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TRAUMATIC DENTAL INJURIES OF ANTERIOR PERMANENT TEETH IN PAEDIATRICS

PhD thesis

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Table of Contents

List of Abbreviations

AAE	American Association of Endodontists
$Ca(OH)_2$	Calcium hydroxide
HRFs	Horizontal root fractures
IADT	International Association of Dental Traumatology
MTA	Mineral Trioxide Aggregate
No	Number
NaOCl	Sodium hypochlorite
NS	Non-significant
PN	Pulp necrosis
R/C ratio	Root-crown ratio
RET	Regenerative Endodontic Treatment
TDIs	Traumatic dental injuries
VRFs	Vertical root fractures
WHO	World Health Organization

1. Introduction

1.1. Prevalence of traumatic dental injuries (TDIs)

Traumatic dental injuries (TDIs) are one of the major dental public health problems among children and adolescents who seek emergency dental treatment [1]. TDIs occur more frequently at a young age as permanent teeth still continue to develop, thus injuries can cause irreversible damage if they occur in the initial stages of development [2, 3, 4, 5, 6].

TDIs do not only pose a health risk worldwide but are also regarded as serious social problems [7–11]. They are highly prevalent from infancy to adolescence in the last few decades [12–13]. TDIs have been observed in 4.2 %–35 % of various age groups [14]. According to Andreasen et al., up to 30% of children and adolescents suffer from an oral injury once or more times during their childhood and teenage years [15–17]. These injuries affect approximately from 20 % to 30 % of permanent dentition [14] and between 9.4 % and 41.6 % of primary dentition [18]. The prevalence of dental trauma among children and adults varies from one country to another [19, 20]. This difference between the ratios is attributed to many factors, for instance, differences in populations studied, methodology used for the different studies and/or the variation in the evaluated variables and the diagnostic criteria (of TDIs) employed [21–24].

1.2. Aetiological factors of TDIs and occurrence

For a considerable period, clinical studies emphasised that the main factors predisposing children to TDIs were gender and age [3, 25]. In later studies, other factors have been reported, such as falls and bicycle accidents [26–31], collisions [32, 33], driving accidents, sport, violence, foreign bodies striking the teeth, inadequate lip protection [34, 19, 35], sex and incisor overjet [36]. According to Bilder et al. [37], patients with inadequate lip coverage are five times more exposed to dental trauma than patients with adequate lip coverage. According to Singh et al. [38], the risk of dental trauma caused by contact sporting activities was higher than the risk related to non-contact sporting activities. Also, it is important to mention that there is a relationship between overweight/obesity and TDIs [39, 40]. The risk among overweight or obese children is approximately 22 % higher than among lean children [41].

The decline in the prevalence and severity of dental caries amongst children in many countries may have made traumatic dental injuries a major dental public health problem among the young. Dental trauma may exceed dental caries and periodontal disease as the most significant threat to dental health among young people [42].

In respect of the places of the occurrence of TDIs, most of the studies in the literature have reported that home and school are the places where traumatic dental injuries usually occur [43–45].

1.3. Consequences of TDIs

TDIs may influence further tooth growth, resulting in irreversible damage if they occur during the initial stages of tooth development [2, 46]. They cause painful, distressing events and show aesthetic, functional, economic and psychosocial effects, which manifest in addition to the loss of teeth in some cases [47–50]. Furthermore, malocclusions may occur in a short time due to the loss of proximal and incisal contacts [46]. Speaking and laughing can be negatively affected by such injuries, which in turn affects the child's self-confidence, self-esteem and quality of life in the long run [51–55].

1.4. Classification of TDIs

Traumatic dental injuries to anterior teeth are classified into two main groups [56]:

- Injuries to the hard dental tissues of the mouth.
- Injuries to periodontal tissues and/or supporting tissues of the teeth.

1.4.1. Injuries to the hard dental tissues of the mouth

1.4.1.1 Crown fracture and their treatment possibilities

A crown fracture is the most common detrimental consequence of traumatic dental injuries [57–61]. It is defined as a type of traumatic injury in which a portion of the hard dental structures is lost due to a perpendicular or obliquely directed impact force to the vestibular surface of a tooth or, indirectly, to the palatal surface of teeth in the upper jaw [62]. Crown fractures comprise 26–76 % of all the traumas to permanent teeth [62–65]. According to Andreasen, they are classified into complicated and uncomplicated fractures [62]. The term "uncomplicated" is used to refer to enamel infractions, enamel fractures and enamel-dentin fractures without pulpal implications, whereas "complicated" defines the enamel-dentin fractures with pulpal implications [57, 62, 66]. Uncomplicated fractures of permanent dentition occur more often than complicated ones. Enamel infractions are the second most common type of fracture after enamel-dentin fractures [62, 51].

Treatment: In the case of crown fractures involving only the enamel, the treatment is limited to shape and polish the sharp edges and to the corrective grinding of the tooth [62]. If the dentin is exposed, appropriate dressing as an emergency treatment should be applied over the exposed parts to prevent external irritation [51]. Whether it is an "uncomplicated" or "complicated" fracture, the immediate treatment of a crown-related fractured tooth is the most important factor for preserving pulp vitality [62]. In the case of complicated crown fractures, the treatment poses a challenge to clinicians [67].

The treatment depends upon various factors:

- the maturity of the tooth;
- the time lapse between the accident and the treatment;
- the severity of pulp exposure;
- the presence or absence of haemorrhage and the size of the remaining crown [62, 68, 69];
- the disruption of blood supply at the apical foramen;

- in the case of luxation injuries, the extent of the damage to the blood and nerve supply to the pulp depends on the severity of the injury [62, 70].

The treatment of permanent teeth in case of pulp exposure varies between [71]:

1. Pulp capping (Direct/Indirect)
2. Partial pulpotomy
3. Cervical pulpotomy
4. Pulpectomy and root canal treatment and filling.

Permanent teeth with pulp exposure can be treated successfully even hours after the injury, depending upon the level of inflammation and necrosis [62]. Beyond 72 hours after the accident, the only treatment option available is pulpotomy or the complete removal of the pulp [72].

1.4.1.2. Root-crown fracture

A root-crown fracture is a type of traumatic dental injury involving the enamel, dentin, and cementum. This type of fracture usually results from a horizontal impact and comprised 5% of dental injuries affecting the permanent dentition [60, 73]. Root-crown fractures may be classified as *complicated*, due to pulpal involvement, which is more frequent, or *non-complicated*, which have an absence of pulpal involvement [74–76]. The treatment of a root-crown fracture constitutes a challenge as the fracture line moves subgingivally, creating difficulty during restorative procedures [77, 78]. More treatment possibilities have been proposed for root-crown fracture; tooth extraction, fragment removal and gingival reattachment, surgical crown lengthening and root extrusion [78, 79].

1.4.1.3. Root fracture and treatment possibilities

Root fracture has been defined as a fracture involving dentin, cementum, pulp and periodontal ligament [80, 81]. Among dental injuries, they are uncommon, comprising nearly 0.5–7 % of the traumas that occur in permanent dentition [82, 83]. The highest incidence range of roots fractures was recorded in maxillary central incisors of male patients during the second decade of their lives [82, 84, 85]. Root fractures can often be associated with other types of injuries. Among these, concomitant fractures of the alveolar process, especially in the mandibular incisor region, were common findings. These types of fractures are classified as follows [86].

a) Horizontal root fractures (HRFs)

Horizontal root fractures are the most common type of root fracture which mainly affect the maxillary anterior region [84, 86]. The classification of HRFs is based on the location of the fracture line (apical third, middle third, cervical third of the root) and the degree of dislocation of the coronal fragment [87–89]. HRFs mostly occur in the middle third of the root and very rarely in the cervical and apical third [87, 88]. The prognosis of teeth with HRFs is clearly influenced by the location of the fracture, as the fractures located in the cervical third showed the worst prognosis [89], while the middle third fractures have a favourable one [87].

b) Vertical root fractures (VRFs)

VRFS are defined as fractures that extend longitudinally from the root apex to the crown [62,90, 91]. They occur mainly in patients above 40 years of age, as with ageing, due to the high concentration of minerals, the teeth get more brittle [17, 91]. They have been seen twice more frequent in males than in females. The most affected teeth in order of susceptibility to injuries are premolars, molars, incisors and canines [92].

Treatment: The management of root fracture depends on the location of the fracture, mobility and the vitality of the tooth [81,87]. When the coronal fragment is displaced, the initial treatment should be the repositioning of the fragments, followed by a firm immobilization with a rigid or semi-rigid splint for three to six months to allow the healing of the surrounding periodontal tissues [86, 87].

Root reposition should be confirmed at this time [86]. Root canal therapy should not be initiated until clinical and radiographic signs of necrosis or resorption are apparent. Jacobsen and Kerekes (1980) reported success in treating the coronal fragments of such fractured teeth with calcium hydroxide [93].

In general, root fractures in the apical and middle third are not always symptomatic and can be identified during routine examinations. In these cases, treatment is often non required and spontaneous healing is frequently reported [84, 94, 95].

If vitality is not maintained, the root canal treatment of coronal fragment should be done to the apical third fracture line with surgical removal of apical fragments [17].

Root fracture at the cervical third often requires extraction [87].

The healing outcome after root fracture can be divided into four groups [86]:

- Healing by hard tissue union.
- Healing by the interposition of connective tissue.
- Healing by the interposition of bone and connective tissue.
- Non-healing (interposition of granulation tissue.

1.4.2. Injuries to the periodontal or supporting tissues of the teeth

A trauma to the supporting tissues can lead to many complications such as pulp canal obliteration, necrosis and root resorption or luxation injuries [96, 97]. Luxation injuries are one of the most prevalent types of traumatic dental injuries in primary dentition [98, 99, 100], due to the resilience of the alveolar bone [15, 101]. Various luxation injuries are possible depending upon the force and direction of the impact [101]. They comprise 15–61% of the dental traumas to permanent teeth, while a frequency of 62–72 % has been reported in the primary dentition [102]. In case of permanent dentition, the recommended treatment is the repositioning of the tooth as soon as possible, the use of splints, an endodontic treatment, as well as clinical and radiographic control [103, 39]. The complication after treatment is significantly related to the type of luxation, reduction [104], the time interval from injury to treatment [62, 104, 105], the degree and type of displacement, treatment delays, root maturation, associated crown fractures and the type of displacement [102, 106, 107].

1.4.2.1. Luxation injuries

a) Concussion and treatment possibilities

A concussion is an injury of the tooth-supporting structures without increased tooth mobility or tooth displacement but with reaction to horizontal or vertical percussion and it may be associated with crown fractures [108, 109]. The pulp sensitivity test is usually positive and changes are not noticeable radiographically [108]. In any case, it is difficult to evaluate the pulp sensitivity test in childhood, especially immediately after a traumatic injury [112].

