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Intrusive luxation of permanent incisors in Norwegians aged 6–17 years: a retrospective study of treatment and outcome

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Abstract – *Background/Aim*: External replacement resorption (ankylosis-related) is a severe complication leading eventually to tooth loss. Little information exists regarding the influence of variables such as degree of intrusion or treatment method on the development of replacement resolution in intruded permanent incisors. The aim of this study was to report the most frequently involved age group, the preferred type of treatment, and the type and frequency of healing complications. Special attention was paid to the effect of treatment on the occurrence of replacement resorption. *Material and Methods*: Fifty-one intruded permanent incisors were studied in 20 boys and 19 girls aged 6 to 17 years. Only three patients were over 12 years of age. Complete intrusion had occurred in 21 teeth, and 31 teeth were classified as immature. Re-eruption was awaited for 37 teeth. The remaining teeth were repositioned orthodontically (7 teeth) or surgically (7 teeth). *Results*: Re-eruption occurred in 35 out of 37 teeth over a period of 3–12 months. After a mean observation period of 4 years ranging from 1–12 years, retained pulp vitality was recorded in 22 teeth (43%). Pulp necrosis had developed in 57%, inflammatory resorption in 26% and replacement resorption in 12%. Whereas all inflammatory resorptions were arrested after long-term calcium hydroxide treatment, replacement resorption always led to complete root resorption. In the analysis all orthodontic and surgical repositioned teeth were combined into an active treatment group. The non-active treatment group consisted of teeth allowed to re-erupt. The distribution of replacement resorption was significantly lower in teeth allowed to re-erupt than in teeth repositioned actively. *Conclusions*: The best treatment of intruded incisors in 6–12 year-old children is to await re-eruption. Should endodontic treatment be required before re-eruption has occurred, a gingivectomy can be performed to gain access to the root canal.

The majority of dental injuries happen in children, and it appears that intrusive luxation of permanent teeth is most frequent in the age group 6–12 years (1). Intrusion represents a very severe type of injury. The tooth is forced axially into the socket resulting in damage to the alveolar bone, the periodontal ligament, the cementum and the pulp. Consequently, there is a high risk of healing complications in particular pulp necrosis, external inflammatory resorption and external replacement resorption. Although 97% of all inflammatory resorptions are arrested after long-term calcium hydroxide treatment (2), there is no effective treatment for replacement resorption. The root is gradually resorbed leading eventually to loss of the tooth.

The frequency of replacement resorption in intruded incisors is reported to range from 5–31% (3–6). A relationship between severity of intrusion and this type of root resorption has been observed (4). Replacement resorption also appears to be more frequent in mature than in immature teeth (7).

A variety of treatment methods are suggested for intruded teeth. One option is to leave the tooth to re-erupt. Another is to reposition the tooth by orthodontic forces. Immediate surgical repositioning is also recommended. However, divergence of opinion exists concerning the best treatment. As intruded teeth are at risk of replacement resorption, treatment with low risk of this complication should be defined as the best method.

The effect of treatment on pulp necrosis and external root resorptions has been discussed by several authors (3, 4, 8–11). However, with one exception (4), no differentiation is made between inflammatory and replacement resorption in these outcome studies. Accordingly, little information exists as to the possible influence of treatment on the development of the most severe complication following trauma.

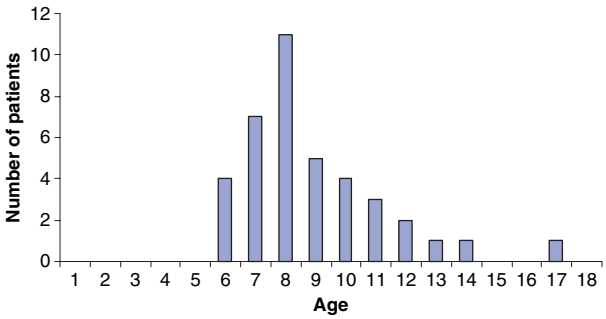

Fig. 1. Age distribution at time of injury for 39 patients with intrusive luxation to 51 permanent incisors.

