Validity of the radiographic assessment of ankylosis

Evaluation of long-term reactions in 10 monkey incisors

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The accuracy and sensitivity of radiographic assessments of reactive processes in dental tissues were evaluated by comparison of radiographs and histologic sections. Experimental lesions inflicted on the roots of 10 monkey incisors had been observed by means of serially obtained radiographs over a period of 315 to 370 days. The material was used for evaluation of radiographic assessment of ankylosis. For comparative purposes, assessment of the experimental lesion penetrating to the pulp and periapical radiolucency was added. True and falsely positive or negative recordings formed the basis for calculation of the accuracy and sensitivity of the radiographic assessment. The sensitivity, or the observers' ability to detect the actual changes, was high for pulp penetration, intermediate for inflammation, and low for ankylosis. □ *Animal study; histology; tooth ankylosis*

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The detection of changes in teeth and surrounding tissues under different clinical conditions is based on radiographs exclusively. Studies have demonstrated that both the radiographic method and morphologic characteristics of the tissues are important for the reliability and validity of the observations (1, 2).

Most investigations into the relationship between radiographic assessment and the corresponding morphologic alterations have been based on artificially prepared lesions in bone and teeth, to establish standards for the radiographic technique. Comparisons of radiographic and direct observation of actual biologic changes such as root resorption and ankylosis have shown considerable discrepancies between the real changes and the radiographic assessment (3–5).

As ankylosis of permanent teeth, particularly in growing individuals, is detrimental to the prognosis of the tooth, an immediate and reliable diagnosis is of significant importance. The purposes of the present study were to evaluate the validity of radiographic assessment of ankylosis and to compare the validity of this assessment with that of some other pertinent variables.

Materials and methods

The material comprised radiographs and histologic sections of 10 monkey incisors and their surrounding tissue taken 315 to 370 days after lesion had been experimentally produced on the dental tissues.

Experimental procedure and material

In 10 central incisors in 5 Cynomolgus monkeys approximately 2.5 years old lesions were inflicted on the apical one-third of the distal aspect of the root during experimental surgery. Cementum and dentin were mechanically removed from the external surface of the root for an extension of approximately 3 mm, whereas the depth of the lesions varied. In six of the teeth the defect penetrated into the pulp. At the end of the

observation period the animals were killed, and histologic sections of the experimental area were produced. Tissue reactions were characterized by the different patterns (Fig. 1A,B,C): normal pulp and periodontal membrane (four teeth); normal pulp, ankylosis between tooth and bone (three teeth); and pulp necrosis, periradicular inflammation (three teeth).

Radiographic technique

Bimonthly during the observation period and immediately before the monkeys were killed, periodic identical radiographs were obtained from the experimental area. To reproduce the position, angulation, and distance, exposures were made by using a specially constructed combined filmholder

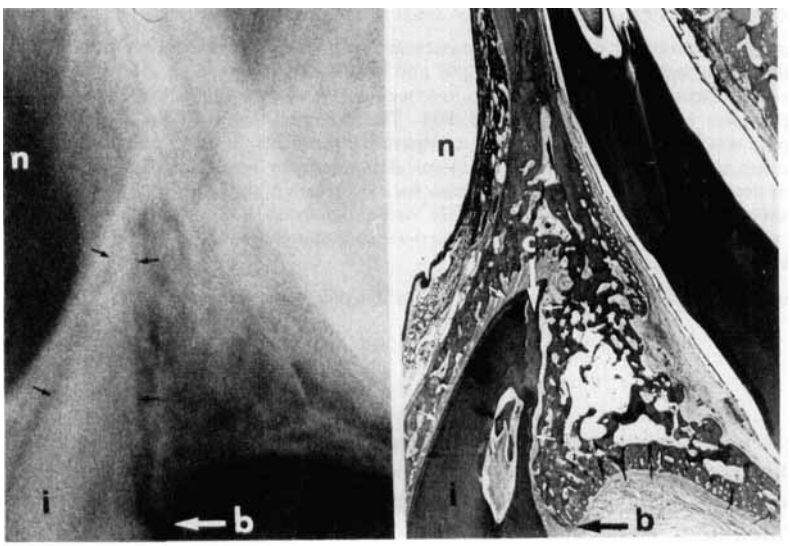

Fig. 1. Radiographic and histologic representation of the apical area of monkey incisors 315 to 370 days after experimental lesion to the root. 1A. A layer of cementum (c) has been deposited over the exposed dentinal surface, and the new alveolar bone (b) has adapted to the root contour. The periodontal membrane is of the same width on both sides of the root (small arrows). i = Incisor; n = nasal cavity.

