Analysis of a Comprehensive Dental Trauma Database: An Epidemiologic Study of
Traumatic Dental Injuries to the Permanent Dentition

THESIS

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the Graduate School of The Ohio State University

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Abstract

**Objective:** To utilize a comprehensive dental trauma database to analyze the demographic profiles of traumatic dental injury (TDI) patients with respect to mechanism of injury (MOI), cost analysis, concomitant injuries, and comorbid conditions.

**Methods:** This study is a retrospective cross-sectional analysis on a population of children seeking treatment for TDIs at Nationwide Children’s Hospital (NCH) Emergency Department (ED) and NCH Dental Clinic over a 28-month period. This study utilizes a comprehensive dental trauma database linked to the patient electronic medical record for analysis.

**Results:** Data collection was completed for a total of 826 patients (284 females, 542 males). A total of 1218 injured teeth were included in the study with patients ranging in age of 5 to 21 years old. The mean age of patients in our study was 13 years old while the peak incidence of TDIs in our study was 9 years of age. The gender distribution of TDIs is weighted towards the male population with males suffering 818 TDIS (67%). A total of 1218 permanent teeth were analyzed for TDIs and periodontal injury types, season of occurrence, and combination fracture injuries. MOI was also correlated to age and gender. The cost of an average ED visit was correlated to type of TDI and compared to TDI charges in the Dental Clinic. Chi-square analysis was used to compare databases for
reliability. TDIs were analyzed for associations with concomitant injuries and patients with comorbid conditions.

**Conclusions:** Descriptive data and TDI distribution is mainly in agreement with other national and international data with regard to gender, age, injury type, and MOI. There is little significant difference between the two databases analyzed in regard to periodontal injury type and tooth fracture types. Facial laceration was found to be the most common concomitant injury. Patients with any comorbidity are significantly more likely to have a severe TDI than patients without comorbidities. Patients with Behavior Disorders (ADHD, ODD) and Seizures (Epilepsy) are significantly more likely to have a severe TDI than patients without these comorbid conditions.
Dedication

This document is dedicated to my family for your support and encouragement. And to my dog, Ruger, for patiently waiting for me to finish school so that we may enjoy our next adventure together.
Acknowledgments

I would like to thank my committee for their time, support, and guidance throughout this project. I would also like to thank Brent Merryman for his expertise and assistance with the Electronic Database Warehouse.
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Fields of Study

Major Field: Pediatric Dentistry
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Chapter 1: Introduction

Dental trauma is a common problem in the pediatric population and its sequelae can result in significant morbidity affecting patients throughout their lives. The impact of trauma affects the individual, their family, and society and spans physical, psychosocial, and economic boundaries. A traumatic dental injury (TDI) is an important public health dental problem due to frequency, costs, occurrence at a young age, and burden of treatment that may occur throughout the patient’s life [1].

Although the oral region comprises as small an area as 1% of the total body area, it accounts for 5% of all bodily injuries. In preschool children, oral injuries make up as much as 17% of all bodily injuries [2]. The incidence of TDIs in children has been reported at 1-3% while the prevalence is steady at 20-30% [2]. In a study by Kaste et al., it was found that 18.4% of a United States population had sustained at least one TDI to their permanent teeth during their lifetime [3]. The significance of TDIs and their overall impact on oral health is further compounded by the fact that dental trauma tends to occur most frequently at a young age. TDIs reportedly demonstrate a bimodal peak incidence at ages 2-4 and ages 8-10. Children at ages 2-4 are learning how to walk and becoming increasingly mobile while children at ages 8-10 are being introduced into organized sports [4]. Thus, the majority of TDIs occurring in the pediatric population when the facial structures and dentition are at important stages of growth and development and the
sequelae of TDIs may have an impact on oral health for the remainder of a patient’s lifetime.

Many epidemiologic studies of TDIs have reported on common injury characteristics and etiology. The majority of TDIs involve anterior teeth, especially the maxillary central and lateral incisors, regardless of the type of study [1]. Background factors such as age and gender are known to have impact on risk of TDIs. Males are known to experience significantly more dental trauma to the permanent dentition than females [5]. Age is another well-known risk factor for TDIs. A majority of TDIs occur in childhood and adolescence—it is estimated that 71-92% of all TDIs sustained in a lifetime occur before the age of 19 years [1, 6]. Other reported risk factors include a large maxillary overjet and incomplete lip closure [7]. Burden [8] observed that subjects with an overjet greater than the normal range (0-3.5 mm) were significantly more likely to have experienced an injury to the maxillary incisors. Race and ethnicity data as well as socio-economic status have been less studied and results have been conflicting. Despite the known risk factors, environment and activity may be of greater importance to the occurrence of TDIs than gender and age [1]. Occurrence of dental trauma is clearly multifactorial and is greatly influenced by a combination of human behavior, activity, and environmental surroundings in addition to the clearly defined risk factors described above. Well-described risk profiles are yet to be developed and few studies have given a full profile on the children involved and the time and place of reported TDIs [9].

Mechanism, or etiology, of TDIs can vary widely. Accidents at home and school account for most injuries to the permanent dentition—with accidents due to falls being the most common factor in both primary and permanent dentitions [5]. Common
accidents resulting in TDIs include falls, sports injuries, motor vehicle accidents, bicycle accidents, horseplay, and being struck by an object. Non-accidental causes of TDI can include assaults and abuse. A previous study by Wilson at Nationwide Children’s Hospital (NCH) in Columbus, Ohio, over an 11-month period reflected the most commonly reported epidemiologic characteristics of TDIs. Wilson [10] reported on 541 patients that had a TDI in an 11-month period with 40% being over 7 years of age and 59% being male. The etiology of TDI in that study was most commonly due to falls (63%), while being struck by an object accounted for 17% and motor vehicle accidents resulted in 2%.

