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Surgical extrusion as a treatment option for crown–root fracture in permanent anterior teeth: a systematic review

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Key words: Crown–root fracture; intrusive luxation; permanent tooth; surgical extrusion; surgical repositioning; intra-alveolar transplantation

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Abstract – *Background*: A crown–root fracture is defined as a fracture involving enamel, dentin, and cementum. The possibility of saving and reconstructing teeth with such fractures has increasingly become a viable alternative to extraction and prosthetic therapy. One such treatment option available is surgical extrusion. *Objective*: The aim of this review is to evaluate surgical extrusion as a treatment modality for management of crown–root fractures in permanent anterior teeth. *Methods*: Electronic search of scientific papers was carried out on Entrez Pubmed and the Cochrane Central Register of Controlled Trials databases using specific keywords. The search yielded 130 papers, out of which 16 relevant papers were identified and included based on predetermined inclusion criteria and the remaining 114 were found to be irrelevant. Hand search yielded 10 articles, which were also included. These 26 articles which included only case reports and case series formed the basis of this systematic review. *Conclusion*: From the existing literature, we can conclude that surgical extrusion can be used to treat crown–root fractures successfully. But the level of evidence is very low as the studies available are only case reports and case series.

Trauma to the teeth may result in different types of injuries to the teeth and supporting structures. Crown–root fracture comprises of one such injury and is defined as the fracture involving enamel, dentin, and cementum. The incidence of crown–root fracture accounts for 5% of all the injuries affecting permanent dentition and 2% in primary dentition (1, 2). Crown–root fractures are classified based on the level of pulpal involvement into uncomplicated and complicated crown–root fractures (3). The common etiologic factors are falls, bicycle and automobile accidents, foreign body striking the teeth, and iatrogenic injuries. The mechanism behind the trauma involves direct impact on the anterior teeth region and indirect impact on the posterior teeth region due to forceful closure of the lower jaw against the upper jaw (1).

Clinical findings reveal a mobile coronal fragment attached to the gingiva with or without a pulpal exposure. According to the force and direction of the impact, a fracture line can start at some point of the crown and extend longitudinally through the pulp chamber to the subgingival area and alveolar crest. Radiographic findings may reveal a radiolucent oblique line that comprises of the crown and root in a vertical direction in primary teeth and in a direction usually perpendicular to the central radiographic beam in permanent teeth (1). Radiographic determination of the oral limit of the fracture is usually difficult as the oblique fracture line is almost perpendicular to the central beam; the fractured fragments are in close proximity to each and result in overlap of the fracture line with alveolar bone (4).

Emergency treatment can include stabilization of the coronal fragment with an acid etch/resin splint. Despite contamination from saliva via the fracture line to the pulp, the tooth generally remains symptom free. However, definitive treatment is ideally started within a few days after injury. The following situations must be considered when choosing a treatment approach: localization and degree to which biologic width has been invaded, the presence or absence of pulpal involvement, the root development stage, the tooth eruption stage, and the degree of adaptation of the fragment to the tooth remnant (5).

The difficulties presented during the restoration of these factors have led to the development of different modalities for management of crown–root fracture following removal of the coronal fragment, which include: restoration above the gingival level, gingivectomy and ostectomy, and subsequent restoration with postcrown, fragment reattachment, surgical extrusion or intra-alveolar transplantation, orthodontic extrusion, intentional replantation with 180º rotation, and extraction when the fracture is more than one-third of the root (6,7).

The possibility of saving and reconstructing teeth with cervical crown–root fractures has increasingly

become an alternative to extraction and prosthetic therapy. Clinical studies have shown that surgical techniques may be useful to extrude and save the root (8). Surgical extrusion as a treatment modality for crown–root fractures has been developed and modified over the years and eventually simplified (9–11).

Consistent recommendations, based on strong surrounding evidences, must be developed that can well address the effectiveness of surgical extrusion as a treatment modality for crown–root fractures. This systematic review addresses the choices a clinician encounters in dental practice and further aims to provide the current best available evidence upon which clinical decisions regarding surgical extrusion as a management strategy for crown–root-fractured permanent teeth can be based.

