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Intrusive luxation lesions in permanent teeth: a Literature review and an up to date on the possibilities of approaches with the orthodontic repositioning technique

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INTRODUCTION

Existing data on the prevalence of traumatic dental injuries varies between countries [Zaleckiene et al., 2014]. In a comparative study of oral and non-oral injuries in Sweden, oral traumas accounted for 5% of total injuries in individuals under 30, increasing to 17% in the 0-6 age group [Petersson et al., 1997]. Although rare, oral trauma is of significant interest in global dental health, as it is the third most common type of injury among children aged 0-12 [Zaleckiene et al., 2014; Petersson et al., 1997]. Furthermore there is an increasing tendency for paediatric population aged 6-12 years to suffer from oral traumas in modern society [Abbott et al., 2008]. Dental trauma is more prevalent in permanent teeth (58.6%) than in deciduous teeth (36.8%) [Zaleckiene et al., 2014] and occurs more frequently in male than in female [Altun et al., 2009]. Intrusive luxations, accounting for 0.5-19% of all dental traumas, are severe dental injuries, representing 0.3-2% of traumas in permanent dentition [Andreasen et al., 2006; Borssen et al., 1997]. Intrusive luxation is defined as the axial displacement of the tooth into its alveolar socket due to a force with an axial direction [Andreasen et al., 2006; Andreasen et al., 1994]. The energy generated by the injury forces the root against the alveolar bone compressing the periodontal ligament (PDL), damaging the tissue in the apical foramen causing ischemia and fracturing the alveolar socket walls [Andreasen et al., 2006; Costa et al., 2007]. Intrusive luxation damages the periodontium due to the axial force and can result in root resorption, bone crushing, pulp injuries such as pulp necrosis and potentially arrest root developing if the root is still developing. According to IADT guidelines, an intruded tooth will clinically appear immobile with an ankylotic sound and sensibility test will likely be negative. Radiographically the enamel junction will appear more apical relative to adjacent teeth [Diangelis et al., 2012]. Treatment options include: spontaneous re-eruption, orthodontic repositioning and surgical repositioning. Factors influencing the treatment choice are: root development, degree of intrusion, and patient age, as well as the time elapsed since the intrusion and the promptness of treatment initiation [Andreasen et al., 2006]. Systematic reviews have concluded that spontaneous re-eruption causes fewer consequences in immature teeth without substantial differences compared to all active repositioning methods. However, no uniform decision-making protocol exists for dental intrusion, leaving the decision to the clinician's discretion [AlKhalifa et al., 2014; Costa et al., 2007]. Even when the treatment decision is made, there is not a solid guideline for active treatment. This article aims to conduct an up-to-date and a scoping review of the scientific literature and to identify if there is a uniform protocol for the active orthodontic management of intrusive luxation of upper permanent incisors. Digital Dental models can aid in defining clinical choices [Zotti et al., 2022]. Finally, we believe it is important to underline that, if the correlation between mothers' and their children's oral health and a lack of awareness about the crucial role of prevention in dental health is demonstrated [Ludovichetti et al., 2022; Tomasin et al., 2015], awareness regarding the correct behavior to adopt in case of dental trauma must be further promoted among parents. Moreover, the studies highlight the link between dental trauma and poor oral health conditions, which can be indicators of neglect in children [Bradbury-Jones et al., 2020; Zerman et al., 2024].

MATERIALS AND METHODS

This paper was conducted using the "Scoping Review" method according to the methodological framework proposed by Arksey and O'Malley [Arksey et al., 2005]. The process includes five steps: 1) specify the research question, 2) identify relevant literature, 3) select studies, 4) map out the data, 5) summarise, synthesise, and report the results, and 6) include expert consultation [Westphaln et al., 2021]. Consequently, a protocol was developed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to improve transparency and standardisation in the paper [Shamseer et al., 2015].

Research Questions

The main purpose of this article was to conduct a review of the scientific literature to determine whether a clear and valid protocol for active orthodontic treatment of intrusive permanent incisor dislocation currently exists. The following points were assessed: age and gender of the patients, which permanent incisor suffered the intrusive luxation, maturation stage of the root, time elapsed after detecting trauma, follow up duration, type of active treatment, characteristic of the treatment and outcomes. The P.I.C.O. method guided the search strategy of the paper [Cumpston et al., 2019].