Dental trauma can result in a number of different types of injury involving the tooth and the supporting structures. Six types of luxation and nine types of tooth fracture have been described and used to classify TDIs [11]. Periodontal injuries are classified as concussion, subluxation, lateral luxation, intrusion, extrusion, and avulsion injuries. The 9 types of fracture injuries are classified as: infraction, enamel fracture, enamel/dentin fracture, enamel/dentin/pulp fracture, crown/root fracture with pulpal involvement, crown/root fracture without pulpal involvement, isolated root fracture, alveolar fracture, and jaw fracture. The complexity of a TDI is further increased by the possibility of combination injuries involving luxation injuries and fracture injuries to the same tooth [12]. Each of these trauma scenarios has a specific treatment protocol and prognosis for healing. Wilson’s NCH study reported that of the 541 TDIs seen in an 11-month period, 33% were tooth fractures, 18% luxations, 12% concussions, 8% avulsions, and 1% jaw fractures. Enamel/dentin fractures were the most common injury in the permanent dentition [10]. Luxation injuries have occurred more frequently in the younger age
groups studied and are the most frequent injury in the primary dentition [13] due to the elasticity of the supporting tissues at a young age.

The burden of treatment of TDIs has great financial and time consuming impact on patients and their families. Substantial life-long time and cost commitments are associated with treatment of TDIs in childhood. Recent cost data estimates that the lifetime cost to replace a single tooth ranges from US $20-$35,000 when accounting for all direct and indirect costs and may require an average of 7.2 hours of treatment time in the first year [14-16]. The overall economic impact of dental trauma can be significant. In Denmark, the annual cost of treatment alone (acute trauma service, follow-up, and subsequent restoration) of TDIs reportedly ranges from US $2-$5 million per million inhabitants per year [17]. Dental trauma is more time-consuming and costly to treat than many other outpatient accidental injuries [2]. The average number of treatment visits on an outpatient basis during 1 year due to dental trauma to a permanent tooth has been shown to range from 1.9-9.1 [18, 19], compared to an average of 1.5 visits for other similar bodily injuries [20].

Beyond the economic cost is the psychosocial burden that TDIs have on the patient and their quality of life. A traumatic injury is a painful and distressing event—injuries to the mouth and teeth can be particularly unpleasant and are often implicated with dental anxiety and fear in patients. It is accepted that the appearance and position of the anterior teeth have psychological and social impacts on children [21]. A study by Cortes et al. stated that children with fractured teeth were 20 times more likely to report impact on their daily living than children with no traumatic dental injury [22]. An injury to the permanent dentition that affects the appearance of the front teeth can significantly
impact a child’s self-esteem and emotional development. When anterior teeth are fractured or lost, children are often self-conscious and hesitant to return to school without an esthetic replacement of the tooth. Full repair of the anterior dentition rarely occurs immediately and is often temporary and with compromised esthetics [23].

Not only can a TDI impact a child’s quality of life—it has an impact on their learning and development. Previous research on the impact of TDIs on children’s quality of life have reported that because of dental visits and problems 117,000 hours of school were lost per 100,000 school-aged children [24]. There is a potential chain of risk from having a dental injury to the development of adverse psychological outcomes, and later in life to experience cognitive, labor and marital adversity [22].

Data warehouses have emerged in many industries during the past 15 years as a standard method for managing enterprise data. The enormous amount of data being collected by Electronic Medical Records (EMRs) has found additional value when integrated and stored in data warehouses [25]. However, their adoption by healthcare organizations has been less pervasive due to the complexity and heterogeneity of biomedical, operational, and clinical data [26].

The Enterprise Data Warehouse (EDW) is a database environment used for reporting and analyzing data from the entire NCH organization. It supports operational, research, and clinical analytics from all hospital departments and allows all data from NCH—a hospital with numerous inpatient and outpatient facilities—to be integrated and analyzed. The EDW supports the principals of data integration, time-variation, and non-volatility. This means that data that are gathered into the EDW from a variety of sources are merged into a coherent whole, all data in the EDW are identified with a particular
time period, and all data in the EDW are stable and though more data are added data are
never removed.

The EDW is constructed into four layers: data acquisition, data integration, EDW
tables, and data access. The EDW is further organized into Universes that are specialized
banks containing data for specific hospital departments. A Universe is custom-made by
the EDW support team to meet the demands of each hospital department pertaining to
content, presentation, and user-friendliness. The goal of the EDW is to deliver
trustworthy data necessary for NCH to engage in reporting and analytical activities
including research, quality and practice improvement and management, outcomes
improvement, cost reduction, and individualized evidence-based medicine.

In 1998, Kaiser Permanente reported that it not only found ways to save millions
of dollars in healthcare costs, but also was able to improve the quality of care with the
knowledge gleaned from its data warehouse [27]. The use of the Dental Trauma Database
(DTDB) within the NCH EDW system provides well-structured and accessible
information about TDI events, risks, outcomes, and resource utilization that have the
potential to fundamentally transform the study of dental injuries within the NCH Health
System. The DTDB also addresses the challenges in dental traumatology research by
creating a standardized and uniform data collection system that allows us to detect
trends over time. These analytics promise to transform the capacity for quality
improvement, research productivity, and evidence based treatment of dental injuries.

It is clear that traumatic dental injuries are an important public health problem
that can significantly impact the growth and development of children. Many
epidemiologic studies emphasize TDI prevalence with little analysis of etiology of injury
and risk profile. A clear description of the risk profile may assist in the allocation of resources and treatment protocols to improve the efficiency and treatment outcomes of TDIs. One aim of this study is to analyze the demographic profiles of TDI patients with a focus on mechanism of injury (MOI) and correlation of etiology to type of dentoalveolar injury sustained. There has also been little investigation of associated systemic trauma and co-morbidities with TDIs. Finally, other epidemiological studies of TDIs have reported demographic data but are limited to dental charts and dental health records [9, 28, 29]. In fact, many published studies and data collected worldwide are limited to dental health centers or dental trauma centers separate of a hospital or overall healthcare setting. Many of these dental-specific trauma centers do not have the benefit of access to a patient’s overall electronic medical record (EMR) and some may still employ paper-charting systems. In this epidemiologic study of TDIs, we have the benefit of a dental trauma database (DTDB) that is linked to the EMR through an Enterprise Data Warehouse (EDW). This provides a novel holistic approach to the study of TDIs and greatly expands the power of dental trauma analysis to include the overall health and demographic information of patients in the outpatient and inpatient hospital setting. The DTDB provides access to continuous long-term data collection on dentoalveolar injuries and unprecedented access to patient health information and data analytics. These data will assist in the development of TDI patient risk profiles, optimization of treatment, costs and resource allocation and preventative measures that will aid in the reduction of personal and financial burden of TDIs.

