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Traumatic intrusion of permanent teeth. Part 3. A clinical study of the effect of treatment variables such as treatment delay, method of repositioning, type of splint, length of splinting and antibiotics on 140 teeth

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Abstract – A prospective study of 140 intruded permanent teeth was examined for the following healing complications: pulp necrosis (PN), root resorption (RR; surface, inflammatory and replacement resorption), and defects in marginal periodontal bone healing (MA). The occurrence of these healing complications was related to various treatment factors such as treatment delay, method of repositioning (i.e. expecting re-eruption, orthodontic reposition and surgical reposition), type of splint (rigid, semirigid and flexible), length of splinting (days) and the use of antibiotics. Treatment delay, i.e. before and after 24 h, had no effect upon healing. Active repositioning in individuals with incomplete root formation (surgical or orthodontic) had a negative effect upon the three healing parameters compared with spontaneous eruption. In teeth with complete root formation and an age of 12–17 no repositioning was still the best treatment in regard to MA. In individuals older than 17 years of age, cases were not anticipated to spontaneously erupt and in these cases, the general choice of treatment was either active orthodontic or surgical repositioning. The former procedure appeared in this treatment scenario to slightly reduce the risk of MA complications. However, this treatment procedure was also found to be more time demanding (an average of 22 consultations for orthodontic repositioning compared with 17 consultations for surgical repositioning). If a surgical repositioning was performed, the type of splint (i.e. flexible, semirigid or rigid) appeared to have no significant effect on the type of healing. The same applied to the length of splinting time (shorter or longer than 6 weeks). No effect of dentin covering procedures for associated crown fractures (enamel–dentin fractures) could be demonstrated. Likewise, antibiotics had no apparent effect upon healing. In conclusion, in patients with intruded teeth with incomplete root formation, spontaneous eruption should be expected. In patients

Key words: traumatic intrusion; pulp healing; periodontal healing; treatment delay; repositioning; splinting; antibiotics

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with completed root formation and with an age of 12–17 spontaneous eruption can still occur, but must be monitored very carefully. In older patients (i.e. >17 years) with completed root formation, either surgical or orthodontic extrusion should be attempted. The latter procedure appeared to lead to a slight reduction (not significant) in the risk of MA complications. The extent and direction of the intrusion may however favour surgical repositioning.

Intrusion of permanent teeth is a rare trauma entity representing 0.5–2% of traumas affecting the permanent dentition (1). This implies that experience in treatment becomes very empirical even in large trauma centers.

The intrusion injury represents an axial impact to the tooth where the energy released will drive the tooth into the alveolar process resulting in extensive injury to the periodontium and the pulp, and normally leading to a more or less extensive crown fracture (2, 3). The injury caused to the periodontium has been found often to result in root resorption (RR) and marginal bone breakdown (MA) and the associated injury to the pulp has been found to lead to pulp necrosis (PN) and arrested root formation in cases of incomplete root formation (2, 3).

The question naturally arises, whether these complications are treatment dependent. A closer look at the healing scenario may give some hints concerning such an eventual relation.

At the moment of the impact, a significant amount of energy is spent to force the tooth into its socket. In the gingival area, shearing stress will sever the gingival fibers and compressive forces in the infrabony part of the periodontium will compress and sever the periodontal ligament (PDL) and crush the alveolar socket wall. Furthermore, the tissue in the apical foramen will be severed and in case of a tooth with an open apex, socket bone will possibly be pressed into the root canal. On top of this, if a tooth with the crown covered with plaque is forced into an injured periodontium, the risk of infection exists.

For a long time, it has been known that intruded primary teeth usually re-erupt spontaneously (3). This may also take place in cases of intruded permanent teeth, especially in instances with immature root formation (3–6). Thus, a conservative observation approach can be a treatment option (3–7).

Another treatment philosophy has been to surgically reposition intruded permanent teeth and this therapeutic approach has had its proponents (8). The arguments for surgical repositioning can be that it will remove the bacteria contaminated crown surface from its position in the socket, the periradicular compression areas are released, whereby osteoclast activity around the tooth may be reduced.

Finally, a third approach has been developed where the tooth is gradually repositioned using an orthodontic appliance and thereby eliminating a part of the trauma elicited by surgical repositioning. (3, 4, 10–12).

The arguments for both spontaneous repositioning and orthodontic repositioning have been that it involves the least extra damage to the tissues and that the eruptive movement by its very nature helps the critical healing scenario in the marginal periodontium.

Today, conflicting evidence exists from the few studies published, with very limited number of teeth involved, concerning the outcome of the three treatment approaches. Thus, in some studies, a better periodontal and gingival healing was found in conservatively treated teeth (spontaneous or orthodontic reposition) vs surgical reposition (4, 13, 14). In another study, the opposite finding was made (8).

The purpose of the present project was to analyze the healing modalities based on a substantial number of intruded teeth and to study how healing complications were related to **preinjury factors**, such as sex, age, stage of root development and extent of intrusion. This part of the project has already been reported (2). The present study relates to the possible influence of **treatment factors**, such as treatment delay, method of repositioning, type of splint, length of splinting and the use of antibiotics.

Material and methods

This is third part of a report on observations of intruded permanent teeth, dealing with the influence of various treatment type upon postinjury healing. The patient material, examination procedures, treatment procedures, and definition of healing complications have been described in the

Table 1. Results and statistical univaried analysis of healing in teeth distributed according to the relevant variables

