A SYSTEMATIC REVIEW OF SENSIBILITY TESTING AND ASSESSMENT OF TRAUMA CASES IN PERMENANT ANTERIOR TEETH PRESENTED AT HBMCDM FROM JANUARY 2008 TO DECEMBER 2016

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ABSTRACT

A systematic review of sensibility testing and assessment of trauma cases in permanent anterior teeth presented at HBMCDM from January 2008 to December 2016

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The work presented here consists of two distinct parts.

Part I: A systematic review of sensibility testing

Introduction: The assessment of pulp vitality during pain response is traditionally performed using an electric, hot, or cold pulp tester. However, these methods have the capability to assess only the vitality of the sensory supply or the blood supply of the dental pulp and they are viewed as better measurement approaches of true health than sensibility. Since such conventional tests may be unreliable for post-traumatic dental conditions, it is imperative to clinically evaluate such teeth using alternative approaches of pulp vitality such as laser doppler flowmetry and pulse oximetry.

Aims and Objectives: To systematically review the literature concerned with sensibility and vitality pulp testing involved in the diagnostic approaches for traumatic injuries of permanent anterior teeth.

Materials and Methods: We conducted our search according to PRISMA reporting system. We selected English articles only without date limitation using the following scientific databases: Medline (PubMeD), EMBASE, The Cochrane Central Register of Controlled Trials and Cochrane Reviews. The data from all included studies were extracted independently using thorough reading and observation. The search consisted of using specific search terms as well as a manual hand searching using either the reference lists in the included articles or using “google scholar” search. The following studies were excluded during our search: 1) Animal studies 2) studies concerned with primary teeth 3) studies concerned with the assessment of diagnostic approaches of permanent anterior teeth after trauma in their predecessors 4) studies investigating assessment of pulp condition following trauma concurrent with any oral pathological condition which may impact the pulp.

Results: The range of the selected articles was between 1936-2016. Initially, we found a total of 739 articles through searching in the aforementioned databases. After duplicate removal and screening for eligible studies, we narrowed the articles to 30 in this review.

Conclusions: The diseased pulp after trauma might undergo unfavorable complications such as inflammatory root resorption. Therefore, a careful follow-up of such teeth is required at periodic intervals up to six months after trauma as the nerves may regain their function later. Despite the lack of response of traumatized teeth to sensibility neurological testing, in what is known as “pulp shock”, during the first few weeks after trauma, several studies have proved pulp vitality by showing the signs of pulpal blood flow using laser doppler flowmetry and pulse oximetry. As a result, the accurate treatment plans can be decided immediately as per reported by the pulp vitality assessment tests without waiting for the positive response yielded by the conventional tests. The follow-up process of the traumatized anterior teeth should be associated with accurate interpretations depending on several evidences from various results of clinical examination and the assistive diagnostic techniques.

Part II: Assessment of trauma cases in permanent anterior teeth presented at HBMCDM from January 2008 to December 2016

Introduction: The assessment of Traumatic Dental Injuries (TDIs) in young and adult patients is important as it gives an opportunity to track the possible trauma reasons in each group as well as identify its consequences and complications. However, the lack of reporting of TDIs as a result of behavioral cultural diversities among different communities may relatively hinder obtaining accurate and significant results in the retrospective evaluations.

Aims and Objectives: A retrospective study was conducted in Hamadan Bin Mohammed College of Dental Medicine between January 2008 and December 2016 in United Arab Emirates using the documentation of 64 patients with 114 traumatized teeth.

Materials and Methods: Hamadan Bin Mohammed College of Dental Medicine patient data base was used. The data were collected from patient notes via the application of certain treatment codes. Radiographs were also assessed and all the extracted information was recorded in excel spread sheets. Statistical tests were applied to check for significant differences ($P<0.05$).

Results: It was found that the most frequently traumatized teeth were detected in tooth 21 (f= 41, 36%), tooth 11 (f= 35, 30.7%) and tooth 12 (f= 12, 10.5%). TDIs were significantly associated with patient gender ($p< 0.001$). Of the males, only 4 patients (7.8%) experienced uncomplicated TDIs, while the remaining male patients (n=47, 92.2%) had complicated TDIs. The most frequent TDI cases were recorded in patients aged more than 18 years (64 cases, 56.1%), followed by patients with age range 12-17 years (26 cases, 22.8%) while the prevalence of TDIs within the age range 7-11 years was 24 recorded cases (21.1%). There was a significant relationship between type of

TDIs, whether being complicated or uncomplicated, and the associated periapical pathologies ($p < 0.001$). Of the total population (n=114), periapical pathologies occurred in 53 affected teeth, while there were 61 teeth presented without pathologies. The incidence of periapical pathology was less prominent in the uncomplicated dental injuries (n=3) while more reported with complicated injuries (n=50). There was a significant relationship between the type of treatment provided and the associated periapical pathological conditions ($p < 0.001$).

Conclusions

1. Traumatic dental injuries occurred almost in equal proportion amongst males and females with a slight tendency toward females.
2. Complicated injuries were more prominent in males than female patients.
3. The most frequent traumatic dental injuries were reported in patients aged more than 18 years old.

DEDICATION

This thesis is dedicated to my beloved parents for their endless love, support and encouragement. They are the reason behind my success as they give me the strength to pass through the difficult times and encourage me to keep going. This degree and all my hard work are a sign of my love to them and I hope to make them proud.

DECLARATION

I, Sara Shablan, declare that this dissertation is my own original work and that it has not been presented and will not be presented to any other university for a similar or any other degree award.

Signature:

Date:

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1. INTRODUCTION

1.1 A systematic review of sensibility testing

Dental pulp is a richly-supplied neurovascular connective tissue in the tooth structure. Free nervous terminations are located in the dental pulp and they are responsible for the pulpal response to different stimuli. Indeed, the expressed response during such stimuli is the pain, which represents an unpleasant individual sensation characterized by a memorized perception. Dentists have the responsibility of pain control involving its dual aspects, the subjective (psychological) and the objective (somatic) sides (Matthews, 1976, Bender, 2000).

The assessment of pulp vitality during pain response is traditionally performed using an electric, hot, or cold pulp tester. However, these methods have the capability to assess only the vitality of the sensory supply or the blood supply of the dental pulp and they are viewed as better measurement approaches of true health than sensibility (Jafarzadeh and Abbott, 2010). Although these tests showed promising results for the evaluation of pulp vitality, there are some considerations which relatively limit their use, including the high cost of using such technologies (Abd-Elmeguid and Yu, 2009). Therefore, the use of pulp sensibility tests (PSTs) has emerged and, nowadays, PSTs have become the major diagnostic approaches for pulpal diseases. In addition, they have some limitations and shortcomings which can hinder their clinical use. PSTs include thermal, electrical and cavity tests which assess the health of the pulp from the sensory response. Usually, the dentists perform PSTs and use the obtained results to assess and estimate the vitality and the state of pulp health (Rowe and Ford, 1990). These results constitute the qualitative sensory manifestations which, if the pulp responds to the stimulus, the dentists can suggest that the pulp is either healthy or inflamed according to the response nature, the history and other considerations.

Generally, there are three varying degrees of pulpal response to PSTs. First, when a normal response to PSTs is obtained, then the pronounced or exaggerated response should be excluded (Chen and Abbott, 2009). Second, an exaggerated response, expressed as pain, indicates the presence of pulpitis (Abbott and Yu, 2007). Finally, the absence of response to PSTs is typically associated with the possibility of pulp necrosis, pulpless tooth, or the tooth has a history of root canal therapy. Furthermore, there are some factors that influence or interfere with the response to PSTs, such as the presence of extensive restorations, incomplete apex formation, or a recent trauma to the tooth (Jafarzadeh and Abbott, 2010, Miller et al. 2004, Gopikrishna et al. 2007).In fact, all of these factors should be considered to avoid misinterpretations.

In thermal PSTs, some agents can be applied to the teeth to increase or decrease the temperature in order to elicit pulp sensory responses by thermal conduction (Mumford, 1976). Interestingly, the sensory response to thermal stimulation takes place before the actual change in temperature reaches the pulpodentinal junction area, which contains the sensory nerve endings (Trowbridge et al. 1980, Ingle et al.2008). Nonetheless, the thermal PSTs cause activation of the fluid movement within dental tubules with subsequent excitation of the A-δ fibers (Cohen and Hargreaves, 2006). Moreover, the C fibers are not stimulated by thermal tests except when there has been an injury to the pulp (Fuss et al. 1986). Therefore, since the thermal PSTs are dependent on the hydrodynamic theory, the pain sensation during such tests requires the presence of some pulp tissues, including odontoblasts (Cohen and Hargreaves, 2006). Multiple techniques can be used for accurate thermal PSTs, including cold tests (using ice, refrigerant spray, or carbon dioxide snow)and heat tests (such as using ethyl chloride and heated gutta percha) (Chen and Abbott, 2009).

For the electrical PSTs, an electrical stimulus is passed causing an ionic change in the neural membrane, producing an action potential and yielding a rapid hopping action at the myelinated nerves (Bender, 2000).The result will be a tingling sensation by the patient once the voltage of the electric stimulus reaches the pain threshold (Kleier et al. 1982). Such threshold may be affected by several factors, including patient's age, pain perception, the surface conduction of the tooth, and its resistance (Mumford, 1967). The use of an electric pulp tester to assess the pulp sensibility may entail some safety concerns in some patients with cardiac conditions.

Since both the electrical and thermal tests may be unreliable for post-traumatic dental conditions (Ohman, 1965, Bhaskar and Rappaport, 1973), it is imperative to clinically evaluate such teeth using alternative approaches. In case of external inflammatory root resorption of the tooth, this may lead to tooth loss in a short time (Tronstad, 1988). In addition, the assessment of teeth with incomplete root formation entails monitoring of circulation survival and revascularization to maintain the pulp space without a risk of infection and allow the tooth to develop correctly. (Ohman, 1965, Kling et al. 1986). Therefore, the measurement of pulpal blood flow has been developed as a more reliable approach for evaluation of tooth vitality if compared to other conventional sensibility tests. It has been reported that the use of flowmetric measurements, using laser doppler flowmetry (LDF), was used to reestablish the vitality of traumatized teeth (Gazelius et al. 1988, Olgart et al. 1988) or to demonstrate the significant diminished blood flow in the maxillary teeth after Le Fort I osteotomy (Geylikman et al. 1995). Indeed, LDF is useful for diagnosis of transient ischemia of the teeth and for detection of teeth at risk of adverse complications including the avascular necrosis and tissue loss (Strobl et al. 2004). In addition, pulse oximetry has been considered a promising diagnostic aid contributing in several significant advances in dentistry to evaluate pulp vitality

(Schnettler and Wallace, 1991). Pulse oximetry, measuring oxygen saturation, is considered a noninvasive, nonpainful method with high accuracy rate used for the analysis of the pathological status of the pulp as well as verification of the vitality of teeth following traumatic dental injuries (TDIs).

TDIs result from an impact; whether a direct or an indirect one. Damage degree is dependent on the shape and resilience of the impacted object, the energy of impact, its direction, and the reaction of the surrounding tooth structure (Zaleckiene et al. 2014). Additionally, there has been a tendency of dental traumatic sequelae to be more severe in the primary dentition than the permanent ones (Zaleckiene et al. 2014). The possible explanation of this fact is related to the features of the underlying bone structure in which the bone composition in primary dentition is less mineralized, a matter which leads to displacement of the tooth. In addition, the increased independent movement during young age augments the risk and liability to such injuries.

On the other hand, the TDIs of the permanent teeth commonly occur due to falls, sports activities, bicycling and traffic accidents, or physical violence (Hecova et al. 2010, Taiwo and Jalo, 2011). Indeed, the majority of dental injuries occur in the anterior teeth. In addition, there is a possibility to involve the gingiva, hard dental tissues, periodontal tissues, dental pulp, and alveolar bones (Glendor et al. 2007). Moreover, a long-term follow-up may be necessary because of the potential development of complications several weeks or even months post injury (Andreasen and Pedersen, 1985, Robertson et al 2000).

Overall, the most common complication of TDIs is pulp necrosis, since it has been reported that the prevalence of pulp necrosis in the luxated teeth varies greatly from 17-100% (Andreasen and Pedersen, 1985, Nikoui et al. 2003, Humphrey et al. 2003). In general, the outcome of pulp survival is influenced by the type of dental injury, stage of root development, or repeated teeth damage (Andreasen and Pedersen, 1985, Nikoui et al. 2003). It is noteworthy that the late diagnosis of post-traumatic pulp necrosis can lead to additional complications, such as the fistulas, apical periodontitis, or inflammatory root resorption (Hecova et al. 2010).

The healing process of TDIs varies according to multiple factors including the extent of damage, the level of root development, and the possible impact of bacterial contamination from the surrounding tissues. Once an acute dental trauma takes place, the healing process begins immediately as a trial to regenerate the damaged nerves and vessels as well as to replace the damaged pulpal tissue (Shibue et al. 1998, Andreasen, 1988). At this stage, it is imperative to urgently identify the pulpal condition to regain the function and the aesthetic of the injured teeth. However, reaching an appropriate diagnosis is relatively hindered because of the temporary loss of pulpal sensibility after trauma (Rock and Grundy, 1981). Furthermore, the aforementioned limitations of some traditional pulp testing may make the challenge harder (Gopikrishna et al. 2009). For assessment of pulp vitality, the PSTs remains the most extensively used diagnostic procedure in spite of several controversial debates regarding the efficiency of such testing.

1.2 Assessment of trauma cases in permanent anterior teeth presented at HBMCDM from January 2008 to December 2016

Traumatic dental injury (TDI) is an impact injury to the teeth and/or other soft and hard tissue within the oral cavity. It is usually an emergency situation which includes sudden unexpected exposure to a traumatic incident. A traumatic injury itself is not considered a disease but rather a subsequent sequelae of unavoidable risk factors during life (Lam et al. 2008). Despite the fact that dental trauma is more common among children and teenagers, it has been demonstrated that any age group is liable to experience such conditions even if the personal oral health precautions are considered (Lam et al. 2008). The cost to the injured individual as well as the community is frequently substantial globally (Bastone et al. 2000). In addition, if compared to other accidental emergency injuries, TDIs are more time consuming and bear high costs (Andersson, 2013). Due to the reported global decline in the prevalence and severity of dental caries among children in the past few years, other aspects of oral health has drawn the attention referring to the TDIs as the most significant among young people (Malikaew et al. 2006). During the past few decades, the prevalence of TDIs (all new or old cases) increased significantly (Bastone et al. 2000) and a further increase is expected in the next years because of the increased numbers of exposed people (Glendor, 2008). This increased risk is possibly ascribed to increased number of people having cars, bicycles, sport activities, etc., but they lack the suitable safety knowledge regarding their use. In addition, the increased trend in violence rate among different countries can be another threatening factor. For instance, it has been reported that the maxillofacial fractures occurred due to assaults from kicking have increased from 30% to 40% in 1981 and 1997 respectively (Kontio et al. 2005). Additionally, an increased prevalence of TDIs among girls who were involved in practicing traditionally male dominant sports has been demonstrated (Burden, 1995). Considering data from most countries, about one third of all preschool children have experienced a TDI which includes the primary dentition (Glendor, 2008). For the permanent dentition, about one fourth of school children (peak at 9-15 years) (Gutmann and Gutmann, 1995) and approximately one third of the adults have a TDI with significant variance between countries for these values.

