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CLINICAL, RADIOGRAPHIC, AND HISTOLOGICAL ASPECTS OF INTRAALVEOLAR FRACTURES OF UPPER CENTRAL INCISORS

by

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In our age of increasing traffic traumatic lesions are becoming even more numerous. As this fact also applies to the teeth, the dentist is often confronted with cases of fractured teeth.

It is difficult, not to say impossible, to obtain accurate figures for the prevalence of tooth fractures. Most of the cases are small fractures of the enamel only and do not present themselves in the office. Therefore, the very few statements made in literature on the prevalence of tooth fractures must be taken with reservation. *Ellis,* 1952, reports that of 4,251 children in secondary schools, 42 per cent had fractured teeth. *Hardwick & Newman,* 1954, reporting an investigation of 1,800 children, specify the different types of tooth fractures. Root fractures constitute only 3.3 per cent of all dental fractures. In this paper only root fractures of erupted upper central incisors will be dealt with.

Most of the papers dealing with root fractures are clinical reports of one or two cases. Larger numbers of intraalveolar fractures have been published by *Austin,* 1930 (40 teeth), *Ottolenghi,* 1926—1927 (13 teeth), *Douniau,* 1950—1954 (8 teeth), and *Anderson,* 1944 (7 teeth). Reports regarding histological examinations of such cases, are infrequent. True enough, the early literature contains some reports of healed root fractures studied in ground or decalcified sections, but instances of frac-

tured roots examined with surrounding bone and in serial sections are scarce.

The purpose of the present paper is to report the clinical and radiographic findings, as well as the therapeutical results in nine teeth with intraalveolar root fractures in eight patients. Three of the teeth have been subject to histological examinations, the results of which are also given below.

CASE REPORTS

The cases will be described according to the age of the patients, beginning with the youngest. The teeth are designated according to the *Haderup* system. + signifies location of tooth in the upper jaw, — in the lower jaw. If the symbol is placed to the right of the figure, the location of the tooth in the right side of the jaw is indicated and *vice versa*.

Case 1

A 9 9/12 year old boy fell on a slide, thus traumatizing the teeth. On clinical examination the upper central incisors were slightly loose and a small 1 mm wide hematoma along the marginal gingiva was observed. The radiograph of 1+ (Fig. 1 A) disclosed a cross fracture in the middle third of the root. The fragments were somewhat displaced. The teeth from 5+ to +5 were ligated to an arch wire for a period of seven weeks. Three weeks after the trauma a termal vitality test showed normal reaction for 1+, and no reaction for +1.

The teeth were last time examined 22 months after the accident. Both central incisors were then firm; 1+ reacted normally and +1 did not respond to electrometrical vitality test[1]. The radiograph taken at the same time disclosed that the space between the fragments had become very narrow and the alveolar bone on the distal side apparently had grown into the fracture line. The pulp canal in the apical fragment was almost obliterated (Fig. 1 B).

[1] In all the cases reported in this paper the electrometrical pulpvitality test was made with the "*Nitram*" pulp testing apparatus. If nothing else is indicated, the vitality test has been made electrometrically. The author wishes to thank *Fr. Lichtenberg Crone*, D.D.S., for making the vitality tests.

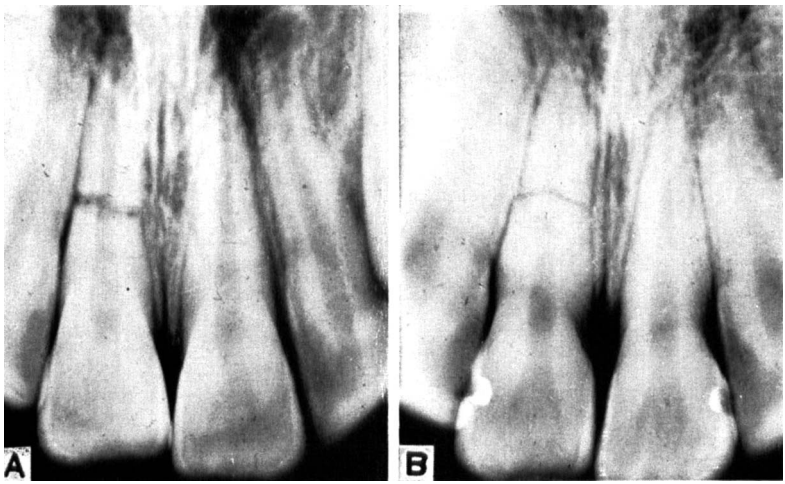

Fig. 1. Case 1: Radiographs one day after trauma (A) and 22 months later (B). Note in B rounding off of fragment surfaces.

Case 2

A 10 7/12 year old boy fell on a slippery road and suffered intraalveolar fracture of +1 and intrusion of 1+ (Fig. 2 and Fig. 3A). The left central incisor was loose and sore. Thirteen hours after the trauma repositioning of 1+ was performed under local anesthesia by means of a forceps. During this procedure the tooth slipped out of its socket into the oral cavity, but was immediately replanted. The teeth from 2+ to +2 were wired together (Fig. 3B) for a period of four months and the bite was raised for about one month. Vitality test two weeks after the trauma disclosed that the pulp of 1+ was non-vital, while +1 showed a questionable response. Root canal treatment was made of 1+. After eleven months +1 responded normally to the pulp test.

The teeth were last time examined eleven months after the accident. Both teeth were firm and appeared to be of normal color; +1 showed normal vitality of the pulp. Figs. 3C and 3D are radiographs taken at the same examination. In the apical part of the right central incisor a slight but distinct resorption was visible (Fig. 3C). The fracture of the left central incisor showed signs of healing with hard tissue formation between the

Fig. 2. Case 2: Photograph 12 hours after accident. Right central incisor is almost entirely intruded. Left central incisor has an intraalveolar fracture.

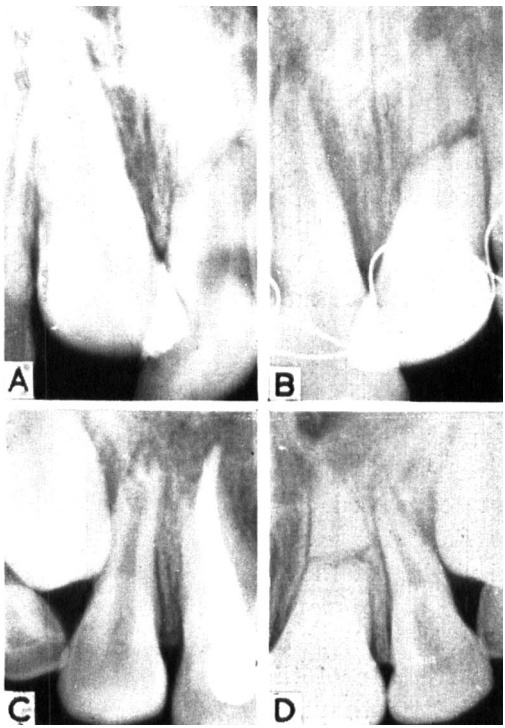

Fig. 3. Case 2: Radiographs few hours after trauma (A), ten days after trauma (B) and 11 months later (C and D). Note in C slight resorption in apical area of right central incisor, and in D ingrowth of lamina dura distally in left central incisor.