	Pulp necrosis (PN)			Root resorption (RR)			Marginal bone loss (MA)		
Treatment variables	–	+	*P-value	–	+	*P-value	–	+	*P-value
Examination delay									
≤24 h	15 (12)	106 (88)	0.32	66 (55)	55 (45)	0.11	86 (71)	35 (29)	0.04
≥24 h	1 (5)	18 (95)		7 (37)	12 (63)		9 (47)	10 (53)	
Repositioning delay									
≤24 h	2 (3)	56 (97)	0.41	30 (52)	28 (48)	0.12	28 (48)	30 (52)	0.27
≥24 h	1 (9)	10 (91)		3 (27)	8 (73)		7 (64)	4 (36)	
Repositioning method									
None	9 (24)	29 (76)	0.02	25 (66)	13 (34)	0.02	8 (100)	0 (0)	0.001
Surgical complete	3 (5)	58 (95)		30 (49)	31 (51)		31 (51)	30 (49)	
Surgical incomplete	2 (17)	10 (83)		2 (17)	10 (83)		6 (50)	6 (50)	
Orthodontic	2 (7)	27 (93)		16 (55)	13 (45)		20 (69)	9 (31)	
Reposition									
None	9 (24)	29 (76)	0.02	25 (66)	13 (34)	0.04	38 (100)	0 (0)	<0.001
Surgical	5 (7)	68 (93)		32 (44)	41 (56)		37 (51)	36 (49)	
Reposition									
None	9 (24)	29 (76)	0.09	25 (66)	13 (34)	0.53	38 (100)	0 (0)	<0.001
Orthodontic	2 (7)	27 (93)		16 (55)	13 (45)		20 (69)	9 (31)	
Reposition									
Surgical	5 (7)	68 (93)	0.99	32 (44)	41 (56)	0.41	37 (51)	36 (49)	0.14
Orthodontic	2 (7)	27 (93)		16 (55)	13 (45)		20 (69)	9 (31)	
Reposition									
Surgical complete	3 (5)	58 (95)	0.18	30 (49)	31 (51)	0.07	31 (51)	30 (49)	0.79
Surgical incomplete	2 (17)	10 (83)		2 (17)	10 (83)		6 (50)	6 (50)	
Reposition									
Surgical	5 (7)	68 (93)	0.13	32 (44)	41 (56)	0.06	37 (51)	36 (49)	<0.001
No or orthodontic	11 (16)	56 (84)		41 (61)	26 (35)		58 (88)	9 (12)	
Splinting									
No	0 (0)	14 (100)	0.38	7 (50)	7 (50)	0.61	10 (71)	4 (29)	0.04
Yes	4 (7)	50 (93)		27 (50)	27 (50)		22 (41)	32 (59)	
Splint type									
Flexible	1 (10)	9 (90)	0.96	5 (50)	5 (50)	0.54	4 (40)	6 (60)	0.07
Semirigid	7 (8)	80 (92)		39 (45)	48 (55)		57 (66)	30 (34)	
Rigid	1 (7)	14 (93)		9 (60)	6 (40)		6 (40)	9 (60)	
Splint type									
Rigid, Semirigid	8 (8)	89 (92)	0.99	44 (45)	53 (55)	0.43	61 (63)	36 (37)	0.16
Flexible	1 (7)	14 (93)		9 (60)	6 (40)		6 (40)	9 (60)	
Splinting length (days)									
7–28	1 (7)	13 (93)	0.58	8 (57)	6 (43)	0.69	6 (34)	8 (57)	0.75
29–42	2 (10)	18 (90)		8 (42)	11 (58)		9 (45)	11 (55)	
43–119	1 (3)	31 (97)		16 (49)	17 (51)		17 (53)	15 (47)	
Orthodontic extrusion time (days)									
15–42	2 (17)	10 (83)	0.56	5 (42)	7 (58)	0.95	9 (75)	3 (25)	0.98
43–75	1 (6)	16 (94)		8 (47)	9 (53)		13 (77)	4 (23)	
76–350	3 (17)	15 (83)		8 (44)	10 (56)		14 (78)	4 (22)	
Dentin coverage									
No	1 (3)	39 (97)	0.71	17 (43)	23 (57)	0.20	25 (63)	15 (37)	0.39
Yes	0 (0)	17 (100)		10 (59)	7 (41)		12 (71)	5 (29)	
Antibiotics									
No	11 (11)	86 (89)	0.58	54 (56)	43 (44)	0.14	70 (72)	27 (28)	0.08
Yes	5 (12)	38 (88)		19 (44)	24 (56)		25 (58)	18 (42)	

Number of teeth in the groups varies because exclusion of teeth with unknown value of the variable. Values are expressed as *n* (%).
*Significance of type of healing.

first part (2). In regard to splinting devices, a classification was made into **rigid** (capsplints made of silver or acrylic), **semirigid** (acid-etch composite splints, orthodontic bands united with acrylic or arch bars and arch bars fastened with 0.3 mm soft steel wires) and **flexible**, i.e acid-etch splints using a flexible resin (Protemp®, 3M, ESPE Dental Products, St Paul, MN, USA) (2, 3). Furthermore, an analysis of the influence of preinjury and injury factors has also been published in a second part (1).

In the present study, a detailed study analysis of the influence treatment variables have upon healing complications, such a PN, RR and MA and tooth loss and are based on a univariate and stratified analysis. The statistical procedures used have been described in a previous study (2). In

Table 2. Stratified analysis of clinical factors as they relate to pulp necrosis (NEC)

Preinjury and injury factors	Sex	Age	Root development	Tooth location	Crown fracture	Bone fracture	Gingival laceration	Intrusion 1–3 and >3 (mm)	Intrusion 1–7 and >7 (mm)	No. injured teeth	No. intruded teeth	Examination delay	Reposition delay	Reposition no/surg.	Reposition no/orth.	Reposition orth/surg.	Splinting rigid/flex	Splinting time	Extrusion time	Dentin coverage	Antibiotics
Sex	X	<0.001	<0.001	0.45	<0.001	0.33	0.04	0.19	0.04	0.32	0.59	0.25	0.48	0.03	0.15	0.09	0.66	0.45	0.55	0.61	0.55
Age	0.14	X	0.005	0.24	0.03	0.15	0.08	0.40	0.24	0.54	0.51	0.94	0.35	0.38	0.59	0.40	0.59	0.35	0.30	0.50	0.50
Root development	0.26	0.10	X	0.13	0.04	0.32	0.27	0.14	0.29	0.46	0.32	0.87	0.80	0.43	0.57	0.25	0.77	0.73	0.39	0.87	0.50
Tooth location	0.09	0.03	<0.001	X	0.001	0.25	0.05	0.24	0.07	0.35	0.60	0.84	0.33	0.04	0.22	0.07	0.37	0.58	0.59	0.84	0.40
Crown fracture	0.04	0.001	0.001	0.54	X	0.16	0.27	0.29	0.16	0.36	0.59	0.32	0.43	0.19	0.36	0.18	0.41	0.59	0.56	0.70	0.57
Bone fracture	0.07	0.001	<0.001	0.36	0.004	X	0.09	0.39	0.18	0.30	0.28	0.76	0.41	0.12	0.49	0.15	0.16	0.70	0.66	0.84	0.56
Gingival laceration	0.05	<0.001	<0.001	0.27	0.01	0.43	X	0.49	0.23	0.46	0.15	0.92	0.56	0.59	0.34	0.34	0.73	0.38	0.58	0.76	0.26
Intrusion 1–3 and >3 (mm)	0.03	<0.001	<0.001	0.52	0.001	0.22	0.06	X	NR	0.25	0.57	0.81	0.44	0.05	0.29	0.08	0.45	0.36	0.58	0.75	0.51
Intrusion 1–7 and >7 (mm)	0.03	0.001	<0.001	0.50	0.001	0.21	0.08	NR	X	0.31	0.52	0.85	0.37	0.04	0.28	0.08	0.49	0.48	0.65	0.67	0.53
No. injured teeth	0.04	0.001	<0.001	0.46	0.001	0.21	0.06	0.22	0.08	X	0.51	0.79	0.38	0.03	0.17	0.06	0.58	0.60	0.65	0.67	0.54
No. intruded teeth	0.06	0.005	<0.001	0.51	0.001	0.16	0.02	0.23	0.07	0.26	X	0.88	0.36	0.03	0.17	0.06	0.62	0.48	0.61	0.77	0.58
Examination delay	0.04	<0.001	<0.001	0.46	0.001	0.16	0.03	0.26	0.08	0.29	0.59	X	0.93	0.02	0.32	0.06	0.63	0.53	0.65	0.68	0.84
Reposition delay	0.24	0.11	0.003	0.56	0.11	0.34	0.29	0.65	0.60	0.71	0.57	0.99	X	0.96	0.99	0.80	0.18	0.28	0.99	0.99	0.72
Reposition no/surg.	0.05	0.005	<0.001	0.63	0.02	0.08	0.01	0.53	0.42	0.41	0.57	0.99	0.33	X	0.99	0.99	0.62	0.46	0.99	0.99	0.60
Reposition no/orth.	0.38	0.04	0.01	0.62	0.11	0.49	0.46	0.27	0.19	0.45	0.53	0.66	NR	NR	X	NR	NR	NR	0.54	0.61	0.60
Reposition orth./surg.	0.08	0.005	<0.001	0.45	0.002	0.27	0.12	0.33	0.09	0.28	0.53	0.71	0.33	NR	NR	X	0.62	0.46	0.54	0.61	0.43
Splinting method	0.07	<0.0001	<0.001	0.18	0.01	0.21	0.04	0.58	0.73	0.28	0.46	0.85	0.21	0.94	0.88	0.21	X	0.48	0.42	0.72	0.34
Splinting time	0.22	0.12	0.005	0.19	0.18	0.18	0.04	0.57	0.55	0.37	0.61	0.99	0.16	0.96	NR	0.86	0.67	X	NR	0.99	0.49
Extrusion time	0.55	0.07	0.005	0.44	0.11	0.55	0.66	0.63	0.42	0.29	0.63	0.74	0.50	NR	NR	0.49	NR	NR	X	0.64	0.62
Dentin coverage	0.52	0.23	0.17	0.29	NR	0.51	0.62	0.90	0.67	0.57	0.67	0.82	0.99	0.99	0.84	0.33	0.92	0.99	0.84	X	0.61
Antibiotics	0.06	0.03	<0.001	0.50	0.001	0.21	0.04	0.22	0.27	0.27	0.58	0.80	0.39	0.03	0.16	0.06	0.60	0.48	0.61	0.65	X
No. of significant relations	7	15	20		15		8		1				1	8							