Materials and methods

The literature search

Structured electronic search of scientific papers was carried out on the Entrez Pubmed and the Cochrane Central Register of Controlled Trials databases using combination of the following specific keywords: Crown–root fracture, intrusive luxation, permanent tooth, surgical extrusion, surgical repositioning, intra-alveolar transplantation. The electronic search was supplemented by hand searching through the following journals after cross-referencing the journals obtained from the electronic search: Swedish Dental Journal, Dental Traumatology, International Journal of Periodontics & Restorative Dentistry, Journal of Endodontics, and International Journal of Oral and Maxillofacial Surgery.

Detailed search strategy

Pubmed search (key words):
((((((“surgical procedures, operative”[MeSH Terms] OR (“surgical”[All Fields] AND “procedures”[All Fields] AND “operative”[All Fields]) OR “operative surgical procedures”[All Fields] OR “surgical”[All Fields]) AND extrusion[All Fields]) OR ((“surgical procedures, operative”[MeSH Terms] OR (“surgical”[All Fields] AND “procedures”[All Fields] AND “operative”[All Fields]) OR “operative surgical procedures”[All Fields] OR “surgical”[All Fields]) AND repositioning[All Fields])) OR (intraalveolar[All Fields] AND (“transplantation”[Subheading] OR “transplantation”[All Fields] OR “transplantation”[MeSH Terms] OR “transplantation”[All Fields] OR “organ transplantation”[MeSH Terms] OR (“organ”[All Fields] AND “transplantation”[All Fields]) OR “organ transplantation”[All Fields]))) OR (intra-alveolar [All Fields] AND (“transplantation”[Subheading] OR “transplantation”[All Fields] OR “transplantation”[MeSH Terms] OR “transplantation”[All Fields] OR “organ transplantation”[MeSH Terms] OR (“organ”[All Fields] AND “transplantation”[All Fields]) OR “organ transplantation”[All Fields]))) OR (intra[All Fields] AND alveolar [All Fields] AND (“transplantation”[Subheading] OR “transplantation”[All Fields] OR “transplantation”[MeSH Terms] OR “transplantation”[All Fields] OR “organ transplantation”[MeSH Terms] OR (“organ”[All Fields] AND “transplantation”[All Fields]) OR “organ transplantation”[All Fields]))) AND ((((“tooth crown”[MeSH Terms] OR (“tooth”[All Fields] AND “crown”[All Fields]) OR “tooth crown”[All Fields] OR “crown”[All Fields] OR “crowns”[MeSH Terms] OR “crowns”[All Fields]) AND (“plant roots”[MeSH Terms] OR (“plant”[All Fields] AND “roots”[All Fields]) OR “plant roots”[All Fields] OR “root”[All Fields]) AND (“fractures, bone” [MeSH Terms] OR (“fractures”[All Fields] AND “bone” [All Fields]) OR “bone fractures”[All Fields] OR “fracture”[All Fields])) OR (intrusive[All Fields] AND luxation [All Fields])) OR (“dentition, permanent”[MeSH Terms] OR (“dentition”[All Fields] AND “permanent” [All Fields]) OR “permanent dentition”[All Fields] OR (“permanent”[All Fields] AND “teeth”[All Fields]) OR “permanent teeth”[All Fields])).

Detailed search flowchart is depicted in Appendix 1.

Inclusion criteria

Studies including case reports, case series, and animal studies on surgically extruded teeth, radiographic outcomes of surgical extrusion, clinical outcomes of surgical extrusion, histological assessment of surgical extrusion were included for this review. Articles in English were only included in this review.

Exclusion criteria

Studies that did not contain information on surgical extrusion of teeth and management of crown–root fracture with surgical extrusion as one of the treatment modalities were excluded.

Study selection and assessment

The search yielded 130 papers, out of which 16 were identified and included based on predetermined inclusion criteria, while the remaining 114 were irrelevant. Hand search yielded 10 articles, which were also included. Finally, these 26 articles formed the basis of this review.

Data extraction

Data extraction was carried out with a data extraction form where the following variables were concentrated for grouping the available data:

Periodontal ligament spacing, root resorption, periapical pathologies and marginal bone loss, probing defects (gingival or periodontal pocket), histological characteristics of inflammatory changes, mobility of tooth, ankylosis, and microbiology of pulp canal.

Detailed tabled data are depicted in Appendix 2.