Treatment:

The treatment may be confined to [101]:

- occlusal grinding of the opposing teeth, or
- a repeated pulp test during the follow-up period.

b) Subluxation and treatment possibilities

Subluxation is an injury to the tooth-supporting structures with abnormal loosening but without displacement. The subluxated tooth is mobile and can be sensitive to percussion and occlusal forces, with or without bleeding from the gingival sulcus. Sensitivity tests may be negative but subsequently, the tooth tends to respond positively to them. Radiographically, the tooth is in its normal position in the socket [108, 109, 110]. The risk of periodontal healing complications after subluxation or concussion as well as injuries in permanent teeth is very low [111] but the most frequent ones are pulp necrosis and the obliteration of the pulpal tissues [26].

Treatment:

- Generally, no treatment is needed for subluxation. A soft diet for two weeks can be advised.
- If the tooth is in occlusion, antagonists can be slightly ground out.
- A flexible splint to stabilise the tooth can be used for the patient's comfort for up to two weeks [112].

c) Extrusive luxation and treatment possibilities

Extrusive luxation is caused by the action of oblique forces. It is characterised by the loosening and the partial displacement of the tooth out of its socket [104, 113], by the severance of the periodontal ligament fibres and the complete rupture of the neurovascular supply to the pulp [114, 115]. The clinical aspect is an elongated tooth and excessive mobility. Compared to intrusion and avulsion, it is characterised by less damage to the periodontium [103]. Immature root development has shown higher levels of healing when compared to teeth with fully formed roots [114, 115]. In general, teeth with open apex often show pulpal obliteration after extensive luxation.

Treatment:

- If tooth mobility after a gentle reposition is increased, flexible splinting should be considered for two or three weeks.
- Endodontic treatment is necessary after the extrusive luxation of a tooth with completed root formation [26].

d) Lateral luxation and treatment possibilities

The lateral luxation of the anterior teeth is one of the most severe types of dental injuries [116, 117]. They are characterised by the buccal-lingual displacement of the tooth with the involvement of alveolar bone fracture [101, 118, 119]. The most common complications after lateral luxation are pulp necrosis, which is common on permanent teeth with closed apex involved in the lateral luxation injury, due to the rupture of the blood supply [111, 116], external root resorption, marginal bone loss and ankylosis [116, 120].

Lateral luxation is more complex than extrusive luxation since the alveolar bone is also damaged [26].

Treatment:

- The repositioning and flexible splinting of the tooth for a minimum of three or four weeks is necessary after adequate regional anaesthesia. If the control shows marginal or periradicular breakdown, splinting should be maintained for another 3 or 4 weeks.

- When the apical foramen is closed, endodontic treatment will be necessary.
- Teeth with incomplete root formation will develop pulp obliteration [26].

e) Intrusive luxation and treatment possibilities

Intrusive luxation has been defined as the dislocation of a tooth in an axial direction into the alveolar bone [121, 122]. This dislocation is considered complete when the tooth is enveloped by the surrounding tissues or partial when the incisal border of the crown is visible [98, 123]. Traumatic intrusion of permanent teeth has a low incidence and has been reported to represent only 0.3–2 % of dental injuries [124, 125]. It is common in primary incisors, and it can have severe consequences in the permanent successors [122]. Young permanent teeth have the potential to re-erupt spontaneously. Altogether, the prognosis of teeth with this injury is poor. Damage to the periodontium and pulp usually causes severe complications including external inflammatory resorption, replacement resorption/ankylosis, pulp obliteration and pulp necrosis with infection of the root canal system [126, 127]. The development of replacement resorption in a young patient may influence alveolar growth and the development of malocclusion [127, 128].

Treatment:

- Treatment for this type of trauma involves observation for spontaneous re-eruption in the case of open apices [59, 127].
- An orthodontic repositioning can be initiated if no movement occurs within a few weeks when apices are closed.
- A surgical repositioning is needed if a tooth is intruded more than 7 mm. Orthodontic or surgical repositioning should be performed immediately [126, 127].

(The treatment recommendations from the International Association of Dental Traumatology (IADT) [59] indicate that teeth with incomplete root formation should first be allowed to re-erupt without intervention, and then an orthodontic repositioning should follow.)

f) Avulsion (total luxation) and treatment possibilities

Tooth avulsion is defined as the complete loss of a tooth out of the alveolar bone socket as a result of an accident and it represents a severe traumatic dental injury. Most teeth affected by a dental trauma are incisors in children and adolescents [129, 130, 131]. Avulsion comprises 0.5–16% of total TDIs [132].

In the case of an avulsion, both the pulpal tissues and the periodontal ligament are disrupted. Preservation of the vitality of the periodontal ligament covering the root will determine the prognosis of the replanted tooth [71, 26].

Treatment:

- It is necessary to replant the tooth as soon as possible to minimise extra-alveolar time. It should be followed by stabilising the tooth in the correct anatomical position to allow optimal healing of the periodontal ligament and the neuromuscular supply while maintaining aesthetic and functional integrity.
- When the replantation cannot be performed immediately after the tooth avulsion (up to 15 minutes) [132–134], the tooth should be stored in appropriate solutions compatible with cell survival [135–140], which greatly enhance the case prognosis. Pasteurised cold milk or the patient's own saliva have been indicated as possible alternatives of storage medium for avulsed teeth in several countries since they can preserve cell viability for up to 6 hours. Keeping the tooth dry compromises the periodontal ligament cells and the prognosis will be poor [138, 141].
- After replantation, the tooth is splinted for one week with semi-rigid splint in the case of mature permanent teeth and for two weeks in the case of immature teeth.

- Tetanus prophylaxis is necessary and antibiotic coverage can be considered (e.g. penicillin 1000mg immediately and a daily shot of 500mg for four days) [130].

1.5. Endodontic treatment traumatic injuries to immature permanent teeth

The endodontic treatment for traumatic immature permanent teeth is considered as a challenge for dentists if the pulp vitality is lost, especially with pulp necrosis in teeth with inadequate radicular development because an open apex in a permanent tooth takes approximately three years to close after tooth eruption [142–144]. In the case of pulp necrosis, pulpectomy and root canal therapy should be preferred [143]. If the apex is not completely formed, the standard treatment option for traumatised immature permanent teeth with necrotic pulp is apexification.

Root formation is broken into seven stages by Moorrees et al. [228]: initial root formation, ¼, half, ¾ of root length is achieved, root length complete with apical foramen wide open, half-closed, the root is complete.

The aim is to induce a hard calcified barrier at the apical end of the root to achieve the definitive root canal filling [145].

1.5.1. Treatment with calcium hydroxide ($Ca(OH)_2$)

The traditional, long-term radicular closure procedure applies calcium hydroxide [146]. This technique was the mainstay for the management of immature apices for over half a decade [147]. $Ca(OH)_2$ was the most widely accepted material, due to its biological and antimicrobial properties, such as reparative dentin to bridge a pulp exposure, induction of hard tissue formation and ability to stimulate the formation of new bone, healing of large periapical lesions and inhibition of root resorption [148–150]. $Ca(OH)_2$ dressing helps to eliminate the microorganisms and inactivates toxic products [151]. The lethal effect of calcium hydroxide on bacterial cells is probably due to protein denaturation and damage to DNA and cytoplasmic membranes [152]. The average time for apical barrier formation ranges from 5 to 20 months [153].

Despite the higher success rate of apical barrier formation using $Ca(OH)_2$, it still has its inherent clinical problems [154, 155]:

- The possibility of cervical root fracture of the weakened teeth because of the desiccating properties of high pH $Ca(OH)_2$.
- Failure to control infection, multiple appointments, which complicated the treatment.
- The nature of the barrier, which might be porous or sometimes contains soft tissues.

1.5.2. Treatment with Mineral Trioxide Aggregate (MTA)

In recent times, interest has centred on the use of mineral trioxide aggregate, due to its wide array of applications in the treatment of complications following dental trauma. These conditions include teeth with exposed pulp, root fracture and pulp necrosis located in the coronal part of the pulp [156–158].

It is the material of choice as an apical plug during the short-term (one-visit) apexification techniques, and adjuvant, placed as a cervical plug in the regenerative endodontic treatment (RET) based on revascularisations techniques [146]. Hydration of MTA powder results in a colloidal gel composed of calcium oxide crystals in an amorphous structure [159]. The use of MTA in endodontics is due to the beneficial properties of this material like the ease of manipulation and placement [160]. It neither gets resorbed nor weakens the root canal dentinal structures [161]. It shows antimicrobial properties, biocompatibility, low shrinkage and the capacity to induce cementum and periodontal ligament (PDL) formation [162, 163]. During setting time, the pH is between 10.2 and 12.5, favouring hard tissue induction and creating a bacteria-tight seal [164, 165]. However, MTA has certain drawbacks such as [166]:

- Difficulty in handling and very slow setting reaction, which might contribute to leakage.
- Surface disintegration
- Loss of marginal adaptation and continuity of the material.

1.5.3. Biodentine

The newest material has good properties such as adequate adhesive ability, insolubility and good marginal seal, long term dimensional stability, biocompatibility and bioactivity. The presence of a setting accelerator results in a faster setting including its handling properties and strength as compared to MTA. It has low fluid uptake and low resorption values.

Due to its low water content, Biodentine offers lower porosity and a good hermetic seal [170]. Some studies have shown no porosity difference between this new calcium silicate repair cement where others have, compared to MTA [171]. According to Han and Okiji [172], Biodentine has a greater ability to produce apatite crystals and release dental elements than MTA. It has a disadvantage: Biodentine has poor radiopacity.

1.5.4. Iodoform

Iodoform is composed of some powder with bright hexagonal crystals of lemon-yellow colour, with penetrating and persistent smell, little soluble in water (1:10.000), soluble in alcohol (1:60), and soluble in ether (1:75). Compounds that contain iodine are wildly employed for infection control in dentistry [167]. Iodoform has many advantages:

- It is bactericidal to microorganisms in the root canal and loses only 20 % of its potency over a ten-year-old period [168].
- It is resorbed from the periapical area [168].
- It remains in paste form and never sets to a hard mass, so the removal of this material for retreatment is very easy [168].
- It does not cause enamel disturbances or other morphological defects [168, 169].

1.6. Root-crown ratio of teeth

The R/C ratio is defined as the value between the root and the crown and may be classified as the anatomical R/C ratio or the clinical R/C ratio [173]. The R/C ratio can be calculated clinically or determined radiographically [174, 175]. It is defined by the alveolar bone level and provides information on the amount of the alveolar support [173]. The definition of the R/C ratio of permanent teeth is of great importance. All prosthetic work as well as the ability of the teeth to bear masticatory forces depend on this factor. In paediatric dentistry, one can differentiate the developmental deficiencies of the teeth from the normal ones by defining the normal values and the variations of the R/C ratios [176]. In the present study, the aim was to compare the R/C ratios in the Hungarian, German and Japanese populations by using the same method.

2. Objectives

2.1. General objective

The general objective of this thesis was to increase the knowledge of the incidence, prevalence, risk, treatment of traumatic dental injuries to permanent teeth in children and adolescents.

2.2. Special objectives

I. To survey the prevalence of anterior tooth TDIs in children between 7 and 18 years old who presented for treatment at the Department of Paediatric Dentistry and Orthodontics, Semmelweis University, Faculty for Dentistry, Budapest, Hungary over a period of 10 years.