The primary objective of this study is to utilize the comprehensive dental trauma database to analyze the demographic profiles of TDI patients. Specifically, we wish to
focus on the mechanism of injury (MOI) and correlation of etiology to type of dentoalveolar injury sustained. Secondary aims include cost analysis of TDIs treated in the NCH Emergency Department and to compare them to TDIs treated in the NCH Dental Clinic. We also wish to analyze average costs for specific injury types. The final aim is to analyze comorbid conditions and concomitant injuries associated with TDIs.
Chapter 2: Methods

**Development**

The digital Nationwide Children’s Hospital (NCH) (Nationwide Children’s Hospital Department of Pediatric Dentistry, Columbus, OH 43205) Dental Trauma Database (DTDB) was conceived in 2003 with the creation of a Microsoft Access (Microsoft Inc., Redmond, Washington) database. The initial Access DTDB was designed to collect information on TDI to the permanent dentition from children presenting to the NCH Emergency Department after hours. TDIs that presented to the NCH Outpatient Dental Clinic during normal office hours were not recorded in the Access Database. All patients who sought treatment at NCH were received regardless of the severity of their trauma and were treated by the resident on-call during the hours of 5PM to 9AM. The on-call resident recorded patient information on a paper-based Dental Trauma Form [30]. These data were then manually entered into the Microsoft Access DTDB. The Access DTDB contained data on dental trauma that occurred at NCH from 08/27/2003 through 12/31/2011. In November of 2011, NCH underwent a hospital-wide transition from a paper-based health record to an electronic medical record (EMR) using the digital EMR software Epic (Epic Systems, Verona, Wisconsin). Thus, the once paper-based Dental Trauma Form evolved into a customized digital Dental Trauma Exam
Flowsheet (DTEF). Additional variables were added to expand the potential for analysis such as the mechanism of injury (MOI), Electric Pulp Testing (EPT), and radiographic findings, as well as the addition of an Initial Exam Dental Trauma Flowsheet and a Follow-Up Exam Dental Trauma Flowsheet. The design and development of these DTEFs was described in a previous master’s thesis publication and has since been beta-tested and optimized [30]. An Epic software team is responsible for active upkeep and support of the DTEFs and design has been optimized to minimize free text and input error. All residents received training on the use of the DTEFs and were standardized in their data entry. With the addition of the new digital DTEFs into Epic, residents were instructed to record data on every TDI seen at NCH, including TDIs seen during clinic hours in the NCH Dental Clinic. The Epic DTEFs went live for use in the NCH Dental Clinic and NCH ED on 10/06/2011.

The input of TDI data into the DTEFs within Epic is made available for search and analysis in the EDW analytics environment. All data recorded in the Access DTDB since 2003 was retroactively backlogged into the EDW and is accessible to search. Data is extracted by querying the DTDB using specific algorithms designed to yield target data in a Web Intelligence (WebI) Report. A user may query and filter data to create customized data reports designed and organized for their specific analytic needs[30]. The creation of the DTDB is within a specific Dental Trauma Universe. A dedicated team of EDW support staff and EDW programmers developed this Dental Trauma Universe in conjunction with a previous dental resident as described in Reynolds et al. [30]. The DTDB went live through EDW on 11/16/2012 and was available for data mining and analysis.
**Study Design**

A retrospective cross-sectional analysis was completed on a population of children seeking treatment for TDIs at NCH ED and NCH Dental Clinic from 11/01/2011 to 02/28/2014 (28 months). Data is accessed in the EDW through a BusinessObjects product called a Web Intelligence Report (WebI). The WebI Reports allow users to mine data and customize how the data is reported and organized. Data was collected from patient records using WebI query methods to develop WebI reports. Only TDIs to permanent teeth were included in this study. Information gathered included patient gender, age at the initial date of trauma, date of trauma, mechanism of injury (MOI), type of TDI, tooth/teeth involved in trauma, history of previous trauma, and associated co-morbidities and concomitant injuries. MOI included animal bite, abuse, assault, automobile accidents (including pedestrian struck), bicycle/scooter injury, fall, gunshot wound, hit by object, sports injury, and skateboard/skates, and other. Type of TDI was divided into Fracture Type and Periodontal Injury Type. Fracture Type includes enamel only, enamel/dentin, enamel/dentin/pulp, isolated root fracture, crown and root fracture, enamel/dentin/cementum (no pulp), and enamel/dentin/cementum (with pulp). Periodontal Injury Type includes concussion, subluxation, lateral luxation, intrusion, avulsion, and extrusion. Data were entered electronically into DTEFs by trained residents standardized in the clinical examination and treatment of TDIs according to the International Association of Dental Traumatology (IADT) Guidelines [31-33]. Periapical
radiographs and review of all clinical cases by the same investigator confirmed the diagnosis.

In order to study risk of TDI associated with having specific comorbidities, we categorized dental injuries as severe or non-severe and analyze the effect of having a comorbidity on the binary outcome of injury severity. Based on a paper by Andreasen et al. [34] which described healing outcomes for various dental injuries, we categorized injuries into severe or non-severe categories.

