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Traumatic intrusion of permanent teeth. Part 2. A clinical study of the effect of preinjury and injury factors, such as sex, age, stage of root development, tooth location, and extent of injury including number of intruded teeth on 140 intruded permanent teeth

Andreasen JO, Bakland LK, Andreasen FM. Traumatic intrusion of permanent teeth. Part 2. A clinical study of the effect of preinjury and injury factors, such as sex, age, stage of root development, tooth location, and extent of injury including number of intruded teeth on 140 intruded permanent teeth. © Blackwell Munksgaard, 2006.

Abstract – A prospective study of 140 intruded permanent teeth was done to evaluate the following healing complications: pulp necrosis (PN), root resorption (surface, inflammatory and replacement resorption) (RR) and defects in marginal periodontal healing (MA). These complications were related to various preinjury and injury factors. Age appeared to be related to all three healing complications in that patients younger than 12 years had the lowest complication rate. Stage of root formation at the time of the injury was very strongly related to PN and MA, with immature root formation (i.e. incomplete root formation or completed root formation with wide open apex) having better prognosis than more mature root development. Lateral incisors showed significantly more defects in MA, a finding possibly explained by the observation that lateral incisors were more often involved in multiple intrusions compared to other teeth and noting that multiple intrusions had a significantly higher frequency of MA. An associated crown fracture with exposed dentin resulted in more frequent PN, a finding possibly related to bacterial invasion through dentinal tubules into an ischemic pulp. The presence of a gingival laceration added to both PN and MA. The extent of intrusion (in mm) showed some relation to both RR with intrusion 1–3 mm having the lowest frequency of RR, whereas PN and MA showed no significant relation to the extent of intrusion. Finally, multiple adjacent intruded teeth were more frequently involved in a significantly greater loss of interproximal marginal bone (MA) than single intrusions. In conclusion, the relationship between healing complications and preinjury and injury factors could generally be explained by better healing possibilities in teeth with

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Key words: traumatic intrusion; pulp healing; periodontal healing; stage of root development; extent of injury; dislocation; age

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immature root formation. A possible explanation for that could be the softer bone surrounding the tooth, whereby trauma to the periodontium might be diminished.

Traumatic intrusion of permanent teeth is a rare injury, which in several studies has been found to represent only 0.3–2% of traumas affecting the permanent dentition (1–4). This implies that experience in treating these injuries is limited even in large trauma centers. Thus, few clinical studies have been presented, and they include very limited numbers of intruded teeth, which in turn implies that the statistical analysis of associated variables related to the frequent healing complications becomes very weak (5–12).

Because of the very nature of intrusion injuries, in which all soft tissue and some hard tissue components are damaged [i.e. gingival tissues, periodontal ligament (PDL), alveolar bone and the pulp] the scene is right for a multitude of complications, including loss of gingival attachment, marginal bone loss (MA), and root resorption (RR) (repair related, infection related and ankylosis related). Furthermore, pulp necrosis (PN) and arrested root formation are frequent in cases of injury to teeth with immature root formation at the time of injury (6).

The question naturally arises whether these complications are mainly injury and/or treatment dependent. A closer look at the healing scenario may give some hints concerning an eventual relation to the extent of trauma. At the moment of impact, a significant amount of energy is spent to drive the tooth into its socket. In the gingival area, shearing stress will sever the gingival fibres, and compressive forces in the infrabony part of the PDL will compress and sever the PDL and crush the alveolar socket wall. Furthermore, the tissues in the apical foramen area will be severed, and in the case of teeth with open apexes, the socket bone will possibly be pressed into the apical opening. In addition, a tooth with the crown covered with plaque has been displaced into a damaged periodontium, a situation that carries a risk of infection. The entire trauma situation points to a complicated healing scenario, resulting in the risk of various healing complications (7).

In the literature, only a few studies have analyzed the number and type of healing complications (5–12). A survey of these studies is given in Table 1. It appears that healing complications, such as PN, RR, and MA are frequent. Also, tooth survival appears compromised in most studies.