II. To correlate the prevalence of TDIs to the classification of traumas, to gender, age, type of affected teeth, type of trauma, aetiology, place of injury, season and to the arch over 10-years.

III. To determine the prevalence of TDIs among different age groups.

IV. To compare the present results with previously published Hungarian data in the years 1985–1999.

V. To present some of the cases treated.

VI. To compare the effectiveness of materials used in the treatment: calcium hydroxide, mineral trioxide aggregate, iodoform paste and Biodentine.

VII. To measure the root-crown ratio (R/C ratio) of teeth in healthy German, Japanese and Hungarian children.

3. Materials and methods

3.1. Source of data

The study protocol was reviewed and approved by the Semmelweis University of Dentistry in Budapest, Hungary. A retrospective study was used, so there was no need for ethical approval. The study included traumatic dental injuries data collected from 7 to18-year-old patients' files. The patients with a history of a traumatised permanent tooth were treated in the Department of Paediatric Dentistry and Orthodontics in Budapest for over a ten-year-long period. One of the main dental medical services in this Department is the complex therapy of dental injuries during childhood, and this Department has the highest patient turnover than any other departments with the same function in Hungary. All electronic charts at a university-based dental clinic for patients who experienced a dental trauma in anterior permanent teeth between January 2007 and December 2016 were included in this study.

Also, a separate survey has been included in the present thesis. 95 Hungarian, 104 Japanese and 110 German young patients' panoramic radiographs were used to evaluate the R/C ratio. The Hungarian sample was obtained from the Department of Paediatric Dentistry and Orthodontics of Semmelweis University, Budapest, Hungary. The Japanese data were received from the Department of Paediatric Dentistry of Asahi University, Hozumi, Japan, and the German sample from Freiburg University, Freiburg, Germany. The determination of the R/C ratio of teeth was carried out by using the same method that Hölttä et al. did in 2004, which had been adapted from Lind's intraoral radiographic method [177]. The method for measuring crown height and root length in the assessment of the root–crown (R/C) ratio is shown in Figures 1 and 2.

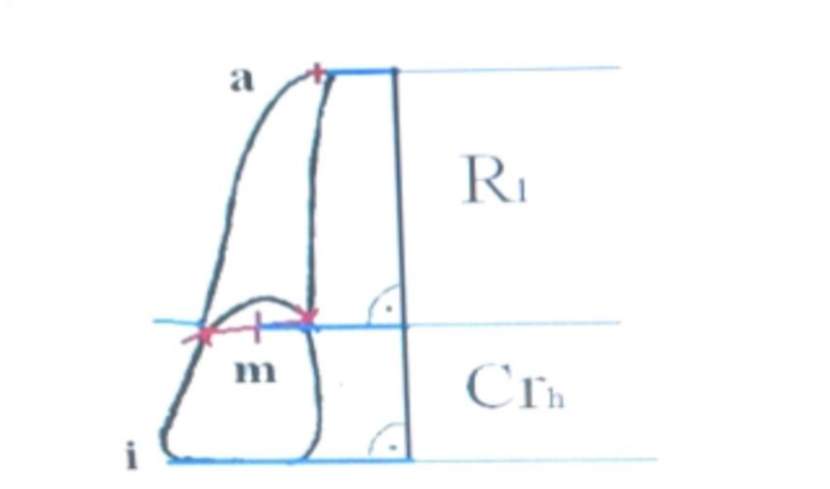

Figure 1. The definition of the measurement points [177]

m, visually determined midpoint of a straight line connecting the points of intersection between the outer contours of the root and crown; *Crh*, crown height measured from point m perpendicular to the incisal reference line *i*; *Rl*, root length measured from point m perpendicular to the apical reference line *a*.

Figure 2. A measurement method on panoramic X-ray

3.2. Collection of data

The following variables were collected from the patients' files:

- Patient's gender
- Patient's age at the time of the trauma
- Tooth location
- Type of TDIs according to Andreasen's classification
- Aetiology of dental trauma
- The season in which the injury occurred
- The reason that caused or led to dental trauma
- Type of treatment.

3.3. Clinical examination

The clinical examination included:

- Dislocation
- Mobility
- Thermal sensitivity.

The study recorded the following details: prevalence of TDIs, classification of dental trauma, patient's gender, type of teeth affected, child's age at the time of the trauma, type of TDIs, aetiological factors, location of the accident, season, type of treatment, distribution of TDIs according to arch, distribution of infection with pulp necrosis in the case of uncomplicated crown fractures, the comparison of the results of 1985–1999 and 2007–2016, and the comparison of the root-crown ratio in healthy German, Japanese and Hungarian children.

3.4. Classification of TDIs

TDIs were recorded according to the World Health Organization (WHO) classification system, which was slightly modified by Andreasen et al. [189], and included two types of injuries:

- Injuries to the hard dental tissues and pulp: enamel and enamel-dentin fractures without pulp exposure (uncomplicated crown fractures), enamel-dentin fractures with pulp exposure (complicated crown fracture), and root fracture.

- Injuries to the periodontal tissues: partial luxation and avulsion.

3.5. Radiographic examination

Intraoral or panoramic radiographs were taken. Three different angles for each traumatised tooth were used, and a traumatised anterior region was covered by one occlusal film and three periapical exposures. The central beam was directed between the two affected teeth. This method ensures the diagnosis of even minor dislocations or root fractures.

3.6. Statistical analysis

All the data obtained from the patient's documentation were entered into MS Excel 2007 for evaluation. The data were organised into files (Microsoft Excel) and analysed by using the Statistical Package for Social Sciences (SPSS), a software programme for statistical analysis, version 10.2 (IBM, 2015).

Statistical significance for the association between the occurrence of dental trauma and gender, age, place and cause were tested by using the *Chi-square* ($\chi 2$) test of significance.

p values < 0.05 were considered statistically significant.

3.7. Search strategy

An electronic search was performed in PubMed and Google Scholar.

The search terms that were used included dental trauma, traumatic dental injuries, dental trauma to permanent teeth, prevalence of dental trauma, treatment for dental trauma, types of dental trauma, aetiological of dental trauma, tooth fractures, luxation injuries, avulsion and R/C ratio.

4. Results

The data collection of TDIs was completed for a total of 454 patients. A total of 899 injured permanent anterior teeth were included in the study with patients ranging in age from 7 to 18 years old. The total prevalence of TDIs among children in this study was 1 %. The peak incidence of the TDIs in our study was at 9 years of age. The results of the current study showed a higher prevalence of dental trauma among male patients than female ones. While 279 boys (61.45 %) suffered from TDIs, the number of the girls was 175 (38.54 %). Of all the 454 children, 247 (54.40 %) had one damaged tooth.

Regarding the R/C ratio evaluation, 95 Hungarian, 104 Japanese and 110 German young patients' panoramic radiographs were included in this thesis. Routine panoramic radiographs exposed between 2001 and 2006 were used.

4.1. Distribution of TDIs by tooth-type

The result shows the distribution of TDIs according to the different tooth-types. The maxillary central incisors were found to be the most affected by dental trauma at the rate of 63.62 % followed by maxillary lateral incisors (17.13 %). The mandibular canines were the least affected teeth by dental trauma with the rate of 1.77 %. The traumatised maxillary central incisors were more common among males than females. While the number of the affected upper incisors among males was 397 (69.40 %), the number of the affected upper incisors was 175 (30.59 %) among females (Table 1).

There was a statistically significant relationship between gender and injured maxillary central incisors (p=0.01).

Table 1. Tooth-type distribution of dental trauma

Tooth-type	n	%
Maxillary central incisors	572	63.62
Maxillary lateral incisors	154	17.13
Mandibular central incisors	52	5.78
Mandibular lateral incisors	24	2.66
Maxillary canine	81	9.01
Mandibular canine	16	1.77
Total	**899**	**100.00**

4.2. Prevalence of TDIs according to age

Regarding the distribution of TDIs according to age, the injuries were the most frequent between the ages of 8 and 10 years. The peak occurred at about the age of 9. Nine-year-old children comprised about 22.02 % of all the patients. They were followed by ten-year-old children who comprised 15.41 %.

The least prevalence of TDIs according to age can be seen at the age of 17. Children at this age comprised about 1,10 %, followed by the eighteen-year-old children, who comprised 1.76 % (Figure 3).

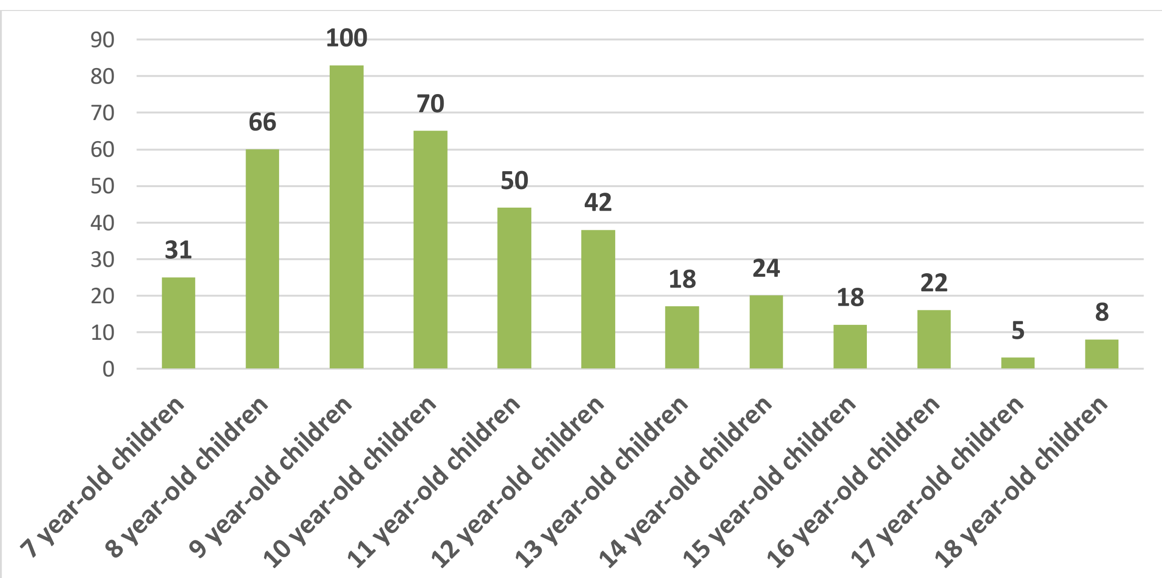

Figure 3. Age distribution of dental trauma

4.3. Distribution of TDIs by injury type

Considering the distribution of dental trauma according to the type of injury, we could notice that luxation injuries were the most common type of trauma. They were present in 50 % of the teeth, followed by uncomplicated crown fractures (37.44 %) and complicated crown fractures (9.67 %), respectively. The prevalence of root fractures was the lowest among all types of TDIs by the rate of 1.02 % (Table 2). A statistically significant difference between gender in the case of uncomplicated crown fractures was found ($p=0.001$), while there was no significant difference between boys and girls in the case of luxation injuries, complicated crown fractures, root fractures and avulsion ($p=0.6$, $p=0.09$, $p=0.5$, $p=0.7$ respectively).