**Statistics**

Descriptive statistics were calculated using Microsoft Excel Software (Microsoft Inc., Redmond, Washington). Statistical analysis was carried out by the Nationwide Children’s Hospital Biostatics Core using the SAS 9.3 software (SAS Institute Inc., Cary, North Carolina). The distribution of dental injury types between the two databases (Access vs. EDW) was compared using Chi-Square test. The effect of having any comorbidity on the binary outcome severity of injury (severe vs. non-severe) was tested using Logistic Regression. The effect of having a specific comorbidity on the binary outcome severity of injury was also provided with odds ratios. P value < 0.05 was considered significant.
Chapter 3: Results

Data collection was completed for a total of 826 patients (284 females, 542 males). A total of 1218 injured teeth were included in the study with patients ranging in age of 5 to 21 years old. The mean age of patients in our study was 13 years old. The peak incidence of TDI in our study was 9 years of age. The gender distribution of dental trauma was weighted towards the male population with males suffering 818 TDIs (67%). A total of 1218 permanent teeth were analyzed for TDIs and periodontal injury types. Periodontal injury was correlated with gender and age as illustrated by Table 1 and Figures 1-4.

<table>
<thead>
<tr>
<th></th>
<th>N (%)</th>
<th>TOTAL</th>
<th>AVULSION</th>
<th>CONCUSSION</th>
<th>EXTRUSION</th>
<th>INTRUSION</th>
<th>LATERAL LUXATION</th>
<th>NONE</th>
<th>SUBLUXATION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total</strong></td>
<td>1218 (100)</td>
<td>76 (6)</td>
<td>545 (45)</td>
<td>48 (4)</td>
<td>47 (4)</td>
<td>149 (13)</td>
<td>92 (7)</td>
<td>258 (21)</td>
<td></td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>818 (67)</td>
<td>59 (5)</td>
<td>355 (29)</td>
<td>31 (3)</td>
<td>29 (2)</td>
<td>116 (10)</td>
<td>63 (5)</td>
<td>165 (14)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>398 (33)</td>
<td>17 (1)</td>
<td>190 (16)</td>
<td>17 (1)</td>
<td>18 (1)</td>
<td>32 (3)</td>
<td>28 (2)</td>
<td>93 (7)</td>
<td></td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-10 years</td>
<td>636 (53)</td>
<td>26 (35)</td>
<td>296 (55)</td>
<td>16 (34)</td>
<td>36 (78)</td>
<td>62 (42)</td>
<td>46 (51)</td>
<td>154 (60)</td>
<td></td>
</tr>
<tr>
<td>11-15 years</td>
<td>381 (32)</td>
<td>41 (55)</td>
<td>162 (30)</td>
<td>21 (45)</td>
<td>8 (17)</td>
<td>48 (33)</td>
<td>32 (35)</td>
<td>69 (27)</td>
<td></td>
</tr>
<tr>
<td>16-20 years</td>
<td>186 (15)</td>
<td>8 (11)</td>
<td>82 (15)</td>
<td>10 (21)</td>
<td>2 (4)</td>
<td>36 (25)</td>
<td>13 (14)</td>
<td>35 (14)</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. TDI Correlated with Age and Gender
Figure 1. Periodontal Injury Type
Figure 2. TDI Correlated with Age
Periodontal Injury Type vs. Gender

Figure 3. Periodontal Injury Correlated with Gender
Figure 4. Periodontal Injury Correlated with Age
The distribution of TDIs correlated with race/ethnicity is illustrated by Figure 5.

Figure 5. TDI correlated with Race/Ethnicity
TDIs were analyzed by time of year, or season of occurrence and day of week the treatment was rendered with results illustrated in Table 2 and Figures 6-7.

<table>
<thead>
<tr>
<th>Season</th>
<th>2012 TDIs (%)</th>
<th>2013 TDIs (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td>53 (10)</td>
<td>96 (17)</td>
</tr>
<tr>
<td>Spring</td>
<td>139 (27)</td>
<td>223 (39)</td>
</tr>
<tr>
<td>Summer</td>
<td>165 (32)</td>
<td>105 (19)</td>
</tr>
<tr>
<td>Fall</td>
<td>166 (32)</td>
<td>143 (25)</td>
</tr>
</tbody>
</table>

Table 2. TDI Correlated with Season

Figure 6. TDI Correlated with Season
Figure 7. TDI Correlated with Day of Week Treatment Rendered
A total of 615 had combination periodontal injuries and fracture injuries with fracture type illustrated in Table 3 and Figure 8.

<table>
<thead>
<tr>
<th>Tooth Fracture Type</th>
<th>N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CROWN+ROOT</td>
<td>6 (1)</td>
</tr>
<tr>
<td>ENAMEL+DENTIN</td>
<td>406 (63)</td>
</tr>
<tr>
<td>ENAMEL+DENTIN+CEMENTUM (NO PULP)</td>
<td>6 (1)</td>
</tr>
<tr>
<td>ENAMEL+DENTIN+CEMENTUM (WITH PULP)</td>
<td>16 (3)</td>
</tr>
<tr>
<td>ENAMEL+DENTIN+PULP</td>
<td>76 (14)</td>
</tr>
<tr>
<td>ENAMEL ONLY</td>
<td>95 (16)</td>
</tr>
<tr>
<td>ISOLATED ROOT</td>
<td>10 (2)</td>
</tr>
</tbody>
</table>

Table 3. Tooth Fracture Types (Combination Injuries)

Figure 8. Tooth Fracture Types (Combination Injuries)
Mechanism of injury correlated with gender and age is illustrated in Table 4 and Figures 9-11.