The purpose of this retrospective study of children and adolescents with intruded permanent incisors was to:

- Report the most frequently involved age group, the preferred type of immediate treatment and the type and frequency of healing complications.
- Analyse the effect of root development, severity of intrusion and performed treatment on healing complications and especially on the development of external replacement resorption.

Material and methods

The material comprised all cases of intrusive luxation referred to two Pediatric Resource Centers in the Public Dental Health Service in Norway during the period 1983–2003. Clinical data were extracted from the patient records. Ten patients were excluded due to inaccurate or incomplete information.

A total of 51 permanent teeth in 39 patients (20 boys and 19 girls) were studied. The age range was 6–17 years and only three patients were over 12 years of age (Fig. 1). The material included 45 maxillary central and six lateral incisors with no difference between the right and the left side.

Most patients (28) had one intruded tooth, ten patients had two intruded teeth and one patient had three intruded teeth. All intrusions were the result of acute trauma sustained either during leisure time (24 teeth) or during activities in school or in kindergarten (17 teeth).

Fig. 2. Condition 6 days after trauma in a 10-year-old girl with complete intrusion of the right central incisor. The right lateral and left central incisor are partially intruded (> 2 mm).

Clinical examination

Degree of intrusion

In 21 teeth, the incisal edge was barely visible. These teeth were defined as completely intruded. The remaining 30 teeth were defined as partially intruded (Fig. 2). This group was further divided into being intruded > 2 mm (22 teeth) or < 2 mm (eight teeth).

Additional injuries to intrusive luxation

An additional injury had occurred in 18 teeth (35%). Enamel-dentin fractures were diagnosed in 15 teeth and complicated crown fracture in three teeth.

Radiographic examination

Generally standardized long-cone paralleling technique was used. All radiographs were examined independently by the authors.

Root development at the time of the accident was graded in seven stages according to Moorrees et al. (12): (1) initial root formation; (2) one-fourth of the root length; (3) one-half of the root length; (4) three-fourths of the root length; (5) root length complete, with apical foramen wide open; (6) apical foramen half closed; (7) apical foramen narrow.

Borderline cases were rated at the preceding developmental stage. In the analysis, 31 teeth were classified as immature (stages 2–5), and 20 teeth as mature (10 in stage 6 and 10 in stage 7).

Choice of treatment

In 37 teeth, re-eruption was awaited and no immediate treatment was performed. Seven teeth were repositioned orthodontically (two teeth within 1 week and five teeth after 1–8 months). The remaining seven teeth were brought down into position with forceps at the day of the injury and splinted with wire and composite for 2–6 weeks.

Exposed dentin was covered with calcium hydroxide and a composite material in seven of the 15 teeth with enamel-dentin fractures. Direct pulp capping was performed in incisors with pulp exposure.

All patients were instructed to rinse twice daily with a 0.1% solution of chlorhexidine. Systemic antibiotics (penicillin) were given to nine patients.

Follow-up examination

The observation period varied from 1–12 years, with a mean of 4 years. In the follow-up period special attention was paid to degree of re-eruption, tooth mobility, percussion sound, color of tooth crown and reaction to electrometric sensibility testing. Radiographs were examined with reference to the periradicular condition and to changes within the pulp cavity.

A reaction to electric stimulation alone was never regarded as proof of either pulp vitality or pulp necrosis. The term retained pulp vitality was used in teeth with positive sensibility reaction, normal tooth color and normal periradicular condition including continued root formation. In teeth with persistent negative response, endodontic treatment was always postponed until a definite sign of pulp infection such as periradicular radiolucency was present.