Table 2. Injury-type distribution of TDIs

Type of dental trauma	n	%
Luxation injuries	486	50
Uncomplicated crown fractures	364	37.44
Complicated crown fractures	94	9.67
Avulsion	18	1.85
Root fractures	10	1.02
Total	**972**	**100.00**

4.4. Aetiology of TDIs to permanent teeth

Most accidents occurred during playtime (30 %) and sports activities (25 %). The percentage of children who suffered from dental trauma caused by a fall was 18 % and 15 % by cycling. The children who suffered from dental trauma caused by accidents and fights comprised 8 % and 4 %, respectively (Figure 4).

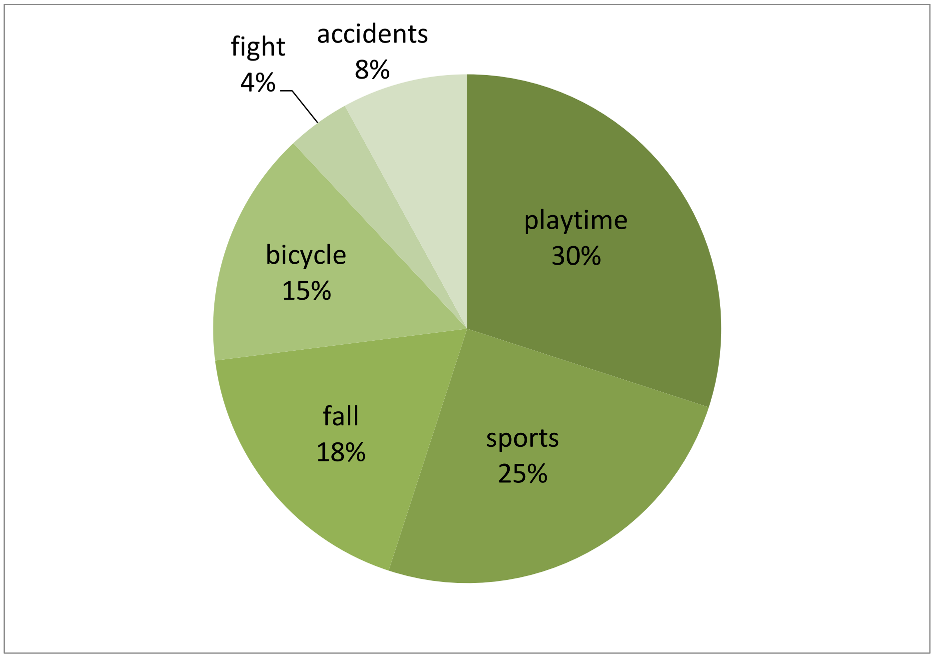

Figure 4. Activities during which trauma occurred

4.5. Distribution of TDIs according to the location of accidents

In Figure 5, we can see that most cases of dental trauma occurred at home (46.47 %) and in school (28.63 %). Playground cases comprised about 15 %.

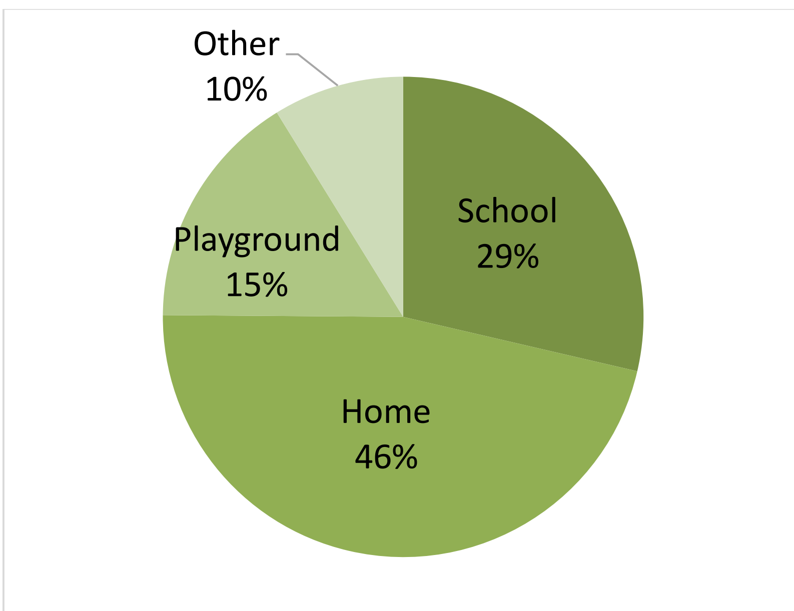

Figure 5. Places where trauma occurred

4.6. Distribution of TDIs according to the seasons

The current survey recorded that the highest rate of dental trauma in children occurred in the spring, followed by autumn, as children who were affected by dental trauma in the spring made up 34.14 % of the total number of children (Figure 6). Children who suffered from TDIs during winter accounted for the lowest percentage (19.82 %). As far as the seasons are concerned, a statistically significant difference between boys and girls was found (p=0.002).

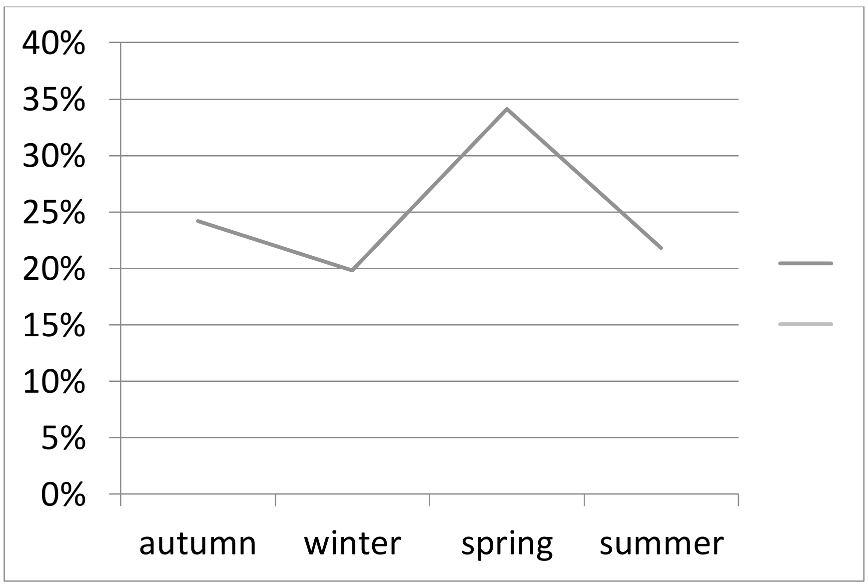

Figure 6. Occurrence of dental trauma by seasons

4.7. Treatment of TDIs

The most common therapy of TDIs was splinting, as it comprised about 58.48 % of all the total types of treatment, followed by treatment with $Ca(OH)_2$ and protective crown [38.15 %].

The replantation ratio constituted 2.17 %. 0.84 % of total treatment was reposition. The lowest percentage was extraction [0.36 %] (Table 3).

Table 3. Therapies of TDIs

Total	Number	%
Splinting	486	58.48 %
$Ca(OH)_2$+ temporary crown	317	38.15 %
Replantation	18	2.17 %
Reposition	7	0.84 %
Extraction	3	0.36 %
Total	831	100.00

4.8. Distribution of TDIs according to arch

Table 4 shows the distribution of TDIs according to arch. From a total of 899 teeth that suffered from dental trauma, 807 (89.76 %) teeth were in the maxillary arch, and 92 (10.24 %) teeth were in the mandibular arch.

Table 4. The prevalence of TDIs according to arch

Arch	Frequency	Per cent
Maxillary arch	807	89.76 %
Mandibular arch	92	10.24 %
Total	899	100 %

4.9. The distribution of infection with pulp necrosis of uncomplicated crown fracture according to the presence of luxation injury

Table 5. shows the frequency of pulp necrosis according to the type of crown fracture. In the teeth with uncomplicated crown fractures and without luxation injuries very low incidence of pulp necrosis was detected as from 291 teeth only 7 (2.41 %) teeth showed pulp necrosis. In the case of teeth with uncomplicated crown fractures with luxation injuries, 31.51 % of total teeth showed the incidence of pulp necrosis.

Table 5. Infection with pulp necrosis of uncomplicated crown fracture

	Teeth without pulp necrosis		Teeth with pulp necrosis		Total	
	N	%	N	%	N	%
Uncomplicated crown fractures, teeth without luxation injury	284	97.59	7	2.41	291	100
Uncomplicated crown fractures, teeth with luxation injuries	50	68.49	23	31.51	73	100

4.10. Differences recorded between the current and former data

Table 6 includes the comparison between the current data over the period between January 2007 and December 2016 as well as the previously published data in the years 1985–1999. Based on the analysis of the data included in this table, the results were compatible for the number of patients, gender, affected teeth and the most frequently affected teeth. While there was no agreement between the proportions concerning the most frequent type of dental trauma, the increase of luxation injuries is noticeable over the past ten years. The rate of luxation injuries over the past ten years comprised 50%, while the enamel-dentin fracture in the years 1985–1999 comprised 78.16 %.

As far as treatment methods are concerned, splinting was the most common type during the period between 2007–2016 with the rate of 58.48 %, while the treatment with $Ca(OH)_2$ and temporary crown formed the highest ratio in the years 1985–1999. It comprised 38.15 %.

Table 6. Comparison of results of 1985–1999 and 2007–2016

Hungarian Data				
	1985–1999		2007–2016	
	N	%	N	%
Number of patients	547	100.00	454	100.00
Girls	228	41.68	175	38.54
Boys	319	58.32	279	61.45
Number of affected teeth	729	100	920	100
The most frequently affected teeth. Maxillary central incisors. (11, 12)	626	85.87	572	63.62
The most frequent type of dental trauma	Enamel-dentin fracture		Luxation injuries	
	587	78.16	486	50
Therapies	1985–1999		2007–2016	
Splinting	105	10.72 %	486	58.48 %
Temporary crown	415	42.4 %	317	38.15 %
Reposition	5	0.51 %	7	0.84 %
Replantation	3	0.3 %	18	2.17 %

4.11. Measurement and comparison of the root-crown ratio in healthy German, Japanese and Hungarian children

The lowest R/C ratios were found in teeth 16 and 17 in all the three populations. Low R/C ratios were found in tooth-types 11 and 14 in all the three populations. Low R/C ratios were found in tooth type 41 in the Japanese population, but medium in the other two populations. The highest R/C ratios were found in tooth-types 43 and 45 in all the three populations. In the German and Hungarian populations, tooth type 44 had the highest R/C values. The R/C ratios of teeth 15 and 13 were found high in the

Japanese population, and the ratios were found medium in the Hungarian and German populations (Table 7). No significant differences were found in the R/C ratios of the tooth-types in the three populations examined by us($P>0.05$). The German and the Japanese populations showed significant differences in all lower tooth-types ($P\leq0,05$-$0,001$), the Japanese and Hungarian populations in almost all lower tooth-types (except for 41, $P>0.05$) ($P\leq0,05$-$0,001$), the Hungarian and German populations showed significant differences in tooth-types 11, 16, 17, 47 ($P\leq0,001$) and 41 ($P\leq0,05$). In the upper arch, the German and Japanese populations showed significant differences in all of the tooth-types ($P\leq0,05$-$0,001$); the Japanese and Hungarian populations in tooth-types 11, 12 and 13 ($P\leq0,05$-$0,001$), the Hungarian and the German populations showed significant difference in tooth types 11, 16 and 17 ($P\leq0,001$) (Table 8).