TDI incidence (the number of new cases in a given period of time) seems to be uniform within each country. For example, a Norwegian study showed that there was a significant increase in TDI incidence in urban than in rural regions (Skaare and Jacobsen, 2003). Generally, the risk of having a TDI is increased at least twice in males than females. However, some studies have revealed a sort of reduction in this variation due to interest differences in some sports in some countries (Rocha and Cardoso, 2001, Traebert et al. 2003). Likewise, study by (Traebert et al. 2006) have found that boys and girls have nearly the same chance of exposure to the risk factors of TDI. Therefore, it seems that both the personal and environmental factors can play a significant role as potent determinant of TDI risk than the gender. Several studies have shown that the majority of TDIs take place in childhood and adolescence. Before the age of 19, it has been reported that about 71-92% of all TDIs occur at this age (Glendor et al. 1996, Davis and Knott, 1984), while this value decreases after the age of 24-30 years (Shulman and Peterson, 2004, Holland et al. 1994). Additionally, the increased risk of accidental falls in elderly people may augment the possibility of having TDIs as reported by (Thomson et al. 2003). A study by (Wong and Kolokotsa 2004) investigated eighty-one children and adolescents with traumatic injuries to the upper incisors for the possible complications and the costs implied by them. Again, male patients have experienced TDIs more than females (ratio: 3:2) with a mean treatment duration of 24.6 months. Teeth with complicated traumas (56%) were slightly more than those with uncomplicated injuries (44%), and the difference was insignificant.

Purpose statement:

This work consists of two distinct parts

(i) A systematic review to highlight sensibility testing related to traumatized anterior teeth.

(ii) A retrospective study of all the trauma cases which presented in HBMCDM during the period January 2008 to December 2016.

(iii) The null hypothesis that there were no association between the type of trauma and age of the patient and gender were tested.

8. MATERIALS AND METHODS

2.1. A systematic review of sensibility testing

2.1.1. Eligibility criteria

Only English articles could be selected and those which meet our search terms before and after the "AND" string was eligible. There was no date limitation to cover as many studies as possible and as there have been some conventional methods which were extensively studied in older studies. During our search, we could not have access to some studies to read the full articles. These studies were excluded after screening. The data from all included studies were extracted independently using thorough reading and observation. We limited the results to the studies employing human participants. The following studies were excluded during our search: 1) Animal studies 2) studies concerned with primary teeth 3) studies concerned with the assessment of diagnostic approaches of permanent anterior teeth after trauma in their predecessors 4) studies investigating assessment of pulp condition following trauma concurrent with any oral pathological condition which may impact the pulp.

2.1.2. Study Selection

The initial study compilation was performed through the election of the compatible studies by screening and analysis of their titles. The abstracts were then thoroughly analyzed where the eligible studies were only selected. Then, the second step consisted of an evaluation of abstract compatibility with the required inclusion criteria and further complete reading to match the same. The details of search process were filled in a distinct flowchart which is recommended by PRISMA.

2.1.3. Search Strategies

In order to identify relevant articles, we conducted our search in the following scientific databases: Medline (PubMed), EMBASE, The Cochrane Central Register of Controlled

Trials and Cochrane Reviews. For part 1, we used the following keywords: “dental sensibility pulp testing”, “pulp sensibility testing”, “sensibility testing”, and “vitality tests”. For part 2, the used search terms were: “traumatized anterior teeth”, “permanent anterior teeth trauma”, “follow-up of traumatized anterior teeth”, and “assessment of anterior permanent teeth”. Finally, these keywords were used to search for the relevant literature of part 3: “sensibility tests of traumatized anterior teeth”, “sensibility tests of traumatized permanent teeth”, “vitality tests of traumatized anterior teeth”, “vitality tests of traumatized permanent teeth”. Each keyword was subsequently searched using the “AND” function with each of the following other keywords: diagnosis, thermal, electric, laser doppler flowmetry, and pulse oximetry. After that, manual hand searching was performed using either the reference lists in the included articles or using “google scholar” search.

2.2. Assessment of trauma cases in permanent anterior teeth presented at HBMCDM from January 2008 to December 2016

A retrospective study was conducted in Hamadan Bin Mohammed College of Dental Medicine between January 2008 and December 2016 (for the period between 2008 to 2012 the Institute was called Boston University) in United Arab Emirates using the documentation of 64 patients with 114 traumatized teeth. The patients were selected according to certain treatment codes from the MBRU patient data base (R4W). These codes are related to procedures related to treatments carried out on anterior teeth such as anterior restorations, pulpal therapy (direct and indirect pulp capping), root canal treatment and retreatment. Radiograph software VixWin was used to evaluate previously taken radiographs of each patient and to classify extent of periapical pathosis. A total of 1768 patient received treatment in anterior teeth between (2008 -

2016). All Notes and radiographs of 1768 patients were evaluated; only 64 patients had a history of dental trauma with 114 traumatized teeth. Data collected from the notes were recorded in an excel sheet (Appendix II). The data collected included age, gender, type of trauma, teeth traumatized, treatment carried out, pathology, caries, external and internal resorption, vitality testing and medical history.

2.2.1. Selection Criteria:

For a patient to be included, he/she should have permanent traumatized anterior teeth evaluated with parallel radiography periapical view and is at least 7 years old otherwise excluded. Also, those with primary teeth, anterior teeth without trauma, or posterior traumatized teeth were not included.

2.2.2. Research tools:

R4W software, VixWin software, SPSS, Microsoft office excel.

2.2.3. Ethical approval:

Ethical approval for this study was obtained from the Ethics Committee in Hamdan Bin Mohammed college of Dental Medicine (HBMCDM-MBRU) on 24th March 2015 (Appendix I).

2.2.4. Statistical analysis:

Statistical calculations were carried out using the Statistical Package for Social Science (SPSS for Windows, version 18.0, SPSS Inc., Chicago, IL, USA). The chi-square test (5% level of significance) was used to determine whether traumatic dental injuries was associated with age gender, type of trauma and pathology. Backward stepwise multivariate regression analysis was performed with variables for which $p<0.025$.

3. RESULTS

3.1. A systematic review of sensibility testing

The range of the selected articles was between 1936-2016. Initially, we found a total of 739 articles through searching in the aforementioned databases. Several duplicate articles were removed and 707 articles remained. We have found 9 relevant studies through search from the references of the included articles. Therefore, the total screened articles were 716 articles. Of these, we have selected 36 studies according to inclusion criteria and 680 articles were excluded at this stage. Then, 6 articles were excluded from being included in the final qualitative analysis due to the following reasons: studies investigating PSTs for primary tooth TDI, lack of access to full articles, and animal studies. Eventually, we got a total of 30 studies to be included in this review. The followed steps in the search process are summarized in Figure 1.

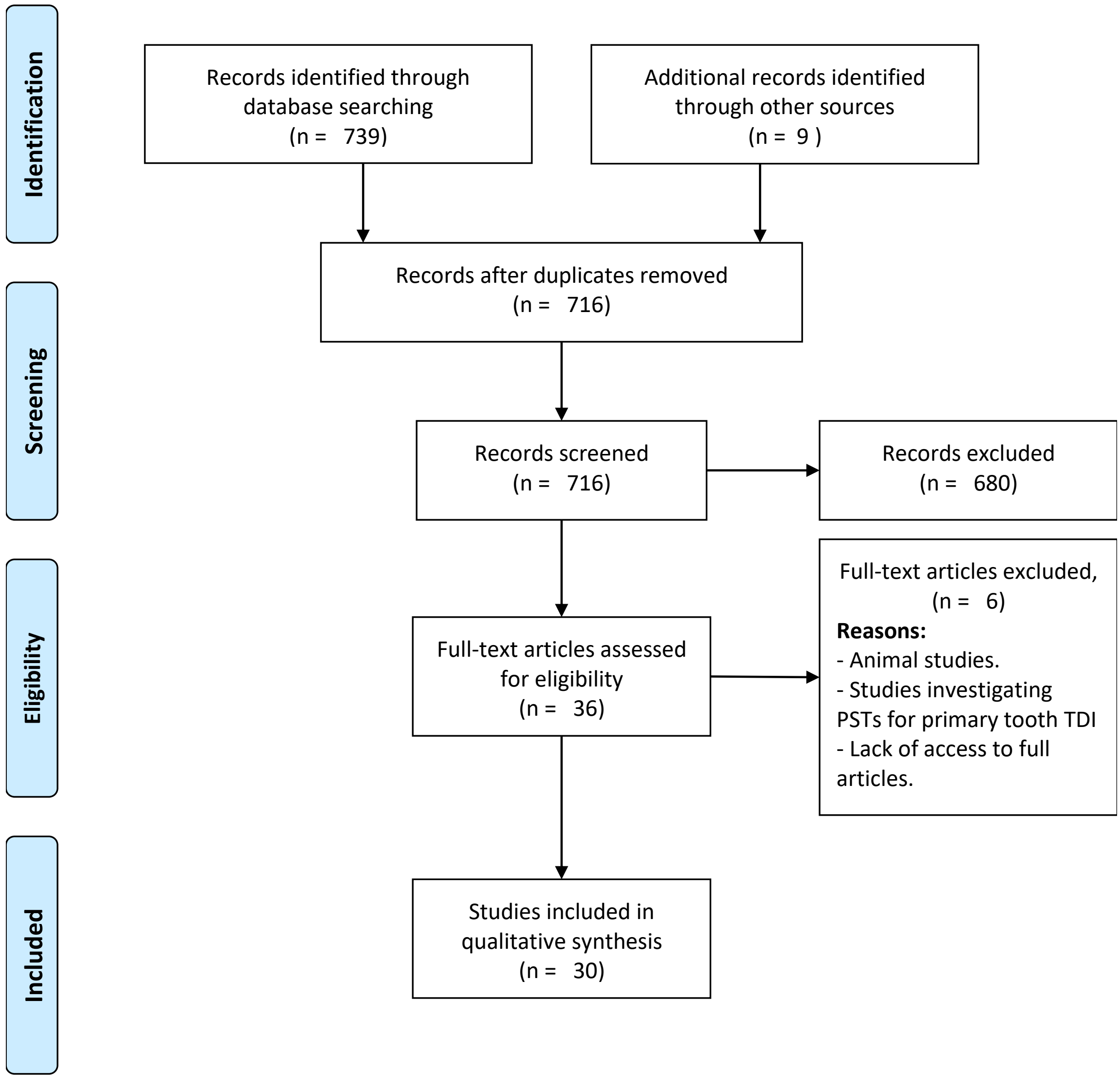

Figure 1: A flow diagram of the search process followed in this review.

3.1.1 Results of Pulp Sensibility Testing:

We have conducted our search in the relevant search engines and this revealed 208 articles. We have screened 196 studies for eligibility and elected 11 articles to be included in the final review. Only 3 studies were excluded at this stage because the authors in 2 of them evaluated sensibility tests in animal models and we could not access the full article in 1 of them. Additionally, we have got 3 additional studies from the references of the included studies to get 11 articles for final inclusion. All included articles of sensibility testing are summarized in Table 1.

Table 1: Summary of the included studies in pulp sensibility testing

Author(s)	Publication Year	Title
Kaletsky and Furedi	1935	Reliability of Various Types of Pulp Testers as a Diagnostic Aid
Austin and Waggener	1941	Vitality Tests with Particular Reference to the Use of Ice
Ehrmann	1977	Pulp testers and pulp testing with particular reference to the use of dry ice
Chambers	1982	The role and methods of pulp testing in oral diagnosis
Fuss et al.	1986	Assessment of Reliability of Electrical and Thermal Pulp Testing Agents
Davies and Rawlison	1988	A comparison between two electric vitality testers and ethyl chloride with special reference to a newly available device
Brandt et al.	1988	Longitudinal study of electrometric sensitivity of young permanent incisors
Schnettler and Wallace	1991	Pulse Oximetry as a Diagnostic Tool of Pulpal Vitality
Petersson et al.	1999	Evaluation of the ability of thermal and electrical tests to register pulp vitality
Goho	1999	Pulse oximetry evaluation of vitality in primary and immature permanent teeth
Jespersen et al.	2014	Evaluation of Dental Pulp Sensibility Tests in a Clinical Setting

3.1.2. Results of traumatic injuries to permanent anterior teeth:

The total identified records after search were 329 for traumatic injuries to permanent anterior teeth. We have screened 316 articles after exclusion of duplicate articles. We got 10 articles to be assessed for eligibility and all of them were included in our qualitative analysis. Table 2 summarizes the articles included in this part.

Table 2: Summary of the included studies in traumatic injuries to permanent anterior teeth

Author(s)	**Publication Year**	**Title**
Zadik et al	1979	The prognosis of traumatized permanent anterior teeth with fracture of the enamel and dentin.
Burton et al.	1985	Traumatized anterior teeth amongst high school students in northern Sydney.
Borssen and Holm	1997	Traumatic dental injuries in a cohort of 16-year-olds in northern Sweden.
Bastone et al.	2000	Epidemiology of dental trauma: a review of the literature
Day and Duggal	2003	A multicentre investigation into the role of structured histories for patients with tooth avulsion at their initial visit to a dental hospital
Bakland and Andreasen	2004	Dental traumatology: essential diagnosis and treatment planning
Brüllmann et al.	2011	The Treatment of Anterior Dental Trauma
Patel et al.	2014	Common dental and orofacial trauma: evaluation and management
Andreasen and Kahler	2015	Diagnosis of acute dental trauma: the importance of standardized documentation: a review

El-Kenany et al.	2016	Prevalence and risk factors of traumatic dental injuries to permanent anterior teeth among 8–12 years old school children in Egypt

3.1.3. Results of sensibility testing related to traumatized permanent anterior teeth

The total identified studies at initial database search were 202 studies, of which we screened 195 studies after removing the duplicates. The total articles assessed for full-article inclusion were 6 studies and we excluded 3 studies due to the following reasons: an animal study, a lack of access to the full article for 1 study, and 1 study was concerned with investigating pulp vitality testing in the primary dentition. In addition, we found 6 relevant studies from the references of the included studies to get a total of 9 included studies for sensibility testing related to traumatized anterior teeth. A detailed summary of the included articles is found in Table 7 in sensibility testing related to traumatized permanent anterior teeth in this review.

