

Intrusive luxation of 60 permanent incisors: a retrospective study of treatment and outcome

Georgios Tsilingaridis¹, Barbro Malmgren^{1,2}, Jens O. Andreasen³, Olle Malmgren⁴

¹Department of Paediatric Dentistry, Eastmaninstitutet; ²Department of Clinical Science, Intervention and Technology, Division of Paediatrics, Karolinska University Hospital, Huddinge, Stockholm, Sweden; ³Department of Oral and Maxillofacial Surgery, Resource Centre for Rare Oral Diseases, University Hospital, Copenhagen, Denmark; ⁴Orthodontic Clinic, Folk tandvården, Uppsala, Sweden

Correspondence to: Georgios Tsilingaridis, Department of Paediatric Dentistry, Eastmaninstitutet, Dalagatan 11, S-113 24 Stockholm, Sweden
Tel.: +46 8 12316540
Fax: +46 8 348272
e-mail georgios.tsilingaridis@ki.se
Accepted 23 October, 2011

Abstract – Background/Aim: Intrusive luxation in the permanent dentition is an uncommon injury but it is considered one of the most severe types of dental trauma because of the risk for damage to the periodontal ligament, pulp and alveolar bone. Management of intrusive luxation in the permanent dentition is controversial. The purpose of this study was to evaluate pulp survival and periodontal healing in intrusive luxated permanent teeth in relation to treatment alternatives, degree of intrusion and root development. **Material and Method:** The material consisted of 60 intruded permanent teeth in 48 patients (32 boys and 16 girls) aged 6–16 years (mean 9.4, median 9.0). The observation time was 6–130 months (mean 47.8, median 40.0). The analysed treatments were spontaneous re-eruption (17 teeth), orthodontic extrusion (12 teeth) and surgical reposition (31 teeth). The degree of intrusion was registered as mild (0–3 mm), moderate (4–6 mm) and severe (≥ 7 mm). Root development was categorized with respect to root formation and development of the apex into four stages; one-quarter to three-quarters root formation, full root formation with open apex, full root formation with half-closed apex and full root formation with apex closed. Ankylosis-related resorption with pulp necrosis was diagnosed in 20 teeth, ingrowth of bone apically in two teeth, pulp necrosis without ankylosis-related resorption in 23 teeth and pulp revitalization occurred in 15 teeth. **Results:** Significant correlations to the treatment outcome were root development ($P = 0.03$) and degree of intrusion ($P = 0.03$). **Conclusions:** No firm conclusion could be drawn for the difference in outcome between orthodontic extrusion and surgical reposition. To conclude, evaluation of the prognosis for intruded teeth should be based on the stage of root development and degree of intrusion. In teeth with immature root development, no active treatment appears to result in fewer healing complications.

An intrusive luxation is defined as a dislocation of the tooth in an apical direction into the socket (1). It is considered one of the most severe types of dental injuries to the teeth because it might cause great damage to the periodontal ligament (PDL), the pulp and the alveolar bone. Intrusive luxation in the permanent dentition is an uncommon dental injury, with a frequency of 0.5–1.9% of all dental injuries (2, 3). Periodontal regeneration may occur in moderate intrusions, but complications like pulp necrosis, infection-related (inflammatory) root resorption, ankylosis-related resorption (replacement resorption) and marginal bone loss are frequent (4). Pulp canal obliteration is common but should be considered as sign of a revitalization of the pulp.

Acute management of an intruded tooth in the young permanent dentition is restricted to three treatment strategies, *spontaneous re-eruption*, *orthodontic repositioning* and *surgical repositioning*. The most significant factors reported for the outcome are type of treatment, degree of root development and degree of intrusion (5–11). There is, however, no consensus about the optimal treatment to minimize the occurrence of complications.

Andreasen et al. (7) concluded that in teeth with immature root development, spontaneous re-eruption should be awaited, in teeth with mature root development in patients in the age interval 12–17, spontaneous re-eruption could be awaited and finally in patients older than 17 with mature root formation, orthodontic or surgical repositioning should be performed. Also Wigen et al. (12) recommended spontaneous re-eruption in 6- to 12-year-old children.

It is important to remember that these recommendations are based on subjective opinions and not on currently supported evidence-based clinical facts.