P - Population. included articles focused on human teeth, specifically permanent incisor at different stage of maturation, excluding different types of dentition (permanent or mixed dentition).
I - Intervention. Considered Active treatments (orthodontic and surgical repositioning).
C - Comparison. The outcomes and stages of root development were compared to develop a guideline for the active treatment management of intrusive luxation.
O - Outcome. the protocols used for treatment were considered focusing on the stage of tooth development in mixed or permanent dentition, gender and age of the patients, quantity and quality of outcomes and follow up duration.

Selection Criteria

We included case reports, case series and retrospective studies on the treatment of intrusive luxation published between 2002 and 2024. Only articles in English were included. Systematic reviews, articles not in English, and articles not fully available were excluded. Papers were excluded if they did not fit into the conceptual framework of the study. Only articles on permanent incisors, regardless of the stage of root development and whether in mixed or permanent dentition were included.

Search Strategy

The following bibliographic databases were searched from September to March 2024: Medline (Pub Med), Cochrane, Scopus and Web of Science using the following keywords: Replacement treatment of dental luxation; Dental Traumatic Intrusion treatment; Treatment intrusion Luxation; orthodontic splint; Dental Luxation injuries. Two reviewers (GL and SC) independently assessed and selected valid studies based on the titles and abstracts. They then collaborated to finalise the list of studies. In cases of disagreement, a third reviewer (ES) resolved the issue.

Study Quality Assessment

Two reviewers (GL and SC) evaluated the quality of the collected papers. The calculated risk of bias did not allow for a systematic review, so a Scoping Review was conducted [Higgins et al., 2019]. The Cohen Kappa coefficient was used to measure the reliability between the two reviewers [Landis et al., 1977], with a calculated agreement coefficient deemed "moderate" (value equal to 0.70). The New Castle-Ottawa Quality Assessment scale was used to assess the quality of the studies [Wells et al., 2000].

Data Extraction

The two reviewers (GL and SC) extracted the following data from the selected papers: authors and year of publication, type of article (case report, case series, retrospective study), number of traumatised teeth, type of incisor traumatised, maturation stage of the tooth at the time of the trauma, time range after intervention was implemented, age and gender of patients, type of active treatment (orthodontic or surgical), follow up duration and outcomes. The collected data were summarised in a PowerPoint spreadsheet for analysis.

RESULTS

This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation, and the experimental conclusions that can be drawn.

