

## Pulp and periodontal healing of laterally luxated permanent teeth: results after 4 years

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**Abstract** – *Aim:* To evaluate the pulp and periodontal healing of laterally luxated permanent teeth. *Material and methods:* Patients presenting with lateral luxation of permanent teeth during 2001–2002 were enrolled in this clinical study. Laterally luxated teeth were repositioned and splinted with a TTS/composite resin splint for 4 weeks. Immediate (prophylactic) root-canal treatment was performed in severely luxated teeth with radiographically closed apices. All patients received tetracycline for 10 days. Re-examinations were performed after 1, 2, 3, 6, 12 and 48 months. *Results:* All 47 laterally luxated permanent teeth that could be followed over the entire study period survived. In 10 teeth (21.3%), a prophylactic root-canal treatment was performed within 2 weeks following injury. The remaining 37 teeth showed the following characteristics at the 4-year re-examination: 19 teeth (51.4%) had pulp survival (no clinical or radiographic signs or symptoms), nine teeth (24.3%) presented with pulp canal calcification, and pulp necrosis was seen in another nine teeth (24.3%), within the first year after trauma. None of the teeth with a radiographically open apex at the time of lateral luxation showed complications. External root resorption was only seen in one tooth. *Conclusions:* Laterally luxated permanent teeth with incomplete root formation have a good prognosis, with all teeth surviving in this study. The most frequent complication was pulp necrosis that was only seen in teeth with closed apices.

A lateral luxation is defined as a traumatic displacement of a tooth in any direction other than axially. Because of its bony lock, a laterally luxated tooth is often immobile, and percussion produces a high, metallic sound. Pulp sensibility testing will likely be negative during the initial follow up. However, the tooth should be monitored until a definitive pulp diagnosis can be made. Considering the risk of pulp necrosis following lateral luxation (1, 2), in particular in teeth with radiographically closed apices, it is recommended to schedule timely re-examinations during the first year after the luxation injury. Recently, the International Association of Dental Traumatology published guidelines for the management of luxation injuries to permanent teeth (3). Slightly modified recommendations for treatment of luxated closed-apex teeth were reported by Lin et al. (4).

Some studies have reported the outcome of luxated permanent teeth without specifically differentiating between the various types of luxation injuries (5, 6). Only a single study has reported the longitudinal results assessing exclusively lateral luxations of permanent teeth (1). Typical sequelae comprise pulp necrosis with possible apical infection or infection-related external root resorption, or less frequently, pulp canal calcification, or replacement root resorption (2, 5, 7, 8).

The objective of the present study was to review the healing and medium term prognosis of the teeth 4 years after lateral luxation and management of the injuries.

### Material and methods

The material comprised 36 patients presenting with 66 laterally luxated permanent teeth. Patients were enrolled during a period of 2 years (2001–2002). Patients were followed for 1 year and recalled after 4 years to establish a final diagnosis. 19 teeth were lost for follow up, and reasons of drop-outs are shown in Table 1.

Four years after trauma, 47 teeth could be re-examined in 26 patients (14 male and 12 female, mean age 25 years, median age 15 years, range 7–59 years). Seventy seven per cent of patients were <20 years of age (Table 2). The re-examined teeth included 31 central maxillary incisors, 11 lateral maxillary incisors, two maxillary canines, two central mandibular incisors, and one lateral mandibular incisor. Six teeth presented with an additional injury to the dental hard substance (two enamel fractures, three uncomplicated and one complicated crown fracture).

Initial and follow-up examinations consisted of taking a history, performing a clinical evaluation (inspection, palpation, percussion, pulp sensibility testing using carbon dioxide snow), and taking radiographs. Apical closure was defined as a radiographic apical foramen <1 mm (2).

Treatment included local anaesthesia, suturing of soft tissue injuries, manual repositioning of luxated teeth, and stabilization with a TTS/composite resin splint (TTS, Medartis, Basle, Switzerland) (mean splinting period

Table 1. Reasons of drop-outs

	No. patients	No. teeth
Initial material	36	66
Immediate extraction	1	1
Patient not willing to come for follow up	4	7
Patient could not be contacted	5	11
Final material	26	47

Table 2. Distribution of teeth related to patient age at time of injury

Age (years)	No. teeth	Teeth (%)
≤7	1	2
8–11	15	32
12–19	20	43
≥20	11	23
Total	47	100

22 days, range 7–28 days). Immediate (prophylactic) root-canal treatment was performed in closed-apex teeth with a displacement > 2 mm. The initial canal medication for this approach was Ledermix® paste (Lederle, Zug, Switzerland). After 2–3 weeks, calcium hydroxide was administered for another 3 weeks before root-canal filling was performed.