3.2. Assessment of trauma cases in permanent anterior teeth presented at HBMCDM from January 2008 to December 2016

3.2.1. Frequency and distribution of trauma cases in HBMCDM from January 2008 to December 2016

The total number of the evaluated traumatized teeth in this study were 114 teeth. Table 3 shows the frequency (f) of trauma in the affected teeth under study. The most frequently traumatized teeth were detected in the tooth number 21 (f= 41, 36%), tooth number 11 (f= 35, 30.7%) and tooth number 12 (f= 12, 10.5%, Table 3.2.1).

Table 3: Frequency of trauma in affected teeth

Tooth number		Frequency	Percent	Cumulative Percent
Valid	11	35	30.7	30.7
	12	12	10.5	41.2
	13	2	1.8	43.0
	21	41	36.0	78.9
	22	8	7.0	86.0
	31	5	4.4	90.4
	32	3	2.6	93.0
	33	2	1.8	94.7
	34	1	0.9	95.6
	35	1	0.9	96.5
	41	4	3.5	100.0
	Total	**114**	**100.0**	

3.2.2. Types of Trauma

Table 4 shows the prevalence of traumatic dental injuries types among age and gender groups of the patients under study. The total number of complicated injuries was 85 cases (74.6%), while 29 cases (25.4%) were considered having uncomplicated traumatic dental injuries. Regarding gender distribution, 51 teeth in male patients were recorded (44.7%) while 63 teeth in female patients (55.3%) were included. Generally, TDIs were significantly associated with the gender of patients ($p < 0.001$). Of the males, only 4 patients (7.8%) experienced uncomplicated TDI, while the remaining male patients (n=47, 92.2%) had complicated TDI. Within the female patient population, the number of cases with uncomplicated TDI was 25 (39.7%) and those with complicated injuries were 38 (60%).

Table 4: Distribution of the types of traumatic dental injuries according to the gender and age of the sample

Items	**Type of Trauma**		**Total [*n* (%)]**	**Chi Square Test**	
	Uncomplicated [*n* (%)]	**Complicated [*n* (%)]**		χ^2	**P-value**
Gender					
Male	4 (7.8)	47 (92.2)	**51 (44.7)**	15.064	< 0.001
Female	25 (39.7)	38 (60)	**63 (55.3)**		
Total	**29 (25.4)**	**85 (74.6)**			
Age					
6-11	10 (41.7)	14 (58.3)	24 (21.1)	12.882	<0.001
12-17	11 (42.3)	15 (57.7)	26 (22.8)		
>= 18	8 (12.5)	56 (87.5)	64 (56.1)		
Total	**29 (25.4)**	**85 (74.6)**			

The most frequent TDI cases were recorded in patients aged more than 18 years (64 cases, 56.1%), then patients with age range 12-17 years with total 26 cases (22.8%)

while the prevalence of TDIs within the range of age 6-11 years was 21.1% with 24 recorded cases (Table 4). Overall, traumatic dental injuries in this patient group were significantly associated with age ($p< 0.001$).

Importantly, the most prevalent type of trauma within age groups was the complicated traumas in patients aged more than 18 years (56 cases, Table 4). In general, the complicated traumas were reported most frequently among all age groups if compared to uncomplicated TDIs. Uncomplicated TDIs in patients aged more than 18 years were the lowest reported traumas with only 8 cases.

Figure 2 presents the age distribution pattern of TDIs in male patients. Particularly for the male patients, TDIs in patients with age range 12-17 years were the most prevalent injuries of the uncomplicated traumas 75%, Figure 2, then patients aged 6-11 years (25%) while there were no reported uncomplicated trauma cases in patients more than 18 years old.

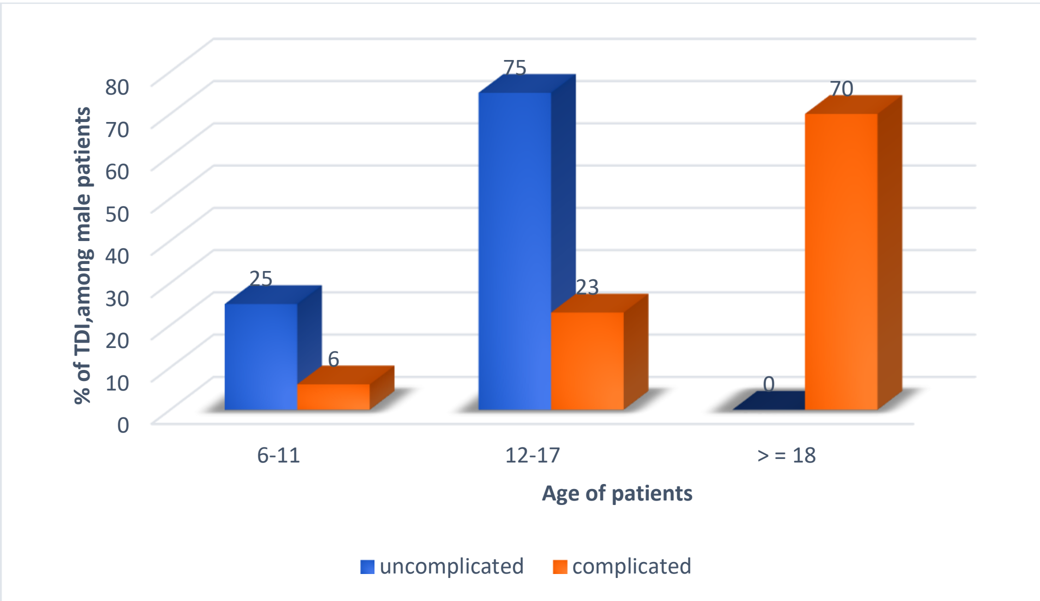

Figure 2: Distribution of TDIs among male patients by age

On the other hand, complicated traumas were significantly higher (P<0.001) in patients aged more than 18 years, then the 12-17 years age group and finally the 6-11 years age group with prevalence 70%, 23%, and 6% respectively Figure 2.

Figure 3 presents the age distribution pattern of TDIs in female patients. In the female patient group, the most prevalent type of injuries was the complicated TDIs in patients aged more than 18 years. Within complicated injuries, the patients' group with more than 18 years constituted 60.5%, while the youngest group (6-11 years) was 29% and the age group 12-17 years was 10.5% Figure 3.

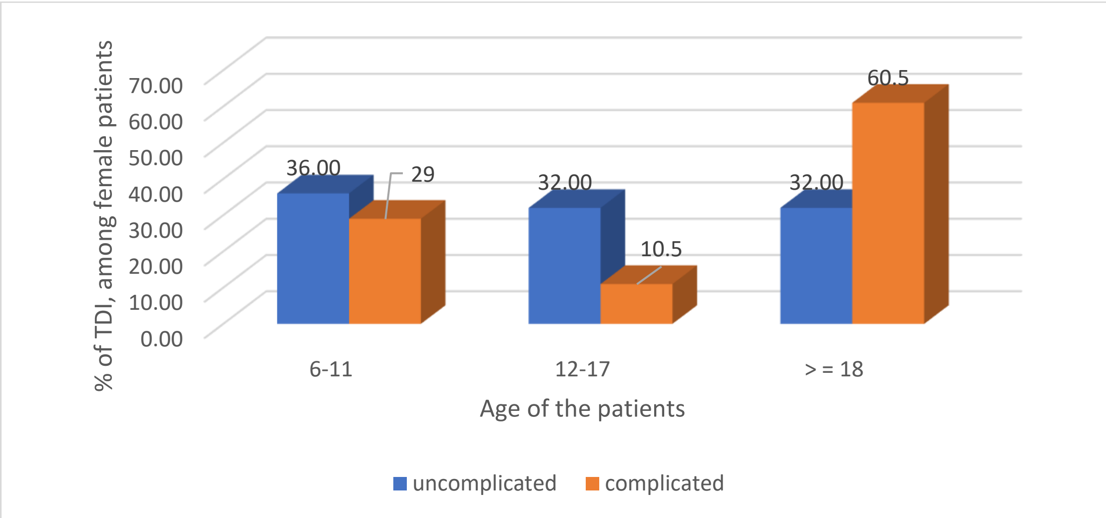

Figure 3: Distribution of TDIs among female patients by age

The uncomplicated TDIs showed a relatively constant distribution pattern among female patients. The youngest group had the most reported injuries, then the group with age 12-17 and more than 18 years with percentages 36%, 32%, and 32% respectively.

3.2.3. Type of trauma and associated pathosis

Table 5 show the relationship between type of traumatic dental injuries and the incidence or possible incidence of associated pathological conditions. Of the total population (n=114), traumatic dental pathologies occurred in 53 affected teeth, while there were 61 teeth presented without pathologies. There was a significant relationship between type of TDIs, whether being complicated or uncomplicated, and the associated pathologies ($p < 0.001$, Table 5). The incidence of pathological conditions was less prominent in the uncomplicated dental injuries, where 3 teeth only presented with pathologies and 26 teeth without pathological incidence. On the other hand, the pathologically-affected teeth were more reported while they are presented with complicated injuries (n=50), whereas 35 teeth with complicated injuries had no pathologies (Table 5).

Table 5: Frequency distribution of the type of traumatic dental injuries according to the incidence of associated pathological conditions

Items	**Periapical Pathology**		**Total**	**Chi Square Test**	
	No [*n* (%)]	**Yes [*n* (%)]**		χ^2	***P*-value**
Uncomplicated	26 (89.7)	3 (10.3)	**29**	20.428	< 0.001
Complicated	35 (41.2)	50 (58.8)	**85**		
Total	**61 (53.5)**	**53 (46.5)**			

3.2.4. Type of treatment and associated pathosis

Table 6 shows the relationship between treated teeth with TDIs and the associated pathological conditions. In general, the total number of teeth received treatment in this study was 82 teeth; of which 51 teeth received primary root canal treatment and 31 teeth retreated by root canal therapy (Table 6). As expected, there was more periapical pathosis in relation to the retreatment than the primary root canal treatment group. This was statistically significant (P<0.001).

Table 6: Frequency distribution of the type of treatment for traumatic dental injuries according to the incidence of associated pathological conditions

Items	**Pathology**			**Chi Square Test**	
	No [*n* (%)]	**Yes [*n* (%)]**	**Total**	χ^2	***P*-value**
Primary RCT	30 (58.8)	21 (41.2)	**51 (62.2)**	16.751	<0.001
Re-RCT	4 (12.9)	27 (87.1)	**31 (37.8)**		

RCT: Root Canal Treatment; Re-RCT: Root canal retreatment

4. DISCUSSION

4.1. A systematic review of sensibility testing

4.1.1. Pulp Sensibility Testing

In conjunction with dental clinical tests, such as percussion, palpation, periodontal probing, and translumination, there have been several tests which imply an assistive role in the diagnostic process. No single element of such process should be relied upon to reveal even an uncomplicated diagnosis of a given case. Therefore, before starting any kind of treatment, at least two independent diagnostic test results should be approached to indicate the disease process. Of these tests, pulp sensibility tests (PSTs) provide valuable diagnostic and therapeutic planning data to the dental clinician to reach the purpose. The application of PSTs is met with varying degrees of success since the late 1970s (Ehrmann, 1977). It is necessary to discern that the ideal diagnostic test is still to be realized (Chambers, 1982).

Uses and Advantages of PSTs

Since the term "sensitivity" means to be a very responsive to a stimulus (mostly in pulpitis), then the PSTs can help to test the sensitivity of the pulp as well. However, they are still considered to be just as sensibility tests. PSTs provides qualitative sensory manifestations to estimate the pulp state and health (Chambers, 1982). Depending on the pulp response to a stimulus, the dentist can assume that the pulp is appropriately supplied, inflamed, or necrosed.

PSTs are used for diagnosis through replication of symptoms by triggering the pain in order to either localize pain source or to exclude the nonodontogenic orofacial pain (Ehrmann, 1977, Johnson and Hinds, 1969). When it comes to pulp testing, the agents used in sensibility tests are very useful when an inflamed pulp is suspected to the source of pain in patients with pain triggered by special thermal triggers(Bender, 2000, Seidberg and Alibrandi, 1987). In addition, when the patient presents with an inconsistent or atypical pain with the referred or nonodontogenic pain, PSTs can provide the required assistance for correct diagnosis by the theory of confirmation or elimination.

PSTs can be used preoperatively where they are carried out on teeth before a restorative or orthodontic procedure, even if the teeth show no symptoms with normal radiographic presentations (Ehrmann, 1977). It is commonly known that there may be a loss of the periapical bone accompanied with a non-vital pulp before it can be detectable in a radiograph. Therefore, an establishment of PST would help diagnose a disorder in the pulp in such cases. In addition, a preoperative PST will avoid going through unneeded complications of expensive, time-consuming interventions.

For pain diagnosis, PST can detect the origin of most oral pains as long as they are of pulpal origin. However, pain localization may be difficult, a matter which requires a set of tests along with a careful history and clinical examination. Actually, PSTs are valuable for diagnosis of pain in the trigeminal area (Mumford and Bjorn, 1962). Additionally, Duquette and Goebel (1973) demonstrated the importance of PSTs in pain diagnosis in patients with pulpitis due to myofascial pain syndrome. Likewise, the normal results obtained from PSTs can help exclude a pain of pulpal pathological origin.

For further investigation of radiolucent areas in a radiograph, PSTs may provide a considerable assistance (Ehrmann, 1977). The periapical extension of a pulpal pathological condition may be expressed as radiolucent areas at the apices of teeth. In addition, these areas may be due to other non-pulpal pathological processes, including the periodontal lesions, cysts, fibrous lesions, neoplasms, and congenital abnormalities, or even represent some normal structures, such as the mental foramen and the incisive canal (Chambers, 1982). Therefore, a normal sensibility test indicates that the pathology of tooth pulp is not responsible for the radiographic abnormality.

Moreover, pulp testers can be used to evaluate a complete tooth anesthesia after a local anesthetic has been injected prior to operative procedures (Grossman et al. 1988). However, this may be unnecessary since the mechanical work of the procedure itself will do the same evaluating role. But this role may be applied in some studies where a comparison of some analgesic drugs is needed (Mumford and Bjorn, 1962). PSTs are used also in the assessment of pulp-capped teeth as well as those requiring deep restorations.

Importantly, PSTs can be applied during the examination and follow-up of traumatized teeth although its validity is controversial. These tests are helpful for determination of therapeutic needs of the involved teeth in jaw fractures (Roed-Petersen and Andreasen, 1970), also the teeth affected by surgical trauma (Johnson and Hinds, 1969) or vital transplantation procedures (Urbanska and Mumford, 1980).

Limitations of PSTs

Technically, all current PSTs have relatively different shortcomings related to the reliability and accuracy of the diagnostic process (Chen and Abbott, 2009). Hence, each dentist should be aware of the correct clinical application of PSTs, since not all clinical situations require distinct PSTs to be used.