Table 7. The lowest and the highest R/C ratios of tooth-types in the three populations

	Low R/C ratio of tooth-type	High R/C ratio of tooth-type
Hungarian population	16, 17, 11, 14	45, 43, 44
German population	16, 17, 11, 14	45, 43, 44
Japanese population	16, 17, 46, 47, 11, 14, 41	45, 43, 15, 13

Table 8. Comparison of R/C ratios of tooth-types in the three populations according to P value

	Tooth-types with P>0,05 relationship	Tooth-types with p≤0,05-0,001 relationship	Tooth-types with p≤0,001 relationship
Hungarian-German population	12, 42, 13, 43, 14, 44, 15, 45, 46	11, 16, 17, 41, 47	11, 16, 17, 47
Hungarian-Japanese population	14, 15, 16, 17, 41	42, 43, 44, 45, 46, 47, 11, 12, 13	12, 42, 43, 44, 45, 46
German-Japanese population	----------------	11, 12, 13, 14, 15, 16, 17, 41, 42, 43, 44, 45, 46, 47	12, 42, 43, 44, 45, 46, 47

$p\leq0.001$, $p\leq0.05$(significant); $p>0.05$(non-significant)

5. Discussion

5.1. Prevalence of TDIs

In the present study, the total prevalence of TDIs among children was 1 %, which appeared to be relatively very low compared to other prevalence in the literature, for example, to the 10.4 % reported by Bilder et al. in Georgia [37], to the 18.6 % reported by Aldrigui et al. [61] in Latin America and the Caribbean [179], to the 22.9 % reported by Rouhani et al. in East Iran school children [34], to the 24.5 % in children who attended two dental clinics in Targu Mures between 2003 and 2011reported by Kovacs et al. [180] and to the 30% reported by Forsberg and Tedestam [49]. The rates of 2.2 % reported by Lexomboon et al. [181] and of the 4 % reported by Zengin et al. [182] are close to the current results. The increase in the prevalence of dental trauma over the past few decades is confirmed by many studies in the literature. Lexomboon et al. [179] reported an increase of TDIs in Brazilian preschool children in the last 10 years and children living in the county of Värmland, Sweden in the past 20 years, respectively. The current Hungarian data reveal a clear decrease in the prevalence of TDIs in the last ten years (1 % current data, 2.5 % former data). The former data is reported by Gábris et al. [183]. The increased health awareness, the wide information and educational campaigns about the risk of dental trauma and prevention methods such as presentations for paediatricians within the frame of a postgraduate course and the continuous advice of dentists to parents on protective methods and procedures to protect their children from traumatic dental injuries or to minimise the complications thereof have largely contributed to this positive change.

Children with maxillary overjet are more prone to TDIs than other children, so it is necessary to initiate a preventive orthodontic treatment for these individuals to be completed before the age of 11, that is, in the early stage to mixed dentition, in the attempt to reduce the risks of trauma. In addition, it may be strategic to pay special attention to children and young teenagers who have a history of previous oral trauma because they are more likely to have another injury compared to those who have never experienced any. Also, the use of mouthguards during sports activities is considered an important factor in decreasing the complications of TDIs.

We suppose that the decrease in the complications of dental trauma might be due to the increased use of mouthguards in Budapest. Unfortunately, no data is available to prove this fact in Hungary but many surveys in the literature hypothesise the effective role of mouthguards in this field. For example, significant risk reduction for complications following dental injuries in rugby union players in Australia after using mouthguards is reported by Ilia et. al. [184]. Also, Green reported the role of mouthguards in preventing and reducing sports-related traumas [185].

Large variability in the reported prevalence of TDIs can be found in the literature. Differences in sample composition as well as in the definitions and classifications of trauma make the comparison between various data on a uniform basis difficult [183, 186].

5.2. Classification of TDIs

Different classification systems have been used in the literature. Noori and Al-Obaidi used Garcia Godoy's classification [187]. Chopra et al. assessed dental injuries according to the Elis classification modified by Holland [14]. Chen et al. used Andreasen's criteria in their study [188]. In the present study, dental traumas were classified according to the World Health Organization [WHO] classification system, slightly modified by Andreasen et al. [189], which is the same classification that was used in the study by Bagattoni et al. [190].

The present study identifies the prevalence of dental trauma of permanent teeth among children according to their gender, type of tooth affected, age, type of trauma, aetiological factors, location of the injury, season, type of treatment, distribution of TDIs according to arch, distribution of the pulp necrosis of uncomplicated crown according to the presence of luxation injury, and comparison of the R/C ratio in healthy German, Japanese and Hungarian children.

5.3. Prevalence of TDIs according to gender

In this survey, the results confirm the general findings in the literature that boys sustain dental trauma more frequently than girls as illustrated in the studies reported by Chen et al., Ritwik et al. [83], and Faus-Damia et al. [42]. The present results (61.45 % males, 38.54 % females) come close to the results (60 % male and 40 % female) published by Zengin et al. [182] and by Nemtoi et al. [191], who reported dental trauma frequencies of 62.1 % in males and 37.9 % in females. They are higher than the former results in Hungary (58.32 % males, 41.68 % females) [183], and lower than the results (79.2 % males, 20.8 % females) reported by Andrade et al. [192], and (64.7 % males, 35.3 % females) observed by Atabek et al. [64]. The difference by gender is explained by the fact that boys are more inclined to pursue vigorous and aggressive leisure activities or sports with a greater risk of accident than girls [193]. According to Bani et al., hyperactivity and social problems were found to be additional risk factors for male patients [2].

5.4. Prevalence of TDIs according to the type of teeth affected

Maxillary central incisors were the most commonly traumatised teeth in this study (63.62 %) (Table 1). This result was close to that of the previous study (63.6 %) by Ilia et al. [184].

It was higher than the rates (of 50 %) in the study reported by Costa et al. [194], the 59 % in patients who were admitted to the Beijing Stomatological Hospital between July 2008 and June 2009 for TDIs in Chin [195] but lower than the finding (75.4 %) by Wang et al. [196], by Chopra et al. (81.4 %) [14], by Gábris et al. (85.87 %) [183] and by Eltair et al. (87.5 %) [197]. The most commonly traumatised teeth after the maxillary central incisors were maxillary lateral incisors with the rate of 17.13 %. This result is consistent with the result (19.67 %) observed in the study of Guedes et al. [198]. The decrease in the anterior teeth affected by dental trauma may have contributed to the decline in the prevalence of dental trauma during the last ten years. The prominent and most vulnerable position of the maxillary incisors makes these teeth more susceptible to injuries compared to the lower teeth [199].

5.5. Prevalence of TDIs according to age

The age when children are most susceptible to dental trauma was investigated in several studies. The variation in the peak incidence of dental trauma was observed in the literature. While the highest frequency of TDIs in the permanent dentition was among 12-year-old Iraqi children in the studies published by Yassen et al. [200] and by Tumen et al. [201], it was in the age group of 13–14 years, more precisely among from 9 to 14-year-old schoolchildren of Navi Mumbai, India [202], and among 8-year-old children in the study reported by Wang et.al [196]. Our results are similar to those of Ritwik et al. [83], who also found the highest incidence of dental trauma at the age of 9 years (Figure 3). The variation in the peak incidence of dental trauma from one study to another was attributed to the different restrictive age ranges [203]. When we compared the former Hungarian data published by Gábris et al. [183] to our findings, we noticed that there was a change in the peak incidence of TDIs from the age of 10 years in the earlier study to the age of 9 in the current study. The occurrence of peak dental trauma around the age of 9 can be explained by the fact that younger children have less sense of fear, which makes them more susceptible to dental injuries [186].

5.6. Prevalence of TDIs according to the type of trauma

In the current study, the most common type of dental injury was luxation (50 %) (Table 2). This result is compatible with the result recorded by Toprak et al. in Turkish children in Istanbul as the most common type of dental injury was luxation (43.3 %) [204]. The recent outcome was contrary to the results of most studies, where uncomplicated crown fractures were the most common type of dental trauma [205–207].

The proportion of 50 % compares well with the corresponding data of Elkarmi et al. (43.1 %) among preschool children in Amman, Jordan [208], and with both data of Rouhani et al. (46.1 %) in an East Iranian school [34] and of Muriithi et al. (47.5 %) in Nairobi [208], but it is considered high compared to the average given by Hecova et al. (23.3 %) [6], or to the range reported by Ritwik et al (29.5 %) at an urban paediatric emergency department [83].

Uncomplicated crown fractures comprised 37.44 % in the current survey. This result is higher than the following averages: 25 % found by Sari et al. [210], 20.8 % reported by Gong Yi [195] and the average (20.5 %) recorded by Toprak et al. [204], but it is lower than the 47 % reported by Zengin et al. in Turkey [182], the 56 % reported by Yassen et al. [200] and the 84.9 % in the study carried out by Costa MM [194]. The literature includes both very high numbers of enamel dentin fractures, for instance, 91.3 % is reported by Bilder et al. in Georgia [37], 84.9 % is observed in the study by Costa et al. [194], 69.2 % in young patients attended at the Federal University of Rio de Janeiro in Brazil [211], and low ratios, for example, 15 % in 12–14-year-old boys in Riyadh, Saudi Arabia [212], 27 % among Brazilian schoolchildren [207] and 22.52 % among 812-year-old schoolchildren in Diyarbakir, Turkey [201].

Regarding complicated crown fractures, they comprised about 9.67 % in this study. This proportion compares well with the corresponding data of Altay N Güngör HC [213]. It is considered low in comparison with other results in the literature, for example, 19.4 % in Turkish children in Istanbul [204], and 28.7 % in children presenting for treatment at the Department of Paediatric Dentistry, Faculty of Dentistry, University of Jordan, 1997–2000 [214].

Overall, the proportion of crown fractures (complicated and uncomplicated) was 47.11 %. This rate is within the range (26–76 %) reported by Andreasen et al. [62].

The least common type of TDIs in the present study was avulsion (1.85 %). Avulsion was also the least common in the survey conducted by Tiryaki et al. with the rate of 1.6 % [215]. The rate of root fracture (0.4 %) was the least common in the study by Andrade et al. [206].

Based on the comparison between current and former data (Table 6), there has been a significant increase in luxation injuries in the last ten years and a significant decrease in crown fractures. Regarding avulsion injuries, the decrease in the proportion of avulsed teeth was considerable (1.85 % current data, 4.39 % former data) These changes between the previous and current data are attributed to the elasticity of alveolar bone in the younger studied age groups and the parents' increased awareness of the importance of mouthguards not only for certain sports activities but also with active children.

