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Longitudinal clinical and radiographic evaluation of severely intruded permanent incisors in a pediatric population

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Abstract – Intrusion is defined as the axial dislodgment of the tooth into its socket and is considered one of the most severe types of dental trauma. This longitudinal outcome study was undertaken to evaluate clinically and radiographically severely intruded permanent incisors in a population of children and adolescents. All cases were treated between September 2003 and February 2008 in a dental trauma service. Clinical and radiographic data were collected from 12 patients (eight males and four females) that represented 15 permanent maxillary incisors. Mean age at the time of injury was 8 years and 9 months (range 7–14 years and 8 months). Mean time elapsed to follow-up was 26.6 months (range 10–51 months). The analysis of data showed that tooth intrusion was twice as frequent in males. The maxillary central incisors were the most commonly intruded teeth (93.3%), and falling at home was the main etiologic factor (60%). More than half of the cases (53.3%) were multiple intrusions, 73.3% of the intruded teeth had incomplete root formation and 66.6% of the teeth suffered other injuries concomitant to intrusion. Immediate surgical repositioning was the treatment of choice in 66.7% of the cases, while watchful waiting for the tooth to return to its pre-injury position was adopted in 33.3% of the cases. The teeth that suffered additional injuries to the intrusive luxation presented a fivefold increased relative risk of developing pulp necrosis. The immature teeth had six times more chances of presenting pulp canal obliteration that the mature teeth and a lower risk of developing root resorption. The most frequent post-injury complications were pulp necrosis (73.3%), marginal bone loss (60%), inflammatory root resorption (40%), pulp canal obliteration (26.7%) and replacement root resorption (20%). From the results of this study, it was not possible to determine whether the type immediate treatment had any influence on the appearance of sequelae like pulp necrosis and root resorption after intrusive luxation, but the existence of additional injuries and the stage of root development influenced the clinical case outcome in a negative and positive manner, respectively.

Dentoalveolar trauma is a very common event in children and represents an emergency situation not only because of the injury itself, which may sometimes be severe, but also due to the emotional distress caused to the patient and the parents. Intrusion is defined as the axial dislodgment of the tooth into its socket. It is considered one of the most severe types of dental trauma because it causes crushing of periodontal ligament fibers, neurovascular bundle and alveolar bone (1, 2). Intrusive luxation in the permanent dentition is an uncommon event, corresponding to 0.3–1.9% of all traumatic injuries (1–4).

Pulp necrosis, loss of marginal bone support, inflammatory and replacement root resorption, arrest or disturbance of root development, pulp tissue calcification, and gingival retraction may occur following intrusive luxations. In spite of these adverse sequelae, normal periodontal and pulp healing may also occur after traumatic intrusion (5, 6). Three treatment modalities have been proposed for intruded permanent teeth: watchful waiting for the tooth to return to its pre-injury position (passive repositioning), immediate surgical repositioning or active repositioning with orthodontic traction. Watchful waiting is indicated for immature permanent teeth because of their high potential for eruption and pulp/periodontal repair (5, 7, 8). Intruded mature and immature permanent teeth may be repositioned either surgically, followed by a retention period (5, 9–11) or orthodontically (5, 12). Indication of the treatment strategy will depend on the stage of root development, severity of the intrusion, and presence of alveolar fracture or multiple intrusions, and must be focused on the elimination or attenuation of post-injury complications (5, 7, 9–22).

Because of the low incidence of intrusive luxation in the permanent dentition, few studies have addressed the sequelae resulting from these injuries, and different management strategies and clinical outcomes have been presented without a consensus about the optimal treatment for traumatically intruded permanent teeth (5, 7, 10–12, 21–23). The present study was undertaken to evaluate clinically and radiographically severely intruded permanent incisors in a population of children and adolescents, assessing the post-injury complications and the outcomes of the proposed treatment modalities.