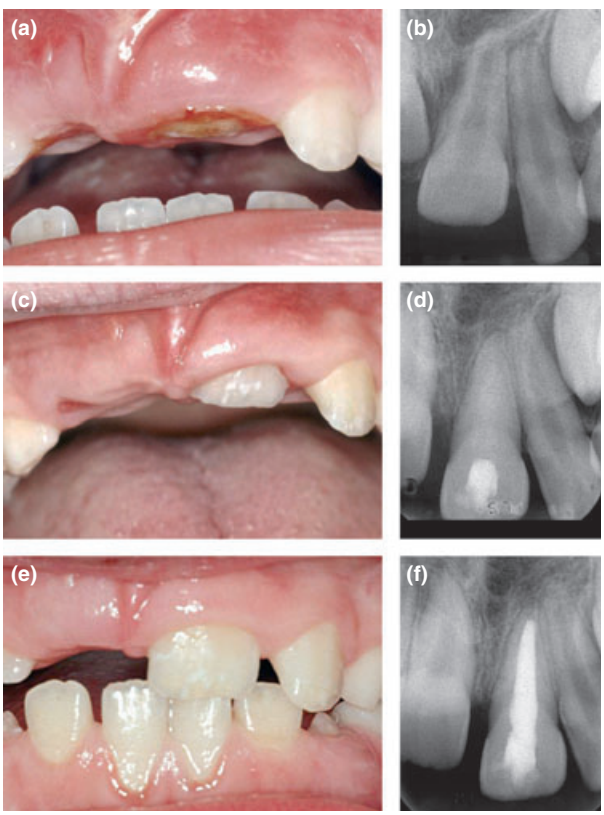

Fig. 3. Complete intrusion of left central incisor. Re-eruption was awaited. (a, b) Condition 5 days after injury, before start of endodontic treatment. A gingivectomy was performed to gain access to the root canal. (c, d) Partial re-eruption 1 month later. Pulp canal is filled temporarily with calcium hydroxide. (e, f) Complete re-eruption and permanent root filling 10 months after trauma. (Delayed eruption of right incisor is due to supernumerary tooth).

Statistical methods

In the statistical analysis Fisher's exact test, chi-squared test, the Kaplan–Meier survival curves and a log rank test were used. The level of significance was set at 5% and the statistical software used was SPSS-version 12 (SPSS Inc., Chicago, IL, USA).

Results

Re-eruption occurred in 35 out of 37 teeth. Two teeth did not re-erupt because of ankylosis. Of the re-erupted teeth nine had been completely intruded and only six had been less than 2 mm intruded. Twenty-seven teeth were immature but eight mature teeth also re-erupted.

The time interval between trauma and complete re-eruption varied from 3 to 12 months with a mean of 5.6 months (Figs 3 and 4). Orthodontic repositioning took 6 to 9 months.

Pulpal and periodontal findings

Retained pulp vitality was observed in 22 teeth (43%). None of the mature and completely intruded teeth retained their pulp vitality (Table 1). In teeth allowed to re-erupt, 19 teeth retained their vitality, and 15 of these were immature (Table 2).

Pulp survival allowed continued root formation and apical closure. However, in 12 of 17 immature teeth the final root length was somewhat shorter compared with the contralateral tooth (Fig. 4d). Among the 22 teeth with retained pulp vitality subsequent pulp canal obliteration was observed in 82% (13 immature and 5 mature) (Fig. 4).

Pulp necrosis developed in 29 teeth (57%). As shown in Table 1, 26 teeth had been more than 2 mm intruded. A significantly higher frequency of necrosis was found in mature compared with immature teeth ($P = 0.04$) (Table 3).

Thirteen of the 18 teeth with an additional crown fracture developed pulp necrosis (72%). In comparison, pulp necrosis was observed in 48% of teeth with intrusion as the single diagnosis (Table 3).

External inflammatory root resorption (infection-related) confirmed the diagnosis of pulp necrosis in seven mature and six immature teeth. Only two teeth had been less than 2 mm intruded. This type of