Data analysis

Data were extracted based on the above variables of interest. The following factors formed the basis of the data analysis:

Presence or absence of normal periodontal ligament, progressive or non-progressive root, presence or absence of periapical radiolucency or pathology and marginal bone loss, presence or absence of probing defects like gingival and periodontal pockets, level of healing observed under histological examination, presence or absence of mobility of tooth, analysis of endodontic therapy based on microbiology of canal.

Results

Level of evidence

Studies included were case reports and case series with an evidence level of 4 based on the evidence pyramid given by Centre for evidence-based medicine (12). Only one animal study was included with an evidence level of 5.

The absence of randomized controlled trials in this context can be attributed to the ethical issues involved in trauma management and the unpredictable patient presentation. Therefore, in this systematic review, we have worked to bring together all the available data to provide an evidence-based approach of treating crown–root fractures with surgical extrusion.

The various individual parameters examined and associated outcome measures

To pool the data from the several studies reviewed, the following parameters were selected based on the observed clinical and radiographic outcome measures to evaluate the success of the surgical extrusion procedure:

Periodontal ligament spacing:- Normal periodontal contour was seen in most of the studies during the three-month follow up (3, 10, 11, 13, 14). Restoration of normal form and function of the periodontium was seen in all the case reports and case series among the reviewed articles (3, 13–19).

Root resorption:- Although present in the few studies reviewed, root resorption was non-progressive in nature (8, 10, 20–23). It was primarily associated with the surgical technique involving periapical surgery and stabilization by bone graft (8, 10). Higher incidence of resorption was also observed in case of endodontic treatment being performed prior to extrusion due to contamination by serum, blood, and saliva (21). Various other case reports and case series have shown no signs of root resorption after an average follow up of 1 year (3, 18, 19, 24–27).

Periapical pathologies and marginal bone height:- Normal periapical healing and resolution of radiolucency was seen in almost all reported case reports and case series (1, 3, 11, 17, 18, 26–29). A study showed a minor loss of marginal bone height in one out of the 20 teeth treated (22). A study with a clinical and radiographic follow up of 10 years has shown the extruded teeth to be free of clinical and radiographic pathologies or complications. No distinguishable marginal bone loss could be observed after the follow-up period of 10 years (14).

Probing defect:- From the reviewed studies, it was derived that normal probing depth with physiological gingival pocket depth was seen after an average follow up of a year. No bleeding on probing was also observed. Normal gingival architecture was observed showing favorable results (11, 13, 24–26).

Histological characteristics of inflammatory changes:- According to Kim et al., (30) intense repair was observed in both groups (surgical and orthodontic extrusion) after a period of 180 days; functional repaired surface resorption was seen in all the root segment thirds evaluated.

Mobility:- Mobility decreased within a period of 3–4 weeks after splinting (9, 10, 24). In a study conducted by Kahnberg (11), mobility was observed in 2 cases after 12 months of follow up.

Ankylosis:- It was not observed in any case, which was managed by surgical extrusion (9, 20, 24, 25).

Microbiology of canal:- In a study conducted by Warfvinge et al., (21) bacteriological testing showed that teeth in Group II (endodontic treatment after surgical extrusion) required fewer treatments to provide a non-infected canal than teeth in Group I (endodontic treatment before surgical extrusion).

Discussion

Accurate reporting and interpretation of results

The case reports and case series described the outcomes of patients who underwent surgical extrusion as a treatment for fractured and intruded teeth due to trauma (3, 13–18, 19, 21, 23, 24, 31). Various other prospective and retrospective studies have shown that the surgical technique involving intra-alveolar transplantation using simple extraction or extrusion was found to be successful in extrusion of teeth with crown–root fractures. There was no serious progression of any complications with evidence of good healing, definitive attachment of the periodontium, and good maintenance of marginal bone height with resolution of periapical radiolucency (8, 10–11, 20–22, 28).

Protocol for surgical extrusion

Preservation and restoration of teeth with deep-seated crown–root fracture with surgical extrusion can be carried out by two surgical techniques described by Kahnberg (10, 11). The first surgical technique involves flap operation with careful exposure of the root apex and extrusion of the tooth with an elevator. After extrusion, autologous bone transplant is obtained from the nasal spine region or adjacent alveolar process (buccal cortex) to secure the tooth in the new position. After repositioning and suturing of the flap, a surgical dressing is placed over the transplanted region to immobilize the root (10). The second technique involves luxation of the roots with a marginal approach without surgical exposure of the apical part of the roots and consequently without stabilization with bone transplants. Luxation and extrusion of the