Material and methods

This investigation was a longitudinal outcome study involving children and adolescents who sustained severe traumatic intrusive luxation to the permanent incisors and attended the Center of Buccodental Trauma (CENTRAU) of the Federal University of Ceará (Brazil) between September 2003 and February 2008. As inclusion criteria for entry into the study, the patients should present at least one severely intruded permanent incisor rated according to the Royal College of Surgeons of England classification of <3, 3–6 and >6 mm as mild, moderate and severe intrusions, respectively (24); initial and follow-up radiographs during the surveillance period, a minimum follow-up of 6 months; and accurate and complete dental files. Patients with systemic diseases were excluded from the trial.

The eligible patients and their parents were fully informed about the diagnosis of severe intrusion, the treatment plan and the possible post-injury complications, and were given explanations about the study design and purposes. The research project was approved by the Research Ethics Committee of the Federal University of Ceará and written informed consent was obtained from the parents/guardians before patient enrollment.

The following information was recorded: gender, age at the time of injury (in years and months), intruded tooth, etiology of trauma (fall, bicycle accident, car or motorcycle accident, sporting activities, physical assault, unknown, others), site of accident (at home, at school, swimming pools, others), treatment strategy [(immediate surgical repositioning or watchful waiting for the tooth to return to its pre-injury position (passive repositioning)], association with other injuries [none, enamel crack, crown fracture (enamel only, enamel/dentin, enamel/dentin/pulp), crown-root fracture, root fracture)] and number of intruded teeth (single intrusion or multiple intrusions). Each tooth was examined radiographically and classified according to Nolla's classification of permanent tooth development based on 10 stages of calcification that range from 0 (absence of bone crypt) to 10 (apical end of the root completed).

Possible sequelae to the intrusive luxation were assessed at all follow-up visits. Pulp vitality was checked during the course of the surveillance period both clinically (pulp sensitivity to cold stimulus, color change, formation of fistula) and radiographically (presence of internal and/or external root resorptions, bone rarefaction, widening of the periodontal ligament space). Pulp condition was rated in three categories: normal pulp, pulp necrosis or obliteration of the pulp canal; the latter was confirmed clinically, by the yellowish coloration of the tooth crown, and/or radiographically. Marginal bone loss was considered when areas of bone rarefaction were detected on the follow-up radiographs. The presence of inflammatory or replacement resorption was also determined by radiographic examination at each visit. The duration of the follow-up period, i.e. the time (in months) elapsed between the emergency visit and the last recall appointment, was also established. Finally, the relative risk for the following variables was calculated in relation to sequelae resulting from the traumatic injury: presence of additional injury, management strategy and stage of root development. The follow-up comprised clinical and radiographic examinations and continued at 2 weeks; 1, 3 and 6 months; and annually.

Results

The sample comprised 15 teeth from 12 patients (eight males and four females) with mean age of 8 years and 9 months (range 7–14 years and 8 months) who were followed up for a mean period of 26.6 months (range 10–51 months).

The analysis of data showed that tooth intrusion was twice as frequent in male children and adolescents. The maxillary central incisors were by far the most commonly affected teeth (93.3%), and falling at home was the main cause of trauma (60%). Surgical repositioning was the treatment of choice in 58.3% of the patients, while watchful waiting for the intruded tooth to return to its pre-injury position was adopted in 41.7% of the cases. It was observed that 66.6% of the teeth sustained other injuries in addition to intrusive luxation. Crown fracture involving enamel and dentin was the most frequent (53.3%). The teeth that suffered other injuries concomitant with the intrusive luxation presented a fivefold increased relative risk of developing pulp necrosis compared to those that suffered no other traumatic injury (Table 1). Regarding the injury pattern, 40% of the cases consisted of multiple intrusions (25). Concerning the stage of calcification according to Nolla's classification of tooth development, 73.3% of the intruded teeth had incomplete root formation at the moment of the trauma; 46.6% of the teeth were in Nolla stages 7 and 8 (one-third of the root completed and two-thirds of the root completed, respectively), 26.6% were in stage 9 (root almost completed) and 26.6% were in stage 10 (apical end of the root completed). The immature teeth had six times more chances of presenting pulp canal

Table 1. Effect of concomitant injuries on the sequelae occurred after intrusive luxation

Post-injury complication	Relative risk
Pulp necrosis	5.0
Pulp canal obliteration	0

Relative risk >1.0 indicates increased risk of occurrence of sequelae, while relative risk <1.0 indicates a protective effect.