Children aged 6–12 years are most frequently involved in intrusions (13, 14). Complications are particularly difficult to handle in these young growing patients with various degrees of somatic maturity, and skeletal, dental and occlusal development. It is therefore important to report knowledge of the outcome of different treatment strategies to eventually create consensus.

The aim of this study was to evaluate treatment alternatives in relation to pulp survival, periodontal

healing, degree of intrusion and root development in intrusive luxated permanent teeth.

Material and methods

The study population comprised 70 patients with intrusive luxation injuries consecutively referred from the Public Dental Health Services in Stockholm to the Department of Paediatric Dentistry, at the Eastman Institute in Stockholm during the period 1977–2007. Clinical data were extracted from patient records with the same protocol as in the studies described by Andreassen et al. (2, 5, 7). Of the total study group, 22 were excluded because of incomplete information. The final group of subjects consisted of 48 patients (32 boys and 16 girls) aged 6–16 years (mean 9.4, median 9.0). Altogether 54 central incisors, four lateral incisors and two canines were included. In 37 patients, one tooth was intruded, in 10 patients two and in one-three intruded teeth, totally 60 teeth. The observation period varied from 6 to 130 months (mean 47.8, median 40.0).

Radiographic documentation

A standardized long-cone radiographic technique was used.

The extent of intrusion was measured to the nearest millimetre with a sliding calliper on the most reliable radiograph as the difference in level of the cementum–enamel junction of the intruded tooth and the homologous control (2) (Fig. 1). All radiographs were examined independently by two of the authors (G.T, B.M.). In patients with more than one incisor intruded, the assessment was made from a combination of radiographs, clinical photos and records. The degree of intrusion was classified as mild (1–3 mm), moderate (4–6 mm) and severe (≥ 7 mm). Twenty-three radiographs, randomly selected from the material, were used for double determination of the classification. Kappa statistics was used for the evaluation. An almost perfect agreement was found (Kappa = 0.90) (15).

Stage of root development (Fig. 2): The stage of root development was classified as: 1 = one-quarter root formation, 2 = one-half root formation, 3 = three-quarters root formation, 4 = full root formation, open apex, 5 = full root formation, half-closed apex and 6 = full root formation, apex closed (2). Stages 1–3 were pooled in the final statistical analysis. Double determination of the root development stages on the same 23 radiographs as above showed complete agreement.

Treatment

Three types of treatment were registered: no active treatment (spontaneous re-eruption), orthodontic extrusion and surgical reposition. A combination of surgical treatment and orthodontic extrusion was performed in four teeth. Two of these were luxated with the fingers and two were treated with gingival exposure followed by orthodontic repositioning. These four teeth were included in the orthodontic treatment group. Two teeth in the orthodontic treatment group started their treatment



Fig. 1. Measurement of intrusion. The extent of intrusion was measured at enamel/cementum borders between the intruded tooth and the homologous no injured control to the nearest mm with a sliding caliper on the most reliable radiograph.

21 days and 4 months, respectively, after the initial trauma. The reason for delay was awaiting spontaneous re-eruption or late referral.

Splinting of the surgically repositioned teeth was performed with a flexible splint (Kevlar splint and flexible orthodontic wire). The splinting period ranged from 6 to 80 days (mean 28.9 days, median 25 days). When systemic antibiotic treatment was applied penicillin in doses of 1 g twice daily for 1 week was used.

Diagnostic criteria for pulpal and/or periodontal healing

The following criteria for pulpal and/or periodontal healing were used (4).

Pulp revitalization: Positive sensibility reaction, normal tooth colour and normal periradicular condition including continued root formation and obliteration.

Teeth with ingrowth of bone and PDL through the apex were also considered as being revitalized.

Pulp necrosis: No reaction to electric stimulation combined with periapical radiolucency and/or inflammatory resorption and/or crown discoloration.

Normal periodontal healing: Equal mobility of the injured tooth in comparison with the non-injured control teeth and no radiographic signs of root resorption.

External surface resorption (repair-related resorption): A radiographic defect on the root surface, bordered by a normal PDL, space and lamina dura.

Infection-related resorption (inflammatory resorption): Radiographic sign of external resorption cavities affecting both the root surface and adjacent bone.

