Healing Patterns in Traumatized Mature and Immature Permanent Incisors

Thesis

Presented in Partial Fulfillment of the Requirements for the Degree Master of Science in the Graduate School of The Ohio State University

By

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2019

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Abstract

Purpose: The aim of this retrospective study is to utilize data from the Nationwide Children's Hospital Dental Trauma Database to analyze the differences in healing between immature and mature permanent incisors that sustained uncomplicated crown fractures with concussion, subluxation or lateral luxation injury.

Methods: The database search was limited to maxillary and mandibular central and lateral incisors (#7-10, #23-26) in children ages six through eighteen at the time of injury. Each subject had at least three months of dental trauma follow up in the dental clinic. Demographic, clinical, and radiographic assessments recorded for the initial presentation and follow up appointments were collected and compared for observation of healing. Each subject's radiographs were then analyzed by three calibrated examiners to determine apical status at the time of injury compared to radiographs at successive follow-up appointments. Teeth were identified as immature or mature at the time of injury based on assessment of apical closure and the two groups were compared to determine if differences existed in healing patterns. 105 patients with 133 teeth fit the inclusion criteria. Chi-squared test was used to assess the association between healing status and tooth maturity and to examine whether this association remains significant after adjusting for confounding factor a logistic regression model was developed.

Results: Traumatized teeth that were immature at the time of injury had significantly more healing than teeth that were mature at the time of injury (Chi-sq statistic=3.41, P-value=0.06). It turned out that the odds of healing among immature teeth was 0.33 times the odds of healing among mature teeth after adjusting for confounding factors (Odds Ratio=0.33, 95% Confidence interval: 0.0998, 0.9557, P-value=0.05). No statistical significance was noted in healing patters of teeth sustaining specific injury combinations.
Conclusions: Apical maturity at the time of injury is significantly related to healing potential- Immature apices have better potential for normal healing. Additionally, this study emphasizes the role of standard/systematic methods of documenting details/characteristics of traumatic dental injuries

Dedication

This document is dedicated to my family, who has supported me throughout my education, and to my research advisors for their guidance and expertise.

Acknowledgments

I would like to thank my thesis committee for their support and guidance throughout my project, as well as my co-residents for their consistent documentation using the trauma database. I would also like to thank Delta Dental for funding my statistical analysis.

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Introduction

Dental trauma affects approximately 20% of the pediatric population and comprises a significant portion of the services provided by pediatric dentists.[1-5] Understanding patterns in healing of certain types of dental injuries can allow for the development of evidenced–based and reliable treatment protocols for these injuries with the aim of maximum preservation of the natural dentition.[6-8] Traumatic dental injuries of permanent teeth in the pediatric populations often occur in combination and are known to have worse prognoses than injuries that do not occur in combination.[3, 6, 9-14] These combinations can involve injuries to the teeth, periodontium, blood and nerve supply to the tooth and thus represent complex healing scenarios[6, 15].

Many factors affect the ability of a tooth to heal after sustaining a traumatic dental injury. Previous studies have explored prognostic factors affecting teeth that have sustained traumatic injuries and have found that injury type and apical maturity at the time of injury to be two of the most important factors[6, 7, 13, 16-20]. Many studies have noted that in various injury types an increase in apical maturity leads to a decrease in healing potential[6, 7, 13, 16-19]. Teeth that are immature at the time of injury are thought to have better healing potential due to rich vascularity present at the apex that diminishes significantly once the root matures[6]. However, regardless of apical status an increase in the severity of the injury itself also decreases the likelihood of healing. Crown fractures represent a direct access point for intraoral bacteria to enter the dentinal tubules and access pulpal tissue[19-22]. Utilizing the Ellis classification scale, it is believed that crown fractures of increasing severity represent increased area and ease of penetrability for oral bacteria to access the inner anatomy of the injured tooth[20, 23-25]. Additionally, luxation injuries represent not only a conduit for entry of oral bacteria but also ischemic injury to the pulp itself [7, 12, 19, 26, 27]. Damage to these complex structures creates an entry point for bacteria as the apical foramen is in direct contact with the periapical tissues including periodontal ligament, cementum, and alveolar bone[6, 19, 24]. Less severe luxation injuries such as concussion and subluxation represent less complex healing scenarios as no displacement of the tooth or damage to alveolar housing occurs as it does with more severe injury types[17, 27, 28]. In teeth with luxation injuries that result in displacement, localized ischemia can result from the disruption of the neurovascular supply and compression of the apical root structure resulting in more severe injury[16, 19, 28]. Crown fracture and luxation injuries often occur concomitantly, and it is important to consider the severity of the injuries individually and in combination when prognosticating pulpal and periodontal healing[20, 22, 25].