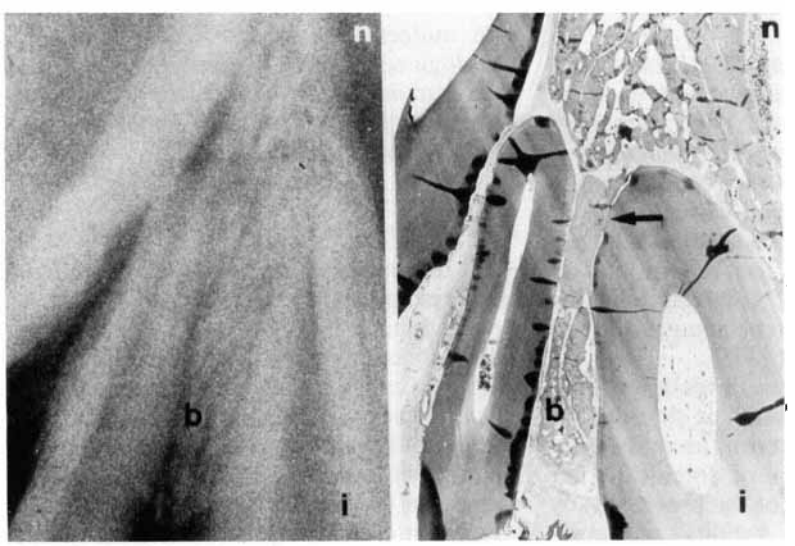

Fig. 1B. The alveolar bone (b) is continuous with the exposed root dentin at arrow (histologic section). i = Incisor; n = nasal cavity.

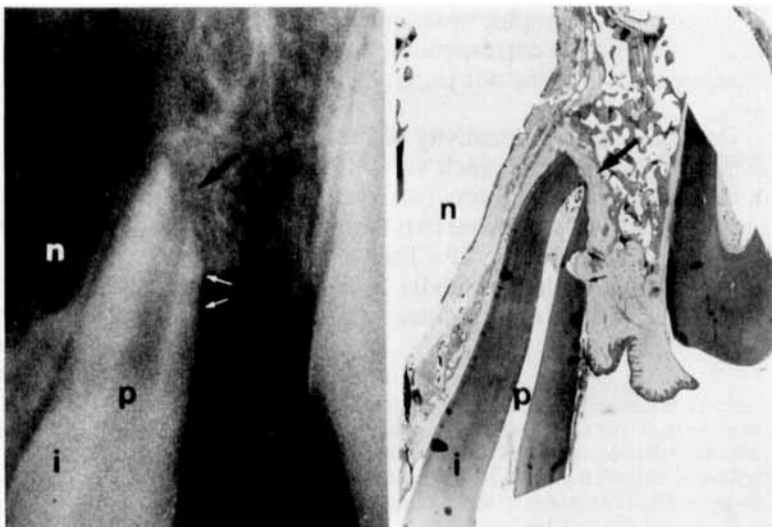

Fig. 1C. The pulp cavity (p) was exposed during surgery. Necrosis of pulp tissue and periapical inflammation were observed, and widening of the periodontal space could be seen (arrow). Multiple resorptive defects were recorded on both bone and root surfaces; a large resorption cavity into the dentin is indicated by small arrows. i = Incisor; n = nasal cavity.

and aiming device with impressions of the teeth and attachment to the X-ray tube. The horizontal angulation was orthoradial. The films (Kodak Morlite Ultraspeed DF 57) were developed under standardized conditions.

Assessment of radiographs

The last radiographs of each longitudinal series were arranged randomly, and three observers were asked to give a positive or negative rating of the following variables: penetration to the pulp of the experimental lesion, presence of periradicular radiolucency, and ankylosis between tooth and alveolar bone.

Pulp penetration and periradicular inflammation were included as variables for comparative purposes: penetration represents assessment of mechanically produced, well-defined changes in hard tissues, and inflammation was included because it is a frequent reactive process routinely diagnosed radiographically.

The radiographs were examined through an X-ray viewer with ×2 magnification. Positive or negative rating was based on agreement between examiners (23 observations) or, alternatively, on majority decision (7 observations). Previously recorded serial radiographs of the area of interest were made available if requested by the individual observer.

Histologic processing

After the monkey had been killed the premaxilla was dissected and divided in the midline. A routine histologic technique including formalin fixation, decalcification, and paraffin-embedding was applied. The experimental area was sectioned in a mesiodistal direction parallel to the tooth axis at 6 μm. Hematoxylin- and-eosin–stained sections representing the same perspective of the area as evaluated in the radiographs were thus available for examination.

Rating method

The histologic observations were established as a basis for evaluation of the validity of the radiographic assessments. When pulp penetration, inflammation, or ankylosis was present histologically and simultaneously observed radiographically, a true positive (TP) rating was recorded. A true negative (TN) rating was recorded when perforation, inflammation, or ankylosis was not observed radiographically and was not present histologically. Corresponding false ratings, falsely negative (FN) and falsely positive (FP), were recorded when negative

or positive radiographic assessments were established and the corresponding histologic changes were or were not present, respectively.