Ankylosis-related resorption (replacement resorption): Loss of the PDL space, a high clinical percussion sound and no or decreased mobility. Transient ankylosis was defined as a lowered mobility that later becomes normal.



Fig. 2. Classification of root development stages: 1 = one-quarter root formation, 2 = one-half root formation, 3 = three-quarters root formation, 4 = full root formation, open apex, 5 = full root formation, half-closed apex, 6 = full root formation, apex closed.

Statistical analysis

To evaluate the relative importance of various factors on the outcome of intrusive luxations, Spearman's rank order correlation and Cox proportional stepwise hazard regression analyses (16) were performed. In these analyses, pulp revitalization, pulp necrosis and/or ankylosis were used as dependent variables and gender, age, degree of intrusion, degree of root development and type of treatment (spontaneous, orthodontic or surgical), systemic antibiotic administration, splinting time and splinting type are used as independent variables. The significance level $P < 0.05$ was used. To illustrate the effect of variables significantly related to the outcome, Kaplan–Meier survival curves (17) were constructed and compared. All data were analysed using STATISTICA v. 10 (STATSOFT; Scandinavia AB, Uppsala, Sweden).

Results

Distribution of the root development and degree of intrusion in relation to type of treatment in the 60 intruded teeth is shown in Table 1. Complete healing with revascularization of the pulp was observed in 15 teeth, pulp necrosis without ankylosis-related resorption in 23 teeth, ankylosis-related resorption without pulp necrosis in 20 teeth and ingrowth of bone apically in two teeth.

Treatment

No active treatment was performed in 17 teeth. Two of these did not re-erupt, one because of replacement-related ankylosis and one because of ingrowth of bone apically. The time interval between trauma and complete re-eruption varied from 1 to 8 months (mean 119 days, median 100 days).

Orthodontic extrusion was performed in 12 teeth. This treatment started within 1 week to 8 months after trauma (mean 93 days, median 63 days). Extrusion failed in two teeth, of which one was started after 21 days and one after 4 months. The duration of extrusion varied from 2 weeks to 3 months (mean 57 days, median 62 days).

Surgical repositioning was performed on two teeth with incomplete root development and open apex (index 1–3), five with complete root development and open apex (index 4), nine with full root development and half-closed apex (index 5) and on 15 with full root formation.

Pulp survival

Pulp revitalization occurred in all 17 teeth with complete healing. In all but one apex was open at the accident, and during the follow-up period, continuous root development and/or obliteration was seen.

Table 1. Number of teeth with different root development and degree of intrusion in relation to type of treatment

Root development	Degree of intrusion			Total
	Mild 0–3 mm	Moderate 4–6 mm	Severe ≥7 mm	
Spontaneous re-eruption				
1–3	3	2	3	8
4	1	4	1	6
5	0	1	0	1
6	1	1	0	2
Total	5	8	4	17
Orthodontic extrusion				
1–3	0	1	0	1
4	1	1	3	5
5	2	2	0	4
6	0	1	1	2
Total	3	5	4	12
Surgical repositioning				
1–3	1	1	0	2
4	1	2	2	5
5	3	4	2	9
6	2	3	10	15
Total	7	10	14	31

Root development 1–3 = one-quarter to three-quarters root formation; 4 = full root formation, open apex; 5 = full root formation, half-closed apex; 6 = full root formation, apex closed.

The follow up ranged from 26 to 110 months (mean 48.6).

Pulp necrosis without ankylosis-related resorption was diagnosed within 14 months in 23 teeth, 14 having almost closed or closed apices, five with full root formation and open apex and four with an incomplete root formation (Fig. 3). Limited infection-related root resorptions were diagnosed in 11 teeth. The teeth healed after endodontic treatment and were followed up from 27 to 110 months (mean 69.5).