NR, not relevant.

*An odds-ratio test that suggests that odds ratio differs significantly by stratum.

Table 3. Stratified analysis of clinical factors as they relate to root resorption (RR)

Preinjury and injury factors	Sex	Age	Root development	Tooth location	Crown fracture	Bone fracture	Gingival laceration	Intrusion 1–3 and >3 (mm)	Intrusion 1–7 and >7 (mm)	No. injured teeth	No. intruded teeth	Examination delay	Reposition delay	Reposition no/ surg.	Reposition no/ orth.	Reposition orth./ surg.	Splinting rigid/ flex	Splinting time	Extrusion time	Dentin coverage	Antibiotics
Sex	X	0.04	<0.001	0.16	0.12	0.08	0.07	0.008	0.11	0.32	0.33	0.13	0.20	0.01	0.01	0.02	0.19	0.32	0.49	0.22	0.57
Age	0.12	X	0.55	0.06	0.29	0.13	0.09	0.01	0.16	0.46	0.35	0.15	0.09	0.009	0.26	0.10	0.26*	0.29	0.55	0.46	0.14
Root development	0.20	0.12	X	0.10	0.17	0.12*	0.12	0.006	0.13	0.38	0.28	0.10	0.17	0.008*	0.22	0.05*	0.20	0.35	0.39	0.37	0.15
Tooth location	0.20	0.05	0.14	X	0.11	0.13	0.05	0.01	0.11	0.39	0.43	0.09	0.36	0.001	0.23	0.02*	0.23	0.40	0.43	0.22	0.18
Crown fracture	0.32	0.08	0.40	0.20	X	0.11	0.24	0.001	0.17	0.27	0.35	0.09	0.16	0.16	0.001	0.03*	0.68	0.24	0.61	0.20	0.10
Bone fracture	0.25	0.26	0.17	0.31	0.007	X	0.13	0.03	0.04	0.32	0.38	0.09	0.68	0.004	0.60	0.04	0.60	0.53	0.32	0.22	0.10
Gingival laceration	0.22	0.18	0.25	0.17	0.06	0.13*	X	0.14	0.07	0.21	0.11	0.13	0.62	0.01	0.13	0.06	0.63	0.24	0.38	0.33	0.29*
Intrusion 1–3 and <3 (mm)	0.33	0.10	0.18	0.17	0.18	0.13	0.18	X	NR	0.29	0.23	0.17	0.27	0.01	0.03	0.06	0.17	0.61	0.27	0.35	0.25
Intrusion 1–7 and <7 (mm)	0.32	0.10	0.30	0.13	0.16	0.10	0.13	NR	X	0.38*	0.25	0.09	0.17	0.001	0.03	0.56	0.20	0.34	0.27	0.18	0.16
No. injured teeth	0.24	0.07	0.23	0.13	0.13	0.09	0.05	0.006	0.10	X	0.26	0.05	0.17	0.001	0.01	0.03	0.04	0.36	0.42	0.22	0.15
No. intruded teeth	0.27	0.07	0.17	0.17	0.11	0.08	0.03	0.006	0.08	0.28	X	0.13	0.27	0.001	0.01	0.02	0.28	0.25	0.52	0.13	0.09
Examination delay	0.31	0.12	0.61	0.14	0.12	0.08	0.05	0.01	0.10	0.38	0.29	X	0.73	0.004	0.02	0.02	0.24	0.26	0.40	0.23	0.10
Reposition delay	0.38	0.39	0.55	0.25	0.53	0.16	0.59	0.11	0.52	0.44	0.03	0.60	X	0.51	0.99	0.30	0.34	0.35	0.99	0.38	0.13
Reposition no/surg.	0.29	0.47	0.51	0.37	0.46	0.37	0.48	0.12	0.58	0.55	0.15	0.18	0.16	X	0.16	0.99	0.16	0.32	0.99	0.57	0.29
Reposition no/orth.	0.50	0.52	0.31	0.09	0.60	0.25	0.27	0.40	0.14	0.40	0.23	0.30	NR	NR	X	NR	NR	NR	0.62	0.16	0.50
Reposition orth./surg.	0.18	0.17	0.56	0.10	0.21	0.16	0.29	0.01	0.12	0.36	0.24	0.04	0.11	NR	NR	X	0.16	0.34	0.62	0.20	0.50
Splinting method rigid/flex.	0.27	0.27	0.54	0.04	0.41	0.13	0.11	0.008	0.23	0.27	0.17	0.17	0.24	0.42	0.50	0.27	X	0.35	0.42	0.32	0.25
Splinting time	0.38	0.11	0.50	0.19	0.56	0.09	0.26	0.06	0.56	0.52	0.01	0.18	0.18	0.47	NR	0.86	0.24	X	NR	0.63	0.24
Extrusion time	0.37	0.46	0.44	0.04	0.39	0.03	0.16	0.05	0.04	0.24	0.39	0.49	0.50	NR	NR	0.04	NR	NR	X	0.33	0.25
Dentin coverage	0.51	0.17	0.23	0.61	NR	0.21	0.50	0.08	0.35	0.48	0.09	0.12	0.17	0.99	0.75	0.23	0.31	0.14	0.23	X	0.13
Antibiotics	0.25	0.06	0.23	0.12	0.11	0.13	0.11	0.01	0.11	0.38	0.21	0.52	0.13	0.002	0.01	0.04	0.14	0.31	0.38	0.20	X
No. of significant relations		3	1	2	1	1	1	13	1		2	2		12	9	10	0				

NR, not relevant.