Fig. 4. Case 3: Radiographs one day after trauma (A) and five months and a half later (B). Note in B rounding off of fragment surfaces.

fragments (Fig. 3D). However, on the basis of the radiograph alone it was difficult to decide, whether the two fragments were really *united* by hard tissue, or whether the shadow in the fracture line was caused by the surrounding bone. The alveolar bone had apparently grown into the distal part of the fracture line.

Case 3

An 11 8/12 year old boy fell from a tree, thus luxating 1+ palatally. The luxation was reduced by a local dentist a few hours after the accident. The radiograph (Fig. 4A) taken the next day revealed a cross fracture in the middle of the root with some displacement of the fragments. The tooth was slightly loose and sore. Six days after the trauma a capsplint including the four upper incisors was cemented into place and kept in position for eight weeks. After removal of the capsplint the right central incisor was found to be of normal color, but slightly loose. The vitality test gave normal response. During a period of five months after the removal of the splint five vitality tests constantly showed normal reactions.

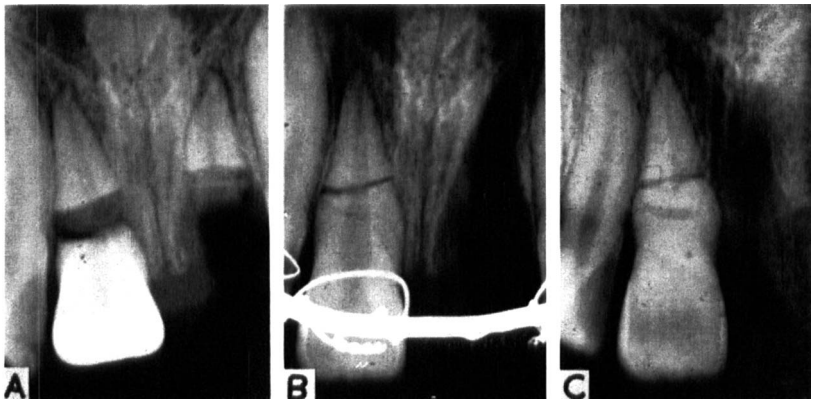

Fig. 5. Case 4: Radiographs immediately after trauma (A), two days after reposition (B), and three months later (C). Note in C healing process in fracture line and obliteration of pulp chamber and canal.

At the last examination five months and a half after the trauma, the tooth appeared to be completely normal from a clinical point of view and the vitality test gave normal values. The radiograph (Fig. 4B) showed distinct rounding off of the edges of the fracture surfaces and indications that, on the mesial surface of the root, the bone had grown in between the fragments.

Case 4

A 13 4/12 year old boy hit another boy with the result that both his central incisors in the upper jaw fractured. The coronal fragment of +1 was totally luxated, while 1+ was luxated palatally and was loose. The radiograph disclosed an intra-alveolar cross fracture of 1+ in the middle third of the root (Fig. 5A). The treatment consisted in surgical removal of the apical fragment of +1, repositioning of 1+ (Fig. 5B), and ligation of canines and incisors to an arch wire for eleven weeks. One month after the trauma 1+ did not respond to a termal vitality test, but the color was normal. One month and a half later the tooth was firm. Vitality tests performed five months after the trauma gave no response from +2. In the case of 1+ a raised pain threshold was found. Two weeks later, however, the central incisor responded normally.

At the last examination 19 months after the trauma 1+ was

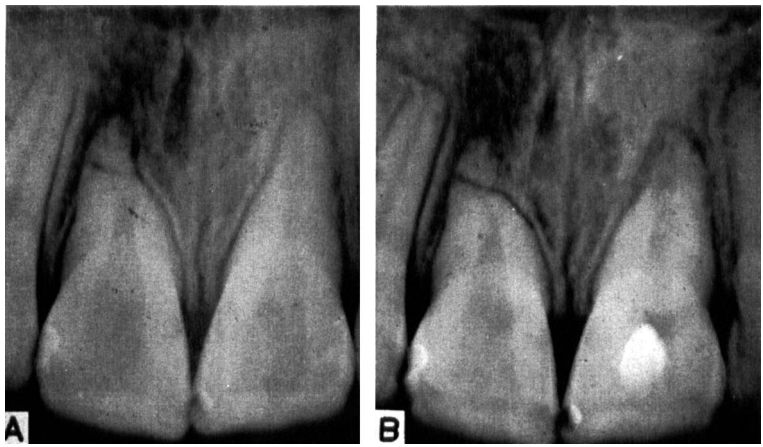

Fig. 6. Case 5: Radiographs two days after trauma (A) and three months later (B). Note in B obliteration of pulp canal in apical fragment.

firm, had a normal color and a somewhat increased pain threshold. The radiograph revealed (Fig. 5C) that the fragments were in good positions. The fracture line was narrow and apparently some hard tissue formation had taken place between the fragments. The pulp cavity in both fragments was obliterated.

Case 5

A boy, 15 5/12 year old, received a blow during a football game, causing the central incisors to become slightly loose and tender at percussion. The radiograph demonstrated a cross fracture in the apical third of the root of 1+ (Fig. 6A). The apices of both central incisors seemed to be somewhat tapered. The treatment consisted in grinding the incisal edge to relieve the occlusal stress. Nine days after the trauma +1 did not respond to vitality test, while 1+ showed normal values.

The tooth was last time examined three months after the accident. The right central incisor was firm and showed normal color and vitality of the pulp. The left central incisor was still non-vital, so root canal treatment was instituted. The radiograph from this examination (Fig. 6B) revealed a distinct fracture line in 1+, apparently with no resorption of the root. The non-vital central incisor had a radiolucent area around its apex.

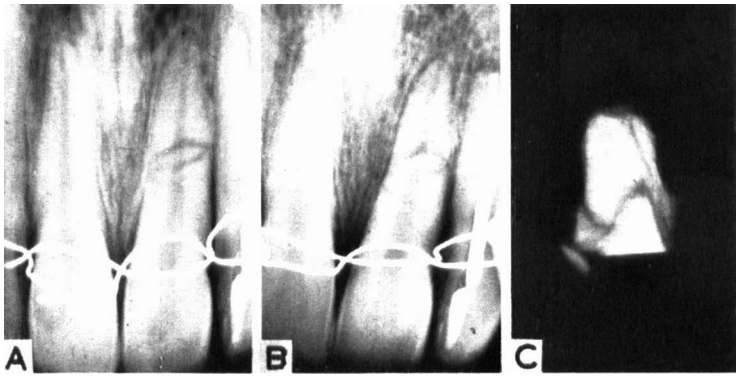

Fig. 7. Case 6: Radiographs four days after trauma (A) and three weeks later (B). Note in B resorption processes in fracture line. C is a radiograph of surgical specimen removed 38 days after trauma. Note in the lateral view the labial alveolar bone plate.