The purpose of the present study was to evaluate the effect of preinjury and injury factors, such as sex, age, stage of root development, tooth location, associated tooth fractures, severity of displacement, and numbers of involved teeth upon healing. The effect of treatment variables (i.e. treatment delay, type of repositioning, type of splint, length of splinting period and antibiotics) will be addressed in a later study (8).

Material and methods

This study represents a part of the previous reported material where complete patient records were available and where the follow-up period was at least 1 year (3). The original material consisted of 216 teeth, and of these 76 had to be eliminated for the reasons documented in Table 1 of Part 1 (3) leaving 114 patients with 140 intruded teeth for statistical analysis.

This group had a mean age of 8 ± SD 11.41, with a range of 6–67. The description of clinical variables and examination procedure has been presented in a previous study, and the same applies to the type of complications registered (3).

The analysis was carried out to examine an eventual relationship between healing complications such as pulp necrosis (PN), progressive root resorp-

Table 1. Clinical studies on prognosis of intrusion of permanent teeth

Author, year (reference)	No. of teeth	Age mean (range)	Tooth survival	Pulp necrosis	Root resorption	Loss of marginal bone
Andreasen, 1970 (5)	23	?	?	22 (96%)	12 (52%)	11 (48%)
Andreasen & Vestergaard Pedersen, 1985 (6)	61	(6–67)	?	52 (85%)	40 (66%)	19 (31%)
Jacobsen, 1983, 1991 (7, 8)	40	8.0 (6–16)	36 (90%)	25 (63%)	?	?
Kinirons & Sutcliffe, 1991 (9)	29	9.5 (7–12)	20 (69%)	?	11 (38%)	7 (24%)
Ebeseleder et al., 2000 (10)	58	11.1 (6–16)	55 (95%)	36 (64%)	18 (31%)	20 (34%)
Al-Badri et al., 2002 (12)	61	9.3 (7.1–14)	48 (79%)	?	36 (59%)	?
Humphrey et al., 2003 (11)	31	9.3 (6–18)	26 (83%)	14 (45%)	25 (80%)	12 (39%)
Chaushu et al.,[a,b] 2004 (13)	31	(8–11)	28 (90%)	26 (83%)	13 (41%)	2 (6%)
Andreasen et al., 2004	140	15.6 (6–67)	112 (80%)	124 (88%)	67 (48%)	45 (32%)

[a]Including 22 case reports from the literature.
[b]All the patients were treated by orthodontic extrusion.

tion (RR) and marginal periodontal healing (MH) and preinjury and injury factors.

The results were statistically analyzed using Fisher's exact test, chi-squared test and Mantel–Haenszel analysis, and a Kaplan–Meier survival analysis (28). Because of the rather few cases examined after 15 years, the latter analysis was limited to cases with observation up to 15 years. The level of significance was set at 5%. To control for interaction between the variables registered, a stratified analysis was subsequently made, where all variables were tested against each other with respect to healing outcome (6, 8).

Results

Diagnosis of healing complication

Pulp necrosis

A total of 124 cases of PN were recorded. It appears from Fig. 1 that the diagnosis of PN was significantly related to root development and most cases were diagnosed within 6 months after the injury; in some cases, however, and mostly in teeth with immature root formation, a late diagnosis of PN was made (Fig. 2). Among 16 cases showing pulp survival, all cases showed subsequent pulp canal obliteration.

Root resorption

Of the 67 cases that showed progressive RR, 24 were infection related (inflammatory resorption), 31 were ankylosis related (replacement resorption), and in 12 cases a combination of infection related and ankylosis related resorption was observed. Among cases of isolated infection related resorption, the resorption process could be arrested by endodontic therapy in 15 cases. Among cases of ankylosis-related resorption, 6 cases appeared to be transient.