*An odds-ratio test that suggests that odds ratio differs significantly by stratum.

Table 4. Stratified analysis of clinical factors as they relate to marginal bone loss (MA)

Preinjury and injury factors	Sex	Age	Root development	Tooth location	Crown fracture	Bone fracture	Gingival laceration	Intrusion 1–3 and >3 (mm)	Intrusion 1–7 and >7 (mm)	No. injured teeth	No. intruded teeth	Examination delay	Reposition delay	Reposition no/ surg.	Reposition no/ orth.	Reposition orth./ surg.	Splinting rigid/ flexible	Splinting time	Extrusion time	Dentin coverage	Antibiotics
Sex	X	<0.001	<0.001	0.02	0.33	0.22	<0.001	0.13	0.04	0.02	0.03	0.02	0.26	0.001	0.06	<0.001*	0.49	0.28	0.18	0.61	0.08
Age	0.09	X	0.03	0.04	0.13	0.09	0.02	0.33	0.43	0.11	0.01	0.64	0.47	0.008	0.13	0.05	0.13	0.49	0.25	0.47	0.08
Root development	0.16	<0.004	X	0.06	0.21	0.31	0.06	0.14	0.27	0.03	0.08	0.42	0.24	0.007	0.22	0.005	0.53	0.28	0.12	0.26	0.08
Tooth location	0.07*	<0.001	<0.001	X	0.16	0.10	0.007	0.18	0.04	0.04*	0.13	0.43	0.13*	<0.001	0.29	<0.001	0.54	0.33	0.41	0.42	0.10
Crown fracture	0.02	<0.001	<0.001	0.01	X	0.06	0.01	0.30	0.12	0.02	0.01	0.04	0.18	<0.001	0.19	<0.001	0.57	0.45	0.50	0.39	0.06
Bone fracture	0.26	<0.001	<0.001	0.002	0.14	X	0.01	0.28	0.05	0.02	0.05	0.09	0.38	0.001	0.57	<0.001	0.39	0.25	0.54	0.42	0.25
Gingival laceration	0.17	<0.001	<0.001	0.006	0.31	0.56	X	0.32	0.07	0.04	0.14	0.26	0.16	0.006	0.01	0.01	0.39	0.04	0.54	0.40	0.26
Intrusion 1–3 and <3 (mm)	0.03	<0.001	<0.001	0.01	0.37	0.22	0.02	X	NR	0.01	0.04	0.45	0.16	0.001	0.12	<0.001	0.61	0.34	0.38	0.47	0.10
Intrusion 1–7 and <7 (mm)	0.02	<0.001	0.01	<0.001	0.42	0.20	0.02	NR	X	0.02	0.04	0.41	0.19	0.03	0.01	<0.001	0.50	0.35	0.44	0.45	0.09
No. injured teeth	0.05	<0.001	<0.001	0.02	0.41	0.22	0.02	0.13	0.10	X	0.10	0.28	0.19	0.001	0.07	<0.001	0.49	0.21	0.25	0.43	0.10
No. intruded teeth	0.04	<0.001	<0.001	0.03	0.39	0.32	0.04	0.22	0.13	0.05	X	0.26	0.27	0.001	0.08	<0.001	0.12	0.27	0.40	0.55	0.46
Examination delay	0.02	<0.001	<0.001	0.02	0.37	0.06	0.001	0.23	0.09	0.01	0.03	X	0.24	<0.001	0.16	<0.001	0.06	0.34	0.15	0.41	0.06
Reposition delay	0.04	0.02	0.08	0.09	0.26	0.22	0.20	0.44	0.27	0.08	0.03	0.99	X	0.48	0.99	0.46	0.34	0.43	0.99	0.54	0.10
Reposition no/surg.	0.02	0.001	0.005	0.10	0.45	0.27	0.10	0.51	0.12	0.01	0.01	0.54	0.33	X	0.72	0.99	0.32	0.42	0.99	0.57	0.10
Reposition no/orth.	0.54	0.003	0.03	0.12	0.34	0.44	0.46	0.47	0.56	0.40	0.50	0.02	NR	NR	X	NR	NR	NR	0.33	0.99	0.36
Reposition orth/surg.	0.09	<0.001	<0.001	0.01	0.47	0.37	0.11	0.40	0.13	0.01	0.06	0.13	0.33	NR	NR	X	0.32	0.27	0.33	0.53	0.36
Splinting method rigid/flex.	0.05	<0.001	<0.001	0.07	0.36	0.29	0.01	0.55	0.26	0.01	0.12	0.33	0.24	0.03	0.78	0.004	X	0.35	0.46	0.35	0.28
Splinting time	0.04	0.01	0.42	0.33	0.26	0.03	0.01	0.57	0.17	0.05	0.05	0.71	0.42	0.50	NR	0.09	0.24	X	NR	0.52	0.35
Extrusion time	0.45	0.001	0.006	0.06	0.61	0.62	0.46	0.46	0.62	0.09	0.53	0.12	0.50	NR	NR	0.28	NR	NR	X	0.34	0.38
Dentin coverage	0.007	0.007	0.002	0.16	NR	0.59	0.56	0.36	0.07*	0.06	0.03	0.40	0.26	0.60	0.87	0.01	0.35	0.06	0.65	X	0.06
Antibiotics	0.03	<0.001	0.01	<0.001	0.32	0.29	0.01	0.22	0.10	0.01	0.06	0.20	0.23	<0.001	0.64	<0.001	0.10	0.35	0.38	0.47	X
No. of significant relations	12	20	18	12		1	15		3	15	11	3		14	2	15		1			

NR, not relevant.
*An odds-ratio test that suggests that odds ratio differs significantly by stratum.

this study, apart from the univariable analysis (Table 1), a stratified analysis was added and this analysis is found in Tables 2–4. This analysis was carried out in the way that the frequency of a given complication (PN, RR or MA) was registered for various variables (e.g. sex). If a significant association exists in the univariate analysis may this also exist, if sex is divided for instance into age groups, or root development groups? Thus, Tables 2–4 should be entered along a vertical column (e.g. sex). At the bottom of each column the number of significant relations are shown for each correlation between each complication (PN, RR or MA) and the examined variable (e.g. sex) and related to other examined variables. In addition, a Kaplan–Meier survival analysis was made of how teeth with incomplete and complete root development 'survived' in relation to PN, RR, MA and tooth loss and in relation to reposition procedure used. This analysis was not considered reliable after 15 years due to the limited numbers of cases seen after this period.

