2003

Clinical Outcomes for Permanent Incisor Luxations in a Pediatric Population. II: Extrusions

Raymond Lee, *Western University*

Dental Traumatology 2003; 19: 274–279
Printed in Denmark. All rights reserved

DENTAL TRAUMATOLOGY
ISSN 1600–4469

Clinical outcomes for permanent incisor luxations in a pediatric population. II. Extrusions

Lee R, Barrett EJ, Kenny DJ. Clinical outcomes for permanent incisor luxations in a pediatric population. II. Extrusions. Dent Traumatol 2003; 19: 274–279. © Blackwell Munksgaard, 2003.

Abstract – A longitudinal outcome study was undertaken to identify variables that significantly influenced outcomes for extruded permanent maxillary incisors of children and adolescents. Clinical and radiographic data was available for 35 patients (18 males, 17 females) representing 55 incisors. Mean age at the time of injury was 10.6 years (range: 7.1–17.8 years). Mean time elapsed to follow up was 1320 days (range: 423–2887 days). Survival analysis was used to identify variables significantly related to the prognosis of these teeth. The loss of an incisor following extrusion was uncommon as only one tooth (1/55) required extraction. There was no statistically significant difference in survival between severely extruded teeth and avulsions that had been stored in physiological media ($P > 0.10$). Pulp necrosis (PN) was the most common complication following injury (43%) and it most often occurred during the first year. Although not statistically significant, a trend towards increased PN was found with more severely extruded teeth ($P = 0.20$, relative risk = 2.08). Pulp canal obliteration (PCO) was the second most common outcome (35%). The degree of extrusion was proven to be significantly associated with the development of PCO ($P = 0.03$, relative risk = 0.33). Root resorption was an uncommon outcome (3/55). This study represents the first outcome data on extrusions to permanent maxillary incisors in an exclusively pediatric population.

Raymond Lee[1], Edward J. Barrett[2], David J. Kenny[2]

[1]The Children's Hospital of Western Ontario, London; [2]The Hospital for Sick Children and University of Toronto, Toronto, Canada

Key words: tooth injuries; survival analysis; dental pulp necrosis; root resorption

Dr Edward J. Barrett, Department of Dentistry, The Hospital for Sick Children, 555 University Avenue, Toronto, Canada M5G 1X8
Tel: +1 416 813 8220
Fax: +1 416 813 6375
e-mail: ebarrett@sickkids.ca

Accepted 10 April, 2003

An extrusion (extrusive luxation) injury is characterized by partial axial displacement of a tooth from its socket. Clinically, the tooth will be excessively mobile while radiographically the injured tooth will appear elongated and demonstrate a widened periodontal ligament (PDL) space and intact alveolar bone (1). Andreasen (2) described the extrusion as a partial avulsion, and although this term is not commonly used, it provides a useful insight. Extruded incisors have nearly complete severance of the PDL like avulsed teeth, yet have not been exposed to the desiccation and chemical injury that frequently accompanies avulsion. Consequently, outcomes of severe extrusions may provide a model for comparison with replanted teeth.

Differentiation of extrusions from other luxation injuries is critical for outcome studies. For example, coronal dislocation of an extruded tooth may lead to its misdiagnosis as a lateral luxation. In these cases, it is imperative that the injury be differentiated from a lateral luxation by determining whether the involved tooth is immobile or not as lack of mobility is characteristic of lateral luxations (1). The alveolar bone sustains minor injury and there is additional injury to the pulp and PDL yet the extent of this damage in humans is not understood (3). Histological changes thought to occur have been derived from the avulsion model or from animal studies (4–6).

Outcome-based protocols for management of luxation injuries do not exist. Current treatment guidelines are derived from animal trials, case studies, and clinical experience. By consensus, the guidelines of Andreasen & Andreasen (1) have become the basis of management of luxation injuries for the majority of clinicians. Nevertheless, these guidelines have yet to be tested in a clinical trial and there remains a lack of information on complications, risks, benefits, and economic factors.