There has been an association between the sensory manifestations of the pulp and its histological appearance. Nonetheless, this relationship seems to be weak and inconsistent with the presence of some limitations giving false responses to PSTs, providing inaccurate prediction of pulp health (Seltzer et al. 1963, Tyldesley and

Mumford, 1970, Dummer et al. 1980). The PSTs are continually criticized because they have only shown good correlations between test results and the necrotic pulps or pulpless teeth (Tyldesley and Mumford, 1970, Dummer et al. 1980). Actually, these criticizing evidences suggest that the PSTs can only be used when an assessment is required to discriminate whether a pulp is alive or necrotic without an accurate quantification of diseased and healthy pulps and thus they cannot be used to judge the degree of a given pulp disorder. Since an accurate assessment of the pulp status is imperative while performing conservative treatment procedures of the teeth, the PSTs are very limited in their ability to do this specifically (Seltzer et al. 1963, Dummer et al. 1980). Although there has been a lack of correlation between PST threshold and the specific histological findings of a pulp, it has been demonstrated that there is a significant relationship between an absence of response to PSTs and the incidence of total pulp necrosis (Seltzer et al. 1963, Lundy and Stanley, 1969, Marshall, 1979). In addition, thermal PSTs are very useful when the patient present with signs of pulpitis as they can identify the diseased tooth by replication of symptoms (Jafarzadeh et al. 2010).

Another major shortcoming of PSTs is the lack of objectivity. Since the pain expression by the patient is subjective in its nature, then any attempt to correlate response intensity with pulpal condition would have the problem of subjectivity (Ehrmann, 1977, Degering, 1962, Stark et al. 1977). To overcome this disadvantage, an employment of a control tooth on the opposite side of the mouth has been demonstrated (Chilton and Fertig, 1972).

The lack of reproducibility by PSTs has been reported also where there was varied response between the different patients to pulp tests on different days, and even at different hours of the same day (Dummer et al. 1980).This was in contrast with several evidence which demonstrated no great differences in response on different occasions of PSTs (Nordenram, 1970, Friend and Glenwright, 1968).

In regards to tooth maturation status, it has been observed that the PSTs threshold is increased in response to electrometric PSTs in the erupting teeth (Mumford, 1965, Fulling and Andreasen, 1976) or may give no response to them (Klein, 1978) despite their undoubtful vitality. In addition, a direct relationship was observed between the response to electrical stimulation and the stage of root development (Klein, 1978). A possible explanation for this observation may be the fact that the nerve endings around the odontoblasts and predentine are not initially present, which would be gradually developed until being fully formed when the tooth has been in function for 4-5 years (Bernick, 1964). Conversely, the use of thermal PSTs using CO_2 snow was found to give a consistent positive response in mostly all maturing teeth under examination (Fulling and Andreasen, 1976). This point is of significant importance since the dentists are frequently confronted with the problem of diagnosing and evaluating the traumatized anterior teeth in younger patients (Klein, 1978). Therefore, the degree of root development should be taken considerably while evaluating the response of electric tests.

Pulp Testing Techniques

Thermal Tests

Although some of thermal pulp testing techniques appear to be “crude” in their nature, their benefits as useful diagnostic approaches cannot be ignored. These tests include either heating or removing heat from a tooth.

Cold Tests

In the past, the use of ice and ethyl chloride was widely applicable, but, recently, the use of CO_2 snow and other refrigerants have taken the lead.

Ice

The use of ice can be the simplest old pulp testing technique which almost requires minimal cost for preparation. Although several investigators have shown an acceptable validity and reliability for pulp assessment (Dachi et al. 1967, Austin and Waggener, 1941), Ehrmann, 1977) stated that the ice is cumbersome and cannot reach the required temperature to efficiently extrapolate the dental sensibility. It has been demonstrated that there is a sort of difficulty of applying the usual ice cube or a piece of chipped ice to a tooth in the posterior part of the mouth, smaller teeth, irregular teeth, or those teeth with a good deal of deposited dentin (Ehrmann, 1977, Austin and Waggener, 1941). A special cone-shaped container was developed to facilitate the accessibility to such teeth. Another way to make it in useful forms and dimensions includes freezing water in empty local anesthetic cartridges (Grossman, 1974). Later on, ice utilization was best described by Ehrmann (1977) in the form of cube held in a piece of gauze.

It is important, for those who assess pulp sensibility using ice, to always compare the response of one tooth to the corresponding one on the other side of the dental arch. The application of ice may be accompanied with a degree of “tolerance” if the patients is in habit of eating much ice cream, drinking much cold water, or those living in areas where they inhale very cold air (Austin and Waggener, 1941). Additionally, other disadvantages of using ice are that it has to be thawed out frequently and some dentist may experience some difficulties in handling ice cubes correctly.

Ethyl chloride

It is a traditional refrigerant which was widely used in the past. After appropriate isolation of the teeth, a cotton wool piece could be sprayed with ethyl chloride and applied to the tooth directly once frosting took place (Davies and Rawlinson, 1988). Ethyl chloride was considered to be relatively cheap and easy applicable. Petersson (1999) found that approximately 83% of the teeth under study with a necrotic pulp were correctly recognized as necrotic by ethyl chloride. However, there are more effective agents that have superseded this type of refrigerants.

DDM (Dichlorodifluoromethane)

DDM was used in the same way as ethyl chloride; after being sprayed on a cotton pellet and then can be applied on the tooth. It has been found that the DDM is equally reliable in yielding a positive response to stimuli in a similar degree as the electrical pulp tests and CO_2 snow in older patients (Fuss et al. 1986). It was proposed that it works by affecting a great number of dental tubules and nerve fibers. Therefore, it produces an impact able to elicit a more profound response. Another potential mechanism of DDM action is that it makes better contact with teeth surfaces. Both DDM and CO_2 snow produced significant reductions in temperature in the pulpodentinal border zone than that yielded by traditional ice or ethyl chloride (Fuss et al. 1986). Being a chlorofluorocarbon, the use of DDM was limited and its market availability and popularity were markedly diminished due to the possible impacts on the atmospheric ozone layer (Miller et al. 2004).

Therefore, other refrigerant sprays utilizing other gas mixtures have emerged including a propane/butane/isobutane mixture or tetrafluoroethane.

CO_2 snow (dry ice)

As described by Ehrmann (1977), carbon dioxide snow is the pulp testing method of choice. The first introduction of CO_2 snow to dentistry was in 1936. CO_2 snow is prepared by a special apparatus consisting of a cylinder containing pressurized CO_2 liquid, a plunger, and a plexiglass tube (Chambers, 1982). When CO_2 pressure is reduced to atmospheric pressure, some of it would evaporate and the remainder is converted into dry ice (at -78°C), where it could be collected in a removable barrier within the plexiglass tube, then can be applied on the tooth through a dry ice pencil.

CO_2 snow produces a rapid thermal change and, hence, it is desirable as the 78°C temperature is responsible for the consistent and rapid action as described by many investigators (Ehrmann, 1977). Carbon dioxide snow can be used on metallic restorations as well as the orthodontically banded teeth (Ehrmann, 1977, Fulling and Andreasen, 1976). It may be also used for fractured teeth covered with temporary metal crowns. The use of test cavity can be then avoidable for these cases. The use of CO_2 snow is quickly performed to an extent that a full mouth vitality test can be applied in a very short time. In addition, no tooth isolation is required while applying such test. Along with the aforementioned advantages, dentists using CO_2 snow can avoid the shortcomings of electric testing in immature teeth. Other major advantages of this test are that it would not yield false positive results in cases of early pulpitis and moist gangrene, where the response would be lingering (Ehrmann, 1977). In fact, this response is far different from that showed by a normal pulp. For patients with cardiac pacemakers, CO_2 snow can be used safely without constituting a health hazard, which is considered problematic in electric testing (Woolley et al. 1974). On other hand, there may be several disadvantages of CO_2 snow as stated by many research authors. It may be less efficient in elderly patients with much secondary dentin, and should be used with precautions on teeth forming part of a metal bridge, and it cannot be used if there is porcelain crowns (Ehrmann, 1977). Moreover, it may be less useful for assessment of traumatized teeth and may also be unreliable if applied on the incisal edge (Fulling and Andreasen, 1976). Another reported disadvantage of CO_2 snow is that it may cause cracks in teeth under testing (Bachmann and Lutz, 1976). However, these cracks may be of less significance clinically (Ehrmann, 1977). Collectively, CO_2 snow would appear to be promising among other pulp testing techniques although its apparently avoidable shortcomings.

Heat Tests

Generally, heat tests are less accurate pulp testing techniques than cold ones. Heated gutta-percha was used extensively during the last few decades (Ehrmann, 1977). It can be heated to melting temperature and applied directly to the tooth surface with a lubricant to be easily removed (Rowe and Ford, 1990). Mumford (1964) tested the effect of using heated gutta-percha and ethyl chloride on 74 normal teeth. Only a consistent response was reported in 10 teeth for gutta-percha and 20 teeth for ethyl chloride. In addition, if overheated, gutta-percha caused severe pain as reported previously (Mumford, 1976), while it would reveal a false negative result if not adequately heated (Lundy and Stanley, 1969). A false positive result would also be obtained in cases of pulpal gaseous necrosis because of the impact of pressure on the periapical region (Mumford, 1976). Zach (1972) stated that, while heating the gutta-percha, an inadequate cooling during the restorative procedures can cause harms to the pulp. Therefore, the use of heat pulp testing using this method may be a safety concern.

Other battery-powered heating equipment can be used to produce this heat effect on the teeth, such as Touch n' Heat and water bathing (Bender, 2000). While using these methods, the tooth is isolated by rubber dam.

Electric Pulp Tests (EPT)

It has been demonstrated that the use of electricity in diagnosing pulp pathological conditions is older than the use of x-ray (Reynolds, 1966). A direct stimulation of sensory nerves present in the pulp would occur while performing EPT. Therefore, the excitation threshold of such nerves can be measured with this technique (Mumford and Bjorn, 1962). Both the direct and alternating current are applicable without essential differences between them (Mumford, 1976). The electrical stimuli results in an ionic change across the neural membrane and, thus, produce an action potential at the nodes of Ranvier of the myelinated nerves (Bender, 2000).

It is important to correctly use the electric pulp tester to obtain accurate responses. The method requires the tooth to be dry (Millard, 1973) and isolated with a rubber dam (Mumford, 1963) or cotton rolls (Grossman, 1974). The electrode is placed away from the periodontium, on the incisal or the occlusal part of the tooth, and should be well-fitted to the localized part of the teeth (Chambers, 1982). Importantly, a conducting contact medium should be present so that the current or the voltage can sufficiently stimulate the nerves (Cooley and Robison, 1980). Several conducting media were used, such as the electrode gel and saline, but the use of toothpaste is preferred as it is most likely to remain in place (Grossman et al. 1988).

In elderly patients, the use of EPT is very useful, overcoming the disadvantage of thermal pulp testing methods for this age group. EPT can provide considerable results in teeth with much secondary dentin (Ehrmann, 1977). Moreover, it is more effective for assessment of pulp vitality in the traumatized teeth, when the tester is applied on the enamel (Fulling and Andreasen, 1976).

Tooth isolation is considered one of the claimed disadvantages of EPT. Also, the EPT is more frightening and painful to the patient and can produce a response from the periodontium (Chambers, 1982). In cases of pulpal liquefactive necrosis, the liquids in the periapical area may elicit a false positive response to EPT (Ehrmann, 1977). Additionally, cavity preparation is a must to use EPT on crowned teeth because there has been a risk of conduction. Several altered thresholds were detected by Burnside while examining the efficacy of EPT in orthodontic patients(Burnside, Sorenson, 1974). Once again, a major disadvantage of EPT is its potential danger if used in patients with cardiac pacemakers (Woolley et al. 1974, Clarke et al.1972).

Test Cavity

A preparation of a test cavity is the last trial when there is no other means to extrapolate the pulp status(Rowe and Ford, 1990). Test cavity preparation is done in teeth covered by full acrylic or porcelain crowns (Ehrmann, 1977). This type of testing entails dentine cutting using a bur without local anesthetic but, however, this procedure may not provide any further information than yielded by thermal or electric pulp testing techniques (Chen and Abbott, 2009). This method is considered invasive and irreversible and, additionally, of a doubtful value in very nervous patients. Moreover, if used with a high speed, it would be difficult to control the depth of the preparation by the working bur. Overall, this type of PST is not recommended.

Laser Doppler Flowmetry (LDF)

LDF is an optical measurement tool by which the number and velocity of particles carried by a fluid flow can be measured. These particles should have a sufficient size (1-20μm) to scatter light so that the signal can be detected but, on the other hand, of small size to flow smoothly (Durrani and Greated, 1977, Drain, 1980, Albrecht et al. 2013). A laser source is used in this dental technique and is targeted to the pulp, where the laser light utilizes dentinal tubules as guides (Matthews and Vongsavan, 1993). A fiber optic probe is placed against tooth surface where a single laser beam emerges (Roebuck et al. 2000, Roeykens et al. 1999) and splits into two equal intensity beams intersected across the target place. The moving red blood cells causes scattering of such beams to be shifted in frequency, while those scattered beams from static tissue remain unshifted (Rowe and Ford, 1990). Both shifted and unshifted beams return back by an afferent fiber inside the same probe to be recognized by a photodetector and a signal is produced (Roebuck et al. 2000, Roeykens et al. 1999). The mixed beam interference is then converted into a semi-quantitative measurement of blood flow, namely the "flux signal", where it is calculated using a preset algorithm in the LDF machine (Roebuck et al. 2000). The net signal is measured in arbitrary units "perfusion units" (PU). Both the probe and the tooth should be completely stabilized. Therefore, a polyvinyl siloxane or an acrylic splint is usually used (Vongsavan and Matthewst, 1996).

For accurate reading, it is important to properly calibrate LDF probe which in contact with the tooth surface. When the distance between the probe and tooth surface is increased, the signal output is then augmented because the area to be covered will be larger (Roeykens et al. 1999) and there will be a higher possibility of contamination of blood flow signal from non-pulpal origin. The average acceptable distance for this technique is usually 0.25 or 0.5 mm (Roebuck, Evans, 2000). In addition, the problem of contamination may take place when the output power of laser beam is increased to 750nm despite its potent penetration (Gazelius et al. 1993). Actually, the contamination problem from the periodontal tissue is nonavoidable at present (Polat et al. 2005). Soo-Ampon and co-authors (2003) revealed that approximately 80% of the output signal into incisor teeth were not scattered from a pulp origin if the tooth isolation was not considered. Similarly, without proper tooth isolation, Polat and colleagues (2005) reported that there may be a degree of signal contamination from the periodontium and, in addition, the laser beam would possibly scatter into the whole oral cavity yielding an augmented contamination. It has been observed also that the restoration as well as any interfering object can make the LDF useless. This was demonstrated clearly with full coverage crowns (Chen and Abbott, 2009).