Case 6

In a fight a 20 year old man got a blow on his teeth. +2 was completely luxated and +1 partially luxated. Considerable gingival damage was recorded. The radiographic examination disclosed an intraalveolar comminuted cross fracture in the middle third of the root of +1. The treatment consisted in replantation of the lateral incisor after root canal filling and reduction of the dislocated central incisor. The teeth were immobilized by continuous wiring (Fig. 7A). One week after the trauma +1 became pinkish in color and showed very slow responses to vitality tests. A radiograph showed blurring of the fracture line and some distention of the fragments (Fig. 7B). After ten more days there was no response at all to the vitality test. The tooth was surgically removed 38 days after the trauma (Fig. 7C). During the operation it was necessary to split the root at the cervical margin.

Histological examination[1]. The tooth was cut labial-lingually in 200 sections. Fig. 8 is a low power magnification of one of the sections. Unfortunately, the splitting of the tooth during the

[1] The teeth in cases 6 and 8 were decalcified with formic acid, embedded in celloidin, sectioned in series, and stained with hematoxylin-eosin and *Van Gieson-Hansen's* connective tissue stain.

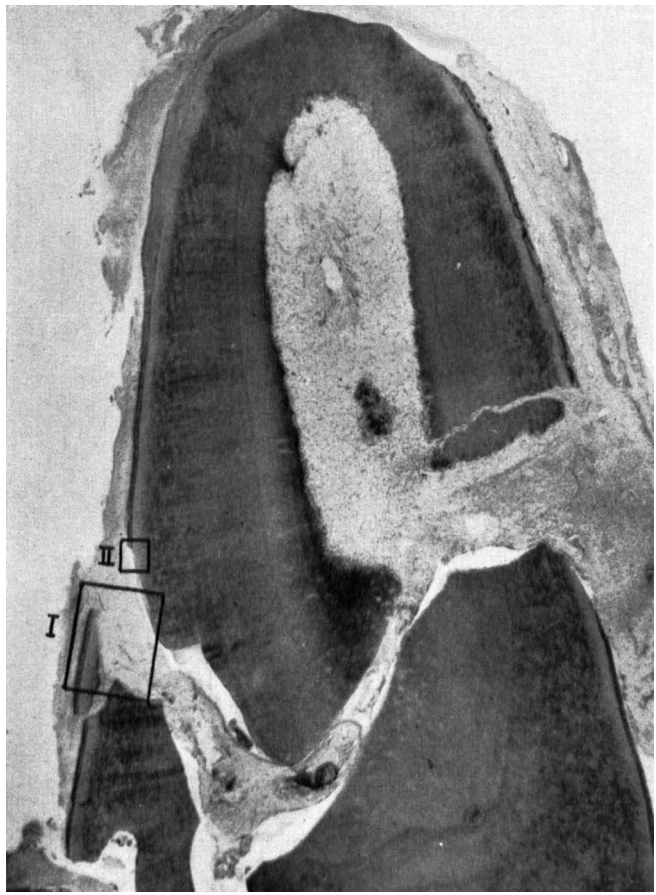

Fig. 8. Case 6: Low power magnification (× 12) of extracted incisor. The section corresponds to radiograph C in Fig. 7. Note splinters of dentin in fracture line, which make the fracture comminuted. Areas marked I and II are shown in higher magnification in Fig. 9 and Fig. 10.

operation caused some deterioration, but at the end of the fracture line, labially as well as lingually, the splintered tissues are retained in the preoperative position.

The fracture line runs from the middle of the root labially (Fig. 8 right) to the cervical third lingually (Fig. 8 left). The labial end of the fracture line is characterized by pronounced resorption processes, both in the coronal and in the apical fragments. In the fracture line, labially, a small fragment of dentin

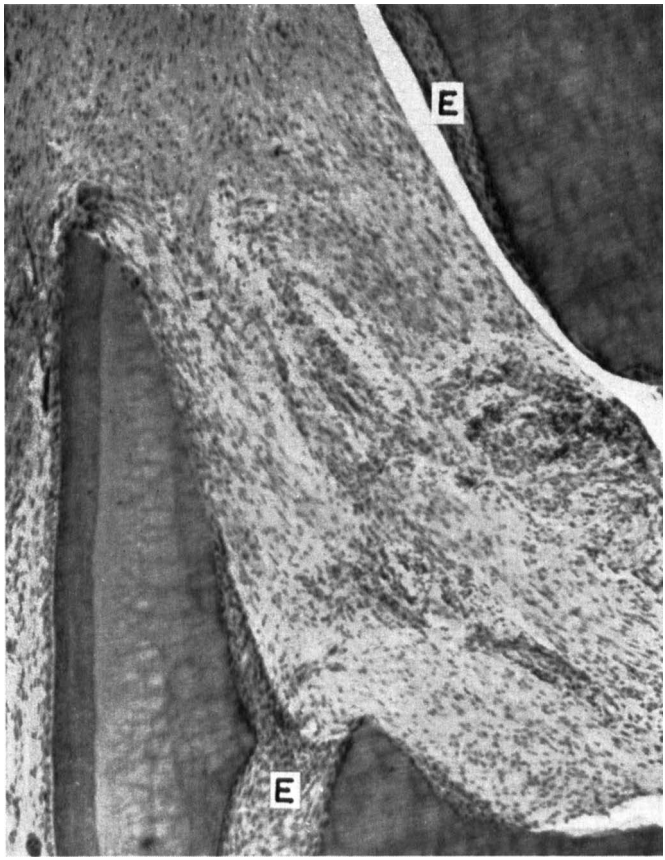

Fig. 9. Case 6: Higher magnification (× 77) of area marked I in Fig. 8. Note squamous epithelium (E) covering exposed surfaces of dentin. Connective tissue in fracture line is infiltrated with lymphocytes.

is undergoing resorption. The soft tissue is a vascular granulation tissue, heavily infiltrated with leucocytes and lymphocytes and, to a smaller extent, plasma cells and histiocytes. The inflammation involves adjacent parts of the periodontal membrane and also extends into the pulp of the apical fragment. Along the coronal fragment the inflamed granulation tissue is in close contact with the surface of the dentin. In one place in this area the granulation tissue is separated from the dentin by a very narrow strip of epithelium.

At the lingual end of the fracture line, there are more small

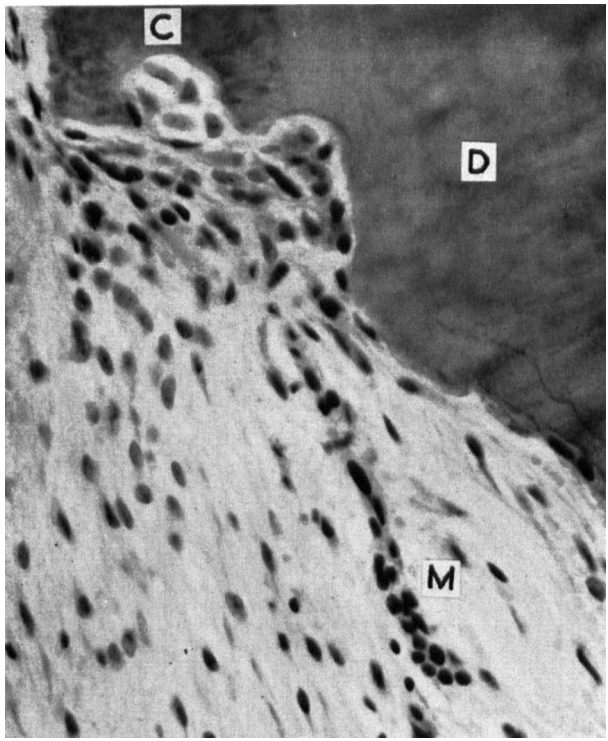

Fig. 10. Case 6: Higher magnification (× 360) of area corresponding to that marked II in Fig. 8. C is cementum, D dentin and M proliferating epithelial rests of Malassez in fracture line.

fragments of splintered hard tissue than at the labial end. The greater part of the exposed surface of the dentin is covered with squamous epithelium, the thickness of which is varying (Fig. 9). In some places the epithelium covering the different splinters is connected by bridges of epithelium. The connective tissue between the fragments is moderately infiltrated with lymphocytes and to a smaller extent, leucocytes and plasma cells. In one place a proliferating rest of Malassez is observed in the fracture line close to the periodontal membrane (Fig. 10).