<table>
<thead>
<tr>
<th>N (%)</th>
<th>ANIMAL BITE</th>
<th>ASSAULT</th>
<th>MVA</th>
<th>BICYCLE</th>
<th>FALL</th>
<th>HIT BY OBJECT</th>
<th>OTHER</th>
<th>SKATEBOARD/SKATES</th>
<th>SPORTS INJURY</th>
<th>SWIMMING POOL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>2 (0.1)</td>
<td>108 (7.2)</td>
<td>67 (4.5)</td>
<td>156 (10.4)</td>
<td>666 (44.4)</td>
<td>213 (14.2)</td>
<td>44 (2.9)</td>
<td>22 (1.5)</td>
<td>205 (13.7)</td>
<td>13 (0.9)</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>1 (0.1)</td>
<td>96 (7.6)</td>
<td>34 (2.7)</td>
<td>95 (7.5)</td>
<td>287 (22.7)</td>
<td>126 (10.0)</td>
<td>28 (2.2)</td>
<td>15 (1.2)</td>
<td>173 (13.7)</td>
<td>7 (0.6)</td>
</tr>
<tr>
<td>Female</td>
<td>1 (0.1)</td>
<td>12 (0.9)</td>
<td>33 (2.6)</td>
<td>59 (4.7)</td>
<td>179 (14.2)</td>
<td>62 (4.9)</td>
<td>10 (0.8)</td>
<td>7 (0.6)</td>
<td>31 (2.5)</td>
<td>6 (0.5)</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-10 years</td>
<td>1 (0.2)</td>
<td>13 (2.0)</td>
<td>22 (3.4)</td>
<td>101 (15.5)</td>
<td>309 (47.4)</td>
<td>108 (16.6)</td>
<td>23 (3.5)</td>
<td>19 (2.9)</td>
<td>52 (8.0)</td>
<td>4 (0.6)</td>
</tr>
<tr>
<td>11-15 years</td>
<td>1 (0.2)</td>
<td>56 (13.7)</td>
<td>30 (7.4)</td>
<td>46 (11.3)</td>
<td>111 (27.2)</td>
<td>56 (13.7)</td>
<td>11 (2.7)</td>
<td>1 (0.2)</td>
<td>91 (22.3)</td>
<td>5 (1.2)</td>
</tr>
<tr>
<td>16-20 years</td>
<td>0 (0.0)</td>
<td>39 (20.0)</td>
<td>15 (7.7)</td>
<td>3 (1.5)</td>
<td>43 (22.1)</td>
<td>24 (12.3)</td>
<td>4 (2.1)</td>
<td>2 (1.0)</td>
<td>61 (31.3)</td>
<td>4 (2.1)</td>
</tr>
</tbody>
</table>

Table 4. MOI Correlated with Gender and Age
Figure 9. Mechanism of Injury
Figure 10. MOI Correlated with Gender
Figure 11. MOI Correlated with Age
The cost of an average ED visit was correlated to type of traumatic dental injury. Charges that were not directly related to the TDI were controlled for. Figures 12-13 illustrate the average ED cost of periodontal injury types and tooth fracture types and are compared to the estimated clinic charges.

Figure 1. Comparison of ED and Clinic Charges for Periodontal Injuries
Figure 2. Comparison of ED and Clinic Charges for Tooth Fractures
Using Chi-square test we analyzed the Access DTDB and the EDW DTDB for significant differences in periodontal injury types and tooth fracture types. This analysis is illustrated in Figures 15-18. By using Chi-square test, p value <0.0001, there is significant difference in the distribution of Periodontal Injury types between two databases. More patients in EDW had “Concussion” type injuries and less patients in EDW had no periodontal injury (“None”) compared to Access as shown in Figures 14-15.

![Access DTDB Total Periodontal Injuries](image)

Figure 3. Access DTDB Periodontal Injuries
Figure 4. EDW DTDB Periodontal Injuries
There is a significant difference in the distribution of Tooth Fracture types between two databases. More patients in EDW had “ENAMEL+DENTIN+CEMENTUM(WITH PULP) type than in Access and less patients in EDW(12.7%) had (ENAMEL+DENTIN+PULP) than in Access (19.7%) as illustrated in Figures 16-17.
The association between TDIs and concomitant injuries is illustrated in Table 5 and Figure 18.

<table>
<thead>
<tr>
<th>Concomitant Injury</th>
<th>N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concussion</td>
<td>10 (1.2)</td>
</tr>
<tr>
<td>Facial Laceration</td>
<td>338 (40.9)</td>
</tr>
<tr>
<td>Facial Bone Fractures</td>
<td>10 (1.2)</td>
</tr>
<tr>
<td>Traumatic Brain Injury</td>
<td>2 (0.2)</td>
</tr>
</tbody>
</table>

Table 5. TDIs with Concomitant Injury

Figure 7. TDI correlated with Concomitant Injury
Patients with TDIs and associated comorbidities were analyzed presence of TDI and injury severity with results illustrated in Tables 6-7 and Figure 19.

<table>
<thead>
<tr>
<th>Comorbidity</th>
<th>TDI (N)</th>
<th>TDI (%)</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDD(Autism)</td>
<td>23</td>
<td>1.58</td>
<td>1</td>
</tr>
<tr>
<td>Behavior Disorder (ADHD, ODD)</td>
<td>143</td>
<td>9.81</td>
<td>8.33</td>
</tr>
<tr>
<td>Seizures (Epilepsy)</td>
<td>34</td>
<td>2.33</td>
<td>1.62</td>
</tr>
<tr>
<td>Cerebral Palsy</td>
<td>19</td>
<td>1.3</td>
<td>0.79</td>
</tr>
<tr>
<td>No Comorbidity</td>
<td>1239</td>
<td>84.98</td>
<td>83.04</td>
</tr>
</tbody>
</table>

Table 6. TDI Associated with Comorbidities
Table 7. Comorbidities Associated with Severe or Non-Severe TDI