It appears from Fig. 3 that the diagnosis of RR was related to root development and that most cases were diagnosed within the first year. Whereas a relative stable plateau of healing took place after 5 years for immature teeth, a recurrence of RR activity was found up to 10 years

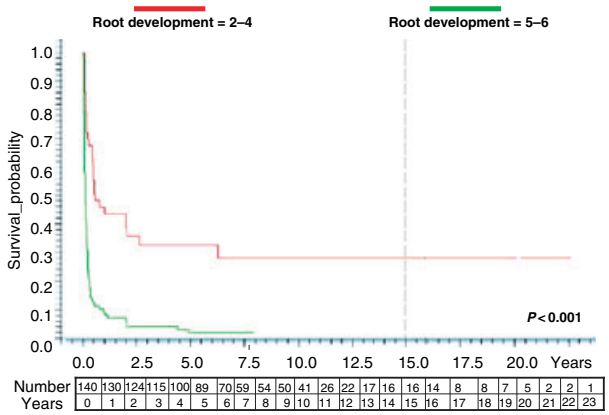

Fig. 1. Pulp necrosis related to root development.

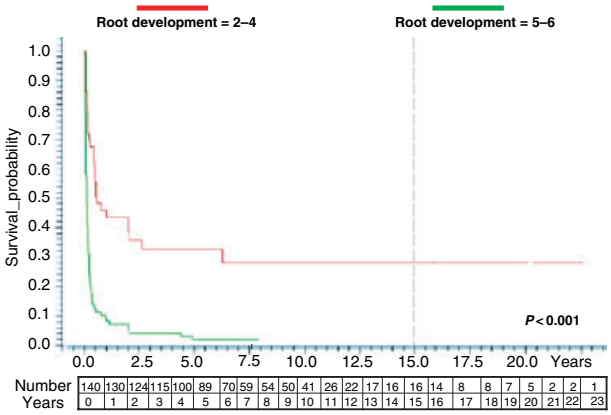

Fig. 3. Root resorption related to root development.

Fig. 2. Partial necrosis of a right central incisor. (a) Time of injury. (b) Status after 2 months; spontaneous eruption is taking place. (c) Six months of full eruption and apical closure. The coronal part of the pulp has developed pulp necrosis. (d) Status 10 years after endodontic therapy.

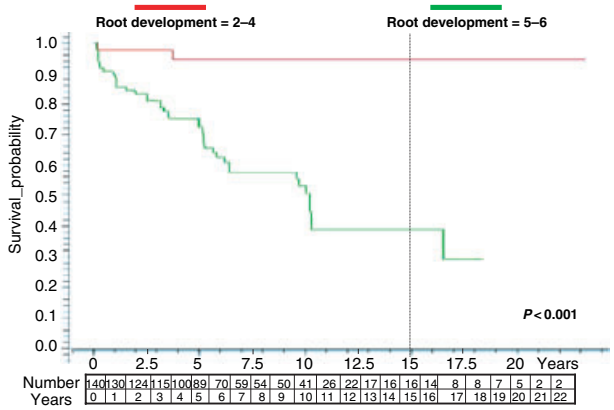

Fig. 4. Marginal bone loss related to root development.

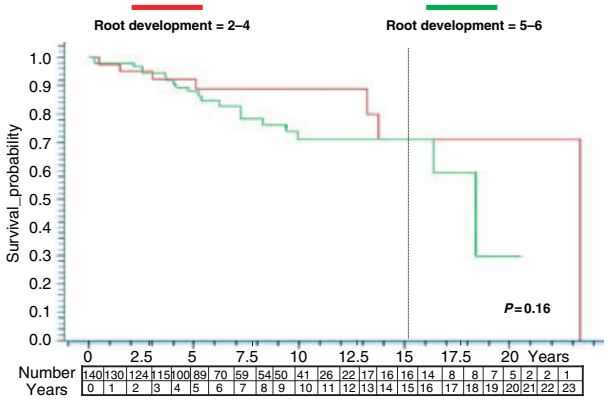

Fig. 6. Tooth loss related to root development.

after the injury. Altogether, 3 cases showed non-progressive root resorption (surface resorption).

Marginal bone loss

MA was found in 45 cases (Fig. 4). The mean bone loss was found to be 1.0 ± SD 1.80 mm (range 1–8 mm). It appears that the finding of MA was clearly related to root development.

During the observation period, most of the MA took place within the first 4 years in the case of incomplete root development, whereas teeth with completed root formation had a constant amount of MA showing up throughout the observation period (Fig. 4). In six teeth (three cases) a transient marginal breakdown occurred (Fig. 5).