Author and Year	Type of Article	No of Samples	Traumatized Tooth	Maturation Stage	Range Time after the Detected Trauma	Age	Gender	Waited for passive	Therapeutic Intervention	Modalities	Follow-Up	Outcome
Thakur et al. 2014	Case report	3	1.1 2.1 2.2	mature	Hours	7y	F	10 weeks	Orthodontic repositioning	• Fixed. Multibracket appliance with elastic traction • Endo treatment • For 26 weeks	7y	• + • PN
Goncalves de Alencar et al. 2007	Case Report	1	1,1	mature	1 week	15y	F	No	Orthodontic repositioning	Ns (not specified)	5y	• + (survival) • PN (pulp necrosis)
Sian JS 2009	Case Report	2	2.1 2.2	Immature	NR	8y	M	3 weeks	Orthodontic repositioning	• Fixed. Multibracket appliance with 0.012 nitinol followed by 0.014 and 0.016 nitinol archwires for 7 weeks • Endo treatment for IRR (External inflammatory root resorptio)	3,5y	• + • No sign of External inflammat ory root resorption
Umesan et al. 2013	Case Report	1	2,1	Immature	2 days	8y	M	9 weeks	Orthodontic repositioning	• Spontaneous re- eruption • Sectional Fixed Multibracket appliance with 018 ss for application of traction using a steel ligature • followed by 016 ss with 0.014 Nickel-titanium and 0.018 nickel- titanium	1 y	
Calasans-Maia et al. 2003	Case Report	4	1.1 1.2 2.1 2.2	mature	1 week	50 y	M	No	Orthodontic repositioning	• Fixed Multibracket appliance with sequence of ss arches: 0.012, 0.014, 0.016, 0.018. • Endo treatment • 8 weeks orthodontic treatment • 16 weeks retention period	8 y	
Ashkenazi et al. 2015	Case Report	2	1.1 2.1	immature	2 weeks	8 y	M	6 weeks	Partial Surgical repositioning followed by orthodontic repositioning	• Forceps 21 • Flexible Splint (0.7- mm) for 2 weeks • Endo treatment 11 • Fixed Multibracket appliance for 9 months • Fixed orthodontic retainer	2 y	• + • PN 11 • 21 underwent apexificati on and positive to pulp testing
Vahid Golpayegani et al. 2007	Case Report	2	1.1 1.2	immature	2 days	10 y	F	10 days	Orthodontic repositioning	• Surgical exposure • Endo treatment • Fixed. Multibracket appliance with elastic traction • Long term retention	6 y	• + • PN
Mota Junior et al. 2021	Case Report	2	1.1 2.1	mature	2 days	10 y	M	No	Orthodontic repositioning	• Fixed. Multibracket appliance with elastic traction and light forces for 5 month and 22days. • 4 weeks of stabilization period • Endo treatment	5y	• + (Successfull)
Singh et al. 2021	Case report 1 Case report 2 Case report 3	4 2 1 (2)	1.2, 1.1, 2.1, 2.3 1.1,2.1 2.2 (2.3)	immature mature Immature	2 weeks 2 weeks 1 week	9 y 9 y 10 y	M F M	No No 1 week	Orthodontic repositioning	• Fixed multi-bracket appliance • Endo treatment	4y 2y 4y	• + (Successfull)
Geevarghese et al. 2024	Case report	2	1.1, 2.1	immature	24h	9 y	F	4 months	Orthodontic repositioning	•Partially spontaneous rieruption •Fixed 0036 ss wire + transpalatal wire •soldered on molar bands and elastic traction for 8 weeks •Fixed sectional bracket appliance •Endo tratment for IRR and PN	20 months	• + (Successfull)

TAB. 1 Classification of articles according to year and author, type of articles, numbers of teeth involved, type of teeth involved in the trauma, maturation's stage of traumatised teeth at the time of intrusion, time range after the trauma were attended to, age and gender of the patients, waiting time before active treatment, type of therapeutic intervention performed, overview of orthodontic approach, follow up and outcomes.

Selection of Sources

The search yielded 2256 articles using the specified keywords on MedLine, Scopus, Web of Science and Cochrane. After the initial screening based on titles, 238 articles remained. After removing duplicates, 170 articles were retained. The reviewers further screened the abstracts, selecting 127 articles for full-text reading. Studies in doubt were included for the full text reading. Article whose full text was not available were excluded, as those that did not meet the inclusion criteria. Disagreements were resolved by a third reviewer until a mutual agreement was reached. Studies focusing on spontaneous re-eruption were excluded, resulting in 21 articles on active treatment, of which 10 specifically focused on the orthodontic treatment of intrusive luxation of upper permanent incisors. These are grouped in Table 1.

Tooth and root development

We selected 21 articles where active repositioning was the chosen treatment. These data suggest that the roots of the permanent teeth involved in luxation injuries are generally immature. The preferred treatment is to waiting for spontaneous re-eruption when the apices are open. Of the 21 articles selected, active treatment was performed with orthodontic repositioning in 10 articles. Among these, 6 studies dealt with teeth having open apices and 4 studies dealt with teeth having closed apices.

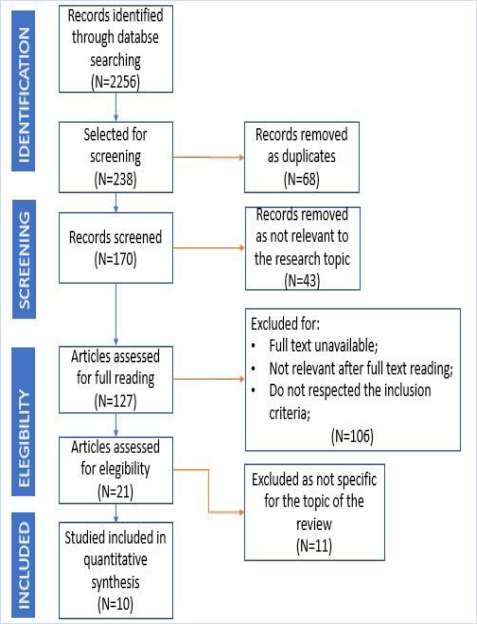

FIG.1 Graphical representation of the selection process used to identify the articles included in the paper.