<table>
<thead>
<tr>
<th>Comorbidity</th>
<th>Total</th>
<th>No Comorbidity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PDD (Autism)</strong></td>
<td>23</td>
<td>565</td>
</tr>
<tr>
<td>Severe</td>
<td>16</td>
<td>302</td>
</tr>
<tr>
<td>Not Severe</td>
<td>7</td>
<td>263</td>
</tr>
<tr>
<td><strong>Behavior Disorders (ADHD, ODD)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>143</td>
<td>561</td>
</tr>
<tr>
<td>Severe</td>
<td>110</td>
<td>298</td>
</tr>
<tr>
<td>Not Severe</td>
<td>33</td>
<td>263</td>
</tr>
<tr>
<td><strong>CP</strong></td>
<td>19</td>
<td>565</td>
</tr>
<tr>
<td>Severe</td>
<td>19</td>
<td>302</td>
</tr>
<tr>
<td>Not Severe</td>
<td>0</td>
<td>263</td>
</tr>
<tr>
<td><strong>Epilepsy</strong></td>
<td>34</td>
<td>562</td>
</tr>
<tr>
<td>Severe</td>
<td>27</td>
<td>301</td>
</tr>
<tr>
<td>Not Severe</td>
<td>7</td>
<td>261</td>
</tr>
</tbody>
</table>

Figure 8. Comorbidity Type associated with TDI
The risk of having a severe TDI for any comorbidity and for specific comorbidity types was analyzed using logistic regression with results illustrated in Table 8 and Figures 20-21.

<table>
<thead>
<tr>
<th>Comorbidity</th>
<th>Odds Ratio</th>
<th>95% Confidence Interval</th>
<th>95% Confidence Interval</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any Comorbidity</td>
<td>2.08</td>
<td>1.476</td>
<td>2.93</td>
<td>0.0001</td>
</tr>
<tr>
<td>PDD (Autism)</td>
<td>1.99</td>
<td>0.806</td>
<td>4.911</td>
<td>0.1355</td>
</tr>
<tr>
<td>Behavior Disorder (ADHD, ODD)</td>
<td>2.942</td>
<td>1.927</td>
<td>4.49</td>
<td>0.0001</td>
</tr>
<tr>
<td>Seizures (Epilepsy)</td>
<td>3.345</td>
<td>1.433</td>
<td>7.807</td>
<td>0.0052</td>
</tr>
</tbody>
</table>

Table 8. Odds of Having Severe TDI by Comorbidity Type
Figure 21. Risk Ratio of Having Severe TDI by Comorbidity Type
Chapter 4: Discussion

The results of this study cohort demonstrate that the majority of TDIs were minor injuries such as concussions and subluxations. The category “None” is an artifact of the initial database when residents did not record fractured teeth as also having a combination periodontal injury. For example, before 2012 crown fractures were not also classified as concussion or subluxation periodontal injuries. Thus, the total number of concussion and subluxation injuries in our study population would likely be larger if the “None” injuries were classified correctly. These data align well with previous studies that used a similar injury classification [6], [12], [35].

Our study showed that a majority of injuries were combination injuries, with almost 50% of injuries (615/1218) involving fractures and periodontal injuries. Reported combination injuries were somewhat lower in a previous study by Lauridsen et al. (31.5%) [12]. The higher prevalence of combination injuries found in our study may be explained by sampling bias as a higher frequency of severe injuries may be expected at a hospital emergency clinic compared with school-based or dental specific health services. For example, a study by Cavalcanti et al. [28] on a population of 7-12-year-old Brazilian children reported 54% of TDIs were fractures in enamel-only, 17% concussion injuries, and 11.7% fractures in enamel and dentin. However, these data were collected in a public
school and thus minor injuries were analyzed retrospectively while a majority of these patients were not likely treated for these minor injuries in a hospital setting.

In our analysis relating TDI incidence to time of year (seasonal injuries), our data are not consistent across seasons from 2012 to 2013. One would assume that summer would be associated with the highest injury rate in this northern hemisphere study. However, our data does not clearly display this pattern. One consistency in our data is that winter months have the lowest TDI incidence. These data do not corroborate current literature, which lists the summer months as the highest rates of injuries for similar climates to Ohio. Wright et al. found a clear peak in the incidence of dental trauma during the three summer months of July through September (33%) [9]. This difference was also noted by Altay et al. [36] in their sample of 246 dental injuries in Turkish children (54% spring/summer vs 46% winter/autumn). One possible explanation for the inconsistency in seasonal TDI incidence from 2012 to 2013 is that we have only collected data over a 2-year period and we need more time to visualize clear longitudinal trends.

The incidence age peak of traumatic injuries in this sample was at 9 years of age. The reported peaks of age related to dental trauma vary from study to study, with some authors presenting a peak age group such as Wright et al. [9] (8-11 years) while some authors present a peak age in single years such as Gabris et al. [37] (10 years of age). It is difficult to make simple and direct comparisons between studies due to the variation in age groupings and sampling methods throughout the scientific literature. However, our study corroborates the general trend of age distribution in the literature with peaks of trauma having previously been reported at 8-10 [35] and 8-11 as described above [9].
The gender distribution within this sample was weighted towards the male population at a ratio of 2.1:1. A study by Wright et al. on a population in Glasgow, UK reported male:female ratio of 1.5:1 [9]. A number of previous studies have also reported a similar distribution of males to females with TDIs with Canakci et al. [38], Tapias et al. [39], and Skaare et al. [35] reporting ratios from 1.8:1 to 2.18:1. These studies were limited to the permanent dentition. However, there is less polarity in gender distribution in the primary dentition as reported by Kramer et al. [40] who described male and female preschool children as being equally effected by traumatic dental injuries.

Our data demonstrate that White and Black/African American patients predominate in incidence of TDI. More information is needed about the hospital-wide demographic profiles and NCH Emergency Department and NCH Dental Clinic patient ethnic distribution to deduce which ethnicities/races have increased risk for TDI. The relationship between dental trauma and race and ethnicity is obscure. Ethnic minorities tend to experience more financial adversities and live in more deprived areas which are factors difficult to control for in TDI studies [1]. Only a few studies have recorded the race and ethnicity of the individuals studied. In one study, a similar prevalence of TDI was noted in various race-ethnicity categories in the USA [3], which is not consistent with our race/ethnicity TDI incidence data.