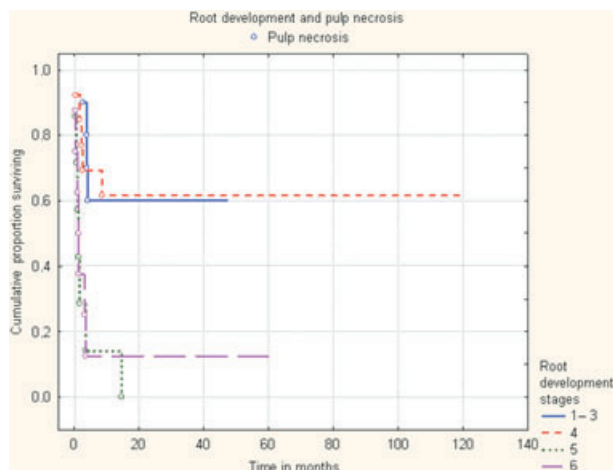


Fig. 3. Kaplan–Meier survival analysis illustrating pulp necrosis without ankylosis in 23 intruded teeth in relation to root development stages.

Periodontal healing

Ankylosis-related resorption with pulp necrosis was diagnosed in 20 teeth and 11 of these were lost. The diagnosis was made within 1 year in eight teeth, and within 2 years in nine teeth and in three teeth after more than 2 years when the patients had finished orthodontic treatment (Fig. 4a). Two of the ankylosed teeth were extracted and five decoronated because of increasing infraposition. Three were later on replaced by autotransplantation of premolars. One tooth was extracted because of a cervical root fracture. The remaining nine ankylosed teeth persisted after 3–9 years with only slight infraposition. The two teeth with ingrowth of bone in the pulp canal apically were extracted because of increasing infraposition.

Degree of intrusion

The degree of intrusion was severe in 22, moderate in 22 and mild in 16 teeth. Only one tooth with mild intrusion developed ankylosis, whereas ankylosis was found in seven teeth with moderate and 12 with severely intruded teeth (Fig. 4b).

Root development

Root development in relation to ankylosis is illustrated in Fig. 4c. Root developments one-quarter to three-quarters root formation (stages 1–3) were seen in 11 teeth. None exhibited replacement resorption including teeth with severe intrusion. Three of 16 teeth with completed root development and open apices (stage 4), and five of the 14 teeth with completed root development and half-closed apex (stage 5) exhibited ankylosis, all of them being surgically repositioned. Five of the surgical repositioned teeth with mature root formation and closed apices had before repositioning, been stored in a solution of doxycycline 0.05 mg ml⁻¹, and only one of these teeth exhibited ankylosis-related resorption.

Significant correlations to the treatment outcome were root development ($P < 0.001$), type of treatment ($P < 0.001$) and degree of intrusion ($P < 0.001$), when each factor was analysed separately. When Cox stepwise regression analysis was performed, only root development ($P = 0.03$) and degrees of intrusion ($P = 0.03$) were significant for the development of ankylosis and only root development for pulp necrosis ($P = 0.01$). No significant correlation was found between the outcome and systemic antibiotic administration, splint type and splinting time.

Discussion

The patients in this study were children and adolescents aged 6–16 years. The material was collected from files covering 30 years of treated patients at the Eastman Institute in Stockholm, Sweden. It represents various types of treatments for intruded incisors with all degrees of severity. The injured teeth had been treated by well-trained pedodontists at the Institute according to standardized procedures (14). The great biological difference