Table 2. Effects of root development stage (immature or mature teeth) on the sequelae occurred after intrusive luxation

Post-injury complication	Relative risk
Pulp necrosis	0.653
Pulp canal obliteration	3.43
Root resorption	0.163
Arrest of root development	4.57

Relative risk >1.0 indicates increased risk of occurrence of sequelae, while relative risk <1.0 indicates a protective effect.

Table 4. Effects of surgical repositioning on the sequelae occurred after intrusive luxation

Sequelae	Relative risk
Pulp necrosis	0.875
Pulp canal obliteration	1.5
Marginal bone loss	4.0
Root resorption	1.5
Arrest of root development	0.75

Relative risk >1.0 indicates increased risk of occurrence of sequelae, while relative risk <1.0 indicates a protective effect.

obliteration and a lower risk of developing root resorption compared to teeth with fully formed roots (Table 2).

Table 3 presents the results distributed according to the intruded tooth, treatment modality, presence of additional injury, stage of calcification according to Nolla's classification and post-injury complications.

All cases evaluated in this study presented some type of sequela to the intrusive luxation over time, the most frequent being pulp necrosis (73.3%), followed by marginal bone loss (60%), inflammatory root resorption (40%), pulp canal obliteration (26.7%) and replacement root resorption (20%). Surgically repositioned teeth had a fourfold increased relative risk of presenting marginal bone loss compared to teeth for which the nonsurgical approach was preferred (Table 4). In two teeth for which the treatment of choice was watchful waiting for the intruded tooth to return to its pre-injury position, a gingivectomy procedure was necessary to obtain endodontic access. Orthodontic treatment was performed subsequently to provide an adequate tooth alignment in the dental arch.

Discussion

Traumatic intrusion of permanent teeth has a reportedly low prevalence (0.3–1.9%) (1–4), and cases of severe intrusive luxation, when tooth dislodgement is >6 mm, are even more uncommon (2). The present study evaluated the main sequelae occurring in severely intruded permanent teeth according to the treatment approach.

Falls followed by bicycle accidents were the most frequent etiologic factors, which is consistent with the results reported (2). In 60% of the cases, tooth injury occurred at home, in the same way as reported in a previous study about the prevalence of traumatic dental injury and associated factors among 12-year-old schoolchildren (26). The predominance of the male gender, with a 2:1 male-to-female ratio, is also in accordance with the literature (2–4, 6, 26). In more than 90% of the cases, the intruded teeth were maxillary central incisors, which is related to their anatomic position in the dental arch (2–4, 23).

According to Andreasen et al. (21), some pre-injury and injury factors, such as age, stage of root development, type of tooth, concomitant coronal fractures, extent of tooth displacement, presence of gingival laceration and number of intruded teeth, may influence healing and case prognosis. In the present study, more than half (66.6%) of the teeth presented an additional injury to the intrusive luxation, which increases the risk of pulp necrosis. According to Humphrey et al. (6) and Andreasen et al. (21), the association of intrusion with crown fractures is strongly related to the development of

Table 3. Sequelae after severe intrusion of permanent incisors according to Nolla stage, choice of immediate treatment and occurrence of additional injuries