Tooth loss

Altogether 28 teeth were lost during the observation period (Fig. 6): 17 related to RR, 4 because of spontaneous root fractures after endodontic treatment, and 7 as a result of treatment decisions such as orthodontics, implants, or autotransplantation of premolars related to poor long-term prognosis. It appears from Fig. 4 that there was a rather constant loss of teeth throughout the observation time. However, after 10 years of observation the curve could no longer be considered representative as most of the failing cases were newly referred patients for treatment with implants or transplants and therefore do not represent diagnosed new cases at a regular follow-up.

Table 2. Interaction between pulp necrosis (PN), root resorption (RR) and marginal breakdown (MA)

	RR			MA		
	0	+	*P*-value	0	+	*P*-value
PN						
0	13	3	0.01	16	0	<0.001
1	60	64		79	45	
RR						
0				52	21	0.23
1				43	24	

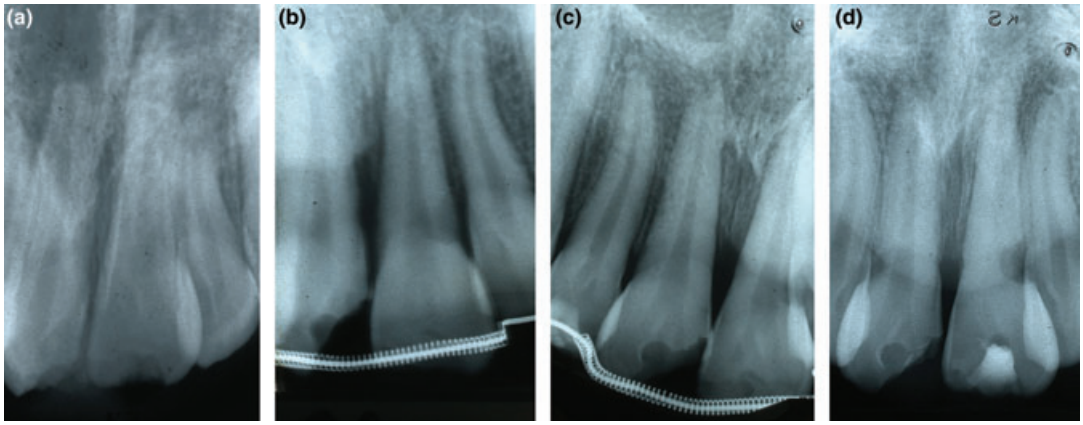

Fig. 5. Transient marginal breakdown. (a, b) Time of injury and after placement of orthodontic appliance. (c) Four months later, after orthodontic extrusion; evidence of interproximally bone breakdown (arrow). (d) After another 3 months, there is evidence of interproximal bone regeneration.

Table 3. Results and statistical univaried analysis of healing in teeth distributed according to the relevant variables. Number of teeth in the groups varies because of exclusion of teeth with unknown value of the variable