Due to the complex nature of combination injuries, clinicians are required to perform and record accurate clinical and radiographic evaluations[8, 26]. These evaluations are critical to the correct diagnosis and treatment of any traumatic dental injury and it is beneficial to have a standardized way in which to correctly and consistently document patient, trauma, and treatment related information[9, 26]. Creation of databases and modules in electronic record systems allow for the consistent documentation of dental injuries and provide a reliable resource for tracking healing of injuries over time[26, 29, 30]. The Dental Trauma Database created by Nationwide Children's Hospital is an integrated flowsheet module created to record uniform information regarding the trauma itself as well as clinical and radiographic findings for each visit. The aim of this study is to utilize data from the Nationwide Children's Hospital Dental Trauma Database to retrospectively analyze the differences in healing between immature and mature permanent incisors that have sustained an uncomplicated crown fracture with concussion, subluxation, or lateral luxation injury.

Methods

This study was approved by the Human Subjects Committee of Nationwide Children's Hospital, Columbus, Ohio (IRB18-00021).

The sample comprised patients presenting to the Nationwide Children's Hospital Dental Clinic for treatment of traumatized permanent incisors. Retrospective search of the Dental Trauma Database located in the Epic electronic records system was completed, identifying patients who fulfilled the following inclusion criteria:

- 6-18 years old at the time of injury
- Trauma sustained to maxillary and mandibular central and lateral incisors (#7-10,#23-26)
- At least three months of dental trauma follow up including tooth-specific clinical and radiographic data
- No previous trauma sustained to injured teeth

Criteria also included patients with teeth that sustained any combination of the following combination injuries:

- Ellis class one fracture with concussion
- Class II fracture with concussion
- Class one fracture with subluxation

- Class two fracture with subluxation
- Class one fracture with lateral luxation
- Class two fracture with lateral luxation

Patients were excluded from the study if they lacked diagnostic periapical radiographs or had less than three months of clinical and radiographic follow up data.

Demographic, clinical, and radiographic assessments recorded in the trauma flowsheets within the Epic system for the initial presentation and final follow up appointment were collected and compared for observation of healing. The following parameters were recorded for each tooth fitting the inclusion criteria at the initial presentation: Gender, language, insurance provider, age, mechanism of injury, soft tissue injury, apical development, displacement direction, pulpal treatment, radiographic findings, restorative treatment, horizontal overjet, presence of pulpal blushing, time since injury, vertical occlusion type, discoloration, gingival laceration, enamel fracture type, surface involved in crown fracture, periodontal injury types, mobility, displacement (in mm),behavior, and previous trauma to tooth. The following parameters were recorded at the final trauma follow up appointment: palpation, percussion, mobility, cold, EPT, presence of sinus tract, fracture, periapical diagnosis and pulpal diagnosis.

Periapical radiographs were exposed at both the initial and final trauma follow up. Radiographs were retrospectively assessed by three calibrated examiners, two board certified pediatric dentists and one board certified endodontist. Initial radiographs were assessed for the following: Apex (open or closed), Moorrees score(1-6)[31], and canal wall thickness (normal or abnormal). Final radiographs were assessed for the following: Apex (open or closed), Moorrees score, and canal wall thickness (Increase, no change, or RCT if tooth was deemed necrotic). Radiographs were viewed on one monitor by the three examiners simultaneously with consistent lighting. Examiners were first shown the initial radiograph, scores were recorded, then they were shown the final radiographs and the scores were recorded. Examiners were blinded to the date of the initial and final radiographs. Discrepancies in ratings were resolved through discussion between examiners and consensus was reached. For analysis and statistical purposes, teeth were separated into immature, Morreess ratings 1-5, and mature, Moorrees rating of 6, at the time of the injury. Teeth were considered to be healed if there was a lack of pulpal necrosis, continued root wall thickness and continued apical development after at least three months.

