The Incidence of Root Canal Therapy or Extraction after Orthodontic Treatment: A Ten-Year Retrospective Study

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THE INCIDENCE OF ROOT CANAL THERAPY OR EXTRACTION AFTER ORTHODONTIC TREATMENT: A TEN-YEAR RETROSPECTIVE STUDY

by

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ABSTRACT
THE INCIDENCE OF ROOT CANAL THERAPY OR EXTRACTION AFTER ORTHODONTIC TREATMENT: A TEN-YEAR RETROSPECTIVE STUDY

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INTRODUCTION: The impact of orthodontic treatment on anterior teeth specifically in relation to root canal therapy and extraction has not been previously described. The objective of this study was to evaluate the incidence of root canal therapy and extraction after orthodontic treatment in the anterior permanent dentition.

Methods: We analyzed insurance claims and enrollment data for individuals enrolled with Delta Dental of Wisconsin from 2008 to 2017. A total of 63,720 teeth from 5310 patients who had Delta Dental insurance at age 10 were included in the study. The Cox Regression model was used to analyze the effect of the predictor variables, including orthodontic treatment on the survival of anterior teeth. The survival time was defined as the time from when patients turned ten years old to when extraction/root canal occurred. Teeth without an adverse event were censored at the end of continuous insurance coverage. All dental treatment procedures were identified using CDT codes (Code on Dental Procedures and Nomenclature).

Results: Out of 63,720 teeth, only 1910 (2.9%) teeth of 1184 unique subjects had a root canal and 54 (.08%) had an extraction. The majority of root canals and extractions occurred in the maxillary teeth, specifically the central incisors. In addition, males were more at risk of extraction or root canal therapy than females (Female vs Male HR =0.650 $p < 0.05$). Cox regression showed that there is no added risk of extraction or root canal after the start of orthodontic treatment compared to before orthodontic treatment (after vs before orthodontics HR 1.105 $p > 0.05$).

Conclusions: Orthodontic therapy is a safe and effective treatment modality for malocclusion and may not be directly associated with an increased risk of root canal therapy or extraction. The risk of endodontic treatment or extraction is considerably higher in males compared to females and is more likely to occur on the permanent maxillary central incisors compared to other anterior teeth.

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INTRODUCTION

Malocclusion is considered the third most common oral health issue worldwide behind dental caries and periodontal disease (1). According to Angle (2), malocclusion can be defined as an irregular or abnormal relationship between the teeth of the maxillary and mandibular arches upon closure of the jaws. While no single index or definition of malocclusion is a clear candidate for epidemiological studies, the prevalence of malocclusion in the United States ranges from 35% to 95% (3). Depending on its severity, malocclusion has the potential to cause disturbances to an individual's craniofacial development, facial aesthetics, and overall oral health and function (4). Thirty to forty percent of the population exhibits moderate to severe malocclusion and therefore treatment is indicated to minimize the disturbances outlined above (3).

Comprehensive orthodontic therapy is an accepted treatment modality to correct malocclusion (5). Treatment is most often initiated upon completion of eruption of the permanent dentition unless the patient exhibits significant skeletal discrepancies (6). Orthodontic treatment creates forces on the jaws, periodontium and teeth to align problem areas (7). According to Whishney (7), potential risks of orthodontic therapy include periodontal damage, pain, root resorption, temporomandibular problems, caries, speech difficulties and damage to enamel. The length of treatment, magnitude of force applied, direction of tooth movement, amount of apical displacement, and method of force application are contributing factors to the risks involved in orthodontic treatment (8).

Given the increasingly litigious nature of our culture, obtaining informed consent could not be more crucial. The doctrine of informed consent requires healthcare

providers to inform patients of the nature of the proposed treatment, the benefits and risks of such treatment, and the alternatives to treatment, including no treatment (9). It is currently not understood if orthodontic forces can lead to pulpal devitalization requiring endodontic therapy or extractions (10, 11). Therefore, the purpose of our study was to evaluate the likelihood of anterior teeth needing root canal therapy or extractions following orthodontic treatment. This information is pertinent as it may be necessary to include in the informed consent to individuals undergoing orthodontic treatment and ultimately may be considered a risk factor.