roots were performed using thin carvers as periotome and elevators after extirpation of covering soft tissue. Immobilization of the roots in their new position was accomplished by interdental sutures and surgical dressing. In teeth where the fracture line slanted toward the palatal side and the level of the gingiva was more apical at the buccal side, the roots were rotated 180 . When the teeth are rotated, it requires less extrusion to provide access to the margins of the fracture on the facial aspect (22). Advantages of technique II over technique I are that the tooth remains free from major complications such as root resorption, periapical destruction, ankylosis, and marginal bone loss as the root surface is not exposed to the external environment; method for fixation and immobilization allowed certain mobility throughout the repair period (8).

Microbiology of the canal following endodontic treatment before and after surgical extrusion procedure

In a study conducted by Warfvinge et al. (21) in teeth *endodontically treated before transplantation,* bacterial sampling showed growth of bacteria after one treatment (before transplantation). Even after two treatments, some teeth showed cultivable bacterial samples. The most resistant bacteria to the root canal treatment are from the genus *Enterococcus*. In teeth *endodontically treated before transplantation*, as the treatment is carried out without rubberdam isolation, there is a chance that 70% of the canals get infected despite the use of calcium hydroxide as an intracanal dressing. The infection of the canals is the result of contamination from blood and bacteria as no rubberdam is used during treatment. Serum has been shown to reduce the antibacterial effect of calcium hydroxide *(Bystrom* et al. *1985)*; this might explain why calcium hydroxide has little antibacterial effect. In teeth *endodontically treated after transplantation,* less number of teeth tested positive for bacterial sample after initial endodontic procedure with calcium hydroxide dressing. However, growth of bacteria can be seen if there are associated root fractures like vertical root fractures or root infractions. Also in the teeth endodontically treated after transplantation, the most resistant bacteria were of the genus *Enterococcus*. It has been seen that in both the treatment options, teeth were free from detectable bacteria after three intracanal treatments. Endodontic treatment before intra-alveolar transplantation does not have any advantage over not treating the tooth until after the transplantation.

Histology of tissue changes: a comparison between surgical extrusion and orthodontic extrusion

Kim et al. (30) in 2009 conducted an animal study comparing the tissue changes occurring after surgical and orthodontic extrusion with a follow-up period of 180 days, where intense repair was observed, with restoration of function and functional repair of surface resorption in the entire root segment. At the repair site, in addition to the new cementum, dense and functional periodontal ligament with well-defined bundles of collagen fibers was seen. Areas of modestly repaired inflammatory resorption were seen, and chronic inflammation was also observed in the gap repaired by new cementum and periodontal ligament. Although periodontal repair appeared, there were no epithelial rests of Malassez at the repaired resorption sites in all specimens.

Author's conclusion

The findings of this systematic review supported by the available literature indicate that surgical extrusion can be used successfully for the management of crown–root fractures. It is a one-step procedure, which is simpler and less time consuming. A treatment option using surgical extrusion as a procedure for exposing the fracture line supra-gingivally is being recommended for use by clinicians as this technique does not require special clinical skills.

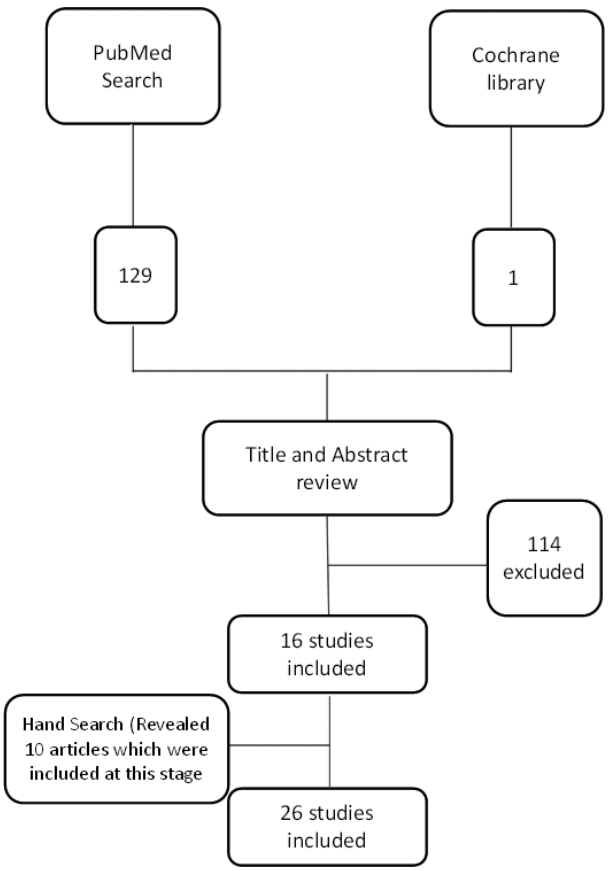
Therefore, we can conclude that surgical extrusion is a viable treatment option in the management of crown–root-fractured permanent anterior teeth. The advantages include minimum chair-side time when compared with other procedures, good esthetics, ready acceptance from the patient, and low incidence of failure. However, more studies with higher levels of evidence are required before reaching further conclusive results.