The accuracy and sensitivity of the radiographic assessment for each variable could then be calculated. The accuracy is the percentage of true observations in relation to all possible observations: TP+TN/TP+TN+FN+FP × 100. The sensitivity is the percentage of correct observations in relation to the same observations plus the number of changes present but not recorded: TP/TP+FN × 100.

Table 1. Radiographic assessment (R) and histologic observation (H) of the variables pulp penetration, periradicular inflammation, and ankylosis in 10 monkey incisors 315 to 370 days after infliction of experimental lesions on the root surface. + and − represent presence or absence of the variable

Tooth no.	Pulp penetration		Periradicular inflammation		Ankylosis	
	R	H	R	H	R	H
1	+	+	+	+	−	−
2	+	+	−	+	−	−
3	+	−	+	+	−	−
4	+	+	−	--	−	−
5	+	+	−	--	−	−
6	+	−	−	--	−	−
7	−	−	+	--	+	−
8	−	+	−	--	−	+
9	+	+	+	−	−	+
10	−	−	−	--	+	+

Results

Radiographic and histologic observations of pulp penetration, inflammation, and ankylosis are summarized in Table 1. Of the six teeth initially penetrated to the pulp, five were correctly diagnosed radiographically. However, two of the four teeth without perforations were falsely assessed as positive, and the accuracy of the radiographic evaluation (Table 2) of the pulp penetration was 70%. The sensitivity of the evaluation (Table 2), or the observer's ability to detect these penetrations, was 83%.

Two of the three teeth with inflammation were correctly diagnosed, but two teeth with no apparent periradicular processes had falsely positive ratings. Thus five of the seven teeth without inflammation were correctly diagnosed. The accuracy and sensitivity of the radiographic evaluation of inflammation were of the same order of magnitude—70% and 67%, respectively.

Only one of the three ankylosed teeth was diagnosed radiographically, but six of the seven teeth without ankylosis were correctly assessed. The accuracy of the evaluation was 70%. The sensitivity of the radiographic

Table 2. Accuracy and sensitivity (%) of the radiographic assessment of changes in dental tissues after experimental lesions had been inflicted in 10 monkey incisors. Ratings of the assessments are based on histologic observations of the same specimen, and the numbers of true and false ratings are given in the table for each variable. Ratings: TP = true positive, TN = true negative, FN = falsely negative, and FP = falsely positive

	Pulp penetration	Periradicular inflammation	Ankylosis
TP	5	2	1
TN	2	5	6
FP	2	2	1
FN	1	1	2
Accuracy: $100 \times \frac{TP+TN}{TP+TN+FP+FN}$	70	70	70
Sensitivity: $100 \times \frac{TP}{TP+FN}$	83	67	33

evaluation was 33%, however, because two of the three teeth were not recognized. One tooth was given a falsely positive rating.

Discussion

The values obtained for accuracy and sensitivity in the present study are based on a limited sample. This implies that the calculations should be regarded as indicative.

Because accuracy comprises all true observations, both positive and negative, the ability to recognize normal and deviating morphology radiographically is of equal importance for the quantification. The same level of accuracy obtained for pulp penetration, inflammation, and ankylosis in the present study mainly reflects the observers' ability to recognize normal radiographic characteristics. For symptoms and characteristics that occur infrequently, such as dental ankylosis, a high score of accuracy is of minor significance for the diagnostic value of the test.

Of greater clinical significance is the sensitivity of the radiographic assessment—that is, the ability to detect deviations from normal. The present results of high sensitivity for pulp penetration indicate the suitability of radiographs for the detection of well-defined lesions to the hard tissues. This was established in an early study of root resorption and was based on microscopic and radiographic observations (3). The experimental defects in the present study obviously exceeded the minimum size necessary for radiographic visualization (1, 2).

The sensitivity of radiographic assessment of periradicular inflammation makes radiography an important tool in diagnosing these processes. In early stages, other symptoms often accompany the process and represent additional information sufficient for a correct diagnosis.

The low sensitivity of the radiographic evaluation of ankylosis observed in the present study is in accordance with other investigations (4, 5). Supplementary tests for the verification of the diagnosis are, unfortunately, few and often unreliable. In growing individuals in particular an early diagnosis of ankylosis of permanent teeth may be of great importance. Successful handling of treatment alternatives such as transplantation and orthodontic closure of extraction spaces will often depend on correct treatment timing. On a long-term basis, ankylosed teeth often undergo extensive root resorption, and dentin is replaced with bone, a process that is readily observed radiographically at a late stage. In children, however, early diagnosis may be mandatory, and radiography will often be a method of limited value, as indicated in the present study.

An ankylosed tooth does not move when it is subject to orthodontic forces. Ankylosis will thus become apparent after a few weeks when orthodontic forces are administered. Even if this may be an inconvenient method, the low sensitivity of the radiographic assessment of ankylosis implies that attempted orthodontic movement should be considered.

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