LITERATURE REVIEW

Indications for Orthodontic Treatment:

Malocclusion can be described as the irregular and abnormal relationship between the teeth and jaws upon closure. Angle's paper in 1899 was the first attempt to classify malocclusion based on molar relationships (2). Additionally, Ackerman and Proffit (12) advanced this classification by evaluating the relationship of the teeth in multiple dimensions as well as the facial profile of the patient.

Angle's classification remains the foundation of describing malocclusion. However, advances in other types of classification and description have allowed for a more thorough evaluation of occlusion and alignment to determine an individual's need for orthodontic treatment. The Index of Orthodontic Treatment Need is particularly useful when evaluating the need for orthodontic treatment. The index value is determined by the presence and severity of abnormalities belonging to five categories: missing teeth, overjet, crossbite, displacement of anatomical contact points and overbite (13).

Indications for orthodontic treatment may include the prevention of trauma, elimination of psychosocial stressors associated with malocclusion, correction of abnormal facial growth and dentitional development (14). Optimal facial aesthetics and smile are also motivators for individuals to seek out orthodontic treatment regardless of their occlusion (15).

Epidemiologic studies show a high prevalence of trauma amongst the pediatric population, specifically children ages 7-11 years old (16). Males have a greater incidence of trauma which increases with age (16). Malocclusion, particularly protruding maxillary incisors, can increase the likelihood of a dental injury (16, 17). Data shows one third of

children with an untreated class II malocclusion will experience significant trauma to the maxillary incisors, resulting in a fracture of the tooth and/or devitalization of the pulp (18). Therefore, orthodontic therapy is often indicated to eliminate an individual's malocclusion and subsequently decrease the risk for dental trauma.

Additionally, facial irregularities have a negative impact on a person's perception of social functionality. Those with an abnormal facial appearance are seen as less intelligent, less employable, and less effective than people with normal appearance (19). Skeletal discrepancies are commonly treated with surgical orthodontic treatment. The aim is to create a cohesive relationship between the upper and lower jaws and to improve occlusion function, with the end goal of the patient's psychosocial well-being (15).

Basic Orthodontic Treatment Procedures:

According to Berry (20), abnormal bites typically start between the ages of 6 and 12. Appropriate timing of orthodontic treatment is often dependent on the type and severity of malocclusion.

Early treatment or Phase I is typically initiated in the primary or mixed dentition with the goal of enhancing the dental and skeletal development before eruption of the permanent dentition (14). The duration of Phase I treatment usually lasts a few months to a year (14). Malocclusions involving anterior crossbites, posterior crossbites, open bites secondary to non-nutritive sucking habits or a skeletal class III relationship should be addressed early with Phase I treatment.

Comprehensive orthodontics is known as Phase II treatment and is usually initiated in the full permanent dentition, lasting an average of 12 to 36 months (21). Treatment approaches vary and range widely, but the first stage of comprehensive

treatment involves teeth alignment and leveling with brackets and archwires. With crossbites, impacted teeth, and diastemas, other methods can be utilized to help with the alignment. The second stage focuses on the correction of molar relationships and space closure, while the last stage involves the adjustment of individual tooth positions, midline placement, and final settling of teeth (5).

Orthodontic tooth movement involves osseous and periodontal tissue remodeling using mechanical forces with wires and brackets (20). The theory proposes that force-subjected periodontal ligament progenitor cells differentiate into compression associated osteoclasts and tension associated osteoblasts causing bone resorption and apposition, respectively (22). The alteration in the blood flow within the periodontal ligament is produced by the sustained pressure that causes the tooth to shift position (23)

Pulpal and Periodontal Changes Secondary to Orthodontic Treatment

There risks of orthodontic treatment may include periodontal damage, pain, root resorption, tooth devitalization, temporomandibular disorder, caries, speech problems, and enamel damage (7). From an ethical standpoint, the clinician must understand and communicate how these risks relate to the patient to ensure they will benefit from comprehensive treatment (24).

Root Resorption:

The American Academy of Endodontic's Glossary of Terms defines resorption as *physiologic or pathologic loss of dentin, cementum, and/or bone not immediately due to caries or trauma* (25). The area of damage and the tissues involved are determining factors in the classification of specific types of resorption. External apical root resorption involves the permanent loss of tooth structure at the root apex (26). Multiple factors may

contribute to the development of external apical root resorption including biologic characteristics, genetic predisposition, as well as the forces involved in orthodontic treatment (27, 28)).