Our mechanism of injury (MOI) data clearly demonstrate that the largest single cause of TDI in our study population was due to falls (44.4%). These data corroborate the findings of Wright et al. [9] (49%) and Tapias et al. [39] (46%). Our data demonstrate that sports injuries (14%) and being struck by an object (14%) are also common etiologies in our population. Wright et al. [9] reported that sports related injuries occurred
in 18% of cases. Further studies in geographically diverse populations have found contradictory rates, with Skaare et al. [35] finding that sports and assault injuries in Norway accounted for 8% of TDIs. Canakci et al. [38] studied a Turkish population and found that falls accounted for 27%, while assault (24%), sports (18%), and road traffic accidents (11%) were the other major etiologies.

Our data relating MOI to gender demonstrates that certain MOIs in our sample are weighted toward male patients such as assaults and sports related injuries. Motor vehicle accidents had no gender predilection. Wright et al. [9] reported a similar gender distribution related to assaults. However, Wright et al. [9] also reported that falls had no gender bias. These data are not corroborated by our population, which also shows a male bias toward falls. As described above, our data show a large gender bias with sports related injuries. However, a recent shows a reduction in this gender difference in sports, which may reflect the increased interest in sports among females [8]. Our population data clearly demonstrate that males have an increased risk for sports-related injuries compared to females. It would be interesting to monitor these data longitudinally to see if there are shifts in gender predilection etiologies over time.

When MOI was correlated to age we found a very clear pattern of younger children (6-10 years of age) experiencing a TDI due to falls, 14 year olds had a majority of TDIs related to assaults, and 15-17 year olds had a majority of TDIs caused by sports. These data are corroborated by Wright et al. [9] who reported that the younger age groups studied had a majority of TDIs caused by falls (89%). However, this study does include injuries to primary teeth and it is widely reported that falls are the most common mechanism of injury in the primary dentition.
Comparison of periodontal injuries and fracture injuries across the Access DTDB and EDW DTDB was completed with a chi-squared analysis to determine significant differences and reliability. When we analyzed periodontal injury percentages across databases, we found that there is a significant difference in the distribution of “CONCUSSION” type injuries and the category of “NONE” with the EDW DTDB having more “CONCUSSIONS” (46.7%) and less “NONE” injury types (7.9%) compared to Access DTDB (26.2%) and (17.8%) respectively. These data are consistent with the modifications to the current EDW DTDB in which any patient with a crown fracture is now, by definition, considered to have a combination injury and those in the previous database did not categorize fractures as having combination concussion injuries. The “NONE” category is an artifact of this same modification and is no longer a valid option for periodontal injury type. Similarly, the Access DTDB and EDW DTDB are similar in fracture types and only differ significantly in the “COMPLICATED” fractures across the databases. These differences may be attributed to several different factors and the evolution of the residency from the induction of the Access DTDB in 2003 to the current EDW DTDB. For example, several changes in the residency have occurred since the Access DTDB began in 2003, with an increase in resident numbers per class from 5 to 7 and a change from in-house call to home-call in 2012. In addition, there are a relatively small number of injuries in the EDW DTDB (1218 teeth) compared to the Access DTDB (3,276 teeth). Over time, the proportions of periodontal injuries and fracture types across both databases will likely become more aligned with further longitudinal analysis and an increase in the injury numbers of the EDW DTDB.
Cost analysis data were averaged for each injury seen in the NCH Emergency Department and organized into periodontal injury types and tooth fracture types. These data were compared to the estimated costs per injury in the Dental Clinic. Only charges directly relating to the dental injury experience were included by filtering out charges non-specific to the dental trauma. This method has some limitations, as it is impossible to control for all charges applied in the Emergency Department. It is interesting that for almost every type of injury, an ED visit was at least double that of a dental visit. Cost was not necessarily directly related to injury severity, though in the ED trauma setting an avulsion, extrusion, intrusion, and lateral luxation would often have a similar treatment protocol. Often, the most expensive ED charge was that decided at the point of triage where the patient was charged depending on their Emergency Severity Index (ESI) [41]. For tooth fracture injuries, ED charges are much greater than clinic charges, as expected. Root fracture charges are higher than other crown fractures as they may involve splinting treatments (a splint or tooth re-implantation charge is $494.75). We would expect an “Enamel+Dentin+Pulp” injury to have higher costs than “Enamel Only” and “Enamel+Dentin” Fracture Types as the pulp exposure tooth fracture should often involve a partial pulpotomy. However, our average charges did not reflect this difference. The utility of the EDW DTDB to determine cost of dental injuries is a unique and powerful feature. There is little evidence available on the true direct long-term cost of dental trauma in terms of US dollars [16, 17, 42, 43]. Most of these investigations of TDI economics estimate long-term costs of TDIs and do not directly average or calculate costs. In a Swedish study by Glendor et al. [42], direct costs (average treatment time, costs of health care professionals and other labor, capital costs, and supplies) plus indirect
costs (costs due to the loss of production or leisure) were estimated to be US $3,300-$4,400 per 1 million individuals in patients up to 19 years of age [2]. In addition, using the EDW DTDB we have the unique ability to separate costs according to location of charges and type of periodontal injuries or tooth fracture types. There were several limitations to these data, for example, we could not control for patients who had multiple injuries. Further investigation into emergency coding language and billing is needed to delineate multiple injury charges and investigate TDI costs further.