Clinical consensus supports timely repositioning of extruded teeth to their original position followed by fixation with a semirigid splint (1, 7). Splinting for less than 14 days is believed to prevent further damage during PDL healing (8). Endodontic treatment is initiated only if pulpal or periodontal pathosis is diagnosed (9). Endodontic treatment is aimed at eliminating infection in order to facilitate healing and retention of the tooth. If there is evidence of pulp necrosis (PN) and the root apex is mature, pulp extirpation followed by conventional endodontic treatment is indicated. If root development is incomplete and a necrotic pulp is diagnosed then initiation of apexification is indicated (extirpation of the pulp followed by placement of calcium hydroxide paste for up to 24 months) (10, 11). Dental injuries have an uncertain prognosis and the final fate of an injured tooth, even with appropriate treatment, may not be apparent for years (12).

The purpose of this study is to describe the survival of extruded permanent maxillary incisors in children and adolescents, to compare the survival of severely extruded permanent maxillary incisors with a sample of replanted incisors and to determine if outcomes (pulp canal obliteration (PCO), PN, and inflammatory root resorption (IRR)) were linked to specific injury-related variables (stage of root development, severity of extrusion, time to treatment).

Methods

Sample

The sample was drawn from patients who attended the Department of Dentistry at The Hospital for Sick Children (HSC), Toronto, Canada between June 1988 and June 1995. Only vital permanent maxillary incisors of healthy children and adolescents were considered for inclusion. A minimum follow up of 1 year was required for inclusion unless incisors had been extracted in which case they were included in the study. Exclusion criteria have been described previously (13). Data collected at the emergency visit included stage of root development (14), severity of the extrusion, and time to treatment. Data collected at follow up included PCO, PN, IRR, and tooth survival. Any teeth with associated root fractures and fractures that involved multiple teeth and alveolar bone, the alveolar process or the maxilla were also excluded.

Management of extrusions

The treatment protocol for extrusions at HSC was implemented in 1988 and based largely upon Andreasen (2, 15). Extruded incisors were anesthetized and repositioned with finger pressure. A passive non-rigid splint made of 0.016 in. stainless steel orthodontic wire was fabricated and placed with light-cured composite resin to include at least two unaffected teeth on either side of the injured tooth for stability (8). Standardized periapical and occlusal radiographs were obtained to confirm the diagnosis and to serve as a standard for follow up (16). The scale developed by Moorrees et al. (14) was used to classify the stage of root development from the radiographs. Incisors were categorized into two groups based upon root development: immature (stages 2–5) and mature (stages 6 and 7) at the time of injury. The amount of extrusion was measured in millimeters based upon clinical and/or radiographic hard tissue landmarks (16). Crown fractures and type (if present) were recorded and managed accordingly.

All patients in the current study received a 7-day course of antibiotics. Penicillin was the drug of choice but patients who were sensitive to penicillin were prescribed erythromycin. All patients were provided with 0.1% chlorhexidine gluconate mouth rinse.

The first follow-up appointment occurred within 2 weeks of the emergency appointment and subsequent visits were made at 3 and 6 months, and annually thereafter. Data collected at each clinical examination included tooth mobility, tooth color, periodontal probing depths, percussion sensitivity and tone, and the presence or absence of fistula and tooth vitality (4) Tooth survival, the presence of PN, PCO, periodontal status, and IRR were based on clinical and radiographic data collected at each follow-up visit.

Diagnosis of PN was based upon the absence of pulp sensibility and at least one other clinical or radiographic sign (color changes in the crown, periapical radiolucency, presence of a fistula or tenderness to percussion) (4, 17). Once PN was diagnosed, endodontic therapy was initiated. The technique and management of incisors diagnosed with PN has been described previously (13). Radiographs from the emergency appointment were used to determine the degree of apical development and follow-up radiographs were used to determine the quantity and type of root resorption and the presence of PCO. Radiographic examination and assessment methods have been described previously (13).

Statistical methods

The study sample was compared with the total potential sample using Student's *t*-test. As some patients had more than one extruded tooth, individual observations were not independent. Therefore, a single tooth was drawn at random from each patient with multiple extrusions (13). Survival analysis (Kaplan–Meier) was performed for the entire sample and for the single-tooth scenarios. A subset of severe extrusions from this investigation was compared with avulsed teeth stored in physiological media (13).

Intra- and inter-rater agreement values for dichotomous responses were measured with the kappa statistic (18, 19). Kappa statistics were calculated for two independent raters in their evaluation of apical development, IRR, and PCO. For censored values (PN, IRR), a proportional hazards regression (20) was performed to determine if the independent variables (degree of extrusion, apical development, time until treatment) were significantly related to survival and development of healing complications. Teeth were censored if they had not developed PN or IRR at the close of the study.