Pulse oximetry

Determination of the percentage of oxygen saturation of the arterial blood is referred to as oximetry (Munshi et al. 2003). It is well-known that the oxygenated hemoglobin and non-oxygenated hemoglobin have different colors and hence varying affinities to red and infrared light absorption. A light is passed (red and infrared) from a photoelectric diode to illuminate the vascular area of the target and a photodetector is used to identify the absorbance and measure oxygen saturation level (SaO_2) and pulse rate.

Kahan and other investigators (1996) evaluated the pulse waveforms using an optimized oximeter probe from mandibular and maxillary anterior teeth and from the participant's fingers as controls. They found that the reading from teeth was synchronous with that of the finger despite its inconsistency. Goho (1999) measured oxygen saturation from the participants' index finger and compared the reading to a modified tooth probe. The test included 10 non-vital teeth and they recorded saturation value of 0%. The tested immature permanent incisors recorded an average 94% SaO2 by the tooth probe and average 98% in the controls. Therefore, these results showed that the pulse oximetry is an effective diagnostic approach for evaluation of pulp vitality.

4.1.2. Traumatic Injuries to Permanent Anterior Teeth

Traumatic dental injury (TDI) is an impact injury to the teeth and/or other soft and hard tissue within the oral cavity. It is usually an emergency situation which includes sudden unexpected exposure to a traumatic incident. A traumatic injury itself is not considered a disease but rather a subsequent sequelae of unavoidable risk factors during life (Lam et al. 2008). Despite the fact that dental trauma is more common among children and teenagers, it has been demonstrated that any age group is liable to experience such conditions even if the personal oral health precautions are considered (Lam et al. 2008). The cost to the injured individual as well as the community is frequently substantial globally (Bastone et al. 2000). In addition, if compared to other accidental emergency injuries, TDIs are more time consuming and bear high costs (Andersson, 2013).

Prevalence and incidence

Due to the reported global decline in the prevalence and severity of dental caries among children in the past few years, other aspects of oral health has drawn the attention referring to the TDIs as the most significant among young people(Malikaew et al. 2006). During the past few decades, the prevalence of TDIs (all new or old cases) increased significantly (Bastone et al. 2000) and a further increase is expected in the next years because of the increased numbers of exposed people (Glendor, 2008).This increased risk is possibly ascribed to increased number of people having cars, bicycles, sport activities, etc., but they lack the suitable safety knowledge regarding their use. In addition, the increased trend in violence rate among different countries can be another threatening factor. For instance, it has been reported that the maxillofacial fractures occurred due to assaults from kicking have increased from 30% to 40% in 1981 and 1997 respectively (Kontio et al. 2005). Additionally, an increased prevalence of TDIs among girls who were involved in practicing traditionally male dominant sports has been demonstrated (Burden, 1995). Considering data from most countries, about one third of all preschool children have experienced a TDI which includes the primary dentition (Glendor, 2008). For the permanent dentition, about one fourth of school children (peak at 9-15 years) (Gutmann and Gutmann, 1995) and approximately one third of the adults have a TDI with significant variance between countries for these values.

TDI incidence (the number of new cases in a given period of time) seems to be uniform within each country. For example, a Norwegian study showed that there was a significant increase in TDI incidence in urban than in rural regions (Skaare and Jacobsen, 2003).Generally, the risk of having a TDI is increased at least twice in males than females. However, some studies have revealed a sort of reduction in this variation due to interest differences in some sports in some countries (Rocha and Cardoso, 2001, Traebert et al. 2003). Likewise, Traebert and co-investigators (2006) have found that boys and girls have nearly the same chance of exposure to the risk factors of TDI. Therefore, it seems that both the personal and environmental factors can play a significant role as potent determinant of TDI risk than the gender.

Several studies have shown that the majority of TDIs take place in childhood and adolescence. Before the age of 19, it has been reported that about 71-92% of all TDIs occur at this age (Glendor et al. 1996, Davis and Knott, 1984), while this value decreases after the age of 24-30 years (Shulman and Peterson, 2004, Holland et al. 1994). Additionally, the increased risk of accidental falls in elderly people may augment the possibility of having TDIs as reported by Thomson and coauthors (2003).

Anterior Dental Trauma

TDI of the anterior teeth is predominantly reported in the maxillary central and lateral incisors. These injuries frequently affect a single tooth but, it may impact multiple teeth in some instances such as violence, traffic accidents, and sport activities (Glendor, 2008). The traumatized anterior teeth should be well handled as the matter constitutes a challenge to preserve the teeth in this esthetically vital area as well as to minimize the potential damage. Indeed, a lack of proper treatment can result in a lifelong dependency on the dental care. Particularly, the possible reasons of traumatic injuries to the anterior teeth are restricted to falls during learning to walk at the age of 1-2 years and falls due to lack of attention during physical play at age of 2-6 years (Brüllmann et al. 2011). Being involved as the leading causes of anterior dental injuries between 7-12 years of age, the sports activities and confrontations augments the incidence rate of such injuries to its maximal values in such age group (Diaz et al. 2010, Day and Duggal, 2010). In persons older than 12 years of age, traffic accidents, physical fights, and sports injuries are the main causes of traumatic injuries of the anterior teeth(Handschel, Schmidt-Hasemann, 2006).

Since the anterior dental trauma is usually associated with other emergency-related issues such as concussions, limb fractures, or serious injuries (Emerich and Gazda, 2010), the care is mostly concentrated on the major problems rather than teeth problems and hence these dental injuries will be possibly overlooked. Consequently, it may become difficult in such conditions to provide an appropriate care and effectively save the affected teeth which, unlike deciduous teeth, don't have the chance to be replaced naturally(Brüllmann et al. 2011). In addition, the lack of providing suitable therapeutic interventions for the anterior teeth may have an impact on the psychological recovery of the injured individual (Craddock, 2009). From the psychological and social perspectives, it has been reported that the loss of anterior teeth in children and adolescents has an unfavorable prognosis. This is can be applied when a study revealed a possibility of developing social deprivation due to exclusion by other colleagues (Rodd et al. 2010) or the feeling of embarrassment when smiling and while being in contact with others (Rodd et al. 2010, Fakhruddin, et al. 2008).

Types of Traumatized Anterior Dental Injuries

When an impact trauma affects the teeth and their supporting structures, an injury results in form of either a crushing or separation injury or a combination of them (Gottrup, 1993). It is imperative to understand the difference between crushing and separation injuries in order to successfully assess the extent and severity of the resultant damage and hence to accurately set the management plan and predict the outcome.

Separation injuries involve teeth displacement in which there is an associated tissue cleavage such as the periodontal ligament. The extrusive luxation and avulsions are clear examples of such injuries. In this type of injuries, there is a minimal injury to cellular components of the affected tissues. Therefore, a rapid healing is expected with appropriate management (Bakland and Andreasen, 2004).

Conversely, crushing injuries involve more extensive damage to the affected tissues and cells as well as the intercellular components. These damaged parts should be removed in order to obtain favorable results. The expected period of healing process will be longer in this kind of injuries. The intrusive luxations can be classified as crushing injuries in which a tooth is displaced into the adjacent alveolar bone (Bakland and Andreasen, 2004).

Over the past years, several attempts have been made to classify dental injuries (Andreasen, 1993). Actually, the most acceptable and commonly used one is that based on the World Health Organization(1995) and modified by Andreasen(1993). If limited to the anterior permanent teeth, traumatic dental injuries are classified into the injuries occurring to hard dental tissues and the pulp, and those occurring to periodontal tissues (figure 4).

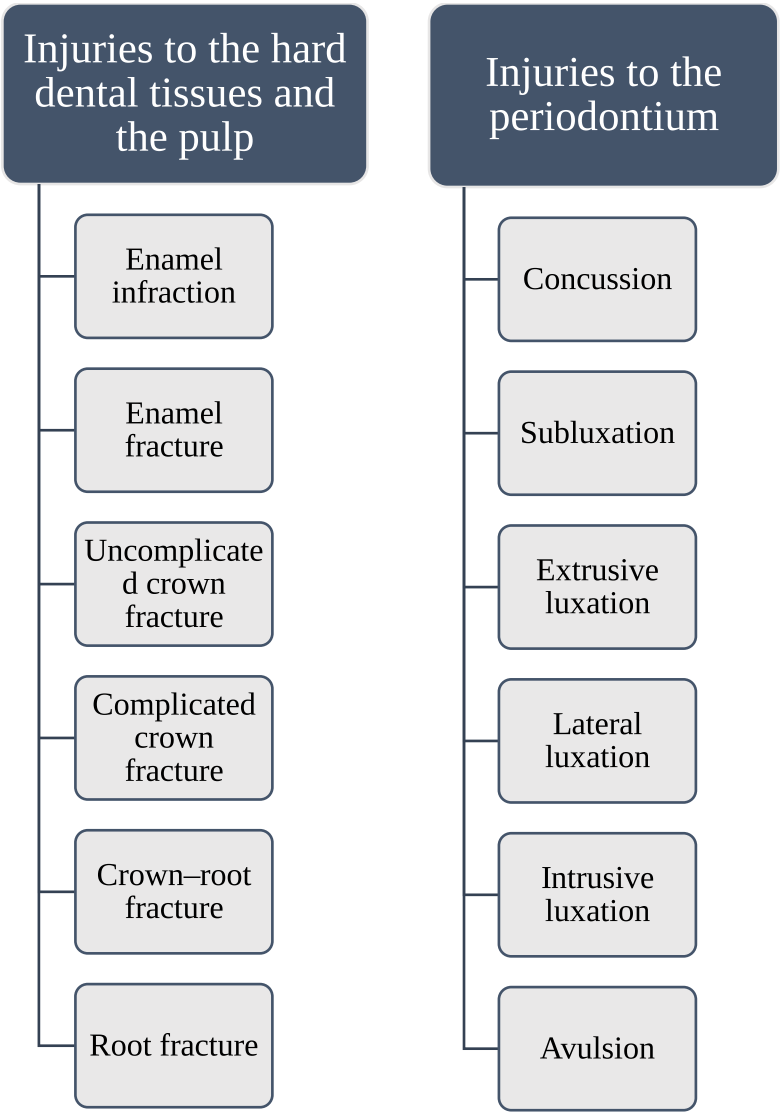

Figure 4: Classification of Traumatic Dental Injuries. Adapted from Andreasen(1993)

Injuries to the hard dental tissues and the pulp

Enamel infraction is an incomplete fracture of the enamel structure without loss of tooth substance. Transillumination usually reveals craze lines and the tooth appears normal radiographically. This kind of injuries is of favorable prognosis and the main goal of treatment is to maintain the structural integrity and pulp vitality (Ravin, 1981, Robertson, 1998).

When fine chalky-white flaws appear on tooth surface, an enamel fracture can be suspected. In general, tooth surface is smooth in this type of fracture and the patient is not in need of an urgent action (Brüllmann et al. 2011).

The uncomplicated crown fracture involves a fracture of the enamel or enamel and dentin without an involvement of the pulp. Injured lips, tongue and gingiva should be evaluated for presence of tooth fragments. The rough edges of the tooth can be smoothed if the fracture is small, and the lost tooth structure can be restored if a bigger fracture exists (Boorum and Andreasen, 1998, McTigue, 2005).

If the pulp is exposed in a fractured tooth along with the fracture of enamel and dentin, it can be referred to as complicated crown fracture. These findings can be detected via both the clinical and radiographic evaluation. The core purpose of management of such cases is to maintain pulp vitality and to restore the function and esthetics. For permanent teeth, the alternatives of pulpal treatment are direct capping of the pulp, partial or full pulpotomy and pulpectomy. The prognosis of complicated crown fractures is basically dependent on the associated injury to the periodontal ligament (Day and Duggal, 2003).

Crown/root fracture occurs when an enamel, dentin, and cementum fracture of a tooth takes place with or without pulp involvement. A mobile coronal fragment can be found attached to the gingiva on clinical evaluation and, radiographically, a radiolucent line perpendicular to the radiographic beam comprising the crown is detected (Flores, 2002). Stabilization of the coronal ligament is the main purpose of emergency interventions. If the pulp is exposed, the available alternatives are pulp capping, pulpotomy, and root canal treatment (Olsburgh et al. 2002). Most of the fractured permanent teeth can be saved despite complicated and laborious treatment approaches (Fuks et al. 1993).

Root fracture is the fracture of dentin and cementum with the involvement of the pulp. Clinical examination may also reveal a mobile coronal fragment attached to the gingiva. In radiographic evaluation, one or more radiolucent lines which separate tooth fragments may be present (Flores et al. 2007). In order to optimize an appropriate healing of the periodontal ligament, it is necessary to anatomically correct the position of the coronal fragment as soon as possible.

Injuries to the periodontium

Tooth concussion is an injury to tooth supporting structure without abnormal loosening or displacement. Clinically, they appear tender to pressure and percussion since the periodontal ligament is affected and inflamed. Therefore, the objective of treating such tooth is to optimize the periodontal ligament healing. It is expected to find no abnormalities in the radiographic evaluation (McTigue, 2005).

If the periodontal injury does not involve tooth displacement but involves abnormal tooth loosening, then the injury is called subluxation. A mobile tooth without displacement will be detected clinically with or without sulcular bleeding (Flores et al. 2007). Treatment of this type of injury includes stabilization of the tooth and applying a tooth splint for no more than 2 weeks.

The luxation is considered to be lateral if tooth displacement is in a direction other than axially with contusion or fracture of the alveolar bone (Holan and McTigue, 2005). The crown is usually displaced in a palatal position and the root is shifted buccally. The tooth is not mobile in this type of injury. A rapid reposition is required for the displaced tooth to optimize healing of the periodontal ligament, and this can be done with digital pressure and little force. It may be necessary to apply a splint for 2-4 weeks (Kahnberg and Ridell, 1979, Andreasen, 2007).

The intrusive luxation entails an apical displacement of tooth in the alveolar bone where it compresses the periodontal ligament causing a crushing fracture of the alveolar socket (McTigue, 2005, Holan and McTigue, 2005). Clinically, the tooth appears missing or shortened as it is displaced into the alveolar process. Also, the tooth is not mobile or tender when touched. A passive, active, or surgical reposition is performed to such tooth in order to stabilize the tooth with applying a splint for 4 weeks to optimize healing of periodontal ligament. However, in permanent teeth with closed apices, there have been reported several risks for pulp necrosis, pulp canal obliteration (Humphrey et al. 2003). A low risk of healing complications should be demonstrated during spontaneous reposition of immature permanent teeth (Andreasen et al. 2006).

Extrusive luxation an axial and partial displacement of the tooth from the socket. Torn of the periodontal ligament is usually associated with this type of injuries. The tooth appears elongated and mobile on clinical examination and an increased apical periodontal space is observed on the radiographic evaluation (Flores, 2002). Tooth reposition is done with slow steady apical pressure and a splint is applied for 2 weeks (Lee et al. 2003).