References

1. Tsilingaridis G, Malmgren B, Andreasen JO, Malmgren O. Intrusive luxation of 60 permanent incisors: a retrospective study of treatment and outcome. Dent Traumatol 2012;28: 416–22.
2. Andreasen JO, Andreasen FM. Crown–root fractures. In: Andreasen JO, Andreasen FM, editors. Textbook and color atlas of traumatic dental injuries, 3rd edn. Copenhagen: Munksgaard; 1994.
3. Kirzioglu Z, Karayilmaz H. Surgical extrusion of a crown-root fractured immature permanent incisor: 36 month follow-up. Dent Traumatol 2007;23:380–5.
4. Sackett DL, Straus SE, Richardson WS, Rosenberg W, Haynes RB. Evidence-based medicine: how to practice and teach EBM, 2nd edn. Edinburgh: Churchill Livingstone; 2000.
5. Eichelsbacher F, Denner W, Klaiber B, Schlagenhauf U. Periodontal status of teeth with crown-root fractures: results two years after adhesive fragment reattachment. J Clin Periodontol 2009;36:905–11.
6. Baratieri LN, Ritter AV, Monteiro Júnior S, de Mello Filho JC. Tooth fragment reattachment: an alternative for restoration of fractured anterior teeth. Pract Periodontics Aesthet Dent 1998;10:115–25.
7. Fariniuk LF, Ferreira EL, Soresini GC, Cavali AE, Baratto Filho F. Intentional replantation with 180 degrees rotation of a crown-root fracture: a case report. Dent Traumatol 2003;19:321–5.
8. Kahnberg KE. Surgical extrusion of root fractured teeth- a follow up study of two surgical methods. Endod Dent Traumatol 1988;4:85–9.
9. Tegsjö U, Valerius-Olsson H, Olgart K. Intra-alveolar transplantation of teeth with cervical root fractures. Swed Dent J 1978;2:73–82.
10. Kahnberg KE, Warfvinge J, Birgersson B. Intraalveolar transplantation (I) The use of autologous bone transplants in the periapical region. Int J Oral Surg 1982;11:372–9.
11. Kahnberg KE. Intra-alveolar transplantation of teeth with crown-root fractures. J Oral Maxillofac Surg 1985;43:38–42.