Results

Univariate analysis

Treatment delay
A 1-day delay appeared only to result in a slight worsening of MA. However, the stratified analysis showed that this very well could be related to the fact that more complex cases (multiple intrusions) had a longer treatment delay (Tables 1 and 4).

Reposition delay
No significant relation was found in relation to complications occurring without or with a 1-day reposition delay (Table 1).

Reposition method
It appeared that non-repositioned teeth had an overall better chance of avoiding both PN, RR and MA (Tables 1–4). A comparison was also performed between incomplete and complete surgical repositioning and no difference was found in relation to healing; however, a trend was found that complete repositioning showed less resorption (RR – see Table 1).

In case of no repositioning total eruption took place with a median of 6.3 months and with a range of 2–13 months. In case of orthodontic reposition, this took place with a median of 2 months and a range of 1 1/2–13 months. Concerning the total number of treatment appointments, no repositioning accounted for an average of 17, surgical repositioning for 18 and orthodontic repositioning for 22 (the last procedure being significantly higher than the others ($P = 0.01$).

Splint type
In case of surgical repositioning, three different splint types (flexible, semirigid and rigid) were used and no significant effect upon healing was found (Table 1).

Splinting time
No difference was found in healing association to this variable (Table 1).

Table 5. Effect of reposition method upon healing at various ages

	Pulp necrosis (PN)		Root resorption (RR)		Marginal bone loss (MA)	
	0	+	0	+	0	+
Age 6–11						
No repositioning	9 (39)	23	22 (68)	10	32 (100)	0
Surgical repositioning	5 (19)	22	13 (48)	14	20 (74)	7
Orthodontic repositioning	2 (14)	12	8 (57)	6	13 (93)	1
P-value between all reposition types	0.50		0.27		0.005	
P-value in comparison between surgical and orthodontic methods of repositioning	0.99		0.82		0.22	
Age 12–17						
No repositioning	0 (0)	6	3 (50)	3	6 (100)	0
Surgical repositioning	0 (0)	21	6 (29)	15	9 (43)	12
Orthodontic repositioning	0 (0)	3	1 (33)	2	0 (0)	3
P-value between all reposition types	0.99		0.61		0.008	
P-value in comparison between surgical and orthodontic methods of repositioning	0.99		0.79		0.26	
Age 18–67						
Surgical repositioning	0 (0)	25	13 (52)	12	8 (32)	17
Orthodontic repositioning	0 (0)	12	7 (58)	5	7 (58)	5
P-value between both reposition types	0.99		0.99		0.16	

Values are expressed as *n* (%).

Table 6. Effect of reposition method upon healing at various stages of root development

	Pulp necrosis (PN)		Root resorption (RR)		Marginal bone loss (MA)	
	0	+	0	+	0	+
Root development 2–4						
No repositioning	8 (28)	20	18 (64)	10	28 (100)	0
Surgical repositioning	4 (57)	3	3 (43)	4	6 (86)	1
Orthodontic repositioning	3 (33)	6	4 (50)	4	7 (88)	1
P-value between all reposition types	0.31		0.51		0.14	
P-value in comparison between surgical and orthodontic methods of repositioning	0.61		0.99		0.99	
Root development 5–6						
No repositioning	1 (10)	9	7 (70)	3	10 (100)	0
Surgical repositioning	1 (1)	65	29 (42)	37	31 (47)	35
Orthodontic repositioning	0 (0)	21	12 (57)	9	62 (65)	8
P-value between all reposition types	0.16		0.22		0.005	
P-value in comparison between surgical and orthodontic methods of repositioning	0.85		0.42		0.34	

Values are expressed as *n* (%).

Orthodontic extrusion time
No significant association was found in relation to this variable (Table 1).

Dentin coverage
No significant difference was found whether dentin coverage was performed or not in case of teeth with associated enamel–dentin fractures (Table 1).

Antibiotic coverage
No significant difference in healing whether antibiotics was used or not (Table 1).

Stratified analysis

Pulp necrosis
In the stratified analysis, sex, age, root development, crown fracture, gingival laceration and repositioning could be considered important factors (Table 2). In this regard sex could be eliminated, as sex was a confounding factor and age and root development was naturally closely related and both significantly related to PN. A crown fracture with dentin exposure was strongly related to an increased risk of PN and the same applied to gingival laceration.

Finally repositioning, whether none or surgical, was of importance favoring no repositioning for pulp survival (Table 2).

Root resorption
This complication was strongly related extent of intrusion (i.e. ≤ or >3 mm.)

No reposition appeared to protect the most against resorption, finally orthodontic reposition showed a significantly better protection against resorption than surgical reposition (Table 3).

Marginal bone loss
In the stratified analysis, increasing age and root development increased the risk of MA (Table 4). Furthermore, the lateral incisor appeared to have an increased risk of MA. Also, gingival laceration and number of intruded teeth had an influence.

The factor 'no repositioning' gave significant better healing in comparison with orthodontic repositioning and also had a more favorable outcome than surgical repositioning (Table 4).

Kaplan–Meier survival analysis of repositioning methods

In this analysis, the patients were divided in two groups according to stage of root development. It appears that for all healing parameters PN: Figs 1, 4, RR: Figs 2, 5 and MA: Figs 3, 6, 'no reposition-

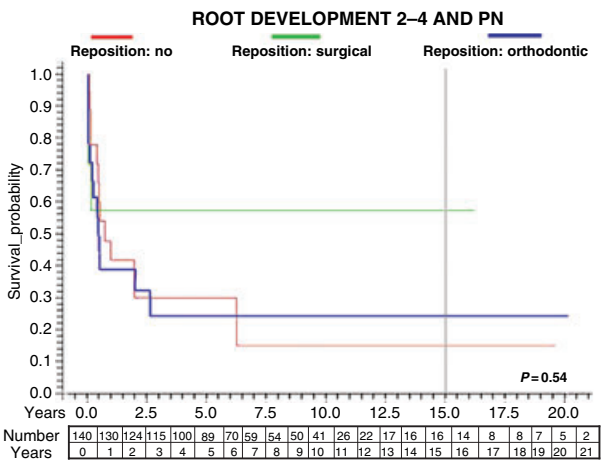

Fig. 1. Survival analysis of teeth with incomplete root formation and pulp necrosis related to treatment.

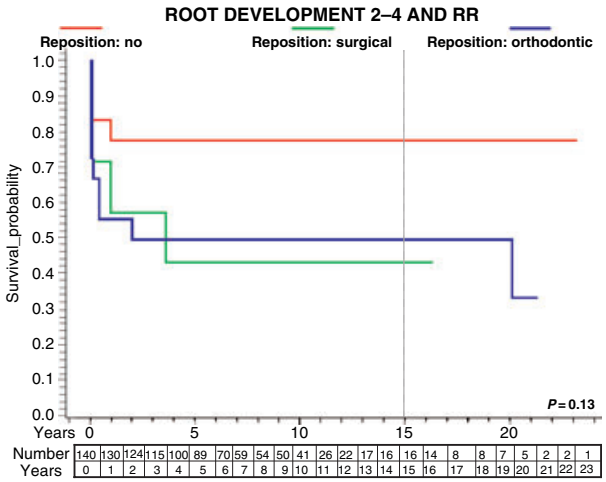

Fig. 2. Survival analysis of teeth with incomplete root formation and root resorption related to treatment.