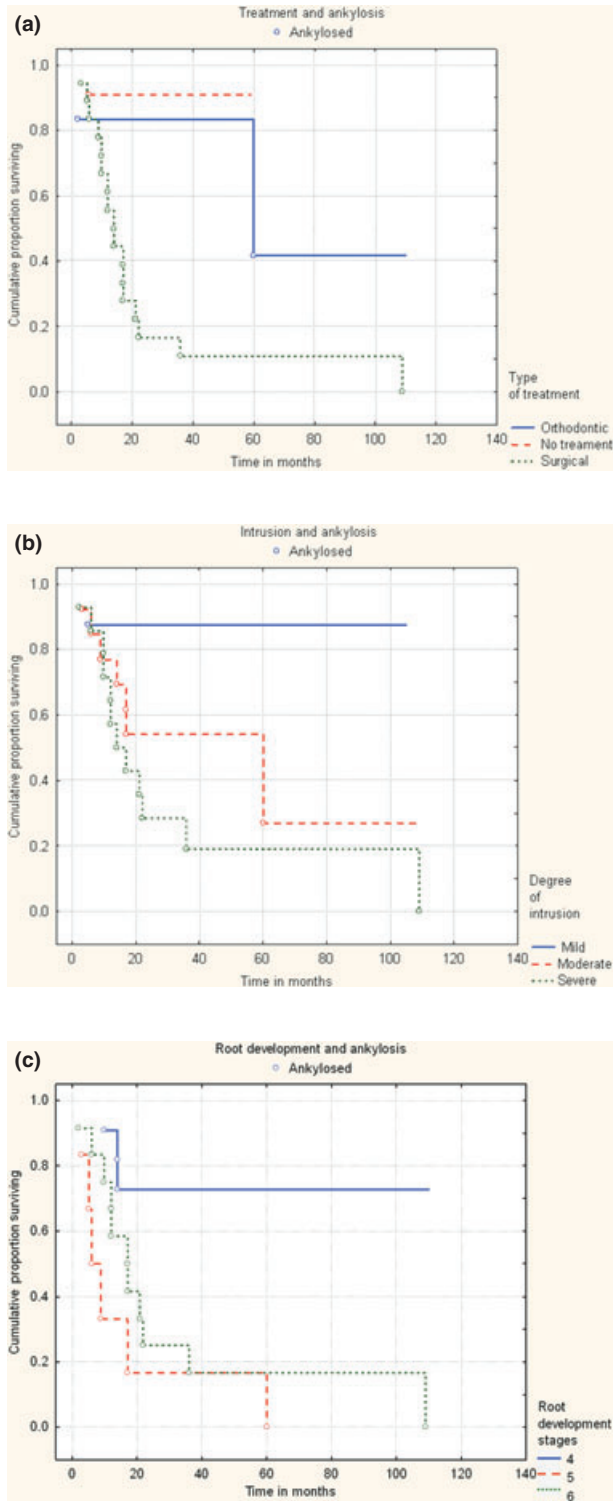


Fig. 4. (a) Kaplan–Meier survival analysis of 20 intruded teeth with ankylosis in relation to the type of treatment. (b) Kaplan–Meier survival analysis of 20 intruded teeth with ankylosis in relation to the degree of intrusion. (c) Kaplan–Meier survival analysis of 20 intruded teeth with ankylosis in relation to root development stages. No teeth with root developments 1–3 developed ankylosis.

in the healing scenarios seen in children and adolescents owing to the growing processes of the face with erupting immature teeth and growing alveolar processes makes treatment decisions difficult and individual judgements of each case must be considered (18).

Treatment

We found that the type of treatment was significantly correlated to the healing outcome, spontaneous re-eruption being most favourable. Spontaneous re-eruption of immature teeth has been recommended earlier (7, 9, 12). This study supports this statement. Surgical repositioning had the least favourable outcome. This treatment was, however, performed in severely intruded teeth with completed or almost completed root development (Table 1), which makes the comparison with orthodontic extrusion and spontaneous re-eruption difficult. The surgical procedure might also have induced additional trauma. This is in contrast to animal experiments in dogs where immediate surgical repositioning neither harmed the repair process nor caused additional damage (19). Al-Badri et al. (20) found that the occurrence of root development was related to the severity of the original injury and the stage of root development rather than the repositioning procedure that is in agreement with our study. In addition, two teeth, where orthodontic treatment was used, had failed to re-erupt. Both these teeth had a delay in orthodontic treatment with 21 days and 4 months, respectively. The delay was because of a late referral or awaiting spontaneous re-eruption. Both teeth were diagnosed with ankylosis and were extracted. Interestingly, both teeth had closed apices (root development, stage 6).

Pulp survival

There is always damage both to the pulp and the PDL in intrusive luxations. The main finding in this retrospective study was that root development is significantly correlated to the clinical outcome after an intrusive luxation. Pulp revitalization occurred in 15 of 27 teeth with incomplete root development, stage 1–4. It is well known that pulp survival more likely occurs in immature than in mature teeth after luxation injuries (21) and that revascularization might occur even in replanted immature teeth (22–24). In teeth with almost closed or closed apices, the outcome was less successful with only one tooth becoming revitalized without ankylosis-related resorption. On the other hand, the long-term prognosis after endodontic treatment is good in mature teeth (25, 26).