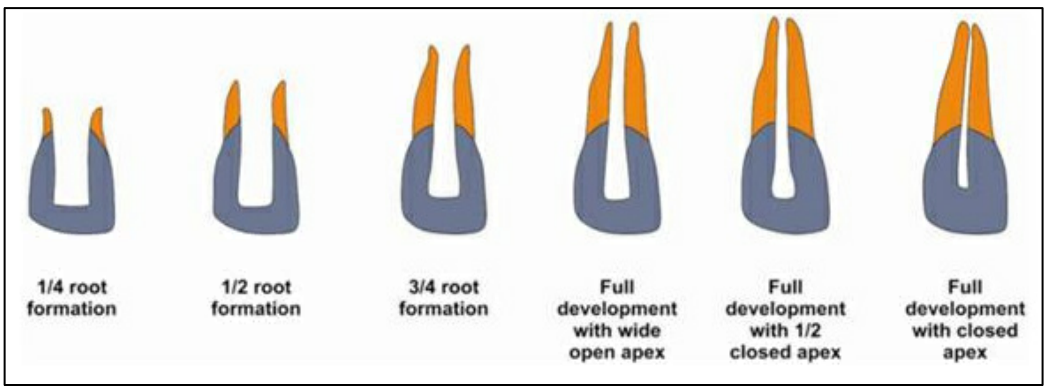

Figure 1 Moorrees Classification of Root Development[32]

Treatment was rendered according to the International Association for Dental Traumatology guidelines dictated by the injury type[1, 8]. Crown fractures received either composite restorations or indirect pulp caps with composite restorations. None of the teeth that suffered lateral luxation were severe enough to require repositioning and splinting. Type of treatment rendered was documented appropriately in the trauma flowsheets.

Results

Subjects who fit the search criteria from the Dental Trauma Database within Epic were screened for diagnostic radiographs and appropriate follow up time. Following this two-step process, 105 patients with 133 teeth were found to fit the inclusion criteria.

Descriptive statistics of the study cohort were generated using frequency values. The association between healing and tooth maturity was analyzed using Pearson's Chi-Squared and logistic regression was used to determine the association of healing and tooth maturity after adjusting for confounding variables.

The study cohort was first analyzed as a whole, considering all injury types and comparing healing in teeth deemed to be mature or immature at the time of healing. Teeth that were immature at the time of injury had nearly significantly more healing than teeth that were mature at the time of injury, with a p-value slightly larger than 0.05 (Chi-sq statistic=3.41, P-value=0.06). The only confounding variable considered in this study was comparing periodontal injury types: concussion versus non-concussion injuries (subluxation and lateral luxation). The odds of healing among immature teeth was 0.33 times the odds of healing among mature teeth after adjusting for confounding factors (Odds Ratio=0.33, 95% Confidence interval: 0.0998, 0.9557, P-value=0.05). Examiners differed in their Ellis Classification rating on four of the initial radiographic scorings and three on final radiographic scorings. When these differences occurred it always occurred by a degree of one Ellis Classification and was settled via majority vote.

	Healed					
	No		Yes		Total	
Tooth maturity	N	Percentage	N	Percentage	N	Percentage
Immature	6	15%	35	85%	41	31%
Mature	27	30%	64	70%	91	69%
Total	33	25%	99	75%	132	100%

Table 1 Two Way Table of Tooth Maturity by Healing Status

The study cohort was then divided into groups based on injury types and analyzed using Pearson's Chi-Squared test (Table 2). The following injury types were individually analyzed and no statistical significance was found between injury type and maturity of the tooth at the time of injury: Ellis Class I fracture and concussion (N=9) , Ellis Class II fracture and concussion (N=99), Ellis Class I fracture with subluxation, Ellis Class II fracture and subluxation (N=20), Ellis Class I fracture and lateral luxation, and Ellis Class II fracture and lateral luxation.

	Healed						
	No		Yes		Total		*P-Value**
Enamel/concussion	N	%	N	%	N	%	
Immature	0		6		6	67%	
Mature	0		3		3	33%	
Total	0		9		9	100%	N/A
Enamel+dentin/concussion							
Immature	3	11%	25	89%	28	28%	
Mature	18	25%	53	75%	71	72%	
Total	21	21%	78	79%	99	100%	p = 0.108
Enamel+dentin/subluxation							
Immature	3	60%	2	40%	5	25%	
Mature	7	47%	8	53%	15	75%	
Total	10	50%	10	50%	20	100%	p = 1