The pulp in the coronal fragment was destroyed during the surgical removal. In the apical fragment the pulp canal is very wide (Fig. 8) due to osteoclastical activity along the walls of the canal. The normal pulp tissue is replaced by a moderately

inflamed connective tissue, highly vascularized and containing bundles of collagenous fibres.

There is little periodontal membrane left at the coronal fragment due to tearing during the operation. However, it should be emphasized that no sign of epithelial attachment can be observed in any of the 200 sections. In the apical fragment labially, the periodontal membrane has an average thickness of 0.23 mm. The fibres are arranged parallel to the root surface and apart from the area corresponding to the fracture line, no signs of inflammation are found.

Case 7

A 29 year old man fell down the stairs, causing the upper central incisor to become palatally displaced. The radiograph (Fig. 11A) disclosed intraalveolar cross fractures of both teeth, viz., in the apical third of 1+ and in the middle third of +1. The teeth were reduced and a capsplint from canine to canine was cemented into place. At the clinical examination a moderate marginal periodontitis was diagnosed. One month after the trauma a radiograph demonstrated slight blurring possibly due to resorption along the fracture line of 1+ and pronounced resorption in +1. Fig. 11B illustrates the condition two months after the trauma showing that the resorption apparently had been further aggravated. The capsplint was removed. The color of 1+1 was a shade darker than that of the other teeth and 1+1 did not respond to vitality test. The central incisors started elongating just after the removal of the capsplint. The patient was referred to his private dentist who performed root canal treatment of both teeth and removed the apical fragments. Orthodontic bands supporting a single arch wire for intruding the central incisors were placed on 4,1 + 1,4. Fig. 11D illustrates the condition seven weeks after the operation; the central incisors are now in normal alignment and the radiograph (Fig. 11C) demonstrates that the defect after apicectomy is in the process of being filled with bone.

Histological examination. The apical fragment of +1 was treated according to the double embedding method and stained with hematoxylin-eosin and *Van Gieson-Hansen's* stain. The pulp is found to be almost normal in histological structure although

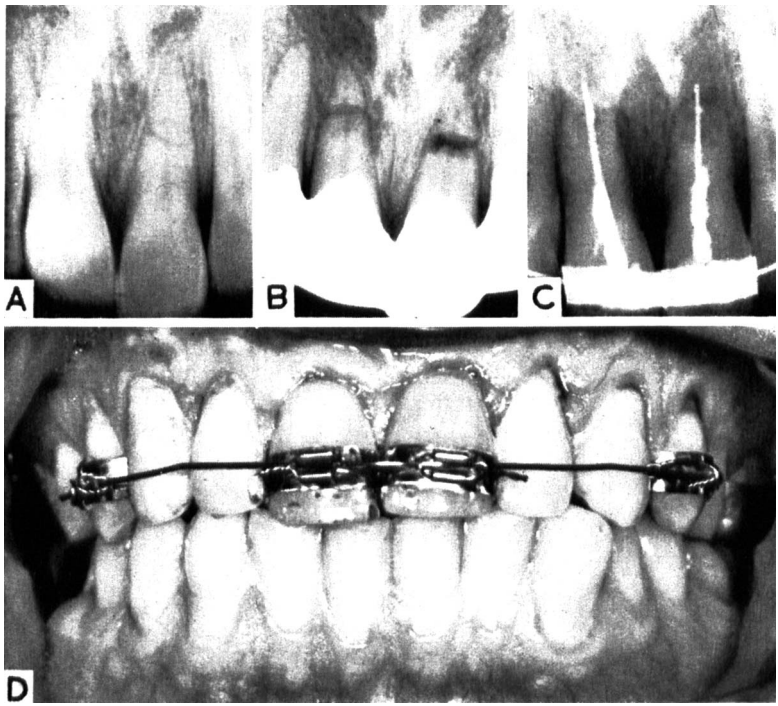

Fig. 11. Case 7: Radiographs immediately after trauma (A) and two months later (B). C is a radiograph three months after apicectomy. Note defect filling in with bone. D is a photograph illustrating the condition seven weeks after apicectomy. The orthodontic appliance has intruded the upper central incisors.

the odontoblasts are degenerated. There are a few bundles of collagenous fibres and slight edema. In many places the walls of the canal have been exposed to resorption, but all the defects are repaired with low differentiated dentin (Fig. 12).

Case 8

A 33 year old man fell off his bicycle, with the result that the right central incisor became completely luxated. The left central incisor was very loose and the radiograph revealed an intra-alveolar comminuted cross fracture in the cervical third of the root (Fig. 13A). The distal end of the fracture line was located just level with the alveolar crest. There was some destruction of the interalveolar crests due to a marginal periodontitis. For five weeks the tooth was ligated to an arch wire and during the

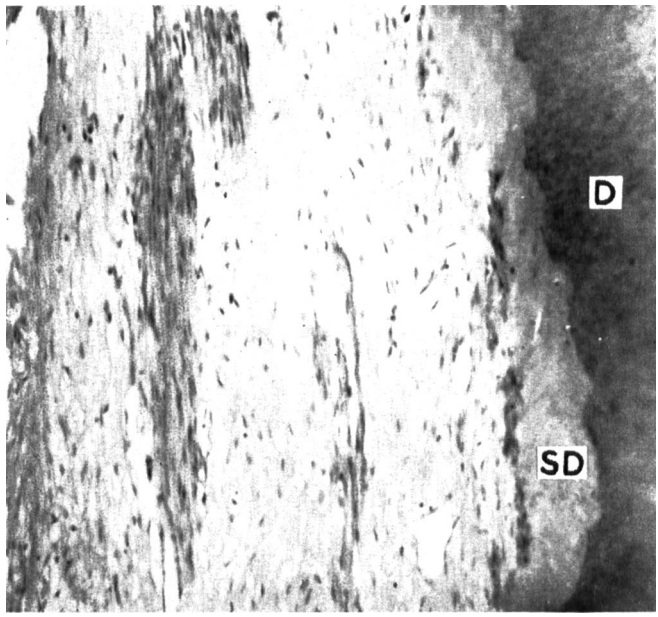

Fig. 12. Case 7: Photomicrograph of pulp in apical fragment of left central incisor. D is dentin, SD low differentiated dentin laid down in areas of preceding resorption. Note slight edema in pulp tissue. Magnification: × 130.

following four weeks a continuous wiring kept the tooth in position. After removal of the fixation the tooth was found to be of normal color, but somewhat loose, although less than before the treatment. Unfortunately, no vitality tests were performed. Eleven weeks after the trauma a radiograph showed no alteration in the fracture line (Fig. 13B). The tooth was surgically removed together with the surrounding bone (Fig. 13C and D).