Some of the data collected was transformed prior to analysis for convenience and ease of manipulation. The continuous variable 'amount of extrusion' was dichotomized into mild and severe categories. For ease of calculation and convenience, time until treatment was log-transformed. For variables found to be significant, the failures were split by that variable and life tables were generated. The Wilcoxon and Mantel–Haenszel or log-rank tests determined significant differences over the strata of the survival tables. A logistic regression was performed to determine if the independent variables were significantly related to the development of PCO. As it was not possible to determine exactly when PCO began, it was decided to define PCO as either present or absent. For all statistical tests, a critical value of 0.05 was employed.

Results

Sample

The database yielded a potential sample of 57 patients (34 males; 23 females) with extrusion injuries to one or more of their permanent maxillary incisors (79 incisors). Information was available for 35 patients (18 males; 17 females) with 55 extruded permanent maxillary incisors (42 central; 13 lateral) and a mean age of 10.5 years at the time of trauma (range: 7.1–17.8 years, SD = 2.9). Seventeen patients could not be contacted/moved and five refused recall or consent. Available and unavailable populations were compared for mean age, mean time to treatment (minutes), mean severity of injury (mm) and in all cases the samples were not significantly different $P > 0.10$. Additional data are shown in Table 1.

Radiographic assessment

Two calibrated raters (not associated with this study) were employed to diagnose the stage of root development and presence of IRR. Where there was disagreement between raters, an expert panel decided the result. Kappa scores for agreement of inter- and intrarater reliability for the radiographic assessment of apical development (0.68) and the presence of IRR (0.50) were both in the range of *moderate to perfect* ($\kappa = 0.50$–1.0) (21). The interrater kappa score for apical development was substantial ($\kappa = 0.68$) and for IRR was moderate ($\kappa = 0.50$). Both were significant ($P \leq 0.006$). The intrarater kappa scores ranged from *perfect to moderate* but only rater 2 was significant ($P = 0.0003$) for apical development.

Tooth survival

As only one incisor was lost from the extrusion sample, survival analysis was inappropriate. However, a subsample of severe extrusions from this study was compared with a subsample of avulsed incisors that had been stored in physiological media (13). The Kaplan–Meier curves were plotted and compared (Fig. 1). The difference in survival was not significant by the log-rank test ($P = 0.10$).

Outcomes

A proportional hazards regression (20) was performed to determine if any variables were significantly related to the development of PN and IRR. However, only three incisors from the entire sample showed evidence of IRR. In this study, 43% of the

Table 1. Initial and recall information on available sample of extruded incisors

Variable	Mean	Median	Range	SD		Immature	Mature
Initial information							
Time to treatment (min)	457		30–3870	708			
Amount of extrusion (mm)	2		1–8	1.3			
Root development ($n = 55$)						24	31
	Mean	Median	Range	SD	Complete	Incomplete	Total
Recall information							
Follow up (days)	1320	1332	423–2887	647			
Endodontic treatment					21	2	23
Time until pulpectomy (days)	256		12–1396	399			

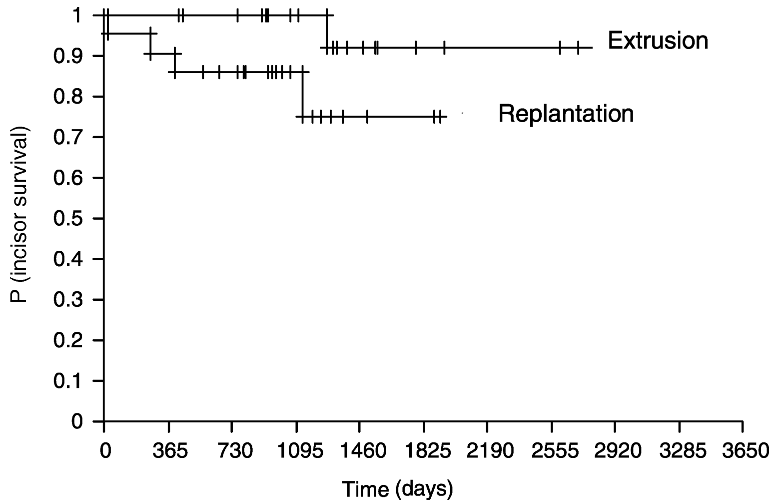

Fig. 1. Comparison of Kaplan–Meier survival curves of data for severely extruded incisors and incisors replanted following storage in physiological media.