Therapeutic Intervention

In all 10 articles discussing orthodontic treatment, the teeth had a complete intrusion of more than 6 mm. Operators waited for spontaneous re-eruption in all cases with open apices, with one exception [Singh et al., 2021], from 3 weeks to a maximum of 9 weeks. The duration of active treatment in the 6 articles involving 15 teeth with open apices, ranged from a minimum of 7 weeks to a maximum of 9 months [Sian, 2009; Umesan et al., 2013; Ashkenazi et al., 2015; Golpayegani et al., 2007]. Five articles, involving a total of 12 teeth, discussed traumatised teeth with closed apices [Thakur et al., 2014; Goncalves de Alencar et al., 2007; Calasans-Maia et al., 2003; Mota Junior et al., 2021; Singh et al. 2021]. For these 12 teeth with closed apices operators waited for spontaneous re-eruption in only one tooth for 10 weeks [Thakur et al., 2014]. The duration of active treatment for these 12 teeth with closed apices was almost comparable to that for teeth with immature roots, with a minimum active treatment period of 8 weeks and a maximum of 26 weeks. The treatment choice for orthodontic extrusion was a fixed multi-bracket appliance in 8 out of the 10 screened articles. One case did not indicate the selected appliance [Goncalves de Alencar et al., 2007]. In only 2 articles the appliance was sectional and bonded to the anterior incisors [Umesan et al., 2013; Geevarghese et al., 2024]. In 6 patients the appliance was anchored with bands on the upper first molars and bonded with brackets on the maxillary (permanent or deciduous) teeth [Thakur et al., 2014; Sian, 2009; Calasans-Maia et al., 2003; Ashkenazi et al., 2015; Golpayegani et al., 2007; Mota Junior et al., 2021]. Teeth with other lesions or a certain degree of mobility after the injury were not initially bonded or used as anchorage. In 2 patients the orthodontic extrusion was performed using progressive light wire forces (0.012, 0.014,0.016 nitinol) and a self-ligating approach [Sian, 2009; Ashkenazi et al., 2015]. In 4 articles the treatment was carried out with a passive arch-wire, typically round or rectangular stainless steel arch-wire, with traction on intruded tooth. The traction was achieved using an elastic chain or steel ligature [Thakur et al., 2014; Umesan et al., 2013; Golpayegani et al., 2007; Mota Junior et al., 2021]. In the analysed studies Nickel titanium (NiTi) arch-wires were used both in the initial and final phase of treating intrusive traumatic lesions. In the initial phases NiTi arch-wires were used in synergy with a Stainless steel (SS) arch-wire retainer, with the NiTi arch-wires placed over the SS arch-wires. In the final stages NiTi arch-wires were used on their own to achieve a better alignment of the traumatised teeth. Rebracketing was performed in 3 patients after traction on button bonded on the intruded teeth [Golpayegani et al., 2007; Umesan et al., 2013; Mota Junior et al., 2021].

Follow up

The follow-up period ranged from 1 to 8 years. In all articles the teeth involved in the trauma were asymptomatic exhibiting normal mobility and position. Radiographic examinations showed no signs of root resorption or periapical lesions.

Outcomes

The consequences of intrusive luxation involve damage at various levels, including the periodontal level (such as ankylosis and replacement resorption), bone level (marginal bone loss), and pulp level (pulp necrosis, inflammatory root resorption) [Spinas et al., 2024].