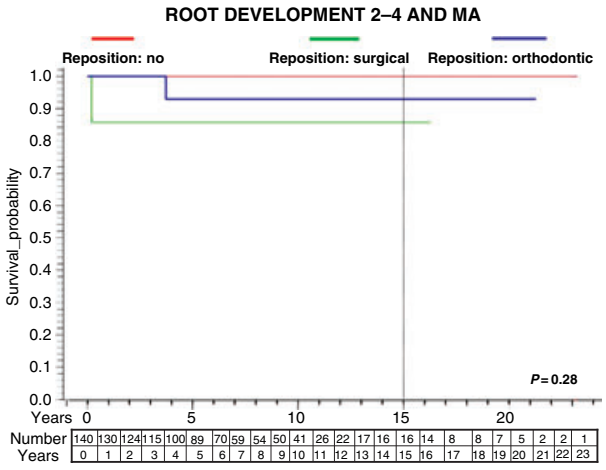

Fig. 3. Survival analysis of teeth with incomplete root formation and marginal breakdown related to treatment.

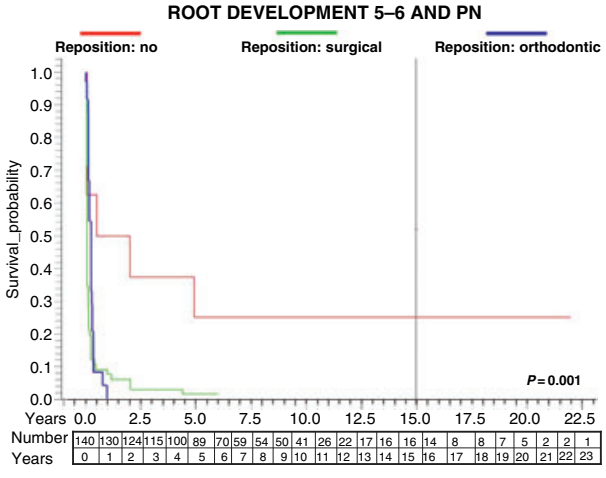

Fig. 4. Survival analysis of teeth with complete root formation and pulp necrosis related to treatment.

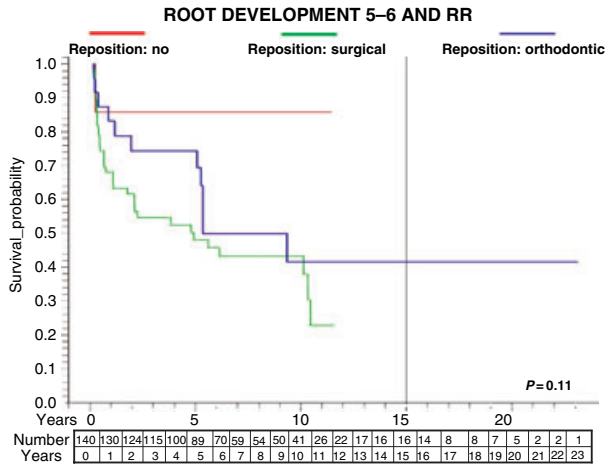

Fig. 5. Survival analysis of teeth with complete root formation and root resorption related to treatment.

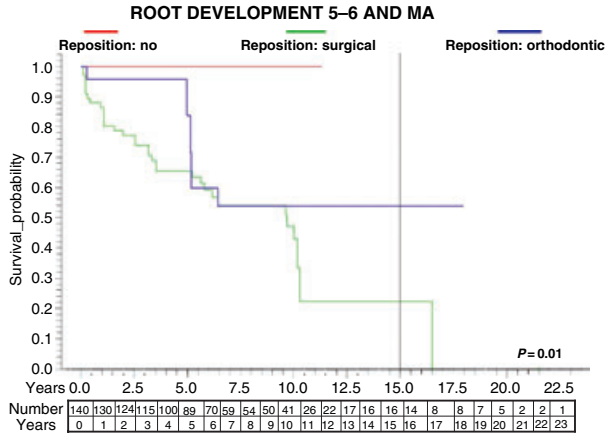

Fig. 6. Survival analysis of teeth with complete root formation and marginal breakdown related to treatment.

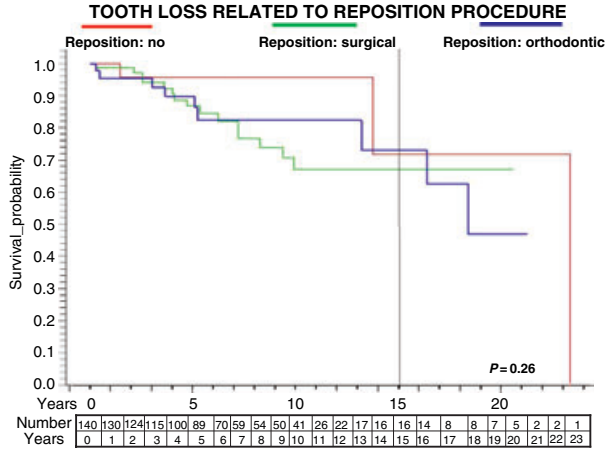

Fig. 7. Tooth loss related to repositioning procedure.

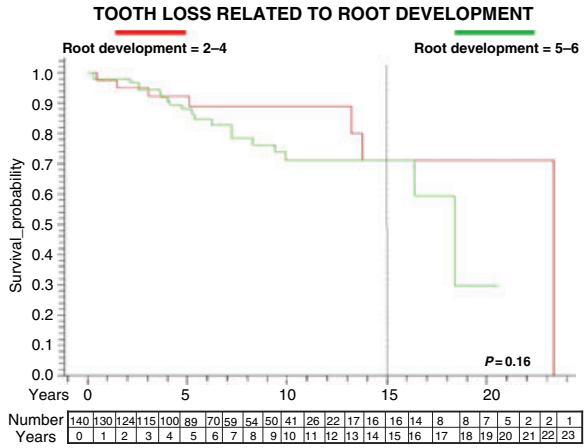

Fig. 8. Tooth loss related to root development. Note that after 15 years there is still odds rate of 70%.

ing' came up with the best results. One exception was surgical reposition in teeth with incomplete root formation (stage 2–4). However, this group consisted of only seven teeth and the difference was not significant (Table 7, Fig. 1).

Very little difference was found between orthodontic and surgical repositioning in relation to NEC RR, MA and tooth survival (Figs 1–7).

Initially teeth with incomplete root formation showed better tooth survival, however this difference disappeared after 15 years observation (Fig. 8).