Periodontal healing

In most studies, all types of external root resorptions (surface, infection-related, ankylosis-related and invasive cervical resorption) have been pooled (5, 7, 12). These resorptions have different disease processes and clinical importance. A surface resorption, which in most cases

only can be detected microscopically, has per se no influence on the prognosis for the tooth. An infection-related resorption will be arrested after endodontic intervention. If this resorption has been detected at an early stage, the long-term prognosis for teeth with closed or almost closed apices is good. In immature teeth, pulp necrosis is more severe. The long-term prognosis for endodontically treated immature teeth with calcium hydroxide and gutta-percha is poor because of the thin dentinal walls with risk of cervical root fractures later on (27). A new approach to the treatment of non-vital immature teeth has been tested. This new treatment consists of disinfection of the pulp with a mixture of antibiotics and inducing a blood clot that seems to trigger a revitalization process (28–31). However, further studies are needed to evaluate this technique.

The worst scenario is ankylosis-related resorption. A vital pulp is rare in these cases, and no such case was found in our study. In the literature, pulp necrosis without ankylosis-related resorption has not been distinguished from pulp necrosis and ankylosis. We found it important to make such a distinction. Ankylosis-related resorption is the most serious complication in growing individuals. The condition is progressive and if the tooth is left *in situ*, infraposition will occur and growth of the surrounding alveolar bone will be arrested (18, 32). Teeth with open apices have been shown to have the best prognosis regarding healing of the PDL (20), which is in agreement with this study. This might be due to a more resilient bone surrounding immature teeth, allowing intrusion with less damage to the PDL (5).

An interesting finding was the positive effect of topical application of doxycycline on periodontal healing. A total of 15 teeth with closed apices were surgically repositioned. In nine of these both pulp necrosis and replacement resorption developed and in six only pulp necrosis. Five of the teeth with just pulp necrosis had been soaked in a 0.05 mg ml⁻¹ doxycycline solution for 5 mins, before replantation. Although the number of teeth in this study are too small to make any strong conclusions, the favourable effect of doxycycline observed supports the findings of Cvek et al. (33) in their *in vivo* monkey replantation study. Topical application of doxycycline in human teeth is an important issue for further studies.

Conclusion

No firm conclusion could be drawn between the outcome of orthodontic extrusion and surgical repositioning. According to this study, the evaluation of the prognosis after intrusion luxations should be based on the stage of root development and the degree of intrusion. In teeth with immature root development, spontaneous repositioning appears to result in fewer healing complications.

References

1. Andreasen JO. *Af. Intrusive luxation*. Copenhagen: Blackwell/Munksgaard; 2007.
2. Andreasen JO, Bakland LK, Matras RC, Andreasen FM. Traumatic intrusion of permanent teeth. Part 1. An epidemi-