Our investigation of TDIs and concomitant injuries reveal that facial lacerations are the by far the most common concomitant injuries. A reason that may account for the lack of other severe concomitant injuries such as concussions, facial bone fractures, and traumatic brain injuries in our study population is that severe trauma patients were likely not initially treated by the pediatric dentist in the Emergency Department. Severe concomitant facial and head injuries are classified as cranio-maxillofacial trauma and are routed to Oral Maxillofacial, Ear-Nose-Throat, or Plastics specialties for treatment. To investigate patients that suffered TDIs and severe concomitant injuries, we would have to perform a retrospective chart audit or access other EDW Universes involving OMFS, plastic surgery, or orthopedic surgery departments. It would be interesting for a further investigation of concomitant injuries to relate facial bone fractures and severe head injuries to mechanism of injury, specifically motor vehicle accidents, sports injuries, and bicycle injuries. Gassner et al. [44] recently showed that children in traffic accidents have a more than twofold risk of facial bone fractures when compared to other injury types. Acton et al. [45] reported that 31% of children under the age of 15 years with facial injuries as a result of bicycle accidents had a TDI. Thompson et al. [46] noted that bicycle
helmets reduce the risk of facial injuries by 65%, but the users are still at high risk of
dental trauma because of lack of protection of the lower face and jaw. Future direction of
the EDW DTDB should explore helmet use and collect data on helmet wear for our
bicycle injury patients and investigate whether TDIs and concomitant injuries are
modified by helmet use.

We analyzed Pervasive Developmental Disorders (Autism), Behavior Disorders
(attention-deficit hyperactive disorder (ADHD) and oppositional defiance disorder
(ODD)), seizure disorders (Epilepsy), and Cerebral Palsy as comorbidities to TDI.
Patients were queried for comorbid conditions based on ICD-9 diagnosis codes. Our data
demonstrate that nearly 10% of patients with behavior disorders such as ADHD have
experienced a TDI. Far less patients in our study cohort had comorbid diagnoses with
seizure disorders, cerebral palsy, and pervasive developmental disorders. These data
corroborate current literature that reports that ADHD is one of the most common
neurodevelopmental/behavioral disorders of childhood, occurring in approximately 6% of
school-aged children [47, 48]. Recently, the association between ADHD and dental
trauma has been studied in 8- to 17-year-old children [49]. This study suggests that
ADHD in children is a predisposing factor for TDIs. A study by Lee et al. [50] reported
that children with ADHD were about 2-3 times more likely to experience an injury that
needed medical treatment compared to unaffected controls. In another study,
Sabuncuoglu [51] concluded that the risk for TDIs is more pronounced before young
patients with ADHD have received treatment and their behaviors normalized. In
disagreement with these studies, some researchers have suggested no relationship
between traumatic dental injuries and emotional symptoms, conduct disorder, or hyperactivity [52, 53].

Using logistic regression, we found that patients with any comorbidity are significantly more likely to have severe TDI than patients without comorbidities, odds ratio=2.08, 95CI of odds ratio = ((1.476, 2.930), P < 0.0001). We found that patients with behavior disorders (ADHD, ODD) and seizure disorders (Epilepsy) are significantly more likely to have a severe TDI than patients without these disorders. We did not have a statistically significant number of patients with Cerebral Palsy and TDI for the risk analysis. Current literature suggests that Epilepsy and Cerebral Palsy are comorbidities that increase patients’ risk of TDIs. Bessermann [54] reported that 52% of epileptic patients had suffered dental trauma, many of which were of a repetitive nature. Far fewer studies have investigated TDI comorbidities such as Autism and Cerebral Palsy. Holan et al. [55] described a prevalence of 57% in CP individuals despite the fact that CP individuals do not take part in risky sport activities as frequently as healthy individuals. A 2010 study by Altun et al. [56] on a Turkish population found an increased rate of TDI (23%) in the Autistic patient population compared to the control group (15%), however the difference in rates between the 2 groups was not statistically significant. Given the variations in prevalence rates of autistic disorder across the literature, it is impossible to reach categorical conclusions regarding the relationship between TDI and autistic disorder. One major limitation of our comorbidity risk analysis is that it fails to answer whether each comorbidity type is directly related to the traumatic dental injury through mechanism of injury. At this time, we do not have the power to answer this question due to limitations in the design of the EDW, but through future development of the EDW
DTDB this question may be further explored. In addition, it has been reported that obese children are significantly more prone to dental trauma than non-obese children [57]. The diagnosis of obesity should be added to future investigations of comorbidity risk analysis for TDIs using the EDW DTDB.

It is clear that the EDW DTDB is a unique and important research tool for the analysis of long-term longitudinal data on TDIs. With the continued collection of data and optimization of the database, there is great potential for expansion of literature directly related to the Nationwide Children’s Hospital organization. Some specific future interests include analyzing the percentage of permanent teeth with open or closed apices and injury outcomes such as pulpal survival. It will also be interesting to include primary teeth in these analyses. It is also important, once the database is further developed, to analyze comorbid conditions and control for injuries that are not directly related to the comorbid condition by further investigating mechanism of injury. Finally, for the comorbidity analysis it would be very powerful to have access to the dental population that has not experienced a dental injury and determine the risk of any dental injury for patients with comorbid conditions compared to those without.
Chapter 5: Conclusions

For the population in this investigation, our descriptive data and distribution of traumatic injuries is mainly in agreement with other national and international data with regard to gender, age, injury type, and mechanism of injury. Minor differences in outcome may reflect social, cultural, and methodological differences between the investigations. Minor inconsistencies between our data and literature may be accounted with further longitudinal analysis. Given the difficulty in making direct comparisons between the variety of confounding variables relating to TDI epidemiology, it would be beneficial for dental traumatology researchers to adopt a uniform method of TDI data collection and reporting. This would enable more accurate planning and protocols for treatment of TDIs.

The access database and the EDW database have few significant differences and are consistent and well-aligned. Cost analysis clearly shows that treatment for TDIs in the ED is a significant burden on the healthcare system and charges are not necessarily aligned with injury type. Facial lacerations are the most common concomitant injury, though it is likely that severe head injury and facial bone fracture are related to severe injuries that the dentist may not see in the ED.

Finally, Patients with any comorbidity are significantly more likely to have severe TDI than patients without comorbidities. Patients with Behavior Disorders (ADHD,
ODD) and Seizures are significantly more likely to have a severe TDI than patients without these disorders.

It is clear after working with the EDW dental trauma database, and the Enterprise Data Warehouse environment as a whole, that it is an extremely powerful analytic tool. The EDW Dental trauma database can create a wealth of knowledge and ultimately expand dental trauma research.
References

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