	Type of healing, *n* (%), significance								
	Pulp necrosis (PN)			Root resorption (RR)			Marginal bone loss (MA)		
Preinjury or injury variables	−	+	*P*-value	−	+	*P*-value	−	+	*P*-value
Sex									
Male	13 (15)	72 (85)	(0.06)	42 (49)	43 (51)	0.26	63 (74)	22 (26)	0.04
Female	3 (6)	52 (94)		31 (56)	24 (44)		32 (58)	23 (42)	
Age (year)									
06–11	16 (22)	57 (78)	0.0006	43 (59)	30 (41)	0.05	65 (89)	8 (11)	<0.001
12–17	0 (0)	30 (100)		10 (33)	20 (67)		15 (50)	15 (50)	
18–67	0 (0)	37 (100)		20 (54)	17 (46)		15 (40)	22 (60)	
Root development (stage)									
2	0 (0)	5 (100)	<0.001	5 (100)	0 (0)	0.13	5 (100)	0 (0)	<0.001
3	4 (33)	8 (67)		8 (67)	4 (33)		10 (83)	2 (17)	
4	10 (38)	16 (62)		12 (46)	14 (54)		26 (100)	0 (0)	
5	1 (17)	5 (83)		4 (67)	2 (33)		6 (100)	0 (0)	
6	1 (1)	90 (99)		44 (48)	47 (52)		48 (53)	43 (47)	
Root development									
Immature teeth (2–4)	14 (33)	29 (67)	<0.001	25 (58)	18 (42)	0.22	41 (95)	2 (5)	<0.001
Mature teeth (5–6)	2 (2)	95 (98)		48 (49)	49 (51)		54 (56)	43 (44)	
Tooth type, location									
Central maxillary incisor	12 (12)	92 (88)	0.64	52 (50)	52 (50)	0.27	77 (74)	27 (26)	0.03
Lateral maxillary incisor	4 (13)	26 (87)		19 (63)	11 (33)		15 (50)	15 (50)	
Other	0 (0)	6 (100)		2 (33)	4 (67)		3 (50)	3 (50)	
Crown fracture									
0 = 0	6 (15)	39 (85)		27 (60)	18 (40)		28 (63)	17 (37)	
1 = enamel	9 (29)	22 (71)	<0.001	18 (58)	13 (42)	0.34	25 (81)	6 (19)	0.19
2 = enamel + dentin	1 (2)	55 (98)		26 (46)	30 (54)		36 (64)	20 (36)	
Bone fracture									
0 = 0	9 (16)	50 (84)	0.20	35 (60)	24 (40)	0.09	43 (73)	16 (27)	0.19
1 = labial bone plate	4 (8)	45 (92)		22 (45)	27 (55)		31 (63)	18 (37)	
Gingival laceration									
0 = 0	11 (17)	53 (83)	0.04	37 (58)	27 (42)	0.08	50 (78)	14 (22)	0.006
1 = yes	2 (5)	41 (95)		18 (42)	25 (58)		23 (54)	20 (46)	
Mm intrusion									
1–3	5 (17)	25 (83)	0.39	22 (73)	8 (27)	0.01	23 (77)	7 (23)	0.18
4–5	6 (11)	48 (89)		22 (41)	32 (59)		34 (63)	20 (37)	
6–7	4 (17)	20 (83)		16 (67)	8 (33)		20 (83)	4 (17)	
8–9	0 (0)	18 (100)		7 (39)	11 (61)		10 (56)	8 (44)	
10–16	1 (7)	13 (93)		6 (43)	8 (57)		8 (57)	6 (43)	
Mm intrusion									
1–7	15 (14)	93 (86)	0.08	60 (56)	48 (44)	0.10	77 (71)	31 (29)	0.08
8–16	1 (3)	31 (97)		13 (41)	19 (59)		18 (56)	14 (44)	
Mm intrusion									
1–3	5 (17)	25 (83)	0.23	22 (73)	8 (27)	0.007	23 (77)	7 (23)	0.17
4–16	11 (10)	99 (90)		51 (46)	59 (54)		72 (66)	38 (34)	
No. of injured teeth									
1–3	12 (13)	79 (87)	0.27	49 (54)	42 (46)	0.35	68 (75)	23 (25)	0.01
4–10	4 (8)	45 (92)		24 (49)	25 (51)		27 (55)	22 (45)	
No. of intruded teeth									
1	7 (11)	54 (89)		30 (49)	31 (51)		47 (77)	14 (23)	
2	7 (13)	45 (86)	0.90	26 (50)	26 (50)	0.48	36 (69)	16 (31)	0.05
3	1 (11)	8 (89)		7 (78)	2 (22)		4 (44)	5 (56)	
4	1 (8)	12 (92)		8 (62)	5 (38)		6 (46)	7 (54)	
5	0 (0)	5 (100)		2 (40)	3 (60)		2 (40)	3 (60)	
No. of intruded teeth									
1	7 (12)	54 (88)	0.94	30 (49)	31 (51)	0.32	47 (77)	14 (23)	0.03
2–5	9 (11)	70 (89)		43 (54)	36 (46)		48 (61)	31 (39)	

Arrested root formation

This complication was found in 14 teeth.

Association between healing complications (PN, RR, MA)

It appears from Table 2 that PN had a certain positive relation to RR and a very positive and

highly significant relation to MA. On the contrary RR was not found related to MA.