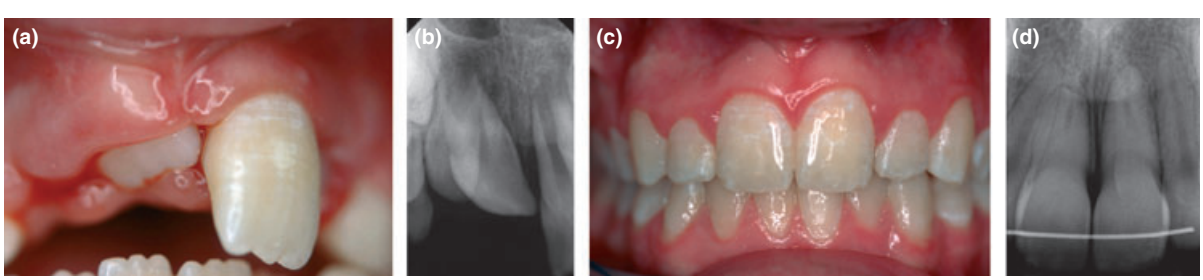

Fig. 4. (a, b) Three weeks after complete intrusion of immature right central incisor and subluxation of left central incisor in an 8-year-old girl. Re-eruption was awaited. (c, d) Five years later with normal clinical findings, completed root development and marked pulp canal obliteration. Note the somewhat shorter root of right incisor (Retainer is due to orthodontic treatment).

Table 1. Pulpal findings related to degree of intrusion and stage of root development in 51 intruded permanent incisors

	Immature			Mature		
	Complete	Partial > 2 mm	Partial < 2 mm	Complete	Partial > 2 mm	Partial < 2 mm
Retained pulp vitality (n = 22)	6	6	5		5	
Pulp necrosis (n = 29)	4	8	2	11	3	1

Table 2. Pulpal findings related to degree of intrusion and stage of root development in 37 incisors allowed to re-erupt

	Immature			Mature		
	Complete	Partial > 2 mm	Partial < 2 mm	Complete	Partial > 2 mm	Partial < 2 mm
Retained pulp vitality (n = I9)	5	6	4		4	
Pulp necrosis (n = 18)	4	8	2	1	3	

resorption was found in 26% of the total material and was identified in the middle or coronal one-third of the root from 2 weeks to 4 months after trauma.

A certain but not significant association was found between multiple intrusions (two or three affected teeth) and the development of both necrosis and inflammatory root resorption (Table 3).

Endodontic treatment was performed in 25 teeth with necrotic and infected pulps, whereas four teeth were extracted without attempting endodontic therapy. A gingivectomy was performed in a few teeth to gain access to the root canal (Fig. 3). Routinely the root canal was filled temporarily with calcium hydroxide. Permanent root filling with gutta-percha was not performed until any inflammatory root resorption was arrested, an apical periodontitis had healed or a hard tissue barrier was formed apically.

Replacement resorption (ankylosis-related) was diagnosed in six teeth (12%) and was more frequent in mature than in immature teeth. An association was also found between complete intrusion and the occurrence of this complication (Table 3). The diagnosis of ankylosis was always made within 1 year and was based on a high metallic percussion sound. Replacement resorption was confirmed radiographically when root substance was gradually resorbed and replaced by bone.

Influence of treatment

The pulpal and periodontal complications are shown in Table 4. It appears that both necrosis and the external root resorptions occurred more often in orthodontically

Table 3. The effect of preinjury, injury and treatment variables on healing complications in 51 intruded incisors