Histological examination. The tooth was cut mesio-distally in 175 sections. Fig. 14 ist a low power magnification of a section and shows the fracture line dividing the tooth into a coronal fragment and an apical one. The distal as well as the mesial end of the fracture line show splinters of dentin. The fracture may therefore be characterized as comminute as is also shown radiographically.

The space between the fragments is filled with a granulation tissue rich in cells and small vessels and slightly infiltrated with lymphocytes most of the dentin and cementum exposed being

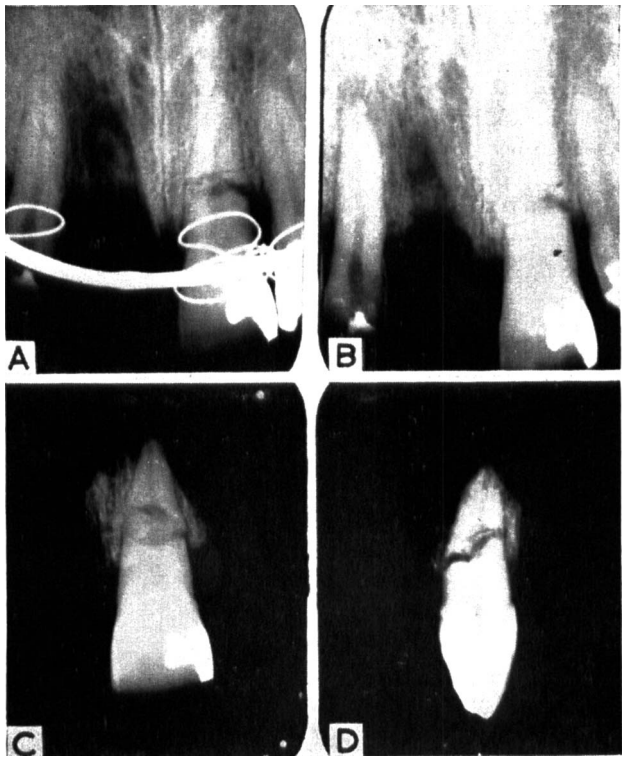

Fig. 13. Case 8: Radiographs one day after trauma (A) and 75 days later (B). Note in B resorption in fracture line. C and D are radiographs (frontal and lateral views) of extracted tooth.

resorbed. Between the small dentin splinters and the coronal fragment in the distal end of the fracture line, a proliferating squamous epithelium is observed (Fig. 15). In a few places only has the resorption stopped and has been followed by apposition of hard tissue.

The pulp tissue in the coronal as well as in the apical part of the tooth shows only minor histological changes. Towards the fracture line the odontoblasts gradually lose their regular appearance. The pulp has reacted upon the trauma by producing hard tissue, especially in the coronal fragment. Fig. 16A is a higher magnification of the area indicated with II in Fig. 14. To the right in Fig. 16A a tubular predentin is seen, but closer to the fracture, the tubules disappear and the hard tissue looks

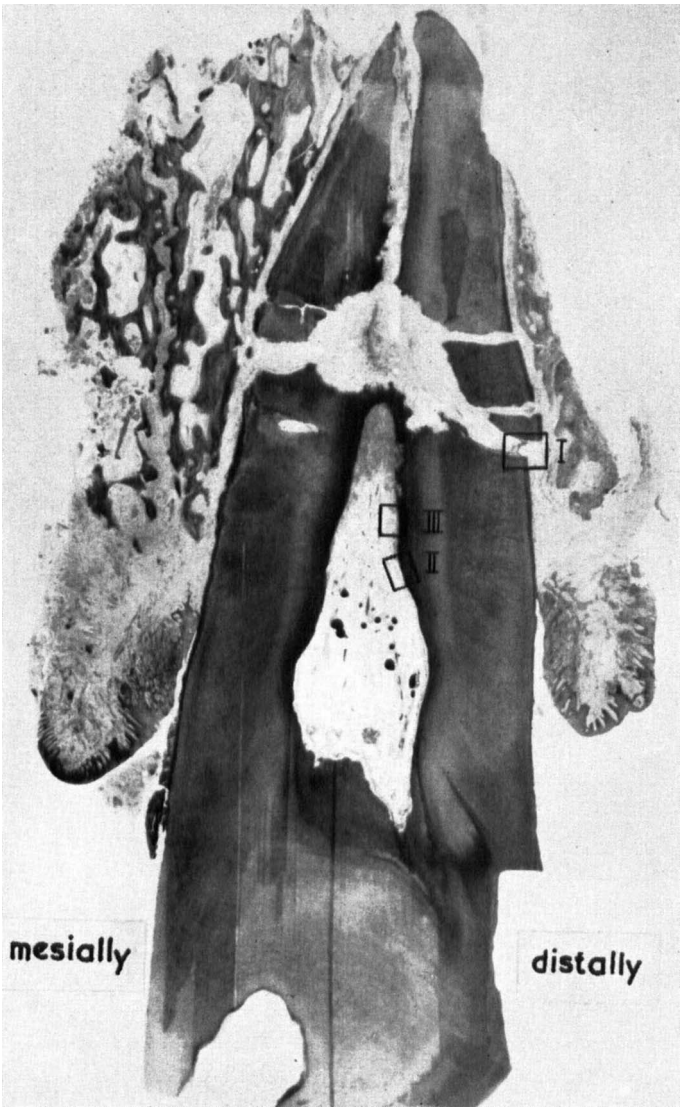

Fig. 14. Case 8: Low power magnification (× 7) of extracted incisor. The section corresponds to radiograph C in Fig. 13. Note splinters of dentin mesially and distally in fracture line. Areas marked I, II, and III are shown in higher magnification in Fig. 15 and Fig. 16.