Table 2. Distribution of teeth with PN for the 'single tooth' scenario and the entire sample

Scenario	Total teeth	PN	Vital	Per cent vital
'Single tooth'	34	16	18	52.9
Entire	54	23	21	38.9

Table 3. Summary of the results from the Cox regression in the 'single tooth' scenario for PN

Variable	χ^2	*P*-value	Relative risk
Degree of extrusion	1.62	0.20	2.08
Apical development	0.19	0.66	0.78
Log time to treatment	2.12	0.15	0.64

surviving incisors (23 of 54 incisors) experienced PN. Of these, 11 had immature apices and 12 had mature apices. The distribution of teeth with PN for the 'single tooth' scenario as well as the entire sample is presented in Table 2. The results of the Cox regression for the 'single tooth' scenario is presented in Table 3. None of the variables proved to be significantly related to development of PN following extrusion ($P > 0.05$). However, the degree of extrusion, although not significant ($P = 0.20$), had a relative risk of 2.08 that indicates a trend towards increased PN with severe extrusions.

Based upon the magnitude of this trend, the data was stratified by degree of extrusion (mild or severe). Kaplan–Meier survival curves for development of PN were plotted and compared (Fig. 2). As expected the Wilcoxon test ($\chi^2(1) = 2.66$, $P = 0.10$) and the log-rank test ($\chi^2(1) = 1.41, P = 0.23$) failed to demonstrate a significant difference between the two curves.

Within the subsample of severe extrusions, six of seven incisors experienced PN by day 122 following injury, while the remaining incisor experienced PN the following year (day 411). From the subsample of mild extrusions, three of six teeth experienced PN by day 125 after injury while the other three teeth experienced PN between years 2 and 4 (days 938–1396). In total, nine of 13 teeth (69%) experienced

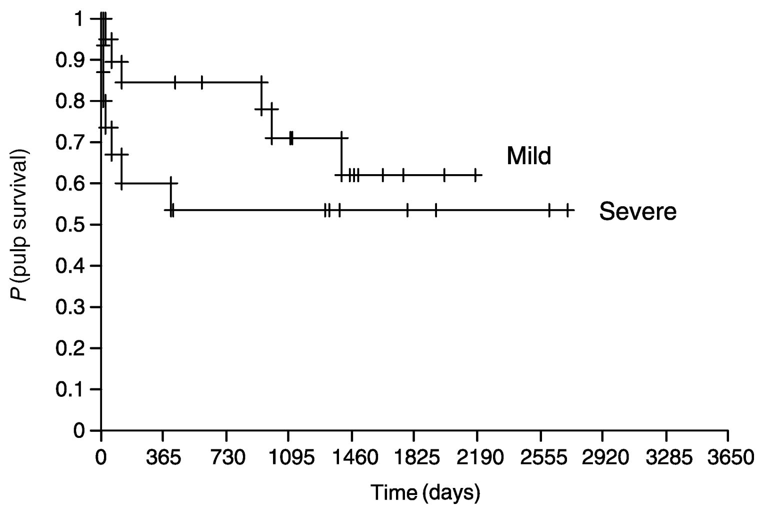

Fig. 2. Kaplan–Meier survival curves showing the development of PN when stratified on the degree of extrusion (mild vs. severe).

Table 4. Summary of the results of the logistic regression model for PCO in 'single tooth' scenario

Variable	*P*-value	Odds ratio (95% CI)
Degree of extrusion	0.03*	0.14 (0.02–0.82)
Apical development	0.66	0.67 (0.12–3.83)
Log time to treatment	0.16	1.00 (1.00–1.00)

The odds ratio and the 95% CI are listed.
*Significant ($P < 0.05$).

PN by the fourth month or in general, within the first year of an extrusion. Early PN was clearly more common if the extrusion was severe.

PCO was the second most common healing complication. Thirty-five per cent of surviving incisors (19 of 54) developed PCO, of which 16 had immature apices. Inter-rater reliability kappa scores for the radiographic assessment of PCO showed agreement to be *substantial* ($\kappa = 0.65\ 21$), and all values were significant ($P \leq 0.0003$). PCO was investigated to determine if any variables influenced its occurrence. Table 4 presents data from the statistical analysis of the 'single tooth' scenario. Following Logistic Regression analysis, the degree of extrusion was shown to be significantly related to the development of PCO ($P = 0.03$).