5.7. Prevalence of TDIs according to aetiological factors

Many previously published surveys studied the aetiological factors of TDIs among children. Falls were the main factor of dental injuries among the patients in many studies [14], [3], [46], [34]. The main factors of dental injuries among the patients of this survey were play and sports injuries (Figure 4). Nemtoi et al. [191] and Agrawal et. al [216] stated that sporting activities were frequent causes of traumatic injuries with the rates of 23.1 % and 22.2 %, respectively, which was close to our data of 25.33 %. The relatively high number appeared in the study [217], as sports injuries comprised about 58 % of all the aetiological factors. In the present study, 18 % of traumatic dental injuries were caused by falls. This rate is considered low when compared to other rates, such as 83.3 % in Brazilian children assisted at the Federal University of Santa Catarina, Brazil [218], 56.6 % in old Schoolchildren of Patiala City, Punjab, India [219], 51.4 % which was reported by Chopra et al [14] and 49.7 % in schoolchildren in Montes Claros in Brazil [220]. In comparison with other results in the literature, a low ratio was registered by Al-Ansari A, as the ratio of fall injuries was 9.3 % [221].

Bicycle accidents comprised about 15 % of total aetiological factors in the present study. This result is lower than the 31.2 % reported by Mesquita et al. [222].

5.8. Prevalence of TDIs according to the location of the accident

The patients involved in this study often sustained dental trauma at home (46 %) followed by school (29 %) (Figure 5). Our results come in line with those registered by Rouhani et al. as the dental injuries at home comprised 46.8 % and those in school comprised 29.9 % of the cases [34]. Regarding the place of incidence of trauma, varied proportions were found in the literature. 48.2 % of TDIs among 12-year-old schoolchildren in Montes Claros occurred at home followed by 25.16 % in school [220]. Amorim reported that 43.5 % of the dental injuries had happened at home and 10.1 % of them had happened in school [3].

5.9. Distribution of TDIs according to the seasons

The relationship between seasons and dental trauma was studied, and there is a clear indication of increased traumatic injuries in the spring, as 34.14 % of children were affected by traumatic injuries during this season (Figure 6). This result is consistent with the outcome in Choi's study, where most of TDIs occurred in the spring there as well [32].

The highest frequency of dental injuries was found in the summer in the studies reported by Guedes et al. [198] and by Schatz and Joho [223]. Most TDIs happened in the autumn in the study reported by Wang et al. [196].

5.10. Treatment of TDIs

Splinting was the most common type of treatment in this study (Table 3). It comprised 58.48 % of all types of treatment. The rate of treatment with calcium hydroxide and temporary crowns was 38.15 %. The treatment with replantation was 2.17 %, followed by reposition (0.84 %). Extraction was the least frequent type of treatment with the rate of 0.36 %. Unfortunately, there are no studies that report the prevalence of types of treatment in detail to compare our results with.

Splinting was the most common type of treatment because luxation injuries comprised the highest ratio of TDIs and they were treated by repositioning and splinting. Also, more modern and better materials came onto the market. On the other hand, the patients' and their parents' attitudes to the treatment changed for the better, too.

5.11. Distribution of TDIs according to arch

From a total of 899 teeth that suffered dental trauma, 807 (89.76 %) teeth were in the maxillary arch, and 92 teeth (10.24 %) were in the mandibular arch (Table 4). Maxillary central incisors (63.62 %), maxillary lateral incisors (17.13 %), maxillary canine (9.01 %), mandibular central incisors (5.78 %), mandibular lateral incisors

(2.66 %), mandibular canine (1.77 %) were also affected. This is in accordance with the reports of some previous studies [224–226].

This can be explained by the fact that in the sagittal plane, the maxillary arch is located more anteriorly than the mandibular arch as a result of which the impact of injury is more likely on the maxillary arch. Within the arch, the protrusion of maxillary central incisors and their forward placement in the sagittal plane also make them more prone to injury [39].

5.12. The distribution of infection with pulp necrosis of uncomplicated crown fracture according to the presence of luxation injury

The findings in the present survey clearly showed the difference in the frequency of pulp necrosis (PN) according to the type of crown fracture. Low incidence of pulp necrosis appeared in the teeth with uncomplicated crown fractures and without luxation injuries, as 2.41 % of all cases of uncomplicated crown fractures without luxation injuries showed PN after trauma, while 31.51 % of uncomplicated crown fractures with luxation injuries suffered PN (Table 5). The findings in the literature supported our results. The frequency of pulp necrosis was significantly higher in crown-fracture teeth with luxation injuries (34.0 %) than in crown-fracture teeth without luxation injuries (22.7 %) in Guan and Qin study [227]. The survey conducted by Viduskalne and Care [93] reported that PN was evaluated in 4,88% of all uncomplicated crown fractures without subluxation and in 56.52 % of uncomplicated crown fractures with subluxation. Many factors play an important role in the healing and prevention of pulp necrosis after the occurrence of fractures. Pulp circulation due to concomitant subluxation as well as the stage of root development and the fracture depth seem compromised [65].

5.13. Comparison of results of 1985–1999 and 2007–2016

Based on the comparison between current and former data (Table 6), there is compatibility concerning the gender and the tooth type the most affected by dental trauma. In both findings, male patients suffered from dental trauma more than female patients (males: females 58.32 %:41.68% former data; 61.45 %:38.54% current data), and the most affected teeth were maxillary central incisors (85.87 % former data, 63.62 % current data). Regarding the most common type of TDIs, there has been a significant increase in luxation injuries in the last ten years, and a significant decrease in crown fractures (78.16 % crown fractures former data, 50 % luxation injuries current data). Concerning avulsion injuries, the decrease in the proportion of avulsed teeth was visible (1.85 % current data, 4.39 % former data). In the case of the type of treatment, splinting was the most common in 2007–2016 years, while the treatment with $Ca(OH)_2$ and temporary crown formed the highest ratio in the years 1985–1999. These changes between the previous and current data are attributed to the elasticity of alveolar bone in the younger age groups and the parents' increased awareness of the high importance of mouthguards for certain sports activities.

5.14. Comparison of the root-crown ratio in healthy German, Japanese and Hungarian children

In 1972, Lind defined a method to determine the R/C ratio of the upper central incisors [174]. Based on Lind's method, Holttä et al. defined a method to determine the R/C ratio of all tooth-types on panoramic radiographs in 2004 [177]. Assessing R/C ratios instead of measuring absolute linear measurements is advantageous in a radiographic study. Alterations in tooth angulation are known to affect the radiographic tooth length but the change in the R/C ratio is negligible [177, 178].

In the present study, Holttä et al.'s method was used. The lowest R/C ratios were found in tooth-types 16 and 17 in all the three populations examined. This is similar to the Finnish findings [177]. In the Japanese and Finnish populations, tooth-types 46 and 47 also had the lowest R/C values, which may be due to the differences in mandible anatomy.

Low R/C ratios were found in tooth-types 11 and 14 in all the three populations. In the Finnish sample, only tooth-type 11 showed even lower R/C ratios [177].

The R/C ratios of tooth type 41 were found to be low in the Japanese and the Finnish populations but were medium in the other two populations.

The highest R/C ratios were found in tooth-types 45 and 43 in all the three populations, as well as in the Finnish report. In the German, Hungarian, and Finnish populations tooth type 44 had the highest R/C values. The R/C ratios of tooth-types 15 and 13 in the Japanese and the Finnish populations were found high, however, in the Hungarian and the German populations they were found medium.

There were no significant differences found in the R/C ratios of the tooth-types in the three populations examined by us which means that it is not possible to determine the nationality of a person depending on the root-crown ratio of their tooth-types.

More differences were found in the R/C ratio of the lower arch, which may be due to different mandible anatomy.

The German and the Japanese populations showed significant differences in all lower tooth-types, the Japanese and the Hungarian populations in almost all lower tooth-types, except for 41, which indicates that there has not been a mixture between these populations throughout history. The Hungarian and the German populations did not show significant differences except for tooth-types 11, 16, 17 and 47, which may be an indication of the mixture of these nations.

These results can serve as useful information for physicians working in the clinic, as well as a comparison for other groups and nations, even for anthropological research. The R/C ratios are of great importance in paediatric dentistry as this method can be applied to follow the R/C ratio after various traumatic dental injuries. It can prove whether there is a difference one year later in the R/C ratio between luxations and fractures.

5.15. Clinical reports

5.15.1. Case no. 1: Apexification by using calcium hydroxide

A 7-year-old boy was referred to the department with a traumatic fracture in the left maxillary central incisor due to a sports accident in school.

5.15.1.1. Clinical examination

The clinical examination revealed a complicated crown fracture with tooth mobility within normal limits. The tooth failed to respond to thermal or electric pulp testing. It was tender to percussion.

5.15.1.2. Radiographic examination

Radiographic examination detected immature teeth with open apices and a large radiolucent area. The root developmental stage (2 to) 3 was established according to Moorrees et al. [228] (Figure 7).

5.15.1.3. Treatment

The tooth was accessed after giving anaesthesia and under absolute isolation conditions. Root canals were cleaned and instrumented (Figure 8). Irrigation with 0.5 % NaOCl was applied. Disinfection and mechanical root canal treatment was extremely difficult and was performed with great care because of the thin dentinal root walls and open apex. The large periapical lesion made appropriate drying also difficult and time-consuming, therefore the long-term apexification using $Ca(OH)_2$ was chosen. The tooth was restored with temporary glass ionomer cement. The $Ca(OH)_2$ dressing was changed every three months. Periapical radiographs were taken periodically. After 12 months, an X-ray examination showed the complete formation of the root apices in the left maxillary central incisor. Permanent root canal obturation with half heated gutta-percha (master point) was performed, followed by additional points, dipped in resin-chloroform using lateral condensation. On the control radiographic examination made after one year, the periapical healing was evident (Figure 9).

Figure 7. Left upper maxillary central incisor before treatment showing large radiolucency in the periapical area

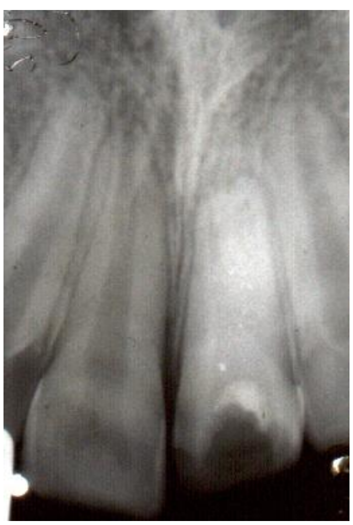

Figure 8.
Calcium hydroxide dressing of the root for tooth 2.1.

Figure 9.
Permanent gutta-percha root canal obturation; 1-year radiographic check-up

5.15.2. Case no. 2: Apexification by using mineral trioxide aggregate

An 8-year-old boy was referred to the Department of Paediatric Dentistry and Orthodontics in Semmelweis University, Budapest for evaluation and treatment of a right maxillary central incisor. He had suffered a traumatic injury during an automobile accident with loss of the coronal fragment of teeth 1.1 and 2.1.

5.15.2.1. Clinical examination

The clinical examination revealed a complicated crown fracture of the right upper central incisor. The tooth failed to respond to thermal or electric pulp testing. It was tender to percussion.