Patients also received non-steroidal analgesics (to be taken only in case of pain), tetracycline for 10 days (1st day: 100–200 mg, 2nd–10th day: 50–100 mg, dosage according to body weight), and 0.1% chlorhexidine-digluconate mouthwash. Recall examinations were performed after 1, 2, 3, 6, 12 months, and after 4 years.

## Results

None of the 47 laterally luxated teeth had to be removed during the follow-up period. Prophylactic root-canal treatment was performed in 10 teeth (21.3%) immediately after trauma. Out of the remaining 37 teeth, nine teeth (24.3%) developed pulp necrosis during the first year post-trauma and were subsequently root-canal treated. 19 teeth (51.4%) showed uneventful pulp healing (pulp survival) at the 4-year follow up (Fig. 1). Another nine teeth (24.3%) presented with pulp canal calcification (Fig. 2) at the 4-year recall.

Pulp healing and relation to stage of root development at the time of injury are summarized in Table 3. Radiographs indicated that only five teeth had an apical foramen diameter that was ≥1 mm, but none of these teeth developed pulp necrosis. With regard to pulp sensibility at the 4-year follow up, six teeth with pulp canal calcification still tested positive, while five teeth without any clinical or radiographic signs/symptoms (classified as pulp survival) tested negative (Table 4).

With regard to periodontal healing, only one tooth developed external root resorption (replacement root resorption) (Fig. 3). At the 4-year follow up, five teeth with probing depths up to 6 mm also presented with bleeding on probing (patients were 24–57 years of age at the time of injury, and had a diagnosis of generalized marginal periodontitis at the final re-examination).

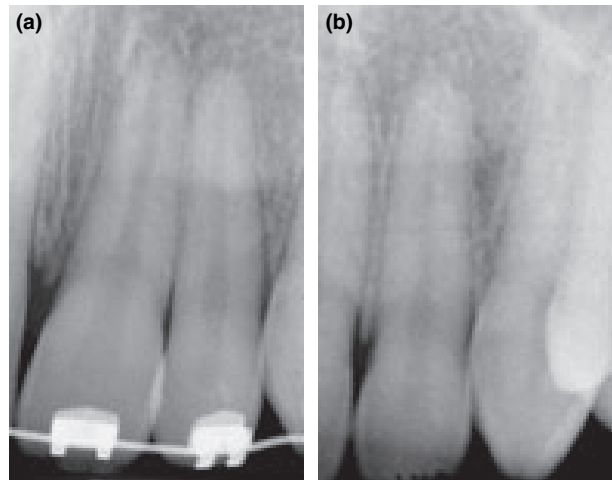


Fig. 1. (a) The left central maxillary incisor of a 12-year-old boy was slightly luxated palatally, with the orthodontic appliance preventing severe dislocation. (b) The 4-year follow-up radiograph shows normal findings.

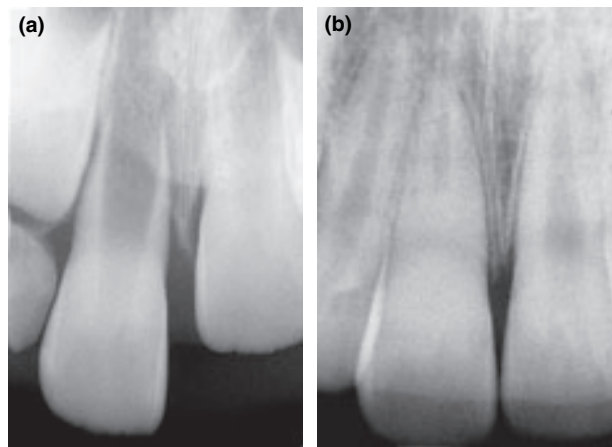


Fig. 2. (a) The right central maxillary incisor of a 7-year-old boy was buccally luxated, and showed a wide open foramen. (b) After 4 years, the radiograph shows complete but shorter root formation (compared with the contra-lateral) with pulp canal calcification in the coronal half of the root.

Another two teeth developed facial recession of the gingiva (1.5–2 mm, patient was 56 years of age at the time of injury).

Pulp and periodontal healing in relation to patient age at the time of trauma is shown in Table 5. Pulp healing was found in all age groups. The greatest proportion of root-canal treatment was found in patients ≥20 years of age. The pulp and periodontal healing of the six laterally luxated teeth with additional crown fractures are summarized in Table 6.