	Pulp necrosis			Inflammatory resorption			Replacement resorption		
Variables	Yes	No	*P*-value	Yes	No	*P*-value	Yes	No	*P*-value
Sex									
Male	13 (50)	13 (50)	0.31	5 (19)	21 (81)	0.30	2 (8)	24 (92)	0.36
Female	16 (64)	9 (36)		8 (32)	17 (68)		4 (16)	21 (84)	
Age									
6–11	24 (53)	21 (47)	0.16	12 (27)	33 (73)	0.60	5 (11)	40 (89)	0.69
12–17	5 (83)	1 (17)		1 (17)	5 (83)		1 (17)	5 (83)	
No. of injured teeth									
1	14 (50)	14 (50)	0.28	6 (21)	22 (79)	0.46	4 (14)	24 (86)	0.54
2–3	15 (65)	8 (35)		7 (30)	16 (70)		2 (9)	21 (91)	
Degree of intrusion									
Complete	15 (71)	6 (29)	0.18	6 (29)	15 (71)	0.91	5 (24)	16 (76)	0.08
Partial	14 (47)	16 (53)		7 (23)	23 (77)		1 (3)	29 (97)	
Crown fracture									
Present	13 (72)	5 (28)	0.10	8 (44)	10 (56)	0.02	1 (6)	17 (94)	0.31
Not present	16 (48)	17 (52)		5 (15)	28 (85)		5 (15)	28 (85)	
Root development									
Immature teeth	14 (45)	17 (55)	0.04	6 (19)	25 (81)	0.21	2 (6)	29 (94)	0.14
Mature teeth	15 (75)	5 (25)		7 (35)	13 (65)		4 (20)	16 (80)	
Repositioning									
No repositioning	18 (49)	19 (51)	0.05	7 (19)	30 (81)	0.08	2 (5)	35 (95)	0.02
Active repositioning	11 (79)	3 (21)		6 (43)	8 (57)		4 (29)	10 (71)	
Dentin coverage									
Yes	8 (80)	2 (20)	0.41	4 (40)	6 (60)	0.67	0 (0)	10 (100)	0.25
No	5 (63)	3 (37)		4 (50)	4 (50)		1 (12)	7 (88)	
Antibiotics									
Yes	8 (53)	7 (47)	0.74	4 (27)	11 (73)	0.90	2 (13)	13 (27)	0.82
No	21 (58)	15 (42)		9 (25)	27 (75)		4 (11)	32 (89)	

Values are expressed as n (%).

Table 4. Pulpal and periodontal findings related to choice of treatment in 51 incisors with intrusive luxation.

Treatment method	Pulp necrosis		Inflammatory resorption		Replacement resorption	
	Yes	No	Yes	No	Yes	No
No repositioning (n = 37)	18 (49)	19 (51)	7 (19)	30 (81)	2 (5)	35 (95)
Orthodontic repositioning (n = 7)	6 (86)	1 (14)	4 (57)	3 (43)	2 (29)	5 (71)
Surgical repositioning (n = 7)	5 (71)	2 (29)	2 (29)	5 (71)	2 (29)	5 (71)

Values are expressed as n (%).

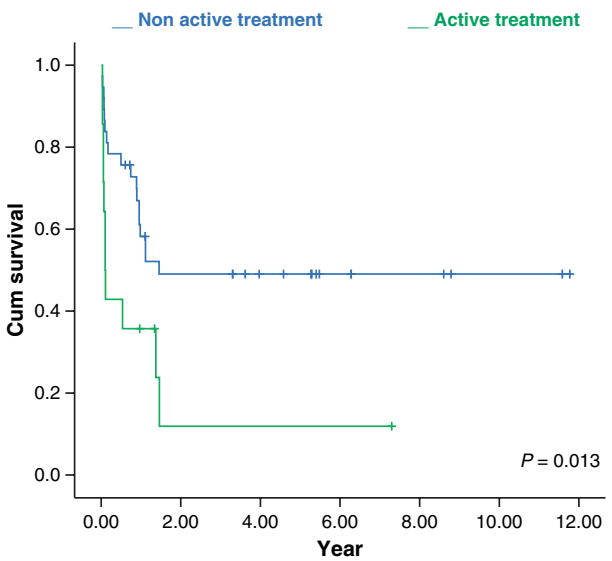

Fig. 5. Survival analysis of teeth with pulp necrosis related to active or non-active repositioning.

and surgically repositioned teeth than in the non-repositioned teeth.

Because of the limited number of orthodontic and surgical repositioned teeth, these were combined and regarded as an active treatment group in the further analysis. The non-active treatment group consisted of teeth allowed to re-erupt.

The survival curves for pulp necrosis, inflammatory root resorption and replacement resorption are presented in Figs 5–7. The log rank test showed a statistically significantly higher distribution of pulp necrosis (P = 0.013), inflammatory root resorption (P = 0.039) and replacement resorption (P = 0.021) in the active treatment group.