5.15.2.2. Radiographic examination

A radiographic examination revealed that the periapical radiographs demonstrated an incompletely formed root apex and periapical radiolucency. The root developmental stage 3 to 4 was established according to Moorrees et al. [228] (Figure 10).

5.15.2.3. Treatment

Because of difficulties in the disinfection and in the drying of the root canal, a modified short-term apexification technique was chosen as a treatment option. A conventional access opening was made after the patient was given anaesthesia and under absolute isolation conditions. The root length was estimated using a periapical radiograph. Root canal instrumentation was performed, and the working length was established at 1 mm short of the radiographic apex. Copious irrigation with 0.5 % sodium hypochlorite (NaOCl) was done throughout the cleaning and shaping procedures. The root canal was dried with absorbent paper points, and filled with calcium hydroxide. $Ca(OH)_2$ was changed at one-week intervals over two months, and the access cavity was restored with a glass ionomer temporary restoration. At the 2-month check-up, the tooth was asymptomatic and insensitive to percussion and palpation. The temporary restoration was removed and the canal was irrigated again with 0.5 % NaOCl. The canal was enlarged up to the size of the root canal instrument ISO number 80. MTA (CERKAMED Poland STALOWA WOLA) was mixed according to the manufacturer's instruction and was applied with a hand plugger. A control radiograph showed an MTA thickness of about 4 mm. The hardness of the apical plug was checked after 1 week and the canal was obturated with heated gutta-percha and a sealer by applying the lateral condensation technique (Figure 11).

The fracture confined to enamel and dentine in tooth 2.1. Treatment procedure comprises application of bandage consisting of $Ca(OH)_2$ and glass ionomer cement to the fractured surface.

For the final crown restoration of both fractured upper central incisors, light-curing composite material was used. After one year, the radiographic examination of tooth 1.1 showed apical closure and a decrease of the radiolucent area was evident (Figure 12). The two-year check-up revealed complete healing of the apical structures (Figure 13).

Figure 10.
Incompletely formed root length of tooth 1.1. and wide-open apex for teeth 1.1, 1.2 and 2.2; complicated crown fracture with pulpal involvement of tooth 1.1; crown fracture without pulpal involvement for tooth 2.1.

Figure 11.
The MTA apical plug and gutta-percha filling

Figure 12.
Check-up after one year

Figure 13.
Check-up after two years

5.15.3. Case no. 3: Apexification of immature teeth by using Biodentine (Septodont)

A healthy 7-year-old boy was referred to the Department with a traumatic fracture of upper central incisors. According to his mother, the accident happened on a water slide two months before. Both incisors of the child were treated at first, right after the incident, in a private praxis with a protective crown using $Ca(OH)_2$ paste (UltraCal XS, Ultradent, USA). Two months later, the mother brought her son to the clinic with periostitis of the upper left incisor. The right upper incisor was sensitive to cold.

5.15.3.1. Clinical examination

The clinical examination revealed a complicated crown fracture of the left maxillary central incisor with periostitis. The right upper incisor showed a complicated crown fracture.

5.15.3.2. Radiographic examination

Radiographic examination detected immature teeth with open apices and a large radiolucent area (Figure 14). Root formation was in stage between 2 and 3 according to Moorrees et al [228]. Calcified tissue could be found in the middle third of the canal. Probably, during the two months that passed after the accident, calcified tissue developed due to the effect of $Ca(OH)_2$ paste (UltraCal XS, Ultradent, USA).

The X-ray of the right upper incisor could not be well seen. The radiograph was not repeated due to radiation danger. The clinical examination revealed inflammation.

Figure 14.
A seven-year-old child's upper incisors sustained dental trauma.

Figure 15.
Two years later both maxillary incisors developed further

5.15.3.3. Treatment

After the administration of local anaesthesia, the teeth were isolated. The left upper incisor was accessed and the pulp was removed. After the pulpectomy, the root canal preparation was performed and the tooth was flushed with 0.5 % NaOCl. The tooth was dried with sterile paper points and filled up with Biodentine (CEDEX France Saint-Maru-des-Fosses) till the calcified obstruction.

In the right upper incisor, the exposed pulp was disinfected with sodium hypochlorite. The pulp was removed to the depth of 2 mm from the level of exposure. When the bleeding has decreased, Biodentine was placed into the wound surface. Both crowns were restored.

One year later, the radiographic picture revealed progress in the growth of both maxillary central incisors (Figure 15).

5.15.4. Case no. 4: Apexification of immature teeth by using iodoform

A healthy 7-year-old boy was referred to the department with a traumatic fracture. According to his mother, the accident happened several months before in school while he was playing.

5.15.4.1. Clinical examination

The clinical examination revealed a complicated crown fracture of the left maxillary central incisor. The tooth failed to respond to thermal or electric pulp testing. It was tender to percussion.

5.15.4.2. Radiographic examination

The radiographic examination detected immature teeth with open apices and a large radiolucent area (Figure 16). Root formation was in the stage 4 according to Moorrees et al. [228].

5.15.4.3. Treatment

Because of the presence of a large radiolucent area around the apical foramen and an incomplete root development, it was decided to perform apexification. An access cavity was prepared and the canal was instrumented carefully by using manual stainless steel, then it was irrigated with sodium hypochlorite 0.5 %. The root canal was dried with sterile paper points. Strong bleeding was induced from the periapical radiolucency careful manipulation with a Kerr needle 12. Bleeding was induced to remove the necrotic remnants and to create a blood clot. The root canal was flushed with 0.5 % of NaOCl. The canal was enlarged up to the size of a root canal instrument ISO number 80. The canal was dried with sterile paper points, then some iodoform paste (1:1 mixing iodoform powder + Chlumskyi solution) was placed in the root canal. At the 2-month check-up, the tooth was asymptomatic and showed no tenderness to percussion and palpation. The temporary restoration was removed and the canal was irrigated again with 0.5% NaOCl (Figure 17). Glass ionomer cement was used to restore the access cavity after the replacement of the iodoform paste. The tooth was controlled radiographically.

After 1.5 years, the follow-up X-ray examination showed the complete formation of the root apices in the left maxillary central incisor (Figure 18). Permanent root canal obturation with half heated gutta-percha was performed, followed by additional points, dipped in resin-chloroform and by using the lateral condensation technique.

For the final crown restoration of both fractured upper central incisors, light-curing composite material was used.

Figure 16.

Left upper maxillary central incisor showing large radiolucency in the periapical area

Figure 17.

Iodoform dressing of the root for tooth 2.1.

Figure 18.
The left upper maxillary central incisor showing complete development of root.

5.15.5. Case no. 5: Treatment of left maxillary central incisor with root fracture

5.15.5.1. Clinical examination

An 11-year-old boy was referred to the department for treatment. He had suffered a traumatic injury due to an automobile accident.

5.15.5.1. Clinical examination

The clinical examination revealed that the left maxillary central incisor was a little bit mobile. It responded to thermal and electric pulp testing. It was tender to percussion.

5.15.5.2. Radiographic examination

The radiographic examination revealed a horizontal root fracture of the left maxillary central incisor (Figure 19). According to Andreasen et al. [86], the root fracture was classified as a middle third root fracture.

5.5.15.3. Treatment

After the administration of local anaesthesia, the tooth was repositioned and splinted with a semi-rigid splint. The splint was applied for six months. After this period, the radiographic control revealed that PDL cells invaded the entire fracture gap enclosing fragments. The mobility of the involved tooth increased. The distance between the fragments also increased, and a small periapical radiolucency around the apical area appeared. Endodontic treatment was required. After isolation, the access cavity was prepared and the canal was instrumented carefully by using manual stainless steel and it was irrigated with 0.5 % sodium hypochlorite. The root canal was filled with silverpoint to fix the fractured fragments (Figure 20).

One year after the beginning of the treatment, the radiographic examination revealed periapical healing (Figure 21).

Figure 19.
Root fracture of the left maxillary central incisor

Figure 20.
Endodontic treatment of the tooth 2.1

Figure 21.
Check-up after one year

5.15.6. Discussion

A large number of different apical configurations can result if an immature tooth with open apex is traumatised. Continued root development, apical doming, in-growth of bone and aberrant root formation have all been reported. Repair appears to be more related to the creation of an environment conducive to repair than the type of medicament used [229].

Apexification is the treatment of choice after the confirmation of pulpal necrosis in immature permanent teeth [145]. It can be achieved by the placement of certain biocompatible materials in the root canals to the apical region. A variety of materials have been proposed to induce apical barrier formation, which includes calcium hydroxide paste, calcium hydroxide powder and iodoform powder in combination with other medicaments, mineral trioxide aggregate and Biodentine [153, 162, 229, 230].

Many studies that compared the effectiveness of $Ca(OH)_2$ versus MTA concluded that MTA equals $Ca(OH)_2$ in the cases with open apex. Furthermore, MTA has proven to be effective in performing the same procedure in a considerably shorter time with more predictable results [160]. By using MTA as a physical barrier apically, root canal filling can be placed immediately without waiting for biological response [231]. MTA was effective in severe crown fracture, too [86]. In the cases where the initial treatment of the injured tooth included long-term apexification with $Ca(OH)_2$ showing no apical stop 3 years later, by replacing it with MTA at the 12-month follow-up, the tooth was asymptomatic and showed repair of the radiolucent apical lesion [232]. The treatment with $Ca(OH)_2$ is time-consuming, ranging from 3 to 21 months, dependent on the diameter of the open apex, the rate of tooth displacement and the tooth repositioning method after luxation injury [154]. Lemon advocated the use of a matrix when the perforation diameter is larger than 1 mm to avoid the extrusion of the sealing material [233]. In Case no. 1 presented here above, at the moment of injury, the root canal was in an early stage of development (between 2 and 3). Moorrees et al. reported that in early root developmental stages, $Ca(OH)_2$ helps not only the regeneration of the surrounding bone tissue and the periodontium but also the subsequent closing of the wide apical opening [228].

The required treatment time was 12 months. A complete formation of the root apices was achieved with complete periapical healing. $Ca(OH)_2$ was applied as a temporary filling material in the apical regions as well, and it produced better results than being placed beyond the coronal half [234].

In Case no. 2, an apical plug of MTA was used for short-time apexification in a combined treatment method. $Ca(OH)_2$ was applied as root canal medicament dressing for two months. According to Moorrees et al., when the root formation is between the stages 3 and 4, the use of $Ca(OH)_2$ for one or two months before the application of MTA helps the apex closure and the drying process by keeping the root canal free from microorganisms and most of the endodontic pathogens [228].

This results in avoiding infections induced by an acidic environment which could affect adversely the setting of MTA [157]. During root canal debridement of the tooth 1.1, the canal was irrigated with NaOCl. NaOCl was diluted to 0.5 % to limit the potential for apical tissue damage [157]. $Ca(OH)_2$ dressing was placed without triple antibiotic paste to avoid tooth discolouration due to minocycline [146]. In the case of 2.1, protective crown was performed. We can see in both cases that radiographic success was achieved.