## Discussion

The present study evaluated the pulp and periodontal healing of 47 laterally luxated permanent teeth after

Table 3. Management and findings in relation to initial pulp sensibility and stage of root development

Initial pulp sensibility	Immediate prophylactic root-canal treatment		Therapeutic root-canal treatment following pulp-necrosis within first year after trauma		Pulp canal calcification diagnosed at 4 years after trauma		Pulp survival (no clinical or radiographic signs/symptoms) diagnosed at 4 years after trauma	
	Apical foramen $\geq 1$ mm	Apical foramen $< 1$ mm	Apical foramen $\geq 1$ mm	Apical foramen $< 1$ mm	Apical foramen $\geq 1$ mm	Apical foramen $< 1$ mm	Apical foramen $\geq 1$ mm	Apical foramen $< 1$ mm
Positive	–	–	–	3	–	2	3	8
Negative	–	10	–	6	2	5	–	8
Sub-total	–	10	–	9	2	7	3	16
Total	10		9		9		19	

Table 4. Pulp sensibility at the 4-year follow-up in teeth with either pulp canal calcification or pulp survival ( $n = 28$ )

Pulp sensibility	Pulp canal calcification	Pulp survival
Positive	6	14
Negative	3	5
Total	9	19

4 years. With regard to the pulp condition at the final recall, 19 teeth (51.4%) presented without clinical or radiographic signs/symptoms, and were classified as teeth with pulp survival. Nine teeth (24.3%) demonstrated pulp canal calcification. Another nine teeth (24.3%) developed pulp necrosis within 1 year after trauma. The remaining 10 teeth (21.3%) received immediate prophylactic root-canal treatment following lateral luxation.

Nikoui et al. (1) retrospectively evaluated 58 laterally luxated permanent teeth with a mean follow up of 4 years. All teeth survived, but pulp necrosis developed in 40% during the first year following trauma. This percentage is similar to the percentage of root-canal treated teeth in this study ( $10 + 9 = 19/47 = 40.5\%$ ). An additional 40% of the teeth in Nikoui's study developed pulp canal calcification during the follow up. This relatively high percentage might be explained that

Nikoui's study population only comprised children and adolescents (mean age 11.4 years, range 6.3–17.8 years) with immature root development at the time of injury.

Andreasen and Vestergaard-Pedersen (8) reported a frequency of 58% for pulp necrosis in 122 laterally luxated permanent teeth (observation period up to 10 years). Out of 122 patients, 44 were in the age range of 12–19 years at the time of injury. In most cases, pulp necrosis developed during the first 3 months after luxation. Pulp necrosis occurred more frequently in teeth with closed apices (79.5%) than in teeth with open apices (25.4%). The frequency of pulp canal calcification was 35% (7% partial and 28% complete pulp canal calcification).

In this study, teeth with open apices neither developed pulp necrosis nor received prophylactic root-canal treatment. Andreasen et al. (2) reported that revascularization of the pulp tissues can be observed in teeth with wide, open apices at the time of trauma. Pulp canal calcification also appears to be associated with immature root development (7, 9). However, it can also be detected in teeth with closed apices. Andreasen et al. (7) reported 9.3% of pulp canal calcification in teeth with closed apices. In this study, 18.9% (7/37) of teeth with a closed apex developed pulp canal calcification, and Nikoui et al. (1) found pulp canal calcification in 73% of laterally luxated teeth with a closed apex. Possible

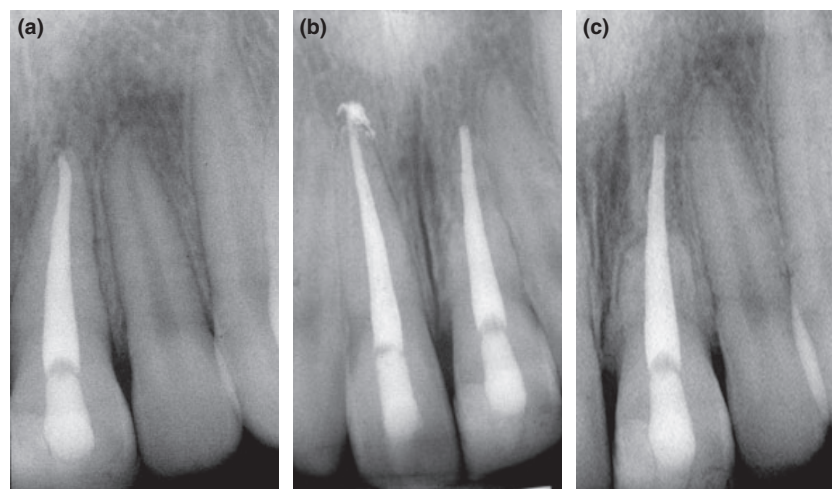


Fig. 3. (a) The left central maxillary incisor developed pulp necrosis with subsequent root-canal treatment 3 months following lateral luxation in a 15-year-old girl. (b) The 2-year radiograph shows beginning replacement root resorption in the apical portion of the root. (c) The 4-year radiograph shows advanced replacement root resorption in the apical half of the root.