Avulsion injury includes total displacement of the tooth out of the socket with the possibility of severance and fracture of alveolus (McTigue, 2005). Both the clinical and radiographic evaluation shows that the tooth is not located in the socket or it has been replanted. Treatment entails replantation of the tooth as soon as possible to its anatomical position with flexible splinting for 2 weeks. It is imperative to consider tetanus prophylaxis and antibiotic coverage while handling avulsion injuries.

4.1.3. Sensibility Testing Related to Traumatized Permanent Anterior Teeth

The accurate assessment of pulp status following dental trauma has been considered a real challenge as the traumatized teeth usually experience a temporary loss of sensibility, a matter which gets worsened by the limitations of the conventional sensibility tests (Andreasen and Kahler, 2015). The pulpal blood supply may be torn after concussion or subluxation, or even severed following the extrusive or lateral luxation. Subsequently, pulpal edema may develop leading to a negative response of the pulp to PSTs just after trauma. Therefore, approximately a period of 10-14 days may be required for the pulpal response to be returned. Moreover, this period may be extended up to 3 months in the case of tooth dislocation with subsequent rupture of the neurovascular supply at the apical foramen or even several years if such apices were closed (Ohman, 1965, Andreasen, 1986).

Table 7: Summary of the included studies in sensibility testing related to traumatized permanent anterior teeth

Author(s)	Publication Year	Objective	Type of Injury	PST	Conclusion
Teitler et al.	1972	Evaluation of the diagnostic and prognostic value of PSTs in permanent teeth after uncomplicated crown fracture	Uncomplicated crown fracture (Ellis Class II)	EPT and ethyl chloride	EPT has a favorable diagnostic and prognostic value for traumatized teeth even at the initial examination
Zadik et al.	1979	Evaluate the prognostic and diagnostic value of vitality tests after TDI	Uncomplicated crown fracture	ethyl chloride and EPT	Both cold tests (ethyl chloride) and EPT are reliable tests during the 6 months follow-up period post trauma
Ravin	1981	Studying teeth with enamel infractions and their response to EPT and other clinical diagnostic tests	Enamel Infractions with or without uncomplicated crown fractures and subluxation	EPT	The infractions are relatively harmless injuries and the pulpal damage was observed if the infractions were associated with damage to the supporting tissue. The majority of teeth responded to EPT immediately after trauma.

Andreasen	1986	Evaluate the relationship between TAB and the response to EPT and discoloration following luxation injuries	Luxation Injuries	EPT	The response to EPT returned to normal as the TAB disappeared frequently within 1 year or more after subluxation injury.
Andreasen et al.	1987	assess the value of EPT for predicting the development of PCO	Luxation Injuries	EPT	EPT may have a prognostic significance during the follow-up period for the development of PCO after luxation injuries
Evans et al.	1999	comparing the reliability of LDF with other pulpal diagnostic tests	Post-traumatic non-vital anterior teeth with pulpectomies	LDF, ethyl chloride, EPT	• EPT and cold test have low specificity and high sensitivity compared to other standard pulp tests. • LDF is highly reliable in discriminating between vital and non-vital teeth
Strobl et al.	2004	assess the outcome of splint application on the values of pulpal blood flow after 3 different types of tooth fracture	uncomplicated crown fractures, complicated crown fractures, or root fractures	LDF	LDF is valuable for detection of ischemic episodes which may occur following TDIs and also useful for identification of patients at risk of adverse pathological complications such as tissue loss and avascular necrosis

Gopikrishna et al.	2007	Comparing the efficacy of pulp oximeter versus thermal (refrigerant spray) and electric pulp testing	uncomplicated crown fractures, concussion, subluxation	Pulse Oximeter, Refrigerant Spray, and EPT	Pulse oximeter is an effective test for evaluating pulp vitality of recently traumatized teeth and its advantages are superior than the limitations of conventional pulp sensibility tests.
Bastos et al.	2014	Studying the accuracy of thermal and electrical sensibility after TDIs	crown fractures and luxations either combined or separated	EPT and thermal (refrigerant spray and hot gutta-percha)	• The initial negative response to sensibility tests after trauma is indicative of pulpal damage rather than a prognostic value of PN • EPT is the most accurate test for long-term follow-up for post-traumatic pulpal diagnosis. • Cold sensibility tests are more preferable in younger patients.

Enamel infraction

Ravin (1981) studied and observed the permanent anterior teeth with enamel cracks or infractions either separated or in conjunction with uncomplicated fractures or luxations in children following acute trauma. Teeth vitality using EPT and other radiographic and clinical evaluation were conducted during the follow-up period. Indeed, the results of this study revealed that about 97% of the teeth under study showed positive response to EPT immediately after trauma and this was unchanged later during the observation period. Only 1.8% of those teeth were later converted to non-vital whereas 21.5% of originally non-vital teeth had their vitality regained. It is imperative to state that the apical foramens of the majority of the latter teeth (which have regained their vitality) were open. Therefore, the state of root development may have a robust impact on the following pathological complications that may take place after trauma. Overall, it has been observed that the infractions are relatively harmless injuries and the pulpal damage was observed if the infractions were associated with damage to the supporting tissue.

Crown fracture

To evaluate the prognostic and diagnostic value of vitality tests in teeth with fracture of the enamel and dentin without pulp involvement, Zadik and co-authors (1979) conducted their study on 84 children with 123 traumatized permanent teeth. The initial examination was performed within 10 days after trauma using the application of ethyl chloride, EPT, percussion, and periapical radiographs. It has been found that about 87.8% of the total included teeth responded positively to the initial vitality tests, while of the remaining teeth which did not show any response (n=14), five gave positive response 3 months following trauma. The possible explanation of this finding is the "shock theory" in which there have been some teeth might show negative response shortly after trauma but the response would eventually return within 3 months. In addition, about half of such teeth required root canal treatment within 4 months. Therefore, the authors suggested that a follow-up period of 6 months after trauma is necessary in order to early assess the possibility of any pathological incidence by using either the cold or EPT testing. When pulp tests were compared to each other, the majority of the teeth (97%) which gave positive response to ethyl chloride showed positive response also to EPT.

Similarly, Gopikrishna and colleagues (2007) studied the efficacy of pulp oximeter in measuring pulp vitality and compared its results with those of thermal (refrigerant spray) and electric pulp testing. The majority of their patients (n=17) presented with uncomplicated crown fractures with some cases with concussion and subluxation. The results were compared also to 30 healthy positive control students as well as 30 negative control patients with endodontic treatment. The results revealed that both the thermal and electrical pulp testing showed positive response within 3 months after trauma, while the normal pulp vitality was detected by the pulse oximeter from the first day post injury and on to over 6 months (table 8). Only one case with subluxation injury showed no response to the conventional testing even after 6 months.

Table 8: Comparison of teeth showing pulp vitality with thermal or electric pulp tests versus pulse oximeter testing. Adapted from Gopikrishna et al. (2007)

Time Interval	Teeth showing vitality with thermal (cold) tests or EPT		Teeth showing vitality with pulse oximeter	
	Number	***%***	***Number***	***%***
Day 0	0	0	17	100
Day 2	0	0	17	100
Day 4	0	0	17	100
Day 7	0	0	17	100
Day 14	0	0	17	100
Day 21	0	0	17	100
Day 28	5	29.4	17	100
2 months	14	82.35	17	100
3 months	16	94.11	17	100
6 months	16	94.11	17	100

Again, these results prove the existence of "shock theory" possibly due to a temporary paresthesia of pulpal nerves after traumatic injuries which renders the pulp unresponsive to conventional sensibility tests. The teeth began to respond to either thermal or electrical pulp tests starting from the 28th day after trauma and increased over time up to 6 months. Overall, at the end of follow-up period, the conventional tests detected pulp necrosis in about 6% of traumatized teeth with uncomplicated crown fractures. However, the proportion of vital teeth detected by pulse oximeter remained constant over the 6-months period without any change.

Conversely, Teitler and other co-authors (1972) revealed different results. They evaluated the diagnostic and prognostic value of PSTs using EPT and ethyl chloride in permanent teeth after uncomplicated crown fracture in 55 children aged 6-14 years. The tests were performed at immediately after trauma, after 6 weeks and 3 and 6 months.

Interestingly, the results revealed that 95% of the traumatized teeth showed a positive response at the initial examination, where 2 of them became negative after 3 months and 6 became negative at the end of observation period. It has been observed that the “shock response” was rarely demonstrated in this study and that the EPT was considered of good prognostic value for such fractures.

Concussion and Luxation

Studying the accuracy of thermal and electrical sensibility after TDIs, Bastos and other investigators (2014) performed their study on 121 teeth with crown fractures and luxations either combined or separated. The sensibility tests consisted of electrical and thermal (refrigerant spray and hot gutta-percha) tests. The initial temporary loss of sensibility was confirmed through the findings of this study where 53 teeth did not show positive responses to sensibility tests. However, this initial response was not associated with the development of PN later during the follow-up period. Therefore, the initial negative response to sensibility tests after trauma is indicative of pulpal damage rather than a prognostic value of PN, a matter which may be explained by the diminished nerve activity after trauma although the vascular supply, which is responsible for pulp vitality, is not ultimately affected (Gopikrishna et al. 2009, Andreasen, 2007). Importantly, the tooth may remain vital even though its weak or absent response to sensibility tests after trauma and this may be attributed the slow rate of neural degeneration in traumatized teeth than vascular regeneration (Schendel et al. 1990, Pileggi et al. 1996). In fact, the time elapsed from the onset of trauma should be considered when the dentist begins to evaluate the pulpal response after traumatic injuries to the teeth.

It is imperative to mention that, according to the study of Bastos and co-authors (2014), the accuracy of each test at the initial and final tests were 55.1% and 67.8% for the heat test, 55.9% and 77.9% for the cold test, and 57.6% and 89% for the EPT respectively. Therefore, it can be concluded that the EPT is the most accurate test for long-term follow-up for post-traumatic pulpal diagnosis. Nonetheless, in younger patients where the apical foramen is open, cold sensibility tests are more preferable.

Andreasen (1986) has tested the relationship between transient apical breakdown (TAB) and the clinical changes of the teeth, represented as coronal discoloration and the loss of response to EPT following luxation injuries. Of all examined teeth (n=637), only 27 demonstrated the occurrence of TAB with 15 of them were considered to have lateral luxation. The author observed that both the sensibility changes due to the electric pulp tester as well as the grey discoloration were consistent along with the course of TAB. In addition, as the TAB disappears, frequently within 1 year or more after injury, the transient sensibility and color changes usually followed the same course. Interestingly, as the TAB returned to normal, the pulpal damage, indicated by EPT, returned to normal at about the same time as normalization of the radiographic condition. In conclusion, as the TAB process appears to be related to the condition of the pulp, as demonstrated by the color and EPT changes, this can be an indicator of the potent role of EPT as a prognostic test to assess the healing process of the traumatized pulp and periodontium of luxated mature teeth.

To assess the value of EPT for predicting the development of pulp canal obliteration (PCO), pulp necrosis (PN), and pulp survival without accelerated hard tissue deposition along the canal walls following concussion and luxation injuries, we reviewed the study of Andreasen and co-authors (1987). They performed electrometric sensibility at the time of injury and at all follow-up examinations to evaluate the sensibility of luxated teeth. Multiple negative sensibilities (n=9) were detected at the time of injury, and this was significantly related to the final outcome after concussion and subluxation. The frequency of PCO and PN tended to increase significantly with the negative sensibility after concussion injuries (versus PS), while the frequency of PN, within 3 months after trauma, was observed to be increased significantly with the negative sensibility following subluxation injuries. With observation periods of 1-5 years, only 1 of 9 teeth with total PCO did not respond to EPT at final examination and all of the remaining 8 teeth responded positively corresponding to the normal sensibility. Therefore, EPT may have a prognostic significance during the follow-up period for the development of PCO after luxation injuries.

Laser Doppler Flowmetry (LDF)

Since the most of PSTs unreliable shortly after dental trauma, it is necessary to focus on pulp vitality tests in this period and later during the follow-up period. After traumatic injuries, the tooth may become necrotic and infected and hence an external inflammatory root resorption may take place. In addition, it is possible to re-vascularize the teeth with incomplete root formation to prevent pulp infection as well as to enable their appropriate development (Ohman, 1965, Cvek et al. 1990).

Therefore, the reliability of LDF has been studied and compared to other pulpal conventional tests (Evans et al.1999). The investigators collected the data of 67 non-vital teeth after TDIs, with pulpectomies were performed to them. The included data were the findings of conventional pulp tests, including pain history, tenderness of the tooth with percussion, coronal discoloration, cold tests (ethyl chloride), EPT, and radiographic findings. Both sensibility tests (EPT and cold test) had lower specifies and higher sensitivities according to a specifically formulated scale for this study. It is important to note that the specificity measures were calculated in comparison to vital samples. Actually, the observed fall in specificity of PSTs may be ascribed to an association between a lack of response to sensibility tests in vital samples and immature root formation. This explanation was consistent with other two studies (Fulling and Andreasen, 1976, Klein, 1978).

The results of the same study (Evans et al. 1999) indicated that LDF is a highly reliable technique as a discriminative approach between vital and non-vital pulps, revealing very high specificity and sensitivity. The discriminating feasibility of LDF can be indicated by its ability to identify vital teeth and teeth with at least necrotic coronal part of the pulp. However, the lack of untraumatized control teeth in the same arch of traumatized patients may be considered a weak point in the LDF technique used in this study. Instead, the researchers used the values of flux and amplitude SWV as absolute measurements with reference to mean values derived from normal populations.

To assess the outcome of splint application on the values of pulpal blood flow after different types of tooth fracture, Strobl and colleagues (2004) used LDF for such purpose. They studied 15 patients with either uncomplicated crown fractures, complicated crown fractures, or root fractures. The authors found that the fracture type had a significant effect on maxillary central incisor pulpal blood flow values, with root fracture of the lowest blood flow finding. This finding is consistent with the concept of the presence of relationship between fracture type and the occurrence of pulpal tissue pathologic changes (Saad, 1991). Collectively, the risk of PN is increasingly associated with the degree of injury to the pulp and periodontal ligament and also in the teeth with complete root formation (Andreasen, 1989). This study revealed also that the splint therapy of root fractures caused significant reduction in pulpal blood flow values on both the short- and long-term periods. In addition, LDF is valuable for detection of ischemic episodes which may occur following TDIs and also useful for identification of patients at risk of adverse pathological complications such as tissue loss and avascular necrosis. However, in the case of tooth discoloration after trauma, the assessment of blood flow by using LDF was found to be affected due to negative reading due to bleeding of the injured pulp (Heithersay and Hirsch, 1993).