Repositioning related to trauma scenario

An analysis was done to look at the various treatment procedures and how they might influence a given trauma scenario defined by given stages of root development, age and intrusion depth (Tables 5 and 6).

Age

In the age groups 6–12 and 12–17 years, 'no repositioning' had the best prognosis in regard to MA (above 17 years, this treatment approach was not attempted) (Table 5). At all ages, there was no significant difference between orthodontic and surgical repositioning (Table 5).

Root development

In cases with incomplete root formation (stage 2–4) 'no repositioning' showed a slight but not significant preference for more optimal healing (Table 6). In teeth with complete root formation (stage 5 and 6) 'no repositioning' showed a significant, more optimal marginal healing (MA) (Table 6).

Dislocation

For dislocation up to 3 mm or exceeding 3 mm a significantly better MA healing was found for 'no repositioning' compared with surgical and orthodontic reposition and with a little preference to orthodontic repositioning in this situation. The same finding with preference of 'no repositioning' and a little preference of orthodontic repositioning compared to surgical (Table 7) was made for dislocation up to or exceeding 7 mm.

Discussion

In the literature, there is no consensus whether to await for spontaneous repositioning, or perform surgical repositioning or reposition by orthodontic means (3–15). Most of these discrepancies can possibly be related to the relatively few cases examined (usually 30–60 cases) and materials with selected age groups (i.e. young children) (5–9, 12, 14, 15). In the present study, a substantial number of cases were examined ($n = 140$) and patients in all age groups were included (age ranges 6–67).

Delay in examination and repositioning

This factor appeared not to be a significant factor but apparently reflected the severity of the injury. This implies that intruded permanent teeth generally do not demand an acute treatment approach. This is a finding that should be included in future treatment guidelines (16).

The value of repositioning

From a theoretical point of view, repositioning may relieve compression zones in the periodontal and pulpal area and thereby facilitate healing. Secondly, the creation of the distance between the root surface and the contused bone socket may favor cemental healing instead of ankylosis (17, 18). The other side of the healing scenario might be that repositioning of an intruded tooth may represent a new trauma in itself, and in this regard may add to the risk of healing complications.

'No repositioning' (awaiting spontaneous eruption) was found to result in superior healing results up to the age of 12 for MA. After 12–17 years of age spontaneous eruption still appeared to be optimal; however, very few cases here treated that way ($n = 6$). Above the age of 17, this treatment was not attempted. This may imply that both orthodontic and surgical repositioning may represent a certain extra trauma, which may be linked to an increase in healing complications.

The overall results of orthodontic repositioning in relation to healing parameters seems comparable

with a previous study on the outcome of this procedure (13).

A comparison between surgical and orthodontic reposition showed a slight preference (but not significant) in healing of the MA, a phenomena, which could be related to the bone inducing capacity of erupting teeth (17, 18).

In a recent study reported by AlBadri et al. (12) of 61 intruded teeth, it was found that treatment factors had very little if any influence upon periodontal healing. However, in that study 'no repositioning' and orthodontic repositioning was compared as one group contrasted with surgical repositioning. By combining the first two groups, a separate treatment effects of no repositioning may have been masked.

In another study by Humphrey et al. (13), of 31 intruded teeth, no healing difference could be seen between the above mentioned three groups; however, the limited number of teeth may have masked a difference between the three treatment groups.

Comparison between orthodontic and surgical repositioning

No significant difference was found between the two treatment approaches when spontaneous repositioning was not attempted. As the latter approach is a much less time demanding process this should be the treatment of choice.

Complete or incomplete surgical repositioning

A slightly better PDL healing (not significant) was found after complete repositioning (Table 1) and this approach should therefore be the treatment of choice.

Splinting type

When splinting was used to stabilize surgically repositioned teeth, three different types of splints were tested. The statistical analysis showed no difference in the treatment outcome (PN, RR and MA) among those. In a special analysis, it was tested whether flexible and semirigid compared to rigid splinting showed any difference in healing, and this could not be demonstrated. This is in contrast to a recent finding on the effect of non-rigid vs. rigid type of splinting in case of root fracture (19). Presently no explanation can be given for this discrepancy, however the difference in trauma/scenario should be considered.

Splinting length

No significant finding was found in the relation to the length of splinting. It may therefore be indicated to keep a relatively short splinting time, i.e. 6–8 weeks, which may be necessary to lead to remodeling and healing of the contused alveolar socket. It should be examined in a future study whether splinting length can be reduced.

Dentin coverage

This study could not demonstrate a positive effect of dentin coverage. However, in this regard, it should considered that very few cases ($n = 17$) had a coverage of exposed dentin to prevent bacteria invasion. Furthermore, very few cases in general had pulp survival. Therefore, it is not reasonable at the present time to detract from the general treatment philosophy that exposed dentin should be sealed in order to prevent bacteria invasion through dentinal tubules into an ischemic pulp (20).

Antibiotics

The lack of effect of antibiotics upon pulpal or periodontal healing is in accordance with previous studies on root fractures (20) and replantation of avulsed teeth (21, 22). The explanation for a lack of positive findings could be that the main responsible factor for healing complication in this type of dental trauma is contusion of PDL and pulpal ischemia, factors that are not likely to be influenced by antibiotics. Another factor, that cannot be ruled out, is that the type of bacteria generally involved in complications are not sensitive to penicillin (which was the drug given). The last explanation is open for discussion and should be examined. Finally, the location of bacteria in traumatized teeth could present an obstacle for antibiotics to reach such areas with poor circulation (PDL and pulp).

General conclusion

Intruded permanent teeth are to some degree treatment dependent and this association may lead to the question of active reposition or not. In regard to healing (PN, RR and MA), no repositioning and awaiting spontaneous repositioning in teeth with incomplete root formation resulted in the lowest number of complications. Concerning complete root formation, only six cases were attempted but all showed spontaneous reposition (stages 5 and 6). The following treatment advices should primarily be based on root development age and the extent of intrusion (Table 7).

Teeth with immature root development: await spontaneous eruption.

Teeth with mature root formation and the patient having an age of 12–17: await spontaneous erup-

Table 7. Effect of reposition method upon healing at various intrusion depths

	Pulp necrosis (PN)		Root resorption (RR)		Marginal bone loss (MA)	
	0	+	0	+	0	+
Up to 3 mm						
No repositioning	4 (33)	8	9 (75)	3	12 (100)	0
Surgical repositioning	0 (0)	11	8 (72)	3	6 (54)	5
Orthodontic repositioning	1 (14)	6	5 (71)	2	5 (72)	2
P-value between all reposition types	0.09		0.98		0.03	
P-value in comparison between surgical and orthodontic methods of repositioning	0.38		0.63		0.63	
>3 mm						
No repositioning	5 (19)	21	16 (61)	10	26 (100)	0
Surgical repositioning	5 (8)	57	24 (39)	38	31 (50)	31
Orthodontic repositioning	1 (5)	21	11 (50)	11	15 (68)	7
P-value between all reposition types	0.17		0.13		<0.001	
P-value in comparison between surgical and orthodontic methods of repositioning	0.99		0.50		0.22	
Up to 7 mm						
No repositioning	9 (29)	24	23 (69)	10	33 (100)	0
Surgical repositioning	4 (7)	50	24 (44)	30	30 (56)	24
Orthodontic repositioning	2 (9)	19	13 (61)	8	14 (66)	7
P-value between all reposition types	0.02		0.05		<0.001	
P-value in comparison between surgical and orthodontic methods of repositioning	0.99		0.27		0.53	
>7 mm						
No repositioning	0 (0)	5	2 (40)	3	5 (100)	0
Surgical repositioning	1 (5)	18	8 (42)	11	7 (37)	12
Orthodontic repositioning	0 (0)	8	3 (37)	5	6 (75)	2
P-value between all reposition types	0.70		0.97		0.01	
P-value in comparison between surgical and orthodontic methods of repositioning	0.99		0.59		0.10	

Values are expressed as *n* (%).