Table 5. Management and findings in relation to patient age at the time of injury ( $n = 47$ )

Age at the time of injury (years)	Immediate prophylactic root-canal treatment	Therapeutic root-canal treatment after pulp necrosis within first year after trauma	Pulp canal calcification diagnosed at 4 years after trauma	Pulp survival diagnosed at 4 years after trauma	Therapeutic root-canal-treatment after pulp necrosis within first year after trauma, and replacement root resorption
≤ 7	–	–	1	–	–
8–11	–	2	5	8	–
12–19	5	3	3	8	1
≥ 20	5	3	–	3	–
Total	10	8	9	19	1

Table 6. Management and findings of teeth with crown fractures ( $n = 6$ )

	Therapeutic root-canal treatment within first year after trauma	Pulp canal calcification diagnosed at 4 years after trauma	Pulp survival diagnosed at 4 years after trauma
Enamel fracture	–	1	1
Uncomplicated crown fracture	2	–	1
Complicated crown fracture	–	–	1
Total	2	1	3

explanations for this marked difference might be that Nikoui's study population only included children and adolescents, and that the assessment of the stage of apical closure might be inaccurate using two-dimensional radiographs (10). In this study, all patients developing pulp canal calcification were <16 years of age at the time of trauma.

With regard to pulp survival (pulp healing) of laterally luxated teeth with a radiographically closed apex, the inaccuracy of two-dimensional radiography might not represent the true three-dimensional clinical situation (10). Apical root formation terminates earlier in a mesio-distal compared with an oro-facial dimension; thereby the standard periapical radiograph presumes a closed apex although it is still open. It has been shown that completion of apical closure in oro-facial direction can last longer than 3 years following tooth eruption (10).

Another feature seen occasionally after lateral luxation is the so-called transient apical breakdown (TAB). It is speculated that this temporary radiographic change correlates with hard tissue resorption as a possible healing response. TAB might increase the diameter of the apical foramen, thereby enabling revascularization of the pulp and subsequent normalization of the radiographic condition (11). TAB is more frequently seen after lateral (12.3%) and extrusive (11.3%) luxation injuries compared with other types of dental injuries (12). In this study, TAB was not observed, may be because 21.3% of the evaluated teeth received immediate root-canal treatment.

Six laterally luxated teeth also presented with concomitant crown fractures that may have confounded the pulp outcome. However, as documented in Table 6, only two teeth with an uncomplicated crown fracture devel-

oped pulp necrosis within the first year after trauma; it can only be speculated whether pulp necrosis was a sequel of luxation, of crown fracture, or of both injuries.

With regard to periodontal healing following lateral luxation, only one tooth demonstrated external root resorption (replacement root resorption). In Nikoui's study (1), no information is given regarding the percentage of root resorption following lateral luxation. The low incidence of external root resorption in this study may be explained that all patients had received a systemic coverage with tetracycline for 10 days after lateral luxation. This limited period (10 days) and amount (500–1000 mg) of tetracycline intake does not produce tooth discoloration; in addition, all patients given tetracyclines were older than 6 years, meaning teeth in the anterior area would not be affected (13–15). The rationale for using tetracycline is to benefit from its anti-resorptive properties. Tetracycline has a direct inhibitory effect on collagenase activity and osteoclasts, thereby reducing the potential risk of post-traumatic external root resorption (16, 17). In addition, its antimicrobial effect may eliminate bacteria that have contaminated the alveolus, periodontal and pulp tissues.

Another reason for the low incidence of external root resorption in the (immediately) root-canal treated teeth may be that all these teeth were first filled with Ledermix<sup>®</sup> paste. After trauma the cell damage on root surface stimulates an inflammatory response that initiates root resorption. Ledermix<sup>®</sup> paste contains the steroid triamcinolone and the broad-spectrum antibiotic demeclocycline. The steroid has shown to have an important anti-inflammatory action in the periradicular area and the antibiotic inhibits the activity of collagenase and osteoclasts (18). With these effects, Ledermix<sup>®</sup> paste has shown favourable results in the treatment of replanted avulsed teeth (18) but may also prevent or diminish external root resorption in luxated teeth.

Several studies (5, 6, 8, 19) have reported that external root resorption is less frequently seen following lateral luxation than following avulsion or intrusion. Andreasen et al. (8) reported 64% external inflammatory root resorption following intrusion compared with 29% after lateral luxation. Oikarinen et al. (5) found external replacement root resorption in 92% of avulsed permanent teeth compared with 36% of laterally luxated permanent teeth.

A laterally luxated tooth remains in the socket, whereas an avulsed tooth is completely pushed out of

its socket. While both injuries may lead to mechanical damage to the cementum, the periodontal tissues adhering to an avulsed tooth may become necrotic when stored improperly, thereby increasing the risk for external root resorption.

In conclusion, the data of this study support the findings of previous reports that teeth with open apices have a very good long-term prognosis, that pulp necrosis is the most frequent complication, and that root resorption is rarely observed in laterally luxated permanent teeth.

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