	Nolla stage				Immediate treatment		Additional injury*				Sequelae**					
Patient (tooth no.)	7	8	9	10	SR	WW	1	2	3	4	1	2	3	4	5	6
1 (11,21)***				2	2				2	2	2		2			2
2 (11)				1		1			1		1				1	
3 (21)		1				1			1		1		1		1	
4 (11)	1				1		1					1	1			
5 (11)	1					1			1		1					
6 (21)			1		1					1	1		1		1	
7 (11,21)***			2		2				2	2	2		2		2	
8 (11)			1			1	1					1				
9 (21)				1	1		1				1		1		1	1
10 (11)		1			1			1			1		1			
11 (11,21)***		2			2		2					2				
12 (11)		1				1			1		1			1		

*1, none; 2, enamel crack; 3, enamel/dentin crown fracture; 4, alveolar fracture.
**1, pulp necrosis; 2, pulp canal obliteration; 3, marginal bone loss; 4, tooth color change; 5, inflammatory root resorption; 6, replacement root resorption.
***Three out of 12 patients with multiple intrusions.

pulp necrosis. This finding has a relevant clinical meaning with respect to case prognosis because the area of exposed dentin may permit bacterial invasion and the subsequent development of pulpal alterations. Protection of the exposed dentin with proper materials is thus an important procedure to be done at the emergency visit and maintained until the definitive clinical procedure can be performed.

Immediate surgical repositioning, repositioning with orthodontic traction and watchful waiting for the tooth to return to its pre-injury position are the treatments proposed for cases of intrusion in the permanent dentition (5, 7, 10, 11, 15–17, 20, 22). However, Al-Badri et al. (23) and Sapir et al. (20) have emphasized that there is no consensus in the literature regarding the optimal treatment for traumatically intruded permanent teeth. The findings of the present investigation showed that surgical repositioning was the treatment of choice in 58.3% of the cases. This management strategy was strongly related with alveolar bone loss in the short-term course, but had little clinical significance on a long-term basis because this alteration was not detected at the subsequent visits during the period of surveillance (5, 9, 13, 21).

Pulp necrosis was diagnosed within the follow-up period in most cases where the treatment of choice was watchful waiting. Under these conditions, when the tooth crown has an intraosseous location a gingivectomy procedure is necessary to grant access for the endodontic treatment (7, 15, 16). In two cases of the present study, gingivectomy was performed to expose the crown and allow for root canal therapy. After completion of the endodontic treatment, orthodontic movement was further performed to position the teeth adequately in the dental arch. Depending on the time necessary for spontaneous re-eruption, loss of space might occur due to migration of the neighboring teeth to the space originally occupied by the intruded tooth. In these cases, placement of an orthodontic wire/composite resin splint involving the teeth adjacent is indicated for space maintenance until the tooth is partially re-erupted. In spite of the possible complications arising from watchful waiting in cases of pulp necrosis, the choice for this treatment strategy is based on the fact that allowing the tooth to return spontaneously to its pre-injury position allows eruption to occur in a more physiological manner, causes less alveolar resorption and avoids the performance of a surgical procedure in a child that is already emotionally distressed by the trauma itself.

Two main conditions are determinant to make a clinical decision between surgical repositioning (SR) and watchful waiting (WW) in cases of severe intrusive luxation and both were considered in the present study: the stage of root development and the presence of multiple intrusions. Surgical repositioning is indicated for teeth classified at Nolla stage 9 (root almost completed) and stage 10 (apical end of the root completed), and also in cases of multiple intrusions. Watchful waiting for the tooth to return to its pre-injury position is indicated for teeth classified at stage 7 (one-third of the root completed) and stage 8 (two-thirds of the root completed). However, there are some modifying factors that can influence the choice for a treatment strategy, such as the patient's systemic, psychological and oral conditions at the moment of examination, as well as the patients'/parents' socioeconomic status (e.g. whether they could afford a subsequent active orthodontic repositioning, in case spontaneous eruption did not occur after watchful waiting). All these variables were also taken into consideration in the present study.