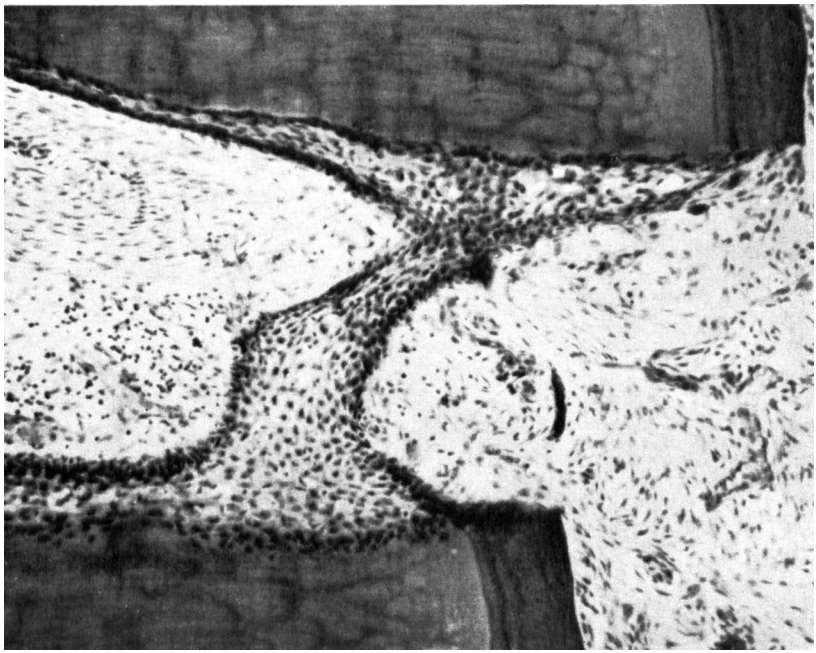

Fig. 15. Case 8: Higher magnification (× 110) of area marked I in Fig. 14. Exposed surfaces of dentin and cementum are covered with squamous epithelium. Note slight infiltration with lymphocytes in fracture line.

more homogenous. Fig. 16B is a photomicrograph from an area indicated with III in Fig. 14 not far from that of Fig. 16A. The hard tissue is without dentinal tubules, but in turn cellular inclusions are observed. The hard tissue along the walls of the pulp increases in thickness in the direction of the fracture.

The average thickness of the mesial periodontal membrane is 0.29 mm along the coronal fragment and 0.17 mm along the apical fragment. Distally the thickness of the periodontal membrane is 0.18 mm. The fibres are orientated as normally i.e. obliquely in the coronal fragment, while the fibres in the apical immobile fragment are arranged parallel to the surface of the cementum. There are only a few small and well limited areas of round cell infiltration. The cementum in the coronal fragment shows only superficial lacunae of resorption, while there are more and deeper lacunae in the apical fragment. The alveolar crest shows break-down owing to the marginal gingivitis present,

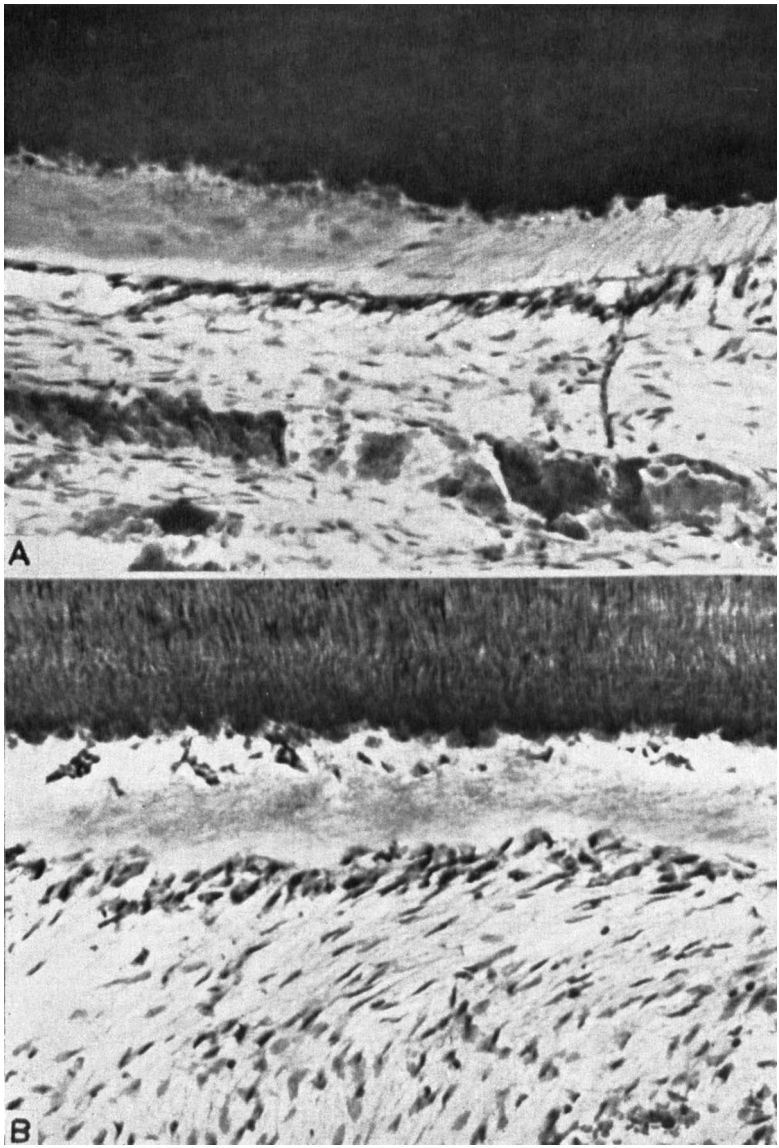

Fig. 16. Case 8: A. Higher magnification (× 175) of area marked II in Fig. 14. Note transition from tubular predentin to atubular hard tissue. B. Higher magnification (× 180) of area marked III in Fig. 14. Note atubular hard tissue with cell inclusions.

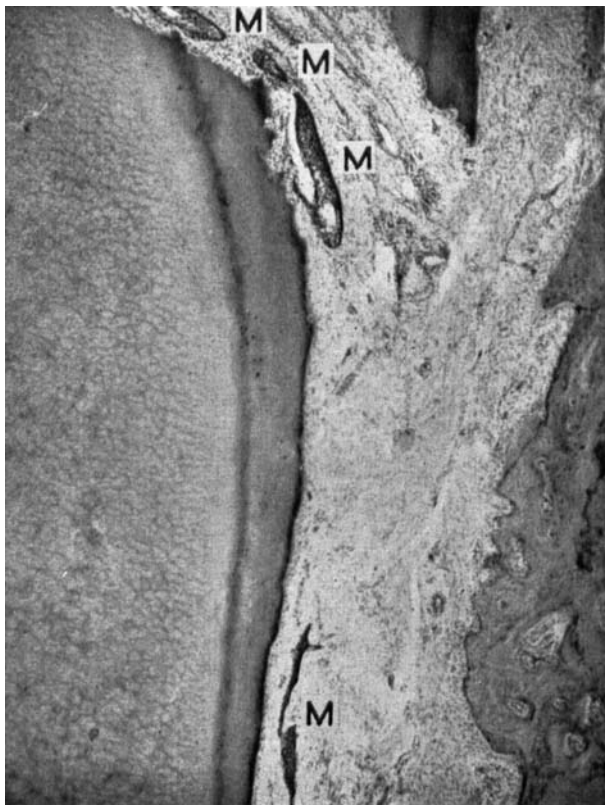

Fig. 17. Case 8: Photomicrograph of an area corresponding to that marked I in Fig. 14. M are proliferating epithelial rests of Malassez. Note infiltration with lymphocytes in fracture line. Magnification: × 34.

and the pathological changes in the medullar cavities extend as far as to the level of the fracture line. The lamina dura shows a slight extension into the fracture line mesially (Fig. 14).

The epithelial attachment is seen on the cementum about 3 mm below the cementum-enamel junction on both sides. In none of the 175 sections examined, has any connection between the epithelial attachment and proliferating epithelium in the fracture line been demonstrated. In the periodontal membrane on the distal surface of the root proliferating clusters of epithelial cells, resembling rests of Malassez are observed in connection with small areas of inflammation (Fig. 17).