Table 8. Treatment suggestions according to trauma scenarios

		Reposition		
	Age (years)	Spontaneous	Orthodontic	Surgical
Root development incomplete	6–11			
	Up to 7 mm	XXXX		
	>7 mm	XXXX	X	XX
Root development complete	12–17			
	Up to 7 mm	XXX		
	>7 mm		X	XX
Root development complete	>17			
	Up to 7 mm		X	XX
	>7 mm		X	XX

XXXX, treatment procedure significantly the best healing; XXX, treatment procedure has a tendency for better healing; XX, treatment procedure practical to use in relation to the endodontic procedure and for simplicity of treatment; X, treatment procedure acceptable.

tion. In both of the above situations, careful monitoring is essential. Above 17 years of age perform orthodontic or surgical reposition. The former procedure appears to lead to a slightly reduced risk of MA but is more complicated to carry out (Table 5).

The above mentioned treatment advice should however only be used as rough guidelines and the extent and direction of displacement may change the treatment choice. Thus, in teeth with completed root formation, total intrusion (i.e. with the incisal edge at or below bone level) surgical repositioning should be the preferred treatment as spontaneous eruption may be prevented by mucosal closure of the intrusion wound. Furthermore, multiple intrusions, especially with labial displacement (i.e. fracture of labial bone), are possibly best treated with surgical repositioning of both teeth and labial bone (1).

Finally central incisors with complete intrusion and penetration into the nasal cavity should also be treated by surgical means (3).

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References

1. Andreasen JO, Bakland L, Andreasen FM. Traumatic intrusion of 140 teeth. 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. Part 2. Dent Traumatol 2006;22:90–98.
2. Andreasen JO, Bakland L, Matras R, Andreasen FM. Traumatic intrusion of permanent teeth. A epidemiologic study of 216 intruded permanent teeth. Part 1. Dent Traumatol 2006;22:83–89.

3. Andreasen JO, Andreasen FM. Luxation injuries. In: Andreasen JO, Andreasen FM, editors. Textbook and color atlas of traumatic dental injuries, 3rd edn. Copenhagen: Munksgaard; 1994. p. 340–382.
4. Andreasen FM, Vestergaard-Pedersen B. Prognosis of luxated permanent teeth – the development of pulp necrosis. Endod Dent Traumatol 1985;1:207–20.
5. Jacobsen I. Clinical follow-up study of permanent incisors with intrusive luxation after acute trauma. J Dent Res 1983;62:486 (abstract no. 37).
6. Jacobsen I. Long-term prognosis of traumatized teeth in children and adolescents. In: Andreasen JO, Andreasen FM, Sjöström O, Eriksson B, editors. Proceedings of the 2nd International Conference on Dental Trauma. Stockholm: Bohusläningens Boktryckeri; 1991. p. 44–52.
7. Barrett E, Humphrey JA, Kenny D. An analysis of outcomes following intrusion of permanent maxillary incisors in children. Int J Paediatr Dent 1999;9:14–22.
8. Kinirons MJK, Succliffe J. Traumatically intruded permanent incisors: a study of treatment and outcome. Br Dent J 1991;170:144–6.
9. Kinirons MJ. UK national clinical guidelines in paediatric dentistry. Int J Paediatr Dent 1998;8:165–8.
10. Spalding PM, Fields HW, Torney D, Cobb HB, Johnson J. The changing role of endodontics and orthodontics in the management of traumatically intruded permanent incisors. Pediatr Dent 1985;7:104–10.
11. Malmgren O, Malmgren B, Goldson L. Orthodontic management of the traumatized dentition. In: Andreasen JO, Andreasen FM, editors. Textbook and color atlas of traumatic injuries to the teeth, 3rd edn. Copenhagen: Munksgaard; 1994. p. 617–20.
12. Chaushu S, Shapiro J, Heling J, Becker A. Emergency orthodontic treatment after the traumatic intrusive luxation of maxillary incisors. Am J Orthod Dentofacial Orthop 2004;126:162–72.
13. Humphrey JM, Kenny DJ, Barret EJ. Clinical outcomes for permanent incisor luxation in a pediatric population. I. Intrusions. Dent Traumatol 2003;19:266–73.
14. Ebeleseder KA, Santler G, Glockner K, Hulla H, Pertl C, Quenhenberger F. An analysis of 58 traumatically intruded and surgically extruded permanent teeth. Endod Dent Traumatol 2000;16:34–39.
15. Al-Badri S, Kinirons M, Cole BOI, Welbury RR. Factors affecting resorption in traumatically intruded permanent incisors in children. Dent Traumatol 2002;18:73–76.
16. Flores MT, Andreasen JO, Bakland LK. Guidlines for the evaluation and management of traumatic dental injuries. Dental Traumatol 2001;17:145–8.
17. Andreasen JO. Interrelation between alveolar bone and periodontal ligament repair after replantation of mature permanent incisors in monkeys. J Periodont Res 1981;16:228–35.
18. Andreasen JO. Periodontal healing after replantation and autotransplantation of incisors in monkeys. Int J Oral Surg 1981;10:54–61.
19. Andreasen JO, Andreasen FM, Mejáre I, Cvek M. Healing of 400 intra-alveolar root fractures. 2. Effect of treatment factors such as treatment delay, repositioning, splinting type and period and antibiotics. Dent Traumatol 2004;20;203–11.
20. Cvek M. Endodontic management of traumatized teeth. In: Andreasen JO, Andreasen FM, editors. Textbook and color atlas of traumatic injuries to the teeth, 3rd edn. Copenhagen: Munksgaard; 1994. p. 517–79.
21. Andreasen JO, Borum M, Jacobsen HL, Andreasen FM. Replantation of 400 avulsed permanent incisors II. Factors related to pulp healing. Endod Dent Traumatol 1995;11:59–68.
22. Andreasen JO, Borum M, Jacobsen HL, Andreasen FM. Replantation of 400 avulsed permanent incisors IV. Factors related to periodontal ligament healing. Endod Dent Traumatol 1995;11:76–89.