*Computed with Pearson's Chi Squared test

Table 2: Two Way Table of Tooth Maturity By Healing Status (Injury Specific)

Descriptive statistics were used to analyze various data recorded in the Dental Trauma Database Flowsheets (Table 3). The most common mechanism of injury was fall (65%), followed by sports injuries (21%), and hit by object (11%). Males (77%) sustained more injuries than females (23%). The most common injury type was class II fracture with concussion injury followed by class II fracture with subluxation injury, class I fracture with concussion, class I fracture with subluxation and then class I and class II fracture with lateral luxation each had one subject. Considering the patient-reported time since the injury occurred, the majority of patients presented to the NCH dental clinic over 24 hours following the initial trauma (N=68), with 30 subjects presenting 1-3 hours from the initial trauma. The most common horizontal overjet was 1-3mm (N=87), followed by 4-6mm (N=34), and the majority of patients were found to have a normal vertical occlusion type (N=89). All patients in this study had some degree of uncomplicated crown facture involving any combination of tooth surfaces. The most common number of affected surfaces was four (N=58), followed by five (N=42), one (N=15), three (N=7), and two (N=3). Behavior was recorded using the Frankl Score of behavior (Figure 2). The majority of patients were given a Frankl score of four at their initial presentation to the clinic (N=77) followed by Frankl scores of three (N=37), and only 13 patients were found to be uncooperative, with Frankl scores of 1or 2. All patients with luxation injuries had displacement that was in the range of 1-3mm (N=3). Mobility was classified using the Miller Classification of tooth mobility[33]. Most patients had a mobility rating of zero, which was considered to be physiologic (N=76), followed by a mobility grade one (N=23), mobility grade two (6), and two patients were found to have no mobility. None of the parameters recorded in the initial flowsheets were found to have a significant effect on the healing of injured teeth.

Table 3: Initial Visit Variables by Healing Status

	Healed					
	No		Yes		Total	
Combined injury type	N	%	N	%	N	%
enamel/concussion	0	0.0%	9	100.0%	9	6.8%
enamel/lateral luxation	0	0.0%	1	100.0%	1	0.8%
enamel/subluxation	1	50.0%	1	50.0%	2	1.5%
enamel+dentin/concussion	21	21.2%	78	78.8%	99	75.0%
enamel+dentin/lateral luxation	1	100.0%	0	0.0%	1	0.8%
enamel+dentin/subluxation	10	50.0%	10	50.0%	20	15.2%
Time since injury						
>24 hrs	15	22.1%	53	77.9%	68	51.9%
1-3 hrs	4	13.3%	26	86.7%	30	22.9%
12-24 hrs	6	40.0%	9	60.0%	15	11.5%
3-6 hrs	1	14.3%	6	85.7%	7	5.3%
30-60 mins	4	57.1%	3	42.9%	7	5.3%
6-12 hrs	3	75.0%	1	25.0%	4	3.1%
Horizontal overjet						
> 6mm	0	0.0%	3	100.0%	3	2.3%
0 mm	4	80.0%	1	20.0%	5	3.9%
1 to 3 mm	21	24.1%	66	75.9%	87	67.4%
4 to 6 mm	7	20.6%	27	79.4%	34	26.4%
Vertical occlusion type						
deep	3	9.7%	28	90.3%	31	24.0%
normal	25	28.1%	64	71.9%	89	69.0%
open	4	44.4%	5	55.6%	9	7.0%
Number of surfaces involved						
1	2	13.3%	13	86.7%	15	12.0%
2	0	0.0%	3	100.0%	3	2.4%
3	1	14.3%	6	85.7%	7	5.6%
4	11	19.0%	47	81.0%	58	46.4%
5	15	35.7%	27	64.3%	42	33.6%
Behavior						
1	0	0.0%	6	100.0%	6	4.7%
2	1	14.3%	6	85.7%	7	5.5%
3	9	24.3%	28	75.7%	37	29.1%
4	19	24.7%	58	75.3%	77	60.6%
Displacement						
0 mm	23	26.7%	63	73.3%	86	96.6%

1-3 mm	2	66.7%	1	33.3%	3	3.4%
Tooth mobility						
0	17	22.4%	59	77.6%	76	71.7%
1	9	39.1%	14	60.9%	23	21.7%
2	4	66.7%	2	33.3%	6	5.7%
no mobility	0	0.0%	1	100.0%	1	0.9%