Biological risk factors that have been identified to potentially increase occurrence of root resorption include genetics, endocrine problems, age and gender, chronic alcoholism, asthma, previous history of root resorption and more (28). Orthodontic treatment risk factors include treatment duration, magnitude of force, direction of tooth movement, amount of apical displacement, and method of force application during treatment (29). Teeth that are moved too rapidly or with excessive force often result in permanent resorption of cementum at the apex of the tooth cementum (29). The hallmark sign of root resorption with pathologic origin is the shortening of the root apex, coinciding with a history of orthodontic treatment (30). Although known risk factors have been identified to increase occurrence of root resorption, the long-term survival of teeth with resorption remains unknown (31).

Orthodontic root resorption is typically mild, with severe radiographically evident resorption occurring only 1-5% of the time and more frequently in maxillary incisors (32). Diagnosis of external apical root resorption can be made via radiographic evaluation as well as histologic analysis. Studies have shown histological incidence of root resorption to be substantially higher than radiographic incidence with more than 90% of orthodontically treated teeth exhibiting some degree of root resorption (33).

The classification for different types of apical external resorption based on severity was proposed by Levander and Malmgram. Level 1 resorption is described as minimal and leaves an irregular apical root contour. Level 2 states the resorption is no

greater than 2mm on the hard tissues. Level 3 is resorption up to the first third of the root. And level 4 is defined as extreme resorption with extension beyond the first third of the root length (34)

A type of resorption that is much less understood and linked to orthodontic treatment is invasive cervical resorption (35). Heithersay (36) defined this defect as a localized resorptive process originating from the external root surface. This pathologic process usually occurs below the epithelial attachment of the tooth at the cervical region (37). Damage to the cementum of the tooth leads to exposure of underlying root surface to osteoclasts which then resorb dentin (38). The etiology of the damage to the cementum has not been concluded. Orthodontic treatment, dental trauma, internal bleaching, and idiopathic etiology have all been linked to invasive cervical resorption (36, 39). Heithersay(37) also determined that orthodontic treatment alone was a predisposing factor for 24.1% of teeth with invasive cervical resorption and this affected mostly maxillary anterior teeth. This defect can lead to root canal therapy or extraction if the defect is extensive.

Pulpal Devitalization:

The pulp of teeth are encased in rigid mineralized tissue and has a low compliance environment, having minimal capacity for defense or repair. Any increased tissue pressure resulting from increases in vasodilation and plasma exudation during inflammation can cause blood vessel compression and pulp necrosis (40).

Orthodontic forces do not only induce changes to the external aspects of teeth but it has been shown to alter molecular changes in the pulp dentin complex (10). It has been thought that orthodontic forces could compromise the tooth permanently by creating non-

vitality, leading to root canal therapy (41). Although root canal therapy is very successful (42), it may cause the tooth to be more prone to root fracture in the future (43).

The histologic changes noted by Oppenheim's study of orthodontic therapy on the pulp concluded the pulp was one of the most sensitive tissues in the body, noting the pulpal degeneration seen by his research (44). In a study by Mostafa (45), it was determined that orthodontic forces can result in pulpal reactions including odontoblastic degeneration, circulatory disturbances, vacuolization and edema of pulp tissues and fibrotic changes. Another investigation by McDonald and Pitt Ford (46) found that human pulpal blood flow decreased when continuous light tipping forces were applied to a maxillary canine. In a study comparing impacted canines to non-impacted canines, 21% of impacted canines displayed radiographic pulpal obliteration, 25% of them did not respond to electric pulp testing, and 3% of these teeth required root canal treatment (47).

However, there is evidence that contradicts these findings. Valadare's research on rapid maxillary expansion in teenagers showed no changes in the pulp or dentin after 120 days (48). Furthermore, it was concluded that induced tooth movement did not promote morphological disturbances in the pulp detectable by light microscopy according to Consolardo (49). It has also been studied that pulpal blood volume increases with orthodontics but returns to normal levels 24 to 72 hours after forces have been placed (50). Most alterations in pulpal blood flow that result from orthodontic treatment are reversible, unless the pulp has been previously irritated by caries, restorations or trauma (51).

Dental Trauma to the Permanent Dentition

Trauma to the orofacial region is a common finding in young patients as stated by Andersson (52). Literature reports that 25% of all school aged children and 33% of adults have experienced dental trauma, with most of these injuries occurring before nineteen years old (53). A large percentage of dental trauma amongst the adolescent population occurs secondary to falls and collisions and most often involves the permanent maxillary central incisors (54). Furthermore, males are more frequently affected by traumatic injuries than females as well as children known to participate in risk-related behaviors (55).