Intrusive luxation is a very severe injury because it involves the rupture of the gingival sealing, crushing of periodontal ligament fibers and damage to the alveolar bone, cementum and neurovascular pulp supply (19). Therefore, the healing process of intrusive luxations may be accompanied by a number of post-trauma complications namely pulp necrosis, inflammatory root resorption, replacement root resorption, marginal bone loss, pulp canal obliteration, arrest of root development and gingival retraction (6, 9, 11, 21, 23). All cases evaluated in the present study presented some type of sequela to the intrusive luxation, with predominance of pulp necrosis (73.3%). The literature has shown that pulp necrosis is one of the most frequently diagnosed complications secondary to traumatic intrusion in the permanent dentition, with a reported incidence ranging from 45 to 88.5% (6, 18, 21). The high incidence of post-injury complications may be explained by the severity of this tooth injury. The treatment of patients with severe intrusion should be undertaken with great care, and patients/parents must be informed about the uncertain prognosis of these cases.

The findings of the present investigation showed some sequelae to tooth intrusion were diagnosed within the first month of follow-up, like inflammatory root resorption and pulp necrosis, or only 1 year after trauma, such as pulp canal obliteration. Andreasen et al. (21) suggest the existence of a relationship between pulp necrosis and root development stage. This alteration is detected early in mature teeth, while in immature teeth the diagnosis of pulp necrosis occurs in a latter phase. According to Andreasen and Pedersem (13), pulp necrosis may be diagnosed even up to 2 years post-injury. Regardless of the treatment approach, clinical and radiographic surveillance is mandatory to allow an immediate and timely intervention at the first sign of post-treatment complication, minimize the sequelae and diagnose late alterations in the traumatized tooth.

It has been reported that the stage of root development may influence the appearance of sequelae (21, 23) and, in accordance with the literature, the results of the present investigation revealed a lower incidence of pulp necrosis and root resorption in immature teeth. These findings are due to the characteristics of the stage of root development and patient's age, since the greater the contact area between the pulp and the periodontal ligament, the greater the chance of revascularization. Also, young patients have a more resilient alveolar bone, which attenuates the damage to the periodontal ligament in cases of tooth injuries (14, 21, 23).

Root resorption is a common complication of traumatically intruded teeth. Some authors believe that root resorption is more likely to be related to the stage of root development and the severity of the tooth dislodgment into the socket rather than to the treatment modality

itself (9, 12, 21, 23). In the present investigation, a high incidence of root resorption (40% resorption inflammatory and 20% replacement resorption) was observed. No relationship was identified between the treatment approach and this sequela. In addition, one tooth was lost due to inflammatory root resorption and another due to replacement root resorption. The early diagnosis of root resorption is of paramount importance to establish an immediate endodontic intervention for cases of inflammatory resorption and a multidisciplinary planning for cases of replacement resorption.

Pulp canal obliteration is a common sequelae in severely intruded teeth that remain vital after trauma. Teeth with post-trauma complication presents a gradual reduction in pulp sensitivity to thermal stimuli and a yellowish color of the crown might be present (12). In the present study, 100% of the vital teeth presented pulp canal obliteration over time, which are consistent with results reported by Andreasen et al. (21) and Chaushu et al. (12). Pulp canal obliteration may be attributed to the trauma itself or to an alteration in the blood flow during orthodontic extrusion (12, 27, 28).

This longitudinal study evaluated clinically and radiographically permanent incisors that sustained severe traumatic intrusion and revealed a high incidence of pulp necrosis and root resorption. From the results of this study, it was not possible to determine whether the type immediate treatment had any influence on the appearance of these sequelae after intrusive luxation, but the existence of additional injuries and the stage of root development influenced the clinical case outcome in a negative and positive manner, respectively. Therefore, the follow-up of patients that sustain severe tooth intrusion due to traumatic injuries should be rendered in a careful, periodical and long-term basis because post-injury complications may arise late and compromise tooth survival.

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