Univariate analysis

The results of the univariate analysis are given in Table 3.

Sex

An almost significant association was found as female patients more often suffered PN than male patients, and the same applied to MA. However, this association disappeared in the stratified analysis, when both age and stage of root development were brought into the analysis (8). This could be explained by the fact that female patients tended to suffer intrusions at a later age (and thereby at a more advanced root formation), a factor that fully explained the earlier mentioned sex association factor.

Age

A very strong age association was found to all three healing complications, with increasing age leading to an increasing number of complications (Fig. 7).

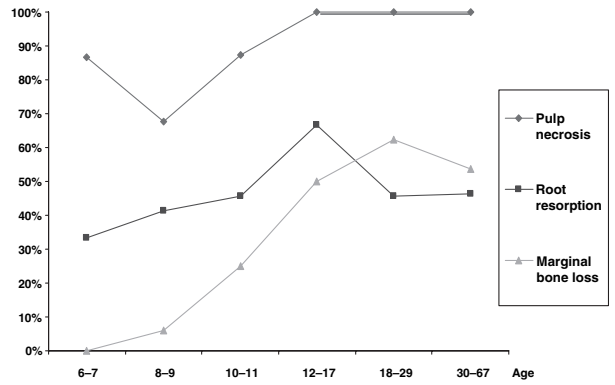

Fig. 7. Age related to healing complications.

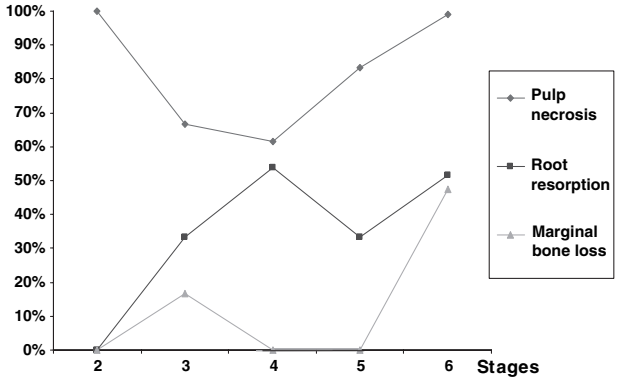

Fig. 8. Root development related to healing complications.

The most significant association was found for PN when age groups below or above 11 years were compared. This finding was also strongly related to root development. In the stratified analysis, it was found that age contributed very little extra information when root formation was complete (8). RR appeared to be less age dependent, having a peak in the age group 12–17 (Fig. 7). MA was also age dependent, with more bone loss with increasing age (Fig. 7) (stages 5 and 6, Table 3).

Root development

A significant relation was found between advancing stages of root development and the risk of various complications (Fig. 8). For teeth with PN the optimal stages for revasculatization appeared to be stages 3 and 4 (Table 3).

In root development stage 2, all five teeth showed partial PN, whereas some months or years later, an apical radiolucency showed up (Fig. 2).

In cases of completed root development (stage 6) only 2 teeth out of 91 showed pulp healing. A significant association was noted between RR and root development, with more developed root formation showing a higher frequency of RR compared to more incomplete root development (Fig. 8). MA became very frequent in stages with full root formation (stage 6).

Tooth location

MA seemed to be significantly more frequent in lateral incisors. If teeth other than central and lateral maxillary incisors were left out of the analysis, the following *P*-values were found. PN: 0.50, RR: 0.14 and MA: 0.01. However, this association appeared in the stratified analysis to be related to the variable, multiple intrusions (8).

Crown fractures

It appears that PN was significantly related to the presence of crown fractures with exposed dentin ($P < 0.001$).

Alveolar bone fractures

No association could be found to an associated fracture of the labial bone (i.e. intrusion direction in axial–labial direction).

Gingival laceration

This factor was found significantly and positively related to both PN and MA.