- ological study of 216 intruded permanent teeth. *Dent Traumatol* 2006;22:83–9.
3. Borssen E, Holm AK. Traumatic dental injuries in a cohort of 16-year-olds in northern Sweden. *Endod Dent Traumatol* 1997;13:276–80.
4. Andreasen FM, Pedersen BV. Prognosis of luxated permanent teeth – the development of pulp necrosis. *Endod Dent Traumatol* 1985;1:207–20.
5. 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. *Dent Traumatol* 2006;22:90–8.
6. Chaushu S, Shapira J, Heling I, Becker A. Emergency orthodontic treatment after the traumatic intrusive luxation of maxillary incisors. *Am J Orthod Dentofacial Orthop* 2004;126:162–72.
7. Andreasen JO, Bakland LK, Andreasen FM. 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. *Dent Traumatol* 2006;22:99–111.
8. Ebeleseder KA, Santler G, Glockner K, Hulla H, Pertl C, Quehenberger F. An analysis of 58 traumatically intruded and surgically extruded permanent teeth. *Endod Dent Traumatol* 2000;16:34–9.
9. Humphrey JM, Kenny DJ, Barrett EJ. Clinical outcomes for permanent incisor luxations in a pediatric population. I. Intrusions. *Dent Traumatol* 2003;19:266–73.
10. Stewart C, Dawson M, Phillips J, Shafi I, Kinirons M, Welbury R. A study of the management of 55 traumatically intruded permanent incisor teeth in children. *Eur Arch Paediatr Dent* 2009;10:25–8.
11. Turley PK, Joiner MW, Hellstrom S. The effect of orthodontic extrusion on traumatically intruded teeth. *Am J Orthod* 1984;85:47–56.
12. Wigen TI, Agnalt R, Jacobsen I. Intrusive luxation of permanent incisors in Norwegians aged 6–17 years: a retrospective study of treatment and outcome. *Dent Traumatol* 2008;24:612–8.
13. Andreasen JO, Ravn JJ. Epidemiology of traumatic dental injuries to primary and permanent teeth in a Danish population sample. *Int J Oral Surg* 1972;1:235–9.
14. Hedegard B, Stalhane I. A study of traumatized permanent teeth in children 7–15 years. I. *Sven Tandlak Tidsskr* 1973;66:431–52.
15. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics* 1977;33:159–74.
16. Cox DR. Regression models and life tables. *J Roy Stat Soc* 1972;34:187–220.
17. Kaplan EL, Meier P. Nonparametric estimation from incomplete observations. *J Am Stat Assoc* 1958;53:457–81.
18. Malmgren B, Malmgren O. Rate of infraposition of reimplanted ankylosed incisors related to age and growth in children and adolescents. *Dent Traumatol* 2002;18:28–36.
19. Cunha RF, Pavarini A, Percinoto C, Lima J. Influence of surgical repositioning of mature permanent dog teeth following experimental intrusion: a histologic assessment. *Dent Traumatol* 2002;18:304–8.
20. Al-Badri S, Kinirons M, Cole B, Welbury R. Factors affecting resorption in traumatically intruded permanent incisors in children. *Dent Traumatol* 2002;18:73–6.
21. Andreasen FM. Pulpal healing after luxation injuries and root fracture in the permanent dentition. *Endod Dent Traumatol* 1989;5:111–31.
22. Ohman A. Healing and sensitivity to pain in young replanted human teeth. An Experimental, Clinical and Histological Study. *Odontol Tidsskr* 1965;73:166–227.
23. Ohman A. Theoretical and practical clinical aspects of healing and vitality investigation in traumatic tooth injuries. *Arsh Goteb Tandlak Sallsk* 1965;123–37.

24. Kling M, Cvek M, Mejare I. Rate and predictability of pulp revascularization in therapeutically reimplanted permanent incisors. *Endod Dent Traumatol* 1986;2:83–9.
25. Orstavik D, Qvist V, Stoltze K. A multivariate analysis of the outcome of endodontic treatment. *Eur J Oral Sci* 2004;112:224–30.
26. Sjogren U, Hagglund B, Sundqvist G, Wing K. Factors affecting the long-term results of endodontic treatment. *J Endod* 1990;16:498–504.
27. Cvek M. Prognosis of luxated non-vital maxillary incisors treated with calcium hydroxide and filled with gutta-percha. A retrospective clinical study. *Endod Dent Traumatol* 1992;8:45–55.
28. Ding RY, Cheung GS, Chen J, Yin XZ, Wang QQ, Zhang CF. Pulp revascularization of immature teeth with apical periodontitis: a clinical study. *J Endod* 2009;35:745–9.
29. Jung IY, Lee SJ, Hargreaves KM. Biologically based treatment of immature permanent teeth with pulpal necrosis: a case series. *J Endod* 2008;34:876–87.
30. Banchs F, Trope M. Revascularization of immature permanent teeth with apical periodontitis: new treatment protocol? *J Endod* 2004;30:196–200.
31. Trope M. Treatment of immature teeth with non-vital pulps and apical periodontitis. *Endod Topics* 2006;14:51–9.
32. Malmgren B, Cvek M, Lundberg M, Frykholm A. Surgical treatment of ankylosed and infrapositioned reimplanted incisors in adolescents. *Scand J Dent Res* 1984;92:391–9.
33. Cvek M, Cleaton-Jones P, Austin J, Lownie J, Kling M, Fatti P. Effect of topical application of doxycycline on pulp revascularization and periodontal healing in reimplanted monkey incisors. *Endod Dent Traumatol* 1990;6:170–6.