Lu & Qin compared an antibiotic paste and Metapex paste (MetaBiomed Co., Ltd, Korea) for their use in apexification [235]. Over a follow-up period of 30 months, they concluded that both materials showed the same level of radiographic success [235]. In Case no. 2, after $Ca(OH)_2$ medication, a plug of 4 mm of MTA was introduced to the apical parts of the canal with a fitted gutta-percha cone under radiographic evaluation. MTA has been considered an excellent root-end filling material as it provides a good sealing ability and is biocompatible to periapical tissues [143]. The apex closure was finalised within one year, and the two-year follow-up showed good periapical repair.

The most recent material Biodentine is a bioceramic material advertised as a "bioactive dentine substitute". It has exclusive properties such as adequate adhesive ability, insolubility, good marginal seal, long term dimensional stability, biocompatibility and bioactivity [170].

It claims to possess improved physical, mechanical, and handling properties as compared to MTA [236]. Han and Okiji reported that Biodentine may have a remarkable biomineralisation capacity as compared to MTA [172]. A comparison was done between MTA and Biodentine in the study reported by Darak et al. [230]. Neither of the two materials (Biodentine or MTA) offered an edge over the other in terms of enhancing the fracture resistance of immature teeth. Thus, Biodentine can be recommended as an alternative obturating material over MTA due to its short setting time and favourable handling characteristics.

In Case no. 3, the left maxillary central incisor was filled with Biodentine till the middle third of the canal. The root canal continued its development and an apical closure was achieved in spite of the difficulties.

Regarding Case no. 4, $Ca(OH)_2$ was applied as root canal medicament dressing for two months. After that, Iodoform-Chlumsky paste was inserted in the root canal as a temporary filling. Glass ionomer cement was used to restore the access cavity after the placement of iodoform paste in the root canal. This was done to provide an adequate coronal seal and prevent any microleakage. Ray and Trope have also stated that the quality of the coronal restoration is more significant than the quality of root canal treatment in eliminating apical periodontitis. Most of the treatment for immature root apices fails not due to failure to create a sterile field at the root apex but due to microleakage from faulty coronal restorations [237]. The tooth was monitored radiographically. After 1.5 years, the complete formation of the root apices was achieved with complete periapical healing. In the literature, the studies that reported the treatment of root canal with iodoform paste were very rare. In most of them, Metapex (MetaBiomed Co., Ltd, Korea) was used as a root canal filling material. It contains iodoform (40.4 %), calcium hydroxide (30.3 %) and silicone oil (22.4 %). The closure of apical foramen was achieved in these studies [229, 238]. In the present survey, we used calcium hydroxide for two months because of its ability to alleviate an inflammatory process and to induce mineralisation of an organic matrix in case of wide apical foramina [239], and to avoid the effect of weakening the tooth and making it more susceptible to fractures [154, 155]. Nonetheless, a study by Ghosh et al. [240] and by Vojinović [239] showed clinical and radiographic evidence of success in achieving apexification with iodoform paste.

In Case no. 5, the patient suffered a horizontal root fracture of the left maxillary central incisor. Complete clinical and radiographic examinations combined with a correct diagnosis of dental pulp status were fundamental for a successful root fracture prognosis [82]. Both clinical and radiographic examinations were performed accurately. The clinical examination revealed that the tooth responded to the pulp sensitivity test and it was a little bit extruded. Commonly, teeth with root fractures present slight extrusion [82].

The horizontal root fracture was in the middle third, and in this case, endodontic treatment is often not required but spontaneous healing frequently occurs [84]. According to Andreasen et al., if the fractured tooth presents mobility and/or displacement, an immediate tooth repositioning should be performed and a rigid or semi-rigid splint can be used for 4–6 months [86].

The tooth was repositioned and splinted with a semi-rigid splint. When tooth mobility is detected, a rigid or semi-rigid splint can be used for 4–6 months [86]. In the present study, the semi-rigid splint was applied for six months. During this time, the tooth was observed radiographically. According to Andreasen et al., 4 categories of root-fracture healing has been described: healing by hard tissue union, healing by the interposition of connective tissue, healing by interposition of bone and connective tissue, and non-healing (interposition of granulation tissue) [86]. The radiographic examination revealed healing with connective tissue as PDL cells invaded the entire fracture gap enclosing fragments.

Also, a small periapical area around the apex of the root has appeared. The mobility of the involved tooth increased and the distance between the fragments also increased. Endodontic treatment was required. After isolation, a cautious canal preparation was done. The two fragments were splinted by using silver fibre posts to act as an intraarticular splint.

The fibre posts offer several advantages such as suitable elastic modulus, aesthetics, lower chair-side time and minimal tissue removal [87]. One year after the beginning of the treatment, the radiographic control observed periapical healing.

6. Conclusions

The prevalence of traumatic dental injuries among children from 7 to 18 years of age who experienced a dental trauma in anterior permanent teeth and were treated at the Department of Paediatric Dentistry and Orthodontics in Budapest between January 2007 and December 2016 was 1 %. Higher prevalence of dental trauma was found among male patients than female patients (61.45 % male and 38.54 % female).

Regarding the type of affected teeth, maxillary central incisors were the most affected by dental trauma with the rate of 63.62% followed by maxillary lateral incisors (17.13%). Traumatic dental injuries were most frequent between the ages of 8 and 10 years. The peak occurred at about the age of 9, as the nine-year-old children comprised about 22.02 % of all the patients. The occurrence of the peak of TDIs at this age can be explained by the fact that younger children have less sense of fear, which makes them more susceptible to dental injuries.

Luxation injuries were the most common type of TDIs as they comprised 50 % of all the injuries, followed by uncomplicated crown fractures (37.44 %) and complicated crown fractures (9.67 %).

TDIs that occurred during playtime comprised 30 % of all the injuries, while 25 % of dental injuries were caused by sports activities. Regarding the place of occurrence of TDIs, most cases of dental trauma occurred at home (46.47 %) and in school (28.63 %). Playground cases comprised about 15 %.

Concerning the distribution of traumatic dental injuries according to the seasons, the highest rate occurred in the spring with a rate of 34.14 %.

From among the possible treatments of TDIs, splinting was the most common therapy as it comprised about 58.48 %, followed by treatment with $Ca(OH)_2$ and protective crown (38.15 %). The most common application of the splinting therapy can be attributed to the fact that luxation injuries comprised the highest ratio of TDIs which were treated by repositioning and splinting.

Regarding the distribution of TDIs according to arch, from a total of 899 teeth that sustained dental trauma, 807 teeth (89,76 %) were in the maxillary arch. This can be explained by the fact that in the sagittal plane, the maxillary arch is located more anteriorly than the mandibular arch as a result of which the impact of injury would be more on the maxillary arch.

In the teeth with uncomplicated crown fractures and without luxation injuries very low incidence of pulp necrosis appeared (2.41 %) in comparison with uncomplicated crown fractures with luxation injuries (31.51 %).

Regarding the materials used in the treatment of the roots of the teeth involved in dental injuries, calcium hydroxide is recommended as a temporary dressing for two months before applying other materials such as MTA, Biodentine and iodoform paste. The importance of the use of $Ca(OH)_2$ is due to its role in stimulating the apical closure process and keeping the root canal dry and free from infection and microorganisms. The purpose of using $Ca(OH)_2$ for short time was to avoid the possibility of cervical root fracture of the weakened teeth because of the desiccating properties of this material due to high pH.

A separate research was carried out on 95 Hungarian, 104 Japanese and 110 German young patients’ panoramic radiographs, and no significant differences were found in the R/C ratios of the tooth-types in these three populations, which means that it can't be possible to determine the nationality of a person depending on the root-crown ratio of their tooth-types. The German and the Japanese populations showed significant differences in all lower tooth-types, the Japanese and the Hungarian populations in almost all lower tooth-types, except for 41, which indicates that there has not been a mixture between these populations throughout history. The Hungarian and the German populations did not show significant differences except for tooth-types 11, 16, 17 and 47, which may be an indication of the mixture of these nations.

The R/C ratios are of great importance in paediatric dentistry as we can determine if the R/C ratios of teeth change after traumatic injuries.

6.1. New achievements of the present work

- The decrease in the prevalence of TDIs in the last ten years. The rate of TDIs was 1 % between January 2007 and December 2016, while it was 2.5 % in the years 1985–1999.
- A significant increase in luxation injuries in the last ten years, and a significant decrease in crown fractures. The luxation injuries were the most common type of TDIs among patients in the last ten years with the rate of 50 %, while crown fractures were the most common in the period of 1985–1999.
- Regarding avulsion injuries, the decrease in the proportion of avulsed teeth was evident (1.85 % current data, 4.39 % former data). These changes between the previous and current data are attributed to the elasticity of alveolar bone in the younger age groups studied.
- Regarding the type of treatment, splinting was the most common one from 2007 to 2016, while the treatment with $Ca(OH)_2$ and temporary crown formed the highest ratio between 1985 and 1999.

7. Summary

The aim of the present study was to determine the prevalence of TDIs over a period of 10 years between 2007 and 2016.

TDIs were recorded according to the World Health Organization (WHO) classification system, which was slightly modified by Andreasen.

The prevalence of TDIs among children involved in this study was 1 %, which means a decrease in the prevalence of TDIs in comparison with the ratio of 2.5 % in the years 1985–1999. 61.45 % of children who suffered TDIs were male, while 38.54 % of them were female. The maxillary central incisor was the type of teeth the most affected by TDIs (63.62 %). The peak of TDIs occurred at the age of nine.

Luxation injuries comprised 50 % of all types of TDIs. These results came in contrast to the results in the years 1985–1999 as the crown fractures were the most common type of dental trauma (78.16 %). Most TDIs occurred during playtime (30 %) and at home (46.47 %). Spring is the month in which most cases of dental trauma occurred. Splinting was the most common therapy of TDIs in the past few years (58.48 %), while the treatment with $Ca(OH)_2$ and temporary crown formed the highest ratio in the years 1985–1999.

Regarding the distribution of TDIs according to arch, 89.76 % of the teeth were in the maxillary arch. The incidence of pulp necrosis was low in the teeth with uncomplicated crown fractures and without luxation injuries (2.41 %).

In this study, we showed the importance of using $Ca(OH)_2$ in the treatment of immature permanent teeth, especially in the case of pulp necrosis, for two months as a temporary dressing before applying other materials such as MTA, Biodentine and iodoform paste. The importance of using calcium hydroxide is due to its advantages in stimulating the apical closure process and keeping the root canal dry and free from infection and microorganisms. The purpose of using $Ca(OH)_2$ for a short time is to avoid the possibility of cervical root fracture of the weakened teeth because of the desiccating properties of $Ca(OH)_2$ due to its high pH value.

The comparison between the R/C ratios of permanent teeth can be applied to follow the R/C ratio after various traumatic dental injuries. It can be proved whether there is a difference one year later in the R/C ratio after luxations and fractures.

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9. Bibliography of the candidate's publications related to the thesis

1. Rencz B, **Alhaddad B**, Remport B, Rózsa NK, Mitsuo I, Tarján I

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3. **Alhaddad B**, Tarján I, Rózsa NK

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   DENTISTRY 5: 12 Paper 1000347, 5 p. (2015)

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