been stored in formalin for undefined periods of time. Dentulous jaws were removed and radiographically exposed to obtain an overview. In this manner, 65 obturated roots could be detected in 26 cadavers. Before the endodontically treated teeth were removed as block sections, they were exposed in orobuccal direction for 0.16 s at 70 kV, placing the radiographic tube at a distance of 100 mm to the object. For exposure, 3 cm × 4 cm D-Speed film (Kodak, Rochester, NY) was used. Films were developed uniformly in an automated developing machine (XR 24; Dürr Dental, Bietigheim, Germany). The crowns of the root-filled teeth were then removed and the roots block sectioned with the surrounding periapical tissues. The blocks were embedded in paraffin and longitudinally sectioned, resulting in 6-μm to 10-μm sections. Every 10th section was stained with hematoxylin and eosin.

Every root tip was histologically evaluated by one operator. Periapical tissues were categorized as either inflamed if leukocytic cellular infiltrate was present (Fig. 1a) or uninflamed in case of the

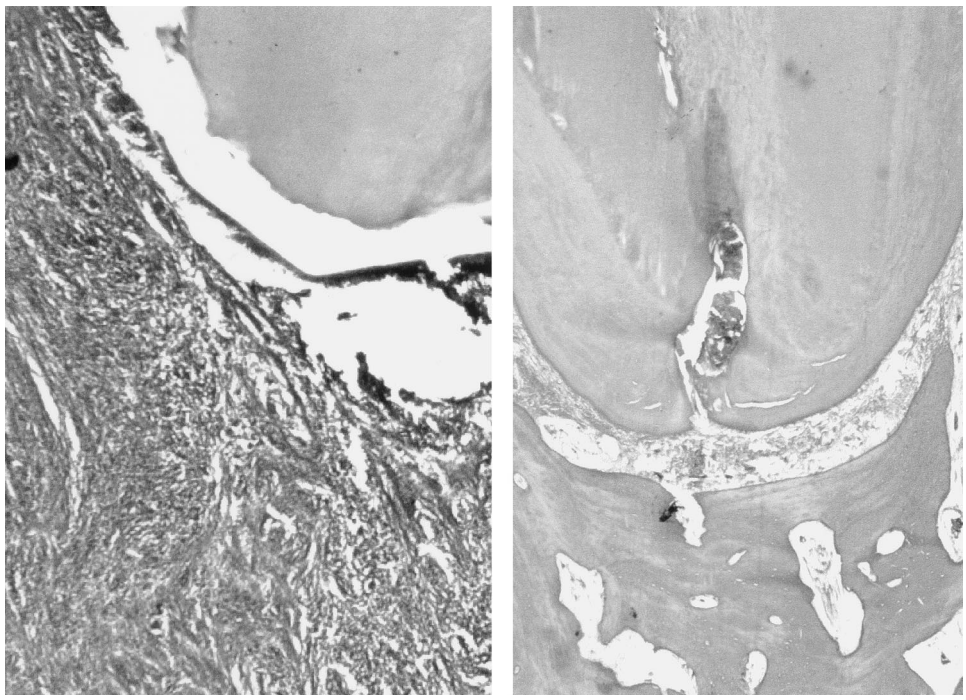

FIG 1. Histologic evaluation: one example for each category. (a) Inflamed, (b) uninflamed.

FIG 2.Radiographic evaluation: one example for each category. (a) Apical lucency, (b) widened PDL, (c) no lucency.

absence of cellular infiltrate (Fig. 1b). In addition, the presence (yes or no) and contents (empty, with tissue, or with filling material) of accessory or lateral canals were recorded for every root.

Radiologic evaluation was performed by two experienced operators. For evaluation, the radiographs were mounted as slides. Every slide was evaluated in a darkened room using a projector. In case of disagreement, the interpretation of the radiograph was discussed until agreement was obtained. The radiographic evaluation was performed blinded from the histologic evaluation. The roots were divided into groups as apical lucency present (Fig. 2a), widened PDL (Fig. 2b), or no apical lucency present (Fig. 2c). Further, the presence or absence of a coronal filling or crown, the presence or absence of posts, the radiographic appearance of the coronal seal (coronal seal intact or not intact), and the quality of the root filling (adequate or inadequate) were recorded. Statistical analysis was performed with the Chi-square test, and the odds ratios were calculated. The level of significance was set at $p < 0.05$.

TABLE 1. No. of inflamed and uninflamed samples split by radiologic parameters

Correlation radiography/histology								
Lucency			Widened PDL			No Lucency		
16	3	**13**	9	4	5	28	19	9
crowns			fillings			No seal		
37	19	**18**	9	5	4	7	1	5

Posts			No posts		
17	6	11	36	20	16
Coronal seal intact			Not intact		
20	13	7	32	12	20
Root filling adequate			Inadequate		
25	15	10	28	11	17

Correlation histology/lateral canals		
Presence of lateral canals		
53	26	27
With tissue		empty
12	7	12	41	19	22

	= Number of cases
	= uninflamed
	= inflamed

RESULTS

Sixty-five roots had been collected from human bodies; however, in some roots, the tip was cut off during block sectioning, and some roots, especially of multirooted teeth, could not be reassigned to the radiographs. Thus, a total of only 53 roots could be evaluated both radiographically and histologically (Table 1). Histologically, 51% of the periapical tissues were categorized as inflamed and 49% as uninflamed. All samples had one or more lateral canals. Endodontic filling material was not present in any of the accessory canals. Of accessory canals, 23% showed tissue remnants, and 77% were empty (Table 1). No relationship was detected between

FIG 3. Lateral canal with tissue remnants in the apical region of the root. The adjacent PDL does not show any inflammatory signs.

unfilled lateral or accessory canals and the status of inflammation at the periapex (Fig. 3). Radiographically, 30% of the roots showed an apical lucency, 17% showed a widened PDL, and 53% appeared with intact periapical structures. Of the teeth, 70% had crowns, 17% had fillings, and the rest were coronally unsealed. Of the roots, 32% contained posts. Regarding the quality of the coronal fillings, only 38% could be labeled as intact. Adequate root fillings were seen in only 47% of the cases (i.e. length within 1–2 mm from the apex and homogenous appearance of filling).