Research has shown that malocclusion, specifically a pronounced overjet, can increase an individual's chance of experiencing dental trauma. Petti(56) reported that individuals with an overjet greater than 3mm were two and a half times more at risk compared to individuals who had normal overjet. In addition, Nguyen(57) stated that the greater the overjet, the greater the risk of injury. A study involving a twelve year old population revealed that dental trauma injuries were significantly higher in patients who were male, had an overjet greater than 5mm, and inadequate lip coverage. The teeth most affected were the maxillary central incisors (58).

Several types of dental injuries exist including crown and root fractures, concussion, subluxation, and luxation. Crown fractures are the most common of all dental injuries to occur in the permanent dentition whereas luxation injuries are more common in the primary dentition (59).

Pulpal and Periapical Outcomes Secondary to Trauma

The primary complications resulting from dental trauma include pulp necrosis and infection, pulp canal obliteration, various types of root resorption and breakdown of marginal gingiva and bone (60).

Pulpal necrosis and infection is more likely to occur in a tooth that experiences multiple types of injuries as compared to a single injury. In addition, a tooth with mature root development is more likely to experience pulpal necrosis following dental trauma as compared to a tooth with immature root development (55). Teeth with immature apices may experience spontaneous pulp revascularization which allows continued root development and avoids need for root canal treatment (52).

Pulp canal obliteration (PCO) or calcific metamorphosis is a common occurrence following dental trauma, especially in teeth with open immature apices. It frequently occurs following extrusion, intrusion and lateral luxation injuries (61). Radiographically, pulp canal obliteration involves the deposition of hard tissue in the canal space while clinically, the coronal aspect of the tooth exhibits a pronounced yellow hue. Up to 25% of anterior teeth with a history of dental trauma can develop pulp canal obliteration, with the frequency being dependent on the severity of the dental trauma and stage of root formation (62). PCO is a response of a vital pulp to severe trauma which could potentially lead to pulp necrosis (52). However, the literature states that pulpal necrosis and apical periodontitis are not common complications of PCO (62). In certain cases of significant coronal discoloration from pulp canal obliteration, root canal therapy is a reasonable option to address aesthetic concerns via internal bleaching (63).

External inflammatory root resorption following trauma is common with avulsed teeth. Avulsion accounts for 16% of all dental traumatic injuries in the permanent dentition (55). The beginning of external inflammatory resorption following trauma results from mechanical damage to the periodontal ligament and to the root surface at the time of injury as well as the presence of necrotic and infected pulp.

Thorough evaluation and follow up is crucial for traumatized teeth, as root canal therapy is often indicated. The potential for a successful outcome is high when patient compliance is optimal allowing for treatment to be completed in a timely manner (55).

Additional Causes of Pulp Devitalization and Tooth Loss:

Dental caries is one of the most common chronic diseases in the world (64). It has been demonstrated to have a multi-factorial etiology in which three primary factors contribute its initiation and progression: the host (saliva and teeth), the microflora (plaque) and the substrate (diet) (65). Dental caries is a localized, destructive and progressive infection of dentin, which can potentially result in pulpal necrosis and tooth loss (66).

Research has suggested that the overall caries prevalence is declining, however is highest amongst the adolescent population. This may be attributed to a high cariogenic diet, poor oral hygiene habits, or immature tooth enamel (67). Adolescents undergoing orthodontic treatment are at a heightened caries risk, especially when treatment involves an appliance given the presence of retentive areas that cause biofilm accumulation (68). Traditional fixed appliances produce stagnation zones which produce a challenge to mechanical plaque control. Bracket design will also influence caries risk and periodontal parameters as well (69). The severity of the resultant dental caries can range from

development of opaque white-spot lesions (WSL) or decalcification, to loss of surface integrity of enamel resulting in cavitation. A study analyzing WSL demonstrated that 49.6% of orthodontic patients exhibited enamel opacities on at least one tooth after orthodontic treatment (70). The prevalence of WSL after orthodontic therapy was reported to be 12% higher compared to pretreatment and this increase lasted for 5 years after appliance removal (71).