Discussion

Sample

This investigation provides the largest sample of extruded permanent incisors examined in a prospective longitudinal study. It is only the second clinical study to specifically address extrusion injuries (22), and it is the first investigation specific to the pediatric population.

Tooth survival

Survival analysis is ideal for studies that investigate rare conditions that must accommodate staggered entry of patients over time. However, such analyses are only useful if: (i) there is an identifiable starting point; (ii) there is a dichotomous and well-defined outcome; (iii) patients lost to follow up are not related to outcome; and (iv) there are no changes in study design over time. These criteria were all met. Barrett (13) was among the first to use survival analysis for incisors involved in avulsion/replantation injuries and Humphrey (2003 this series) used similar methodology to report the effects of severe (>6 mm) versus mild (<3 mm) intrusions on incisor survival. Survival analysis had been used in other clinical studies to examine the relationship between injury and treatment variables and the development of healing complications such as PN (4) and PCO (23). In this study, survival analysis was designed to quantify outcomes following extrusions but was abandoned as only one incisor was lost (1/55).

We arbitrarily chose 2 mm or less to divide the variable into mild and severe extrusion categories as the mean amount of extrusion in this sample was 2 mm, and a previous animal study demonstrated a marked increase in injury for extrusions between 2 and 3 mm (5). In order to compare survival of extruded incisors with avulsion/replantation, severe extrusions were compared with a subsample from Barrett & Kenny (13). Analysis revealed no statistically significant difference between survival of severely extruded and avulsed incisors stored in physiological media ($P > 0.05$). This is consistent with clinician's expectations that outcomes for severely extruded incisors and incisors replanted under 'favorable' conditions should be similar.

Outcomes

The most common outcome in the current study was PN and this is consistent with previous studies of extrusion injuries (4, 9, 22, 24). Although in this study, immature teeth experienced fewer incidents of PN, root development was not statistically significant in the 'single tooth' scenario ($P = 0.66$). However, the increased relative risk of PN with severe extrusions was suggestive of a trend that stimulated further analysis. Although the Wilcoxon and the log-rank tests reiterated the lack of statistical significance between the pulp vitality survival curves stratified according to degree of extrusion, observation of the severe extrusion subsample suggests that if PN occurs it is likely to be an early event. This finding is consistent with other descriptive studies (4, 17).

The relatively large number of teeth with PCO was also expected as root maturity has been identified as the main predictor of PCO (23). As the exact time when PCO began could not be determined based on the follow-up data, a logistic regression was performed. In the 'single tooth' scenario, the degree of extrusion was significantly related to the development of PCO ($P = 0.03$). Teeth that sustained only mild extrusions were nearly threefold as likely to be diagnosed with PCO than teeth with severe extrusions. Presumably, teeth with severe extrusions are more likely to sustain complete severance of the pulpal vasculature and become necrotic as opposed to those with mild injuries. In the latter scenario, there is likely to be damage to the apical pulp tissue with retention of tissue perfusion, but the injury is of sufficient magnitude to lead to development of PCO. In this sample, only two of the 19 incisors identified with PCO progressed to PN.

Root resorption was a rare finding in the current study and was not further analyzed because of the small number (3/55) of events observed.

Clinical application

This study shows that outcomes are favorable for extruded permanent incisors in the pediatric population. The prospects for long-term retention of extruded permanent incisors of preadolescents and adolescents were excellent over the 8-year duration of the current study. Just one extruded incisor was lost from the entire sample. This indicates that current treatment methods for extruded permanent incisors are adequate based on the outcomes described.

The healing complications PN and PCO are common for extrusions but IRR was rare (13). PN occurred in approximately 43% of this sample with a trend towards increasing frequency in teeth that sustained severe extrusions. The relative risk of PN increased twofold for severe extrusions and PN commonly occurred within the first year of injury. Parents will appreciate prognostic information on the likelihood of PN and subsequent need for endodontic treatment. This information will help families prepare for future costs and time demands. Based on this study, parents can be told that a mildly extruded tooth is more likely to develop PCO than a severely extruded tooth. Clinicians can now provide prognostic information on tooth survival and the chances of developing PN and PCO following extrusion injuries to the permanent maxillary incisors of preadolescents and adolescents.

Acknowledgements – The authors thank our indepen-dent raters of radiographs, Drs Peter Judd and Michael Casas. The Dental Trauma Research Group database was established and supported by the Toronto Academy of Dentistry Crown and Bridge Study Club. This study was supported by a grant from the New Initiatives Fund of the Hospital for Sick Children Foundation.