DISCUSSION

Clinical findings

In Table 1 the eight case histories are summarized. From the table it can be seen that five of the patients are below the age of 16 years, but above 10 years. This is in good accordance with the view of *Brauer,* 1936, and *Ellis,* 1952, that root fractures are less frequent in children of 7—10 years of age, because in this period the roots are not fully formed and the teeth have some resilience in their sockets.

It is the writer's experience that the upper central incisors are the teeth most frequently showing intraalveolar fractures. The cases reported in this paper were observed within a period of two years and during that time no other root fractures appeared in the office. Austin's material of 40 root fractures from 1930 comprises 37 central incisors, one lateral incisor and one canine. The same predominance of the upper central incisor is evident in Table 2.

The clinical symptoms of root fractures may vary according to the localization of the fracture. The more cervically the fracture is located, the greater are the chances of displacement of the coronal fragment. Accompanying the displacement is increased mobility of the teeth. In all the cases described in this paper the teeth became loose, and the writer is rather sceptical towards the statement made in literature that many patients are unaware of having fractured roots. In some cases the coronal fragments of the fractured teeth have a tendency to elongate which may aggravate the prognosis (cf. case 7).

Table 1 also gives information as to the vitality of the pulps of the fractured teeth at the last examination. Below the age of 16 years the response to the vitality test is normal, but above the age of 20 years the responses are negative. The problem of vitality of the pulp in teeth with root fractures has given rise to a great deal of discussion in the literature. It is a well-known fact that a tooth sustaining a blow may temporarily fail to respond or give a questionable response to vitality test. The response may, however, return days or even months after the trauma (cf. case 4). However, it must be considered rather an exception when *Fliege,* 1933, found that it may last until two years before the pulp showed normal vitality. *Omnell,* 1953,

Table 1

The eight cases exhibiting intraalveolar root fractures described in the present paper. The cases are arranged according to patient's age at the time of the trauma.

Case number	Age in years at trauma	Tooth involved	Localization of fracture	Treatment	Period of treatment	Period of observation	Response to last vitality test	Appearance at last radiographic examination
1	9 9/12	1+	middle third	ligation to arch wire	46 days	22 months	+	rounding off. Ingrowth of alveolar bone in fracture line. Obliteration of pulp canal
2	10 7/12	+1	middle third	continuous wiring	130 days	11 months	+	some displacement of fragments. Ingrowth of alveolar bone in fracture line. Hard tissue formation
3	11 8/12	1+	middle third	capsplint	64 days	5 months	+	rounding off. Some resorption mesially
4	14 4/12	1+	middle third	ligation to arch wire	77 days	19 months	+	rounding off. Obliteration of pulp chamber and canal
5	15 5/12	1+	apical third	relieving of occlusal stress by grinding	--	3 months	+	very small apical fragment, totally obliterated
6	20	+1	middle third	continuous wiring	38 days	38 days	--	resorption processes apparently active in fracture line
7	29	1+	apical third	capsplint	58 days[1]	3 months after apicectomy	—	resorption processes (osteitis?) in fracture line. Most pronounced in +1
		+1	middle third	capsplint	58 days[1]		—	
8	33	+1	cervical third	ligation to arch wire	63 days	75 days	[2]	resorption process apperently active in fracture line

[1] After this period the root canals were filled and the apical fragments removed.
[2] No vitality test performed, but histological examination showed vital pulp tissue.

stresses that lack of sensitivity does not necessarily mean a diseased vascular system in a pulp, and French authors (*Deliberos & Renard-Dannin,* 1948, and *Marmasse,* 1948), emphasize that the vitality in fractured teeth is independent of the healing of the hard tissue. The point in *Kronfeld's* conclusion is that in the majority of cases of root fracture, the pulp can be expected to remain vital. This is illustrated by *Austin,* 1930, who found that among 40 anterior teeth with fractured roots 31 were vital and by *Anderson,* 1944, who reported seven cases in which the pulps were all vital one year after the trauma.

It is generally assumed that a discolored tooth is non-vital, but this must be taken with some reservation. *Lange,* 1939, published a case of root fracture, in which the color was yellow and the pulp vital. Another interesting case was reported by *Kisling,* 1953, who demonstrated that a discoloration may be transient.

Radiographic findings

The radiographic examination is a *sine qua non* in diagnosing an intraalveolar root fracture. The interpretation, however, can be difficult, because the fracture line, having an oblique course labially-palatally, appears as a double line, often disc-shaped on the radiograph. It may be necessary to take radiograms at different angles to disclose the fracture and determine the localization. Due to overlapping of the fragments it is difficult to diagnose a fracture as being comminuted. Root fractures are usually transverse, but may be oblique. In *Austin's* material the fracture line was situated in the apical third in four cases and in 36 cases situated in the middle third of the root. Considerable displacement of the fragments aggravates the prognosis. The radiograph is a valuable help in following the healing or non-healing process of an intraalveolar fracture. It is typical during healing for the edges of the opposing surfaces of the fragments to become rounded off (cf. cases 1, 2, 3 and 4) and the alveolar bone to grow in between the fragments. However, it is almost impossible to decide whether a union of fragments with calcified tissue has taken place. It is also difficult to tell from a radiograph, whether the filling-in with hard tissue in the fracture line comes from the pulp or from the periodontal membrane

(cf. *Ingeborg Gottlieb,* 1952). On the other hand, the radiograph gives rather exact information concerning the gradual obliteration of the pulp (*Riha,* 1929). In the material presented in this paper, total obliteration occurred in cases 4 and 5, and reduction in the size of the pulp chamber and/or canal in cases 1 and 2. Apparently, no rules can be laid down about a root fracture later resulting in obliteration of the pulp. It is not uncommon for fractured teeth with an obliterated pulp chamber and root canal to respond normally to vitality tests (cf. case 4 and *Ellis,* 1952).

Histological findings

The literature in this field has been reviewed. The results are tabulated in Table 2. The table comprises histological examinations of fractured incisors and canines only and is limited to erupted teeth.

Hard tissue union between the fragments is only proved in one instance, i.e. *Howe's* case from 1927. In *Omnell's* case (1953) the fracture was not complete so the conditions for healing were more favorable than in the cases with total fractures. *Brauer,* 1936, reported a case of *Kronfeld & Ing,* but although the radiograph showed the fragments "firmly united", they came apart during the removal of the tooth. The reason for the small number of cases reported with either calcified union or pseudarthrosis proven histologically, is probably due to the fact that any indication for an extraction is rare, when two fragments are apparently solidly united in the alveolus. Instead of a calcified union the fragments can be kept in position by a pseudarthrosis, the nature of which will be described below. Whether the healing occurs in one way or the other, resorption processes will always take place, and much attention has been given to the cause of these processes. The cross fracture of a root is accompanied by bleeding and subsequently inflammation. The increased pressure in the fracture line causes a differentiation of osteoclasts and the exposed surfaces of dentin and cementum undergo resorption. The extent of the resorption is among other things dependent of complicating infection. In cases 6 and 8 the inflammations were infectious, for which reason the processes of resorption were severe and the formation of hard tissue

very scarce. In cases with favorable prognosis the resorption processes are superseded by processes of apposition. It is not possible to state definitely, when the apposition will replace resorption, because several factors may influence the healing process.