12. American academy of Pediatric Dentistry. Clinical Guideline on Management of Acute Dental Trauma.
13. Kim CS, Choi SH, Chai JK, Kim CK, Cho KS. Surgical extrusion technique for clinical crown lengthening: report of three cases. Int J Periodontics Restorative Dent 2004;24:412–21.
14. Filho PN, Faria G, Assed S, Pardini LC. Surgical repositioning of traumatically intruded permanent incisor: case report with a 10-year follow up. Dent Traumatol 2006;22:221–225.
15. Roeters J, Bressers JP. The combination of a surgical and adhesive restorative approach to treat a deep crown-root fracture: a case report. Quintessence Int 2002;33:174–9.
16. Kim SH, Tramontina V, Passanezi E. A new approach using the surgical extrusion procedure as an alternative for the Reestablishment of biologic width. Int J Periodontics Restorative Dent 2004;24:39–45.
17. Güngör HC, Cengiz SB, Altay N. Immediate surgical repositioning following intrusive luxation: a case report and review of the literature. Dent Traumatol 2006;22:340–4.
18. Calişkan MK, Tekin U. Surgical extrusion of a partially erupted and crown dilacerated incisor. Dent Traumatol 2008;24:228–30.
19. Dias RS, Cajazeira Neto JA, de Carvalho FM, Moreira Neto JJ. Surgical repositioning of a traumatically intruded permanent incisor in a patient with rheumatic fever: case report. Dent Traumatol 2009;25:e12–5.
20. Tegsjö U, Valerius-Olsson H, Frykholm A, Olgart K. Clinical evaluation of intra-alveolar transplantation of teeth with cervical root fractures. Swed Dent J 1987;11:235–50.
21. Warfvinge J, Kahnberg KE. Intra-alveolar transplantation of teeth: endodontic considerations. Swed Dent J 1989;13:229–33.
22. Caliskan MK, Turkun M, Gomel M. Surgical extrusion of crown-root fractured teeth: a clinical review. Int Endod J 1999;32:146–51.
23. 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.
24. Caliskan MK. Surgical extrusion of a completely intruded permanent incisor. J Endod 1998;23:381–4.
25. Caliskan MK, Gomel M, Turkun M. Surgical extrusion of intruded immature permanent incisors. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1998;86:461–4.
26. Calişkan MK. Surgical extrusion of a cervically root-fractured tooth after apexification treatment. J Endod 1999;25: 509–13.
27. Kirzioğlu Z, Karayilmaz H. Repositioning of a completely intruded permanent incisor with surgical extrusion: a 4-year follow-up case. Pediatr Dent 2009;31:253–6.
28. Kahnberg KE. Intra-alveolar transplantation. I. A 10-year follow-up of a method for surgical extrusion of root fractured teeth. Swed Dent J 1996;20:165–72.
29. Mazumdar D, Roy P, Kumar P. Management of intrusive luxation with immediate surgical repositioning. J Conserv Dent 2009;12:69–72.
30. Kim SH, Tramontina VA, Ramos CM, Prado AM, Passanezi E, Greghi SL. Experimental surgical and orthodontic extrusion of teeth in dogs. Int J Periodontics Restorative Dent 2009;29:4445–443.
31. Garg S, Bhushan B, Singla S, Gupta KP. Surgical repositioning of intruded immature permanent incisor: an updated treatment concept. J Indian Soc Pedod Prevent Dent 2008; 26 (Suppl 2):82–5.
32. Chung MP, Wang SS, Chen CP, Shieh YS. Management of crown-root fracture tooth by intra-alveolar transplantation with 180-degree rotation and suture fixation. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010;109:e126–30.

Appendix 1: Search Flowchart



Appendix 2: Data Extraction Table

Sl. No.	Author's name	Materials	Treatment	Outcome
1.	Tegsjö et al. (1978) (9)	Twelve patients with root fractures.	Intra-alveolar transplantation with apical bone graft. Stabilization achieved with interdental sutures.	None of the cases showed ankylosis or resorption in the root or any negative effects on the adjacent teeth after 12 months of follow up. Normal mobility was observed within 4 weeks of the procedure.
2.	Kahnberg et al. (1982) (10)	Fifteen patients with 15 complicated crown–root fracture.	Intra-alveolar transplantation of the 15 fractured root with apical surgery and placement of autologous bone transplant to stabilize the new position of the tooth.	Mobility decreased considerably after 3 weeks. Radiographic control showed normal periodontal space around roots after 3 months; minor resorption was observed in 10 cases, which was non-progressive. Two patients showed periodontal problems after 2 years of follow up.
3.	Kahnberg (1985) (11)	Twenty-three crown–root-fractured teeth in 23 individuals.	Surgical extrusion of the 23 teeth. Immobilization achieved by interdental sutures and surgical dressing.	A normal periodontal contour was seen at 3-month follow up. At 12-month follow up, clinical examination revealed slight mobility in 3 cases with normal probing depth; radiographic examination revealed resolution of radiolucency and normal marginal bone height.