The odds ratio of finding a histologically inflamed root tip with radiologic lucency versus a radiographically intact apex was 9.2 with a significance of $p = 0.002$. The odds ratio of finding a histologically uninflamed apex with a radiographically tight coronal seal versus an inadequate seal (i.e. marginal gap, caries, or no restoration) was 3.7 at $p = 0.053$.

The positive predictive value was 0.81, whereas the negative predictive value was 0.67. This means that if an apical lucency was detected, it was inflamed in 81% of the cases, and if an intact PDL was radiographically diagnosed, only 67% of the cases were histologically uninflamed. For these calculations, the nine samples with a widened PDL were not included, because it could not be decided whether to assign them to the lucency group or the no lucency group.

No correlation could be detected between the coronal type of seal (crown, filling, or none) and the histologic status of the periapex. Similarly, there was no clear relationship between radiographically adequate root fillings and histologically uninflamed tissues.

DISCUSSION

The histologic outcome of root canal fillings in patients cannot be assessed for ethical reasons. Only when failure is diagnosed and followed by endodontic surgery may it be possible to remove parts of the root and surrounding tissues (3). The use of human cadavers for investigation of successful and failed endodontic treatment seems an ethically acceptable alternative. However, a disadvantage of this model is the diversity of study material. It is not known how long the examined root canal fillings have been incorporated or which filling technique or filling materials have been administered. In the present study, it was also impossible to obtain further data about the bodies, i.e. cause of death or age. In her study, Brynolf (2) examined tissues from people who had died shortly before performing her investigation, so the histologic material was unfixed and in a good cellular state. In the present study, the bodies had been fixed in formalin and stored for unknown periods until they were used for educational anatomical work.

Histologic evaluation finally could be performed with the gathered tissues; however, it was possible only to categorize the apical tissues as inflamed versus uninflamed. A more detailed classification such as that performed in several other studies (2, 4, 6) could not be obtained.

Rowe and Binnie (6) determined histologic and radiologic signs of inflammation in beagles. From their cross-tables, with the cases with widened PDL omitted as in the present study, their results showed a positive predictive value of 1 and a negative predictive value of 0.55. This means that whenever they detected an apical lucency radiologically, it always corresponded with a mild or severe inflammation histologically. As in the present study, when they observed a radiologically intact PDL, it was uninflamed histologically in only 55%. When the corresponding data were extracted from the complex study by Brynolf (7), a positive predictive value of 61% and a negative predictive value of 53% were obtained. However, these values of diagnosis were significantly improved when as many as three radiographs were taken at different angles. In the present study, only one radiograph was taken and evaluated.

From 53 evaluated roots, 16 showed an apical lucency, nine showed a widened PDL, and 28 roots were radiologically intact. If the widened PDL group is assigned to the pathologic group, 47% of the teeth had an apical lucency; this percentage is less than that observed in two representative studies performed in two different areas in Germany (8, 9). Weiger et al. (8) and Hülsmann et al. (9) detected in their cross-sectional studies a 60% incidence of apical lucencies associated with endodontically treated teeth. In Scandinavian studies, these numbers ranged between 20% and 34% (10). However, the intention and the number of cases in these cross-sectional studies differed from those of the present study.

We found a strong tendency that teeth with radiologically insufficient coronal restorations or no coronal restorations had a histologically inflamed periapex ($p = 0.053$). It is conceivable that with more cases, a significant difference would have arisen. The quality of the root filling had no correlation to the histologic status of the periapex. This finding supports the findings of Ray and Trope (11), who found in a retrospective radiographic study that the quality of the coronal restoration was more important than that of the root filling for periapical health. Tronstad et al. (12) and Hommez et al. (13) observed in their studies that the quality of the root filling had a stronger impact on the status of the apex than the quality of the coronal seal (12, 13).

All roots showed the presence of accessory canals that partially contained tissue remnants. No correlation between unfilled lateral

canals and the inflammatory status of the PDL could be detected in the present study. However, the study material did not contain positive controls, i.e. teeth with properly filled lateral canals, which might have changed the relation between healthy and inflamed PDL in relation to the lateral canal.

CONCLUSIONS

Fifty-three roots of human bodies were evaluated histologically and radiologically. There appears to be a clear relationship between radiologic lucency and histologic inflammation at the periapex in human root canal-treated teeth. However, in more than 30% of cases with histologic signs of inflammation, no radiolucency was detected. There seems to be a tendency that root canal-treated teeth that are not properly restored coronally as seen on the radiograph will appear inflamed histologically. No relationship was detected between unfilled lateral or accessory canals and the status of inflammation at the periapex (51% inflamed, 49% uninflamed).

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