Tooth survival

After a mean observation period of 4 years 40 out of 51 teeth (78%) were functioning adequately with normal reactions to mobility and percussion tests. All ankylosed

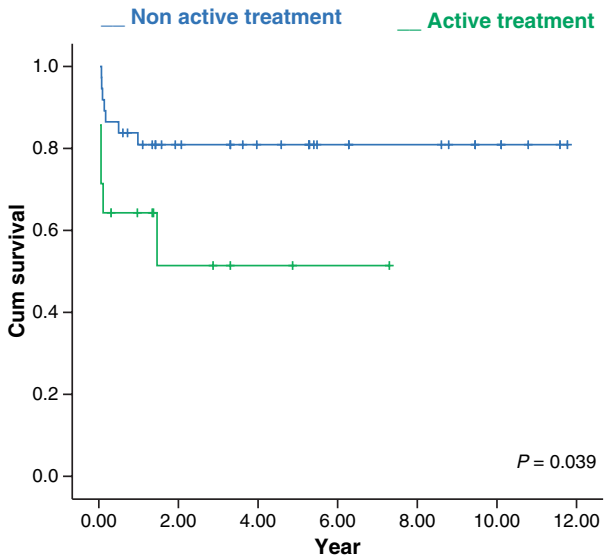

Fig. 6. Survival analysis of teeth with inflammatory root resorption related to active or non-active repositioning.

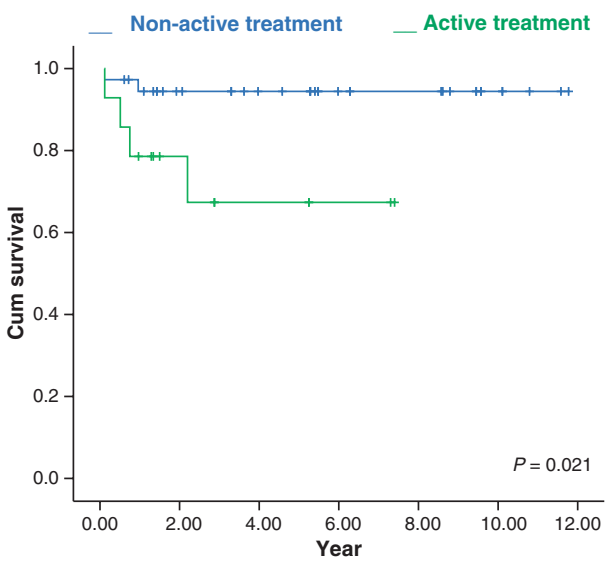

Fig. 7. Survival analysis of teeth with replacement resorption related to active or non-active repositioning.

teeth and four immature teeth with necrotic pulps had been extracted. In addition, one mature tooth was extracted for orthodontic reasons.

Discussion

In this retrospective study all patients were referred to Pediatric Resource Centers with an upper age limit of 18 years. The age range 6–17 years corresponds well with other clinical studies of pediatric patients (3, 4, 8, 10). Consistent with Andreasen et al. (1), intrusions were found to be most frequent between 6 and 12 years of age.

In general, the patient records contained the required data regarding examination, treatment and

follow-up. However, the severity of intrusion was not always precisely described. Based on a combined clinical and radiographic evaluation the involved teeth were defined as either completely or partially intruded. Only 8 out of 51 teeth were intruded less than 2 mm. It was not possible to compare the observed severity with previous observations, as the definition of severity differed considerably from one study to another (4, 6, 8–10).

Throughout the 20 year study period (1983–2003), no general agreement existed concerning the best treatment for intruded permanent teeth. In a Norwegian clinical study from 1983, no immediate treatment other than establishing adequate oral hygiene was performed for 37 intruded incisors. During the follow-up period, re-eruption took place in all teeth (3). This finding may explain why awaiting re-eruption was preferred for 37 of 51 teeth in this study. There was a tendency to choose either orthodontic or surgical repositioning for completely intruded mature teeth. Re-eruption occurred for 35 of 37 incisors, thus confirming the likelihood of re-eruption observed in the above-mentioned study. Recently Andreasen et al. reported that re-eruption was awaited in 38 out of 140 teeth (11). However, the exact number of re-erupted teeth was not presented.