Discussion

These results support the findings of other studies regarding the healing of permanent teeth following certain injury types of varies apical statuses[19 7, 10-14, 17, 18, 23, 25] Statistical analysis found a near significant association between apical maturity at the time of injury and healing. Across all injury types, teeth with a Moorrees score of five or less were found to have better healing that teeth with a Moorrees score of 6 at the time of injury, indicating a mature apex. These results represent important clinical significance in terms of predicting the ability of a tooth to heal following dental injuries that occur in combination as teeth that are mature at the time of injury are more likely to have pulpal necrosis and lack of continued apical development and root wall thickening. All teeth involved in a dental injury should be monitored closely and teeth with mature apices should be scrutinized carefully due to the increased risk of pulpal necrosis. In contrast to previous literature, this study did not find any differences in the type of injury sustained and the ability of teeth to heal following injury[6, 19, 23, 25]. However, this is likely the result of the limited sample size that was obtained. A minimum follow up time of at least three months was chosen for this study based on the findings of Soares, et al, who found that healing complications were more frequently diagnosed after three months[35].

Interestingly, none of the initial visit flowsheet parameters were found to have a significant effect on the healing of the study cohort. These descriptive findings tend to support previous literature regarding the epidemiology of dental trauma[3, 4, 9, 25]. More severe periodontal injuries, such as lateral luxation injuries, occurred with less frequency than less severe periodontal injuries like concussion and subluxation. However, class II fractures were reported more frequently than class I fractures. This may be due to lack of documentation of injuries that are perceived to be less severe in the dental trauma flowsheets.

Electronic medical record (EMR) systems have revolutionized the ways in which medicine and dentistry are practiced and have greatly influenced data collection in these fields[29]. EMRs have created a more streamlined way to store and access data and to communicate between providers. The Dental Trauma Databased flowsheets are an effective system for recording demographic and clinical information regarding dental trauma. These flowsheets have allowed for intrinsic standardization of multiple clinicians and allow for all clinical and radiographic data to be readily accessed and compared at successive appointments. At the research level, this data can be accessed retrospectively in a comprehensive and organized way[30, 36]. The ability to easily pull this data can aid in large scale analyses to be performed in order to understand and creation treatment protocols for many aspects of clinical dentistry[9, 36].

This study had many strengths in its methods, calibration, and patient sample. In utilizing the trauma database flowsheets, the recording of dental trauma was limited in the subjectivity of assessments. Clinical documentation requires subjective assessments of certain aspects of dental trauma which can vary widely by practitioners. The

Nationwide Children's Hospital Dental Clinic contains over fifteen providers (pediatric dental residents) who are assessing and entering the trauma flowsheet data, and this is complicated by resident turn over in this setting. The trauma flowsheets eliminate a large amount of the subjectivity associated with the assessment and recording of dental trauma by providing a standard list of responses to each recorded parameter. Additionally, this study was unique in the calibration utilized for radiographic review. Utilizing three calibrated examiners viewing the radiographs under the same consistent conditions allowed for reliability in the radiographic analysis. This again aids to eliminate subjectivity in the documentation of dental trauma. Finally, This study had a relative large sample size compared to other studies of combination dental trauma[10-12].

This study had a few notable limitations. While the flowsheets attempt to decrease the subjectivity of the clinical and radiographic assessments, this could not be entirely eliminated. Additionally, this study was limited by the retrospective data pull itself. The retrospective data was obtained by a data specialist who is not a dental practitioner and without specific knowledge of the dental traumas that were being investigated. It is likely that there was a reduction in sample size at the level of the retrospective data acquisition due to this lack of dental knowledge. The final major limitation to this study was a lack of standardized radiographic technique. Radiographs were exposed by a number of dental assistants with varying radiographic technique, resulting in a wide range of captured radiographic information. A number of subjects were excluded due to a lack of diagnostic radiographs, resulting in a decrease in sample size. Having standard radiographic technique would eliminate these errors and could improve the accuracy of radiographic scoring among examiners.

Conclusion

This study supports the notion that apical maturity at the time of healing is significantly related to healing potential following certain combinations of dental trauma. Teeth with immature apices at the time of healing have better healing that those with mature apices at the time of injury. Clinicians can more reliably predict prognosis following injury and determine treatment plans for patients following trauma. Electronic databases are important tools for documentation of dental trauma over time and serve as a reliable tool for studying this information over time.

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