These outcomes may also extend to pulp obliteration, even in cases where the overall results are favorable with pulp survival [Andreasen et al., 1985]. Intrusive luxations invariably result in damage to periodontal fibers and compression of the vascular complex, leading to ischemia [Humphrey et al., 2003]. The severity of consequences depends on the degree of root formation and the grade of intrusion. A systematic review from 2017 highlighted that teeth with open apices and incomplete root formation generally exhibit better outcomes in every aspect of the potential damages caused by intrusion [Costa et al., 2017]. When a splint is necessary at the end of the extrusion movements, rigid splints are crucial to prevent unwanted movements during the critical healing phase, similar to the management of root fractures, including those of deciduous teeth, but is not useful in the stabilisation of intrusive trauma [Spinas et al., 2022]. Regarding endodontic treatment for pulp necrosis, in the 10 articles examinated it was always performed in 9 studies, with no subsequent signs of pulp pathology during the follow up. Umesan et al. [2013] was the only case report selected that did not perform endodontic treatment on the traumatised tooth. Endodontic treatment was carried out using various modalities to ensure the absence of pathology. Immediate endodontic treatment was performed in only one case [Thakur et al. 2014]. Generally endodontic

treatment involved initial treatment with HCa++ which was changed every month in four articles before definitive obturation with gutta-percha or mineral trioxide aggregate MTA [Thakur et al., 2014; Goncalves de Alencar et al., 2007; Calasans-Maia et al., 2003; Golpayegani et al., 2007]. In one of these four cases [Goncalves de Alencar et al., 2007], after an unspecified period of time when the hydroxide was changed every month, the HCa++ was changed every 3 months. This treatment protocol, changing hydroxide every three months, from the beginning, was also reported in the article Sian Js et al. [2009]. The studies by Ashkenazi et al. [2015]; Mota Junior et al. [2021] did not specify the endodontic treatment in detail. All examined studies reported no signs of pulp pathology during the follow-up.

DISCUSSION

The optimal treatment option for intruded permanent teeth is controversial and poorly defined. The long-term prognosis of the treatment is also challenging. Intrusive luxations are associated with damage to the cementum, making them at a high risk for developing Inflammatory Root Resorption (IRR). In such cases, immediate endodontic treatment is recommended due to the rapid progression of IRR. Intrusive luxations also lead to pulpal necrosis in 57% to 89% of cases. Another risk is ankylosis. Alveolar bone loss and pulp canal obliteration are other potential consequences of intrusive luxation [Chaushu et al., 2004]. For the treatment of external inflammatory root resorption, it is recommended to remove the necrotic pulp and obturate the root canal with non-setting calcium hydroxide to elevate the pH at the root surface and reverse osteoclastic activity [Tronstad et al., 1981]. Radiographically, intrusive luxation may exhibit a missing or diminished periodontal space, different apical levels, or alveolar fractures. Monitoring clinically and radiographically the luxated teeth is crucial for 5 years following the successful repositioning of them. Standard antibiotic treatment, typically penicillin in doses of 1000 mg followed by 500 mg for 4 days, is administered. The treatment plan depends on the severity of the intrusion and the stage of root formation [Kinirons, 1998]. The International Association of Dental Traumatology (IADT) recommends treatments approaches for intruded teeth based on the severity of the intrusion, stage of root development, and any complications observed during follow-up. Intruded teeth generally have three treatment options [Andreasen et al., 1985]:

- Wait-and-watch approach to permit passive re-eruption;
- Orthodontic extrusion;
- Surgical repositioning.