Most of the re-erupted teeth were immature, but consistent with previous findings re-eruption of mature teeth also occurred (3, 11). Irrespective of the degree of intrusion re-eruption took several months. In agreement with Andreasen et al. (11), the time interval from trauma to complete re-eruption varied from 3 to 12 months. Should endodontic treatment be required for a severely intruded incisor before re-eruption has occurred, a gingivectomy can be performed to gain access to the root canal (Fig. 3).

The frequency of retained pulp vitality is reported to range from 11 to 34% in clinical studies differing both in age, severity and type of treatment (3, 5, 6, 9). A higher frequency (43%) of pulp survival was noted in this study. It is pointed out that 17 of the 22 teeth with pulp survival were immature, thus demonstrating the excellent recovering capacity of young pulps in general and also the potential of pulp healing despite severe intrusive luxation.

Pulp survival was also found in five teeth classified as mature (5). Radiographic evaluation of root maturity is based on the mesio-distal dimension (12). According to a study by Friend (13), the apical foramen is not closed in the bucco- palatinal direction until on average 13 years of age. Four patients in this study with apparently mature roots were either 10 or 11 years and this may explain why pulpal healing was possible.

Although retained pulp vitality allowed further root formation, 12 out of 17 teeth developed shorter but nevertheless well-functioning roots. Presumably the root development had been disturbed because of damage of the Hertwig's epithelial root sheath.

Consistent with previous findings pulp canal obliteration was frequently seen, and mainly in teeth with open apices (3, 4, 6).

As expected, pulp necrosis was the most common complication (3, 4, 6–9) and a higher frequency was found in mature compared with immature teeth. Intrusion of 7 mm or more is reported to give a slightly increased chance of pulp necrosis (6). In this study a relation was observed between complete intrusion of mature teeth and the development of necrosis. Whether or not the pulpal prognosis was worsened at or above intrusion of 7 mm could not be determined.

The additional injuries were either enamel-dentin fracture or complicated crown fracture. As suggested previously, enamel-dentin fracture was found to have a negative effect on pulp healing (4, 6, 8). It was not possible to demonstrate a difference between teeth with or without a dentin covering procedure.

Cervical root fracture of non-vital immature incisors is a considerable risk, and this may explain why four teeth were extracted without attempting root canal treatment. The endodontic treatment was judged as successful in both mature and immature incisors after a mean observation period of 4 years ranging from 1 to 12 years. However, a cervical fracture can occur up to 6 years after root canal treatment has been started (2). Consequently the final outcome should be regarded as uncertain for a few endodontically treated incisors with wide root canals and thin dentinal walls cervically.

All inflammatory resorptions were arrested after long-term calcium hydroxide treatment. In contrast, replacement resorption always led to complete root resorption.

Conflicting evidence exists concerning the influence of treatment on the occurrence of external root resorptions. Furthermore, in the previous outcome studies, a differentiation between inflammatory resorption and replacement resorption has only been made by Humphrey et al. (4). These authors observed a relationship between active repositioning with traction forces and the presence of replacement resorption.

In this study, replacement resorption occurred in 5% of teeth allowed to re-erupt and in 29% following both orthodontic and surgical repositioning. In the analysis all orthodontic and surgical repositioned teeth were combined into an active treatment group. Teeth allowed to re-erupt were regarded as the non-active treatment group. A higher distribution of replacement resorption was found in the active treatment group, and this difference was statistically significant.

Moreover, the frequency of pulp necrosis and inflammatory resorption was also higher for teeth actively repositioned. Consequently the question arises whether repositioning either by orthodontic or surgical forces acts as a new trauma, thereby adding to the risk of healing complications.

Main conclusions

- Intrusive luxation of permanent incisors was most frequent in the age group 6–12 years.
- Awaiting re-eruption was the preferred treatment.
- Re-eruption took place in 35 out of 37 incisors over a period of 3–12 months.
- Replacement resorption (ankylosis-related) was the main reason for tooth loss.

- The occurrence of replacement resorption was significantly lower in teeth allowed to re-erupt than in teeth repositioned orthodontically or surgically.
- The best treatment of intruded incisors in 6–12-year-old children is to await re-eruption. Should endodontic treatment be required before re-eruption has occurred, a gingivectomy can be performed to gain access to the root canal.

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