Appendix 2 Continued

Sl. No.	Author's name	Materials	Treatment	Outcome
4.	Tegsjö et al. (1987) (20)	Fifty-six teeth with complicated crown–root fracture with patient's ages ranging from 9 to 33.	Intra-alveolar transplantation of the 56 teeth. Among these, 8 teeth were extracted due to further trauma/prosthetic reasons.	All teeth exhibited healing without ankylosis. In 12% of cases, unhealed resorption was observed within the apical area.
5.	Kahnberg 1988 (8)	Cervical root fracture in 58 single roots in 53 patients.	Seventeen patients underwent surgical extrusion with autologous bone transplant. (Group I) Rest of the patients underwent surgical extrusion where stabilization was carried out with interproximal sutures. (Group II)	Apical resorption was seen in 17 roots. The resorption was evidenced by slight shortening of the roots, but was non-progressive in nature in all cases. Root resorption was more evident in Group I.
6.	Warfvinge et al. (1989) (21)	Twenty-six crown–root-fractured teeth	Intra-alveolar transplantation. Group I: Endodontically treated before transplantation Group II: Endodontically treated 3–4 weeks after transplantation.	Bacteriological testing showed that teeth in Group II required fewer treatments to provide a non-infected canal than teeth in Group I. Only in 5 of 21 teeth treated. periapical destruction was observed over a period of 2 years; 3 of which belonged to Group I.
7.	Kahnberg et al. (1996) (28)	Twenty-one root-fractured teeth in 19 patients.	Intra-alveolar transplantation of the cervical root fractures.	Except for one out of the 21 intra-alveolar transplanted roots, all functioned with different kinds of crown restorations and without pathological complications.
8.	Caliskan (1998) (24)	A 10-year-old boy with completely intruded left central incisor.	Surgical extrusion of the central incisor. Immobilization carried out by interdental sutures and surgical dressing.	Follow up of 18 months showed no signs of periapical lesion, root resorption, marginal bone loss and signs of ankylosis on radiographic examination and no mobility, normal gingival pocket depth, and no periapical tenderness on clinical examination.
9.	Caliskan et al. (1998) (25)	An 8-year-old boy with intrusion of the central incisors.	Surgical extrusion of the central incisors and stabilization was achieved with interdental sutures and surgical dressing.	On 2-year recall, the patient was asymptomatic. There were no probing defects, and radiographically there was no apical pathosis, root resorption, marginal bone loss, or ankylosis.
10.	Caliskan et al. (1999) (22)	Twenty patients with crown–root fracture with patient's age ranging from 10 to 45 years.	Surgical extrusion of teeth followed by endodontic treatment in 7 teeth. In 13 teeth, endodontic treatment was initiated before extrusion.	Radiographic and clinical evaluation in the follow-up period between 6 and 36 months showed no progressive resorption or bone loss, other than 1 tooth, which showed loss of marginal alveolar bone
11.	Calişkan (1999) (26)	Incisor fractured below the alveolar crest 6 months after completion of apexification treatment.	Surgical extrusion for receiving prosthetic coronal restoration. After the surgical procedure, a dowel post was placed in the root canal, a core was built using glass-ionomer cement and a porcelain veneer crown restoration was completed.	24-month follow-up examination after surgical, endodontic, and prosthetic treatments showed that the tooth was clinically and radiographically healthy and functioned well.
12.	Ebseleseder et al. (2000) (23)	Fifty-eight traumatically intruded teeth.	Forty-eight teeth were repositioned surgically. Immobilization was achieved by wire and composite splint. Nine teeth were left for spontaneous re-eruption.	Necrotic pulps were found in 61% of all immature and 88% of all mature teeth. External root resorption was seen in 68% of all immature and 73% of all mature teeth. Three teeth were lost out of 48 extruded teeth.
13.	Roeters et al. (2002) (15)	Complicated crown–root fracture of maxillary left central incisor.	Surgical extrusion of the crown–root-fractured incisor. Splinting was achieved by resin composite splint.	Eleven months after trauma, the treated teeth exhibited good healing and normal function, with no signs of root resorption.