4.2. Assessment of trauma cases in permanent anterior teeth presented at HBMCDM from January 2008 to December 2016

The present study provided a retrospective investigation of the distribution of traumatic dental injuries in patients with varied ages, without limiting the results to younger populations, where such injuries are more frequent. Assessment of TDIs in young and adult patients is important as it gives an opportunity to track the possible trauma reasons in each group as well as identify its consequences and complications. Nonetheless, the lack of reporting of TDIs as a result of behavioral cultural diversities among different communities may relatively hinder obtaining accurate and significant results in the retrospective evaluations.

Classifying TDIs into uncomplicated and complicated injuries has been presented earlier (Glendor et al. 1996) and utilized in our study by the assessment of the risk of complications, such as root resorption or pulp necrosis. Indeed, this method of TDIs identification is useful to show the therapeutic and economic implications of such injuries to the teeth, as stated by several studies in Sweden (Glendor et al. 2001) and in Denmark (Borum and Andreasen, 2001). In addition, this classification makes it easier to identify whether the severity of injuries is increasing or decreasing.

This study showed an approximate equal distribution of traumatic dental injuries among males (44.7%) and females (55.3%) with a slight tendency toward females. However, there was a significant correlation between the consequences of TDIs in each gender group. The complicated injuries constituted significant increases (74.6%) within males' and females' populations as well. This is inconsistent with the results of Viduskalne and Care (2010) who have employed 160 fractured teeth to investigate pulp survival and the possible injury complications. The distribution of injuries in their study was nearly twice in boys (69.5%) than girls (30.5%) with a significant difference. In fact, the majority of studies related to studying TDIs have shown that the traumatic injuries occur in boys and girls with a ratio 2:1 (Castro, Poi, 2005, Marcenes et al. 2000). Additionally, the distribution of uncomplicated (70.3%) and complicated (29.7%) injuries in the study of Viduskalne and Care (2010) favored the uncomplicated ones in both males and females.

In general, the greatest ratio of male to female experiencing TDIs may be due to the greater participation of males, particularly younger ones, in sport activities, fights, and car accidents (Eyuboglu et al. 2009, Altun et al. 2009). Furthermore, this might be attributed to the fact that girls are more mature in their behavioral aspects than boys, who usually show more energetic and active attitudes. On the other hand, some studies, including our study, have shown a reduction in this ratio as a result of the increased participation in sport activities among girls (Traebert et al. 2006) and this could subsequently expose the girls to the same risk factors of TDIs especially in the modern Western societies. In fact, girls can also have had traffic accidents and violent acts in the same way as boys. In our study, the actual reason of this reduced ratio as well as the overall increase in the incidence of complicated injuries versus uncomplicated ones could not be clearly explained.

Age is also significantly associated with the type of traumatic injuries to the teeth as per results of our study. The most frequent injuries were reported in patients aged more than 18 years (56.1%). Few studies have included both children and adults in their investigations for TDIs. Kaste and colleagues (1996) have studied the prevalence of incisor trauma patients 6-50 years of age in the United States through a survey of the representative data in order to provide national estimates for the US population in the period between 1988 and 1994. Consistent with our results, the authors found that there have been 1156 traumatized teeth in patients with an age range of 21-50 years (67.9%), while the reported TDIs in younger patients, aged 6-20 years, were in 546 teeth (6-20 years old; 32.1%). The possible explanation of this finding is that a higher risk of injury in older patients due to longer time of exposure may be comparable to the younger age group. However, the trauma may have occurred earlier in life without the ability to remember such incidence and the clinical evidence may be unable to demonstrate such injuries (for example, when enamel fractures becoming smooth over time) leading to inability to identify traumatized and non-traumatized teeth.

Later on, Shulman and Peterson (2004) have used the data of the latter survey and developed a more complicated plan with a larger cohort to demonstrate the association between incisal trauma and occlusal characters in young and adult population. Of total 15364 injured teeth, the older adults aged 21-50 years (57.3%) experienced TDIs more than younger patients (42.7%) although the association was insignificant.

A recent retrospective study has been conducted to identify and analyze the characters and factors related to TDIs in a Brazilian population presented at a single referral center (Borin-Moura et al. 2017). The authors examined the records of 545 patients and found that the TDIs were reported increasingly in the younger patients (n=239; 59.3%) than the older ones (n=226; 40.7%). Regarding the severity of trauma, there has been a higher prevalence of uncomplicated injuries among patients (66.7%) than complicated ones (33.2%). Actually, this is inconsistent with our findings which revealed a low prevalence of uncomplicated TDIs among different age groups (25.4%). The complicated injuries in our study were prevalent in different age groups with percentages of 16.5%, 17.6%, and 65.9% in the groups aged 6-11, 12-17, and more than 18 years old respectively. On the other hand, the prevalence of complicated TDIs in the study of Borin-Moura and co-authors was 20.4% for the patients between 7-12 years old, 35.8% for those aged between 13-19 years, and 43.8% for the patients more than 20 years old. The higher prevalence of complicated injuries in our study may be because the patients with less severe traumatic injuries are usually not referred to our medical center as their injuries are resolved in the private health centers.

Overall, the most common injury to permanent dentition in most studies is the uncomplicated crown fractures (Kania et al. 1996, Davis and Knott, 1984, Stockwell, 1988, Lee-Knight, Harrison, 1992). However, some hospital-based studies have shown that subluxations and complete luxations are frequent dental injuries among their patients (Galea, 1984, Martin et al. 1990).

As a consequence of dental trauma, pulp necrosis may develop providing favorable nutritional supply for the bacteria. Dental pulp infection will then occur due to multiple microbial attacks with predominantly gram-negative bacteria. However, in some cases, the periapical inflammation may begin before the pulp has been totally necrotic (Khayat et al. 1988). Our results revealed rare periapical pathologies with uncomplicated injuries (10.3%), while they were more frequent with the complicated injuries (58.8%). Indeed, Andreasen (1972) classified injuries according to their clinical management into complicated injuries, where the injury involves the pulp and requires pulp therapy, and uncomplicated injuries.

Particularly after traumatic injuries to the anterior teeth, an infection of the root canal takes place as a result of stimulation of the immune and inflammatory response in the area surrounding the dental root apex. This is called a periapical lesion or apical periodontitis. Bone resorption is a common feature of the periapical lesion and it leads to incomplete wound healing with granulation tissue formation (Sasaki et al. 2016). Although it can be considered a protective response to the bacteria, the periapical lesions are eventually unpleasant outcomes resulting in chronic inflammation.

If left untreated, crown fracture would result in cyst-like periodontitis and it should be treated with apical surgery (Kim and Kratchman, 2006). If periapical lesions are detected, root canal therapy would be required, focusing primarily on the removal of microbial infection from the root canal system. Root canal therapy is the most preferred type of treatment of the traumatized teeth due to the possible association of pulp necrosis after prolonged times post-injury. Even the teeth with simple crown fracture may have this kind of treatment due to the delay in diagnosis and the subsequent inflammatory changes and pulp necrosis (Andreasen, 1972).

Of the total 82 teeth requiring interventions, we have performed root canal treatment on 51 patients, of which 41.2% were experiencing periapical pathologies. The majority of teeth which required endodontic retreatment had periapical lesions (87.1%). To our knowledge, our study is the first to address the correlation between both parameters.

5. CONCLUSIONS

5.1. A systematic review of sensibility testing

Treatment of traumatized anterior teeth by the clinician is usually delayed until the development of clinical symptoms or the vitality of the pulp could be detected by the conventional sensibility tests to properly identify pulp status prior setting up the management approach plan. Nonetheless, an actually diseased pulp might undergo unfavorable complications such as inflammatory root resorption. Therefore, a careful follow-up of such teeth is required at periodic intervals up to six months after trauma as the nerves may regain their function later. In addition, despite the lack of response of traumatized teeth to sensibility neurological testing during the first few weeks after trauma, several studies have proved pulp vitality by showing the signs of pulpal blood flow using LDF and pulse oximetry. As a result, the accurate treatment plans can be decided immediately as per reported by the pulp vitality assessment tests without waiting for the positive response yielded by the conventional tests. Up to our understanding, the clinician cannot depend on 1 of the pulp vitality tests to confirm the diagnosis regarding pulp vitality and also cannot decide the suitable treatment plan based on a sole test. Overall, the follow-up process of the traumatized anterior teeth should be associated with accurate interpretations depending on several evidences from various results of clinical examination and the assistive diagnostic techniques. This work can easily be extended to a meta-analysis.

5.2. Assessment of trauma cases in permanent anterior teeth presented at HBMCDM from January 2008 to December 2016

1. Traumatic dental injuries occurred almost in equal proportion amongst males and females with a slight tendency toward females.
2. Complicated injuries were more prominent in males than female patients.
3. The most frequent traumatic dental injuries were reported in patients aged more than 18 years old.

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7. APPENDICES

Appendix I: Ethical approval- Ethics Committee, Hamdan Bin Mohammed College of Dental Medicine, Mohammed Bin Rashid University of Medicine and Health science

David Wray, MD, FDS, F Med Sci.
Dean & Professor of Oral Medicine
Hamdan Bin Mohammed College of Dental Medicine

Ref: HBMCDM/EC/2007
Date: April 1, 2015

Dr. Sara Saeed Al-Shablan
Resident, Endodontics Department
Hamdan Bin Mohammed College of Dental Medicine
PO Box 505097
Dubai Healthcare City
Dubai

Title of project: Aspects of Dental Trauma

Reference: EC0315-002

Dear Dr. Sara,

Thank you for submission of your proposal for approval to the Ethics Committee.

On behalf of the Committee, I am pleased to confirm a favourable ethical opinion, effective 24th March, 2015, on the basis described in the application form.

The favourable opinion is given provided that all data used for the study and that are archived are anonymous. There should not be any patient identifiers on the study casts.

Yours sincerely,

Professor David Wray
Chairman, Ethics Committee

Appendix II: Excel sheet- Raw data of 114 traumatized permanent anterior teeth presented at HBMCDM during the period of January 2008 to December 2016

S. N.	Rx Code	Chart Number	Gender	Age	Age of trauma	Type of Treatment	Teeth Traumatized	Date of the radiograph	Type of trauma	Caries	Internal resorption	External resorption	Post	Restoration type	Medical Hx	Pathology	Vitality test used
1	D3310	AHMAY001	Male	15	8	RCT	#11	note 04/02/2010	complicated crown fracture for	non	non	non	non	composite build ups	rickets	0	
2		AHMAY001	Male	15	8	Composite filling	#12	note 04/02/2010	Uncomplicated crown fracture	non	non	non	non	composite build ups	rickets	0	
3	D3310	ALIZA001	Female	20	15	RCT	#11	note 11/04/2010	uncomplicated crown fracture	non	tooth 11	non	non	composite build ups	special needs ,convulsion	0	
4		ALIZA001	Female	20	15	Composite filling	#21	note 11/04/2010	uncomplicated crown fracture	non	non	non	non	composite build ups	special needs ,convulsion	0	
5	D3310	ALMAL008	Female	25	20	RCT	#21	note 23/01/2012	complicated crown fracture	non	non	non	non	composite build ups	clear	0	cold test :(+)
6		ALMAL008	Female	25	20	RCT	#13	note 23/01/2012	complicated crown fracture	non	non	non	non	composite build ups	clear	0	cold test :(+)
7		ALMAL008	Female	25	20	RCT	#12	note 23/01/2012	complicated crown fracture	non	non	non	non	composite build ups	clear	0	cold test :(+)
8		ALMAL008	Female	25	20	RCT	# 22	note 23/01/2012	complicated crown fracture	non	non	non	non	composite build ups	clear	0	cold test :(+)
9		ALMAL008	Female	25	20	RCT	#11	note 23/01/2012	complicated crown fracture	non	non	non	non	composite build ups	clear	0	cold test :(+)
10	D3310	ALSAB004	Male	18	13	RCT	#11	note 28/07/2010	complicated crown fracture	non	non	non	non	post and crown	clear	0	
11		ALSAB004	Male	18	13	RCT	#21	note 28/07/2010	complicated crown fracture	non	non	non	non	post and crown	clear	0	
12		BALAH000	Male	15	13	Composite filling	#11	note 14/07/2014	uncomplicated crown fractre	non	non	non	non	coposite build up for both teeth	clear	yes	cold test: (-) for tooth 11
13	0	BALAH000	Male	15	13	Composite filling	#21	note 14/07/2014	uncomplicated crown fractre	non	non	non	non	coposite build up for both teeth	clear	0	cold test:(+) for tooth 21
14	D3310	FAELI000	Female	34	29	Composite filling	11	note 05/08/2010	uncomplicated crown fracture	non	non	non	non	coposite build up for both teeth	clear	0	cold test: (-) for tooth 11
15		FAELI000	Female	34	29	Composite filling	12	note 05/08/2010	uncomplicated crown fracture	non	non	non	non	coposite build up for both teeth	clear	0	cold test: (-) for tooth 12
16	D3310	HUSOM000	Male	16	13	Re-RCT	32	note 07/05/2013	complicated crown	non	non	non	non	composite build	clear	yes	

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	
18	16	D3310	HUSOM000	Male	16	13	Re-RCT	32	note 07/05/2013	complicated crown fracture	non	non	non	non	composite build ups	clear	yes	
19	17		HUSOM000	Male	16	13	Re-RCT	31	note 07/05/2013	complicated crown fracture	non	non	non	non	composite build ups	clear	yes	
20	18	D3310	MALJA000	Male	39	34	RCT	11	note 06/07/2010	complicated crown fracture	non	non	non	non	composite build ups	clear	yes	col re
21	19	D3310	MELCE000	Female	31	29	RCT	#11	note 01/11/2014	complicated crown fracture	non	non	non	non	coposite build up	clear	0	cold
22	20		MELCE000	Female	31	29	Composite filling	#21	note 01/11/2014	Uncomplicated crown fracture	non	non	non	non	coposite build up	clear	0	cold f
23	21	D3310	MENLE000	Female	18	13	Re-RCT	11	note 23/01/2011	complicated crown fracture	non	non	non	non	composite build ups	clear	4	
24	22		MENLE000	Female	18	13	Re-RCT	21	note 23/01/2011	complicated crown fracture	non	non	non	non	composite build ups	clear	yes	
25	23	D3310	RACKE000	Female	20	8	extraction and implant	11	note 04/06/2014	complicated crown fracture	non	non	non	yes(fiber post) and crown	no treatment	clear	yes	
26	24	D3310	WOLWE000	Male	47	22	Re_RCT	31	note 13/10/2014	complicated crown fracture	non	non	non	yes	crown	diabetic	yes	
27	25	D0171	MANRA001	Male	16	14	RCT	#11	note 19/02/2014	complicated crown fracture	non	non	non	non	no treatment	clear	0	cold upper E
28	26		MANRA001	Male	16	14	RCT	#12	note 19/02/2014	complicated crown fracture	non	non	non	non	no treatment	clear	0	cold upper E
29	27		ALAAD001	male	15	7	Composite filling	# 21	06/12/2009	uncomplicated crown fracture	non	non	non	non	composite build ups	clear	0	
30	28		ALMMA011	male	15	7	Composite filling	# 11	12/11/2012	uncomplicated crown fracture	yes	non	non	non	composite build ups	clear	0	
	29		FARKH001	male	15	7	Composite filling	# 11	10/04/2010	uncomplicated crown	non	non	non	non	composite build	clear	0	col