For immature teeth, spontaneous re-eruption is advised. If spontaneous re-eruption doesn't occur within four weeks, orthodontic repositioning is necessary. It is essential to monitor the pulpal condition with sensitivity test during follow-up appointments. As teeth with incomplete root formation might manifest spontaneous revascularisation. However, if the pulp becomes necrotic or signs of inflammatory root resorption (IRR) appear, root canal treatment should be initiated as soon as tooth positioning allows it. For teeth with complete root formation, non-surgical re-eruption is recommended if the tooth is intruded by 3mm. If no re-eruption occurs within eigth weeks, surgical repositioning and splinting for about 4 four weeks are advised. The splint must be passive and flexible [Spinas et al., 2022; Spinas et al., 2024]. This protocol ensures that treatment is tailored to the specific needs of the tooth and its stage of development, optimising outcomes and minimising complications. Alternatively, orthodontic repositioning can be performed before ankylosis occurs. If the tooth is intruded 3-6 mm, surgical or orthodontic repositioning is preferable to waiting for spontaneous re-eruption. For intrusions beyond 6 mm, surgical repositioning is typically the most common approach. However in a case of severe intrusion (>10mm) orthodontic repositioning was effectively employed. In this case [Geevarghese et al., 2024] the treatment involved in a first phase of traction using a 0.036 stainless steel arch attached to a transpalatal band and anchored to molar bands with elastic ligatures for of approximately 8 weeks. This was followed by a classic alignment phase using sectional bonding. This two-phased orthodontic approach, involving initial traction and subsequent alignment, highlights the flexibility and effectiveness of orthodontic methods even in cases of severe intrusion. For teeth with complete root formation, pulp necrosis is common necessitating root canal treatment within 2 weeks or as soon as the tooth position permits. This treatment should include antibiotic/corticosteroid or calcium hydroxide intracanal dressing to prevent the development of inflammatory (infection-related) external resorption. Spontaneous re-eruption of teeth with immature roots and a mild degree of intrusion has the lowest percentage of complications associated with pulp necrosis, root resorption, and marginal periodontal bone healing [Andreasen et al., 2006]. For severe intrusive luxation (more than 6mm of intrusion), the options are orthodontic extrusive traction or surgical repositioning. However, researchers agree that starting extrusion immediately is important to increase the chances of successful treatment, especially in patients with closed root apices [Kallel et al., 2020]. The shorter the time between injury and the start of treatment, the better the chances of avoiding ankylosis and external root resorption [Andreasen et al., 1985]. This underscores the importance of timely intervention to optimise treatment outcomes and reduce the risk of complications. Chaushu et al. [2004] concluded that repositioning intrusive teeth ideally should occur within 3 weeks of the episode. Orthodontic repositioning initiated between 1 and 90 days post-intrusion boasts a success rate of 96.7%. This underscore the importance of minimising further disruption to the periodontal ligament and the dental neurovascular system. Early intervention facilitates dental extrusion enhancing endodontic access and potentially reducing risks such as root resorption or ankylosis. Utilising modern radiographic techniques, particularly three-dimensional CBCT scans [Singh et al., 2021], is crucial prior to initiating any therapeutic approach. These methods ensure accurate assessment and planning, optimising treatment outcomes. Orthodontic repositioning necessitates the application of controlled, biologically optimal forces utilising multi-bracket fixed appliances. Removable appliances with vertical elastics are considered a secondary option for orthodontic extrusion as they do not rely on patient compliance, unlike fixed appliances. It is advised against using adjacent teeth as anchorage due to the risk of potential damage. In fixed appliances, the use of flexible wires is discouraged as they can cause unintended movements in adjacent anchorage teeth [Chaushu et al., 2004]. It is recommended to use passive stainless-steel wires with bands on upper molars and brackets on posterior teeth, including primary teeth, as anchorage units. The intruded incisors are subsequently ligated to the arch-wire using metallic ligatures or an elastic chain to ensure correct axial alignment. Initial traction is applied using buttons bonded to the surfaces of the intruded teeth, applying a light force ranging from 30 to 40 gr. A superimposed nickel titanium wire is then attached to the passive arch to facilitate the extrusion of the injured tooth. Rebracketing may sometimes be necessary during the final stages of treatment. The duration of orthodontic repositioning is influenced by factors such as the severity of intrusion, the number of affected teeth, presence of fractures, age, stage of tooth maturation, and condition of periodontal tissues. According to Chaushu et al. [2004], the average duration of repositioning treatment typically spans from 21 to 150 days. However, advancements in materials suggest that treatment durations can now range within 60 to 90 days [Geevarghese et al., 2024].

CONCLUSIONS

The stage of root maturation plays a critical role in determining the appropriate treatment for intruded permanent incisors. If passive re-eruption does not occur within 4 weeks, orthodontic repositioning appears to be an optimal treatment option for permanent teeth whether they have open or closed apices, with mild (3 to 6 mm) to severe (>6 mm) intrusion. However, the current literature on the use of orthodontic dental repositioning technique after intrusive luxation injuries is not exhaustive. The lack of standardised data collection and the difficulty in achieving precise and detailed superimposition of clinical data make it impossible to provide clear clinical indications in a field that therefore demands further research. The results of the present scoping review highlight the need for further randomised clinical studies to provide a clear repositioning orthodontic protocol for the intruded luxated permanent teeth.

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