The reparative processes always occur in areas of preceding resorption. The hard tissue is laid down in lacunae of *Howship* and in rare cases the hard tissue will unite the two (or more) fragments together. The hard substance, formed in the fracture line, is often difficult to classify, *Claus & Orban,* 1953. Different authors have characterized it as calcified repair tissue, bony tissue, secondary calcified tissue, cementoid, osteocementum, osteodentin etc. Also the "protective" formation of hard tissue in the pulp of fractured roots is difficult to classify. There is no doubt, however, that secondary dentin, formed close to the fracture line, is more irregular (i.e. containing a smaller number of tubules) than that formed remote from the fracture, cf. case 8, Fig. 16. It is a controversial question whether the repair tissue is derived from the pulp or from the periodontal membrane. The writer agrees with *Omnell,* 1953, that in root fractures the repair can be organized both from the pulp and the periodontal membrane. In the process of healing, the apposition of hard tissue in the fracture line stops at a certain point and fibrous bundles running between the fragments constitute the final result of healing, a pseudarthrosis. In reality a new periodontal membrane is established and due to the movements of the coronal fragment the fibres become orientated. Especially *Kronfeld,* 1936, has emphasized the adaptive changes in the periodontal membrane in a fractured tooth. The figures for the thickness of the periodontal membrane in cases 6 and 8 correspond very well to *Kronfeld's* measurements in a similar case. In the apical fragment the periodontal membrane is thin with fibres orientated parallel to the root surface, while the periodontal membrane in the coronal fragment is thick with obliquely orientated fibres.

In cases 6 and 8 no healing occurred, probably because the presence of a marginal periodontitis gave rise to infection in the fracture line. Besides the acute and chronic inflammation causing heavy resorption of dentin and cementum, in both cases

a squamous epithelium has proliferated along some of the exposed surfaces of dentin and cementum, Fig. 9 and Fig. 15. When a surface is covered with epithelium no apposition of hard tissue can take place and the prognosis for healing is hopeless. The origin of these epithelial cells is problematic. A natural explanation would be downgrowth of the epithelial attachment as demonstrated in the cases of *Aisenberg*, 1952, and *Kronfeld*, 1936. In cases 6 and 8 a careful examination of the serial sections did not disclose any connection between the epithelial attachment and the proliferating epithelium in the fracture line. Some of the sections in both cases demonstrate proliferating epithelial rests of Malassez in the fracture line, Fig. 10 and Fig. 17. From the apical area it is well known that inflammation can cause proliferation of the epithelial rests of Malassez, and it would not appear unreasonable therefore to assume a similar explanation for the occurrence of epithelium in the fracture line in cases 6 and 8.

In all three cases examined histologically by the present writer, the pulp in the apical fragment was vital. Cases 7 and 8 demonstrated processes of repair along the walls of the canals, while the pulp in case 6 was dominated by resorption processes. There is no doubt that an "apical" pulp can survive, even though the "coronal" pulp is necrotic, probably because the apical fragment receives its vascular supply from two sides.

Treatment

The treatment of an intraalveolar root fracture will depend on the localization of the fracture, the degree of displacement of the fragments, the periodontal conditions, the conditions of neighbouring teeth, the age and general health of the patient. The principles of treating root fractures are the reduction of the displacement, immobilization, and the relieving of occlusal stress. Regular radiographs and vitality tests must be made. It should be mentioned that many cases of root fractures, especially in the apical third, heal without any treatment. The immobilization can be accomplished in several ways: continuous wiring, ligation to an arch wire, a capsplint or a bandsplint. There are various views on the duration of fixation. *Ellis*, 1952, recommends the use of a capsplint for a period of three to six

months, while *Kristen,* 1952, removes the capsplint after three or four weeks. It is difficult, not to say impossible, to lay down rules for the duration of fixation. Table 1 demonstrates the differences in treatment, both in methods and lengths of periods. *Jung,* 1953, reports an unusual type of treatment, performed in a 12 year old girl, who had an unhealed three year old cross fracture in the middle third of the root of 1+. The fracture was not consolidated. By means of vigorous movements of the coronal fragment with the fingers the fracture line was "freshened up" and the teeth provided with an orthodontic appliance. At control examinations three months and eleven months later the tooth was firm, had a normal color and the radiograph gave evidence of healing.

Prognosis

Previously, the prognosis of teeth having root fractures was considered poor. To-day this attitude has changed somewhat and the prognosis is deemed more favorable in most cases, provided proper treatment is instituted. The prognosis is bad in teeth with comminuted fractures, when the fracture line is located cervically or when the teeth are suffering from a marginal periodontitis (cf. cases 6, 7, and 8). *Roy,* 1938, stresses that to obtain healing the lamina dura must be intact and the fracture line located definitely below the circular ligaments. The age of the patient naturally plays an important role, the prognosis being better in youth, but even in older people, healing of fractured roots has been observed (cf. Table 2). Several authors have compared the reaction of the pulps in teeth having sustained a blow without fracturing and fractured teeth. It is generally agreed that the pulp of a traumatized tooth without a fracture is more likely to become necrotic than the pulp of a fractured tooth, cf. cases 1, 2, and 5. The explanation is probably that the fracture of the root provides immediate decompression and facilitates collateral circulation, *Anderson,* 1944.

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SUMMARY

Nine upper central incisors (in eight patients) with intra-alveolar root fractures are described. In Table 1 information is given of the nine teeth. The ages of the patients (all male) varied from 10 to 33 years. The fractures were located in the apical thirds of the roots in two teeth, in the middle thirds in six teeth, and only one tooth had a fracture in the cervical third of the root.

The treatment consisted in reduction of displaced coronal fragments, fixation by means of continuous wiring (two teeth), ligation to arch wire (three teeth) or capsplints (three teeth). In one case no treatment other than relieving of occlusal stress was performed. The period of treatment varied from 38 days to 130 days.

Five teeth gave positive responses to vitality tests during observation periods from three to twenty-two months. In these cases the radiographs gave evidence of healing; three teeth showed obliteration of pulp chamber or canal (Figs. 1, 5 and 6).

Two teeth becoming loose despite of the treatment were surgically removed with the surrounding bone. The radiographs disclosed active processes of resorption. In both teeth the histological examination revealed comminuted fractures (Figs. 8 and 14), and covering with squamous epithelium of exposed surfaces in the fracture lines (Figs. 9 and 15). It is suggested that the epithelium originates from the epithelial rests of Malassez, which may have been stimulated to growth by a present marginal periodontitis (Figs. 10 and 17).

In one patient the two central incisors were found to be non-vital two months after the trauma (Fig. 11C), whereupon root canal treatment was made and the apical fragments surgically removed. Histological examination of a fragment from the left incisor demonstrated vital pulp tissue in the root canal and formation of secondary dentin in areas of preceding resorption.

Table 2 is a tabulation of 21 previously reported cases of intraalveolar root fractures examined histologically.