Confirmed Trauma Cases | all patients

Ready 60%

C2 Chart Number

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	
29		FARKH001	male	15	7	Composite filling	# 11	10/04/2010	uncomplicated crown fracture	non	non	non	non	composite build ups	clear	0	col
30		FLEAL000	male	15	15	Composite filling	# 11	no notes were recorded	uncomplicated crown fracture	non	non	non	non	no treatment	clear	0	
31		KAATA000	male	15	7	Composite filling	# 21	05/10/2008	uncomplicated crown fracture	non	non	non	non	composite build ups	clear	0	
32		KEETH000	male	15	9	Cvek pulpotomy	# 21	07/04/2010	complicated crown fracture	non	non	non	non	composite build up	clear	0	
33		PINJO000	male	16	9	RCT	#11	03/04/2012	complicated crown fracture	non	non	non	non	composite build ups	Hyper activity	0	
34		PINJO000	male	16	9	RCT	#21	03/04/2012	complicated crown fracture	non	non	non	non	composite build ups	Hyper activity	0	
35		PINJO000	male	16	9	RCT	#22	03/04/2012	complicated crown fracture	non	non	non	non	composite build ups	Hyper activity	0	
36		MOHRA000	male	17	8	Composite filling	# 11	08/05/2008	uncomplicated crown fracture	non	non	non	non	composite build ups	clear	0	cold bo
37		MOHRA000	male	17	8	Composite filling	# 12	08/05/2008	uncomplicated crown fracture	non	non	non	non	composite build ups	clear	0	cold bo
38		ALSAB004	male	19	12	RCT	# 11	24/07/2010	complicated crown fracture	non	non	non	non	post and crown	clear	0	col
39		ALSAB004	male	19	12	RCT	# 21	24/07/2010	complicated crown fracture	non	non	non	non	post and crown	clear	0	col
40		MABMA000	male	37	10	RCT	#11	13/07/2013	complicated crown fracture when he was young	yes 11 and 21 mesially	non	non	non	composite build ups	clear	0	
41		MALJA000	male	40	33	RCT	#11	06/07/2010	complicated crown fracture	non	non	non	non	composite build ups	clear	yes	cold
42		KARSM000	female	41	38	RCT	# 21	05/02/2014	complicated crown fracture	non	non	non	non	crown	clear	0	
43		ISALE000	male	45	39	Composite filling	11	28/05/2011	uncomplicated crown fracture	non	non	non	non	composite build ups	clear	0	cold
44		ISALE000	male	45	39	Composite filling	41	28/05/2011	uncomplicated crown	non	non	non	non	composite build	clear	0	cold

Confirmed Trauma Cases | all patients

Ready

C2 | Chart Number

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	
45		ALMAH009	male	43	43	Composite filling	11	26l5l2014	uncomplicated crown fracture	non	non	non	non	composite build ups	clear	0	
46		ALSAH009	male	21	21	Re-RCT	21	10/03/2014	complicated crown fracture	non	non	non	non	crown	clear	yes	
47		CURLE000	female	41	41	Extraction and implant	13	note 19/10/2008	complicated crown fracture	non	non	non	non	no treatment	clear	yes	
48		GHEAH000	male	24	8	Re_RCT	tooth 21	15l3l2014	complicated crown fracture	non	non	Replacement resorption	non	no treatment	clear	0	
49		MCNGE000	male	49	49	RCT	tooth 21	19/10/2008	complicated crown fracture	non	non	non	non	crown	clear	yes	
50		RAMME000	male	36	36	RCT	teeth 11	09/05/2014	complicated crown fracture	non	non	non	non	composite build ups	epilepsy	0	
51		RAMME000	male	36	36	RCT	teeth 12	09/05/2014	complicated crown fracture	non	non	non	non	composite build ups	epilepsy	0	
52		RAMME000	male	36	36	RCT	teeth 21	09/05/2014	complicated crown fracture	non	non	non	non	composite build ups	epilepsy	0	
53		RAMME000	male	36	36	RCT	teeth ,22	09/05/2014	complicated crown fracture	non	non	non	non	composite build ups	epilepsy	0	
54		YANLI000	female	22	22	RCT	teeth 11	11/12/2010	complicated crown fracture	non	non	Replacement resorption	non	no treatment	clear	0	
55		YANLI000	female	22	22	RCT	teeth 21	11/12/2010	complicated crown fracture	non	non	Replacement resorption	non	no treatment	clear	0	
56	D3310	11345	Male	20	18	RCT	11	note 19/01/2016	complicated crown fracture	non	non	non	non	post and crown	clear	yes	cold
57		11345	Male	20	18	RCT	12	note 19/01/2016	complicated crown fracture	non	non	non	non	post and crown	clear	yes	cold
58		11345	Male	20	18	RCT	21	note 19/01/2016	complicated crown fracture	non	non	non	non	post and crown	clear	yes	cold
59		11345	Male	20	18	RCT	22	note 19/01/2016	complicated crown fracture	non	non	non	non	post and crown	clear	yes	cold
60	D3310	12271	Male	56	12	RCT	21	note 02/05/2016	uncomplicated crown fracture	yes on tooth# 21	non	non	non	composite build up	diabetic	yes	

Confirmed Trauma Cases | all patients

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C2 Chart Number

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	
61	D3310	12507	Male	43	43	RCT	22	note 18/07/2016	complicated crown fracure	yes	non	non	non	composite build up	HCV	yes	cold
62	D3310	13566	Male	32	15	RCT	21	note 26/09/2016	complicated crown fracture	non	non	non	non	crown	clear	0	
63	D3310	ABDAH004	Male	40	38	RCT	21	note 15/06/2015	complicated crown fracure	non	non	non	non	composite build up	clear	0	
64	D3310	ARERI000	Female	38	32	Re-RCT	12	note 08/03/2015	complicated crown fracure	non	non	non	non	bridge	clear	yes	
65		ARERI000	Female	38	32	Re-RCT	21	note 08/03/2015	complicated crown fracure	non	non	non	non	bridge	clear	yes	
66	D3310	HUSMU000	Male	29	27	RCT	11	note 13/09/2015	complicated crown fracture	non	non	non	non	composite build up	clear	yes	cold
67	D3310	KHASA008	Male	51	49	Extraction and implant	21	note 04/10/ 2015	complicated crown fracure	non	non	yes	non	no treatment	clear	yes	
68	D3310	RAHSH000	Male	44	22	RCT	41	note 08/08/2015	complicated crown fracure	non	non	non	non	composite build up	clear	yes	
69		RAHSH000	Male	44	22	RCT	31	note 08/08/2015	complicated crown fracure	non	non	non	non	composite build up	clear	yes	
70	D3346	11828	Female	10	8	Re-RCT	11	note 02/03/2016	complicated crown fracture for 11	caries on 11	non	non	non	crown	clear	yes	cold
71		11828	Female	10	8	Composite filling	21	note 02/03/2016	uncomplicated crown fracture	caries on 11	non	non	non	crown	clear	yes	cold
72	D3346	12481	Male	27	23	Re-RCT	31	note 17/04/2016	complicated crown fracure	non	non	non	non	composite build up	clear	yes	
73		12481	Male	27	23	Re-RCT	32	note 17/04/2016	complicated crown fracure	non	non	non	non	composite build up	clear	yes	
74		12481	Male	27	23	Re-RCT	33	note 17/04/2016	complicated crown fracure	non	non	non	non	composite build up	clear	yes	
75		12481	Male	27	23	Re-RCT	34	note 17/04/2016	complicated crown fracure	non	non	non	non	composite build up	clear	yes	
76		12481	Male	27	23	Re-RCT	35	note 17/04/2016	complicated crown fracure	non	non	non	non	composite build up	clear	yes	

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C2 | Chart Number

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	
77	D3220	PARNA000	Male	14	13	Cvek pulpotomy	11	note 20/01/2015	complicated crown fracture	non	non	non	non	composite build up	clear	0	
78	D3348	AMIMO000	Male	11	10	Re-RCT	21	note 15/04/2015	complicated crown fracure	non	non	non	non	composite build up	clear	yes	
79		AMIMO000	Male	11	10	Re-RCT	11	note 15/04/2015	complicated crown fracure	non	non	non	non	composite build up	clear	yes	(+
80	D3348	KHASA012	Male	41	27	Re-RCT	21	note 21/09/2015	complicated crown fracture	non	non	non	non	crown	clear	yes	
81		KHASA012	Male	41	27	Re-RCT	22	note 21/09/2015	complicated crown fracture	non	non	non	non	crown	clear	yes	
82	D3310	KASBA000	Female	12	8	RCT	21	note 16/11/2015	complicated crown fracture	non	non	non	non	composite build up	clear	yes	cold
83		KASBA000	Female	12	8	RCT	22	note 16/11/2015	complicated crown fracture	non	non	non	non	composite build up	clear	yes	cold
84	9431	KHAAZ001	Male	52	41	Re-RCT	41	note 30/04/2016	complicated crown fracure	non	non	non	non	crowns	clear	yes	
85		KHAAZ001	Male	52	41	Re-RCT	12	note 30/04/2016	complicated crown fracure	non	non	non	non	crowns	clear	yes	
86		KHAAZ001	Male	52	41	Re-RCT	11	note 30/04/2016	complicated crown fracure	non	non	non	non	crowns	clear	yes	
87		KHAAZ001	Male	52	41	Re-RCT	33	note 30/04/2016	complicated crown fracure	non	non	non	non	crowns	clear	yes	
88		KHAAZ001	Male	52	41	Re-RCT	32	note 30/04/2016	complicated crown fracure	non	non	non	non	crowns	clear	yes	
89		KHAAZ001	Male	52	41	Re-RCT	41	note 30/04/2016	complicated crown fracure	non	non	non	non	crowns	clear	yes	
90	D3320	12957	Male	42	42	RCT	11	note 02/05/2016	complicated crown fracure	non	non	non	non	composite build up	clear	yes	col
91		12957	Male	42	42	RCT	12	note 02/05/2016	complicated crown fracure	non	non	non	non	composite build up	clear	yes	cold b
92	9431	11865	Male	44	43	RCT	21	note 07/03/2016	complicated crown fracure	non	non	non	non	composite build up	clear	yes	

Confirmed Trauma Cases | all patients

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C2 | Chart Number

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
94	92	9431	11865	Male	44	43	RCT	21	note 07/03/2016	complicated crown fracure	non	non	non	non	composite build up	clear	yes	
95	93	9431	13494	Male	36	36	RCT	21	note 26/07/2016	complicated crown fracure	non	non	yes	non	composite build up	clear	yes	
96	94	D3346	13585	Male	36	17	Re-RCT	11	note 06/12/2016	complicated crown fracure	non	non	non	non	crowns	clear	0	
97	95		13585	Male	36	17	Re-RCT	21	note 06/12/2016	complicated crown fracure	non	non	non	non	crowns	clear	0	
98	96		13585	Male	36	17	Re-RCT	31	note 06/12/2016	complicated crown fracure	non	non	non	non	crowns	clear	0	
99	97		13481	Male	20	20	Re-RCT	21	note 19/07/2016	complicated crown fracure	non	non	non	non	no treatment	clear	yes	
100	98		11914	Male	35	35	RCT	12	note 28/03/2016	complicated crown fracture	yes on teeth 11 and 21 mesially	non	non	non	composite build up	clear	yes	all tee respo
101	99		11914	Male	35	35	RCT	11	note 28/03/2016	complicated crown fracture	yes on teeth 11 and 21 mesially	non	non	non	composite build up	clear	yes	all tee respo
102	100		11914	Male	35	35	RCT	21	note 28/03/2016	complicated crown fracture	yes on teeth 11 and 21 mesially	non	non	non	composite build up	clear	yes	all tee respo
103	101	D3410	11943	male	12	12	Composite filling	# 21	19/03/2016	Uncomplicated crown fracture	non	non	non	non	composite filling	clear	0	
104	102	D3310	KHASA004	female	7	6	RCT	#21	25/04/2015	complicated crown fracure	non	non	non	non		clear	0	colo too
105	103	D2335	TARNA001	female	15	13	Composite filling	#11	28/11/2015	uncomplicated crown fracture	non	non	non	non	composite filling	clear	0	
106	104		TARNA001	female	15	13	Composite filling	#21	28/11/2015	uncomplicated crown fracture	non	non	non	non	composite filling	clear	0	

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	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	
102	100		11914	Male	35	35	RCT	21	note 28/03/2016	complicated crown fracture	yes on teeth 11 and 21 mesially	non	non	non	composite build up	clear	yes	all tee respo
103	101	D3410	11943	male	12	12	Composite filling	# 21	19/03/2016	Uncomplicated crown fracture	non	non	non	non	composite filling	clear	0	
104	102	D3310	KHASA004	female	7	6	RCT	#21	25/04/2015	complicated crown fracure	non	non	non	non		clear	0	colo too
105	103	D2335	TARNA001	female	15	13	Composite filling	#11	28/11/2015	uncomplicated crown fracture	non	non	non	non	composite filling	clear	0	
106	104		TARNA001	female	15	13	Composite filling	#21	28/11/2015	uncomplicated crown fracture	non	non	non	non	composite filling	clear	0	
107	105		TARNA001	female	15	13	Composite filling	#12	28/11/2015	uncomplicated crown fracture	non	non	non	non	composite filling	clear	0	
108	106		TARNA001	female	15	13	Composite filling	#22	28/11/2015	uncomplicated crown fracture	non	non	non	non	composite filling	clear	0	
109	108		JAMMO002	male	8	8	Composite filling	# 21	03/01/2017	uncomplicated crown fracture	non	non	non	non	composite filling	clear	0	
110	109		ABIMU000	male	9	8	Composite filling	# 21	02/07/2016	uncomplicated crown fracture	non	non	non	non	composite filling	clear	0	col
111	110		12968	male	32	31	RCT	# 21	03/03/2016	complicated crown fracture	non	non	non	non	coposite filling	clear	0	
112	111		12968	male	32	31	Composite filling	# 11	03/03/2016	uncomplicated crown fracture	non	non	non	non	coposite filling	clear	0	
113	112		KALMD000	male	39	37	Re_RCT	# 11	01/11/2015	complicated crown fracure	non	non	non	non	crown	clear	yes	
114	113		KALMD000	male	39	37	Re_RCT	# 21	01/11/2015	complicated crown fracure	non	non	non	non	crown	clear	yes	
115	114		11971	male	42	41	RCT	# 21	11/01/2016	complicated crown fracure	non	non	non	non	composite filling	clear	0	