Appendix 2 Continued

Sl. No.	Author's name	Materials	Treatment	Outcome
14.	Kim et al. (2004) (16)	Case I: Grossly decayed maxillary 1st premolar. Case II: Grossly decayed mandibular 2nd premolar.	Surgical extrusion of the roots. Immobilization achieved by interdental sutures.	Clinical and radiographic monitoring showed the ability of the periodontium to adapt and restore function and good esthetics was achievable.
15.	Kim et al. (2004) (13)	One horizontally fractured maxillary left incisor. One horizontally fractured mandibular right lateral incisor. One root-fractured maxillary canine below gingival margin.	A traumatic surgical extrusion was performed using a periotome. Immobilization achieved through interdental sutures.	Clinical examination revealed reduced probing depth, without bleeding on probing. Periapical radiograph showed new bone formation and normal periodontal ligament space.
16.	Güngör et al. (2006) (17)	Severe intrusive luxation of mature maxillary lateral incisor in a 10-year-old boy.	Surgical extrusion of the intruded teeth and splinting. Tetracycline therapy was initiated at the time of repositioning and maintained for 10 days.	Clinical and radiographic examination conducted 28 months after the surgical extrusion revealed satisfactory apical and periodontal healing.
17.	Filho et al. (2006) (14)	A 10-year-old male patient with completely intruded maxillary left central incisor.	Surgical extrusion after placing a vestibular flap. Immobilization was carried out with a wire composite splint.	Clinical and radiographic follow up of 10 years showed an initial external inflammatory root resorption with periapical radiolucency, which resolved and the tooth was asymptomatic, with healthy periodontium and no loss of marginal bone.
18.	Kirzioglu et al. (2007) (3)	A 9-year-old boy with a uncomplicated crown–root fracture	Surgical extrusion of the tooth and stabilization was achieved with an 8-ligature wire and a light-cured resin.	Radiographic and clinical examination performed at 3rd, 6th, 12th, 18th, 30th, and 36th months revealed no progressive root resorption, marginal bone loss, or periapical lesion.
19.	Calişkan et al. (2008) (18)	Incompletely erupted maxillary central incisor with crown dilaceration in a 12-year-old boy	Repositioning done with surgical extrusion and endodontically treated with calcium hydroxide paste.	Clinical and radiographic examination performed 2 years after the completion of combined surgical and endodontic treatment revealed periapical healing and no signs of root resorption.
20.	Garg et al. (2008) (31)	Completely intruded maxillary right central incisor in a 10-year-old boy.	Surgical extrusion of teeth. Stabilization was achieved by 0/9 mm stainless steel wire and light cure composite resin.	At 6-month recall visit, radiographic evaluation revealed no periapical pathology
21.	Kirzioğlu et al. (2009) (27)	A completely intruded permanent maxillary right central incisor with a concomitant uncomplicated enamel fracture in a 9-year-old boy	The intruded tooth was repositioned via surgical extrusion and splinted with a semirigid splint for three weeks	Clinical and radiographic examination conducted 48 months after the surgical extrusion revealed no signs of progressive root resorption, marginal bone loss, or periapical disease.
22.	Mazumdar et al. (2009) (29)	A 42-year-old male with 5-6 mm intrusion of central incisors.	Surgical extrusion of the intruded central incisors. Splinting was done with an Erich's arch bar technique because of the associated alveolar fractures and extreme mobility.	Two-year follow up showed asymptomatic status of the incisors both clinically and radiographically.
23.	Kim et al. (2009) (30)	Eighteen adult male dogs, divided into 6 groups. Two maxillary lateral incisors were used, that is, 36 teeth.	One lateral incisor in each dog underwent orthodontic extrusion and the other, surgical extrusion after being experimentally intruded.	The animals were sacrificed at 7, 14, 45, 90, 120, and 180 days, and histological assessment of cross sections of coronal, middle, and apical third of the teeth was done. Although orthodontic extrusion is more physiological than surgical extrusion, the function and form of the supporting structures were restored over a period of time.

Appendix 2 Continued

Sl. No.	Author's name	Materials	Treatment	Outcome
24	Dias et al. (2009) (19)	10-year-old male patient with complete intrusion of the permanent maxillary right central incisor	Surgically repositioned 7 days after the first visit. Root canal therapy started 1 week after repositioning with bimonthly changes of a calcium hydroxide-based paste used as an intracanal dressing.	Asymtomatic both clinically and radiographically after 38 months of follow up.
25.	Chung et al. (2010) (32)	One crown–root-fractured tooth	Intra-alveolar transplantation with 180 (degrees) rotation. Immobilization was achieved by interdental sutures.	At 1-year follow up, the replanted tooth had normal function and no obvious inflammatory root resorption on radiographic examination.
26.	Tsilingaridis et al. (2011) (1)	Sixty intruded permanent teeth in 48 patients (32 boys and 16 girls) aged 6–16 years	Spontaneous re-eruption (17 teeth), orthodontic extrusion (12 teeth), and surgical repositioning (31 teeth)	No firm conclusion could be drawn for the difference in outcome between orthodontic extrusion and surgical repositioning.