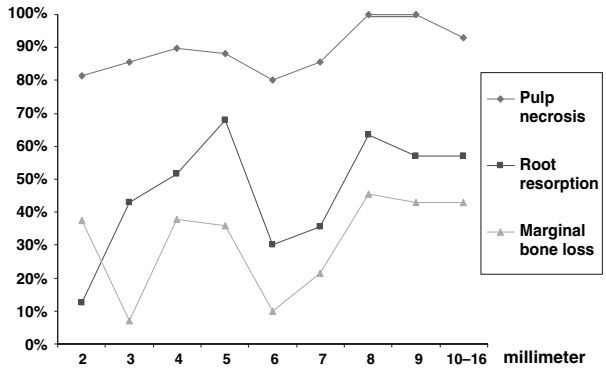

Fig. 9. Extent of intrusion related to healing complications.

Extent of intrusion

A certain, but not significant, association was found to the extent of dislocation. Thus, intrusion of 7 mm or more appeared to give a slightly increased chance of PN, RR, and MA (Fig. 9) (Table 3). The division line 7 mm gave slightly more predictable separation between healing and non-healing cases than 3 mm.

Number of injured teeth

The total number of injured teeth including those that were not intruded had a significant relation to MA.

Number of intruded teeth

This variable also had a significant association to MA (Table 3). A more detailed analysis of this factor showed that when 59 instances with intrusion of two or more adjacent teeth were analyzed, 40 teeth showed no bone loss mesially or distally. In 17 teeth the proximal areas showed more bone loss than peripherally and only in two teeth was the opposite the case ($P < 0.001$) (Fig. 10). Thus, proximal PDL areas of two adjacent intruded teeth had a poorer prognosis than the peripheral areas. (Average bone loss 0.9 mm proximally vs 0.4 mm peripherally.)

Discussion

The purpose of this study was to collect data that could be used to develop an understanding of the various preinjury and injury variables in relation to results from other studies, as well as their interpretation in relation to wound healing processes after intrusion. In that regard a problem exists in that only a few experimental studies have been reported concerning the histological events after intrusion. Studies have been made in rats (14, 15) and dogs (16–18). Both animal models, however, are not that comparable in relation to a human situation, because of significant differences in anatomy.

Sex

An unexpected association was initially found between sex and both PN and MA; this relationship, however, was clarified in a subsequent stratified analysis to be fully explained by the stage of root development, and the latter was related to the later exposures of girls to intrusions compared to boys (8).

Age

An age association was certainly operating for all healing complications with more severe complications arising later in life. This became apparent when the frequency of complications was analyzed for the patients before and after the age of 11. It illustrated a general steady increase in complications. This phenomenon could possibly be related to the denser and more mineralized alveolar bone surrounding the tooth with increasing age, thus

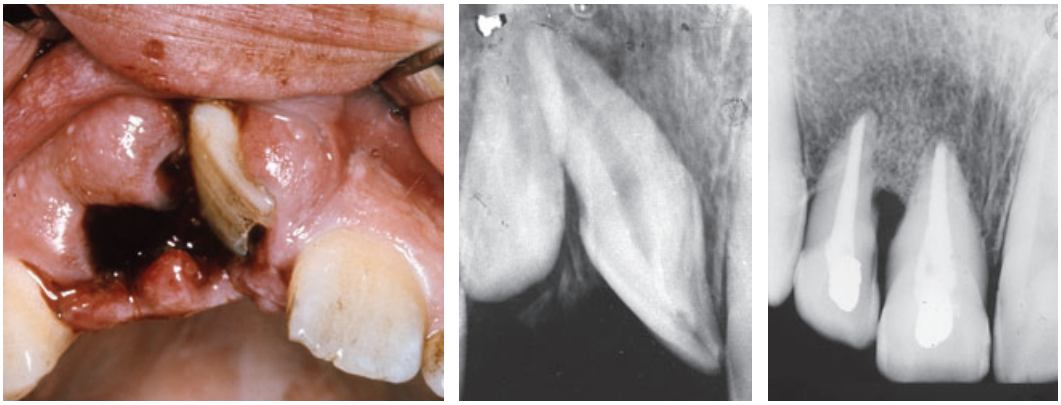

Fig. 10. Multiple intrusions in a 16-year-old boy. More marginal bone loss is found proximally compared to peripherally.

allowing more injury to the root surface. Furthermore, an age factor operating in the wound healing response cannot be ruled out (19).