References

1. Andreasen FM, Andreasen JO. Luxation injuries. In: Andreasen JO, Andreasen FM, eds. Textbook and Color Atlas of Traumatic Injuries to the Teeth, 3rd edn. Copenhagen: Munksgaard; 1994. p. 318.
2. Andreasen JO. Luxation of permanent teeth due to trauma. A clinical and radiographic follow-up study of 189 injured teeth. Scand J Dent Res 1970;78:512–23.
3. Andreasen J. Challenges in clinical dental traumatology. Endod Dent Traumatol 1985;1:45–55.
4. Andreasen FM, Vestergaard-Pedersen B. Prognosis of luxated permanent teeth – the development of pulp necrosis. Endod Dent Traumatol 1985;1:207–220.
5. Mandel U, Viidik A. Effect of splinting on the mechanical and histological properties of the healing periodontal ligament in the vervet monkey (*Cercopithecus aethiops*). Arch Oral Biol 1989;34:209–17.
6. Miyashin M, Kato J, Takagi Y. Tissue reactions after experimental luxation injuries in immature rat teeth. Endod Dent Traumatol 1991;7:26–35.
7. Roberts G, Longhurst P. Luxation injuries. In: Roberts G, Longhurst P, eds. Oral and Dental Trauma in Children and Adolescents. Oxford: Oxford University Press; 1996. p. 76.
8. Oikarinen K. Tooth splinting. a review of the literature and consideration of the versatility of a wire-composite splint. Endod Dent Traumatol 1990;6:237–50.
9. Crona-Larsson G, Bjarnason S, Noren JG. Effect of luxation injuries on permanent teeth. Endod Dent Traumatol 1991;7:199–206.
10. Cvek M, Granath L-E, Hollender L. Treatment of non-vital permanent incisors with calcium hydroxide 3. Variation of occurrence of ankylosis of reimplanted teeth with duratrion of extra-alveolar period and storage environment. Odontol Revy 1974;25:43–56.
11. Cvek M. Prognosis of luxated non-vital incisors treated with calcium hydroxide and filled with gutta percha. A retrospective clinical study. Endod Dent Traumatol 1992;8: 45–55.
12. Kaste LM, Gift HC, Bhat M, Swango PA. Prevalence of incisor trauma in persons 6–50 years of age: United States, 1988–1996. J Dent Res 1996;75 (Spec No):696–705.
13. Barrett EJ, Kenny DJ. Survival of avulsed permanent maxillary incisors in children following delayed replantation. Endod Dent Traumatol 1997;13:269–75.
14. Moorrees CFA, Fanning EA, Hunt EE. Age variation of formation stages for ten permanent teeth. J Dent Res 1963; 42:1490–502.
15. Andreasen JO. Traumatic Injuries of the Teeth, 2nd edn. Copenhagen: Munksgaard; 1981. p. 153–77.
16. Andreasen FM, Andreasen JO. Diagnosis of luxation injuries: the importance of standardized clinical, radiographic and photographic techniques in clinical investigations, Endod Dent Traumatol 1985;1:160–9.
17. Jacobsen I. Criteria for diagnosis of pulp necrosis in traumatized permanent incisors. Scand J Dent Res 1980;88:306–12.
18. Fleiss JL, Shrout PE. The effects of measurement errors on some multivariate procedures. Am J Public Health 1977; 67:1188–91.
19. Hunt R. Percent agreement, Pearson's correlation, and kappa as measures of inter-examiner reliability. J Dent Res 1986;65:128–30.
20. Cox D. Regression models and life-tables. J R Stat Soc, 1972;34:187–220.
21. Landis J, Koch G. The measurement of observer agreement for categorical data. Biometrics 1977;33:159–74.
22. Dumsha T, Hovland EJ. Pulpal prognosis following extrusive luxation injuries in permanent teeth with closed apexes. J Endod 1982;8:410–2.
23. Andreasen FM, Zhijie Y, Thomsen BL, Andersen PK. Occurrence of pulp canal obliteration after luxation injuries in the permanent dentition. Endod Dent Traumatol 1987;3: 103–15.
24. Oikarinen K, Gundlach KK, Pfeifer G. Late complications of luxation injuries to teeth. Endod Dent Traumatol 1987;3: 296–303.