Root development

Root development was as expected the most significant factor determining healing events. This factor has been found to influence healing events in a number of dental injuries, such as luxations (6), root fractures (20–21), crown features (22), and avulsions (23). With respect to PN, this association can be explained by the larger apical foramen, where a strong association has been found between the width of the apical foramen and the chance of revascularization (24). The lack of revascularization in teeth with only partially formed roots can possibly be related to the chance of bone invading the wide pulp canal and compressing the pulp at the moment of impact. With three quarters or full root formation with a wide-open apex (stages 3 and 4), about one third of intruded teeth revascularized. This chance was halved in stage 5 (half-closed foramen) and was practically nonexistent in teeth with a narrow apical foramen, a finding that is supported by a previous study on luxated teeth (24).

RR was surprisingly only weakly related to the stage of root development with stages 2–4 having a slightly lower frequency of healing compared to stages 5 and 6 ($P = 0.22$). The minor resorption rate in the early stages is possibly related to the softer and less mineralized bone in these cases. The more frequent resorption found in teeth with more complete root development has also been found in previous studies (10,12).

MA was very much dependent on the stage of root development, being almost nonexistent in case of root development up to stage 5 and being very prominent in teeth with completed root formation, stage 6. The reason for this association could be the more intensive damage in cases with denser and more mineralized bone in the latter case, which may result in more compressive damage to the PDL.

Tooth type

A surprising finding was that lateral incisors showed significantly higher frequency of RR than central incisors. The stratified analysis could partly explain this finding by the more frequent involvement of lateral incisors in multiple intrusions. The central incisors showed significantly more frequent MA than lateral incisors. This finding can possibly be explained by the difference in root anatomy, where the more tapered central incisors possibly release more damage to a periodontium during intrusion compared to the more cylindrically shaped lateral incisors.

Associated crown fracture

It appears that a crown fracture with exposed dentin leads to an increased chance for PN. Such an association could be expected because of bacterial invasion into ischemic pulp through dentinal tubules (25). In a subsequent report, it will be analyzed whether temporary coverage of the exposed dentin can reduce or eliminate the risk of PN (8).

Extent of intrusion

A surprising factor was that PN and MA were apparently not related to the extent of dislocation. In case of RR, teeth with 1–3 mm dislocation generally showed less resorption than teeth with more dislocation ($P = 0.007$). As 7 mm intrusion appeared in relation to PN and MA to represent a borderline with respect to frequency of complications, this was examined closer to see whether such a distinction could represent a significant effect on healing complications. A level of intrusion that showed a tendency for more complications was above 7 mm (PN, RR, and MA) ($P = 0.08$, 0.10, and 0.08, respectively), a finding that possibly indicates that the extent of injury to the periodontium is related to the depth of intrusion. With regard to the extent of intrusion and RR similar findings have previously been found (10,12).

Gingival laceration

This clinical finding appeared to increase the risk of PN, RR, and MA, and a subsequent stratified analysis revealed that the explanatory factor very well could be the extent of intrusion (8).

Number of injured teeth

This variable showed a significant association to MA, a finding possibly reflecting the effect of the number of intruded teeth.

Number of intruded teeth

This variable showed a strong relation to single or multiple intrusions. A detailed analysis of this variable showed that when adjacent teeth were intruded, there was usually poor bony healing between the intruded teeth, while bony healing between the intruded teeth and adjacent non-injured teeth showed better healing. This phenomenon is possibly related to the bone induction capacity of a vital PDL of adjacent teeth, a finding

that has been shown both clinically (26) and experimentally (27).

Conclusions

A number of preinjury and injury factors have significant influence on the healing outcome. The most prominent factor is the stage of root development. Less risk of complication was found in cases with immature root formation. This is possibly a reflection of softer bone surrounding teeth with immature root development, which may allow intrusion with less trauma to the PDL. Associated crown fracture (with exposed dentin) had an expected negative influence on pulp healing. Extent of intrusion had some influence with a dependable division line at 7 mm of dislocation. Finally, adjacent intruded teeth had a negative influence on marginal bone healing between the intruded teeth.

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