It is not clear in the literature review if orthodontic therapy is a completely safe treatment modality for children with malocclusion. There are many risks to orthodontic therapy (7). However, children are also likely to experience trauma(55) and/or caries(70) in their adolescence which can also cause teeth to need root canal therapy or extraction, similarly to orthodontic treatment. The goal of our study is determining if orthodontic therapy poses a significant additional risk to an adolescent needing root canal therapy or extraction.

MATERIALS AND METHODS

The data for this study was obtained from the electronic insurance enrollment and claims database for Delta Dental of Wisconsin. The database contained information of 63,720 teeth from 5310 unique patients who had insurance at the age of 10 years between 2002 and 2014. From the dataset, a total of 1,184 patients who underwent orthodontic treatment were identified based on the Code on Dental Procedures and Nomenclature (CDT) codes for comprehensive orthodontic treatment. CDT codes are used to properly and uniformly document dental treatment procedures in patients' health records, and to process insurance claims. The main codes used for our age group were comprehensive orthodontic treatment of the adolescent (D8080) and interceptive orthodontic treatment of the transitional dentition (D8060), and were identified as initiating events. All anterior teeth(6-11, 22-27) were followed and untoward events were recorded. Untoward events were defined as having initial root canal therapy (D3310, D3320, D3330) or extraction (D7140, D7210), as defined by CDT codes.

Teeth were considered healthy until an untoward event with follow up or a until lapse in the patient's enrollment status occurred. The variables were summarized by the mean, standard deviation, median and range for continuous variables. Categorical variables of frequency and percentage were also recorded. Due to the low number of events, a tooth and its contralateral have been grouped together as well as grouped into upper (Teeth 6-11) and lower (Teeth 22-27) teeth. Analyses were performed using the SAS 9.4 software(SAS institute Inc., Cary, NC). A Kaplan-Meier analysis was completed to plot survival probability. Survival time was taken as the time from when a patient turned 10 to when an untoward event occurred. Clustering within the subject was

accounted for by using the software to obtain robust standard error estimates. Kaplan Meier plots and the survival estimates at several time points are provided for each variable of interest. Cox proportional hazards regression was used to compare survival distributions between categories for each predictor and the p-value from the robust score test was obtained. Orthodontic treatment was treated as a time-dependent covariate in the Cox regression analysis, with subjects transitioning to the "post-orthodontic treatment" status on the date of the start of the orthodontic treatment. The effect of the predictors on tooth survival was analyzed. A significance level (alpha) of $p< 0.05$ was used throughout all analyses.

RESULTS

After exclusion criteria were applied to the dataset, 63720 teeth from 5310 unique patients had insurance at age 10 between 2002-2014. Of the 5310 patients enrolled in the study, 1184 had orthodontic treatment. The mean age of the patients at the receipt of treatment was 12.93 years old and 89.4% of those patients were between the ages of 10 and 15, with a range from 10 to 20 years of age. The CDT code 8080 was used 95% of the time and 8060 code was used the other 5%.

A summary of events by tooth number was calculated for all anterior teeth of the entire data set as seen in Table 1. A tooth was categorized as "failed" as soon as a root canal or extraction code was encountered. The set of 63720 teeth produced 1963 failures. Root canals accounted for 1910(3%) and extraction accounted for 53(0.1%). Of the failures, majority of the root canals were completed on #8 and #9, with 1271 root canals completed. Teeth #7 and #10 accounted for 365 root canals, and teeth 6/11 had 42 root canals completed. On the mandible, 167 root canals occurred on #24 and #25 compared to 56 on teeth #23/25, and 9 on teeth 22/27. Majority of extractions were in the maxilla with teeth #8 and #9 with 23 extractions, teeth #7 and #10 with 15 extractions, and teeth 6/11 with 10 extractions. Only 5 extractions were completed on the mandible, with 3 extractions on #24/25.

Table 1: Age at orthodontic treatment and type of orthodontic treatment.

Variable	All (N = 1184)
Age	
Mean (SD)	12.93 (1.64)
Median [Min, Max]	12.81 [10.00, 20.94]
Freq Missing	0
Age	
10 - <11	136 (11.5%)
11 - <12	228 (19.3%)
12 - <13	295 (24.9%)
13 - <14	258 (21.8%)
14 - <15	141 (11.9%)
15+	126 (10.6%)
Freq Missing	0
Type of orthodontic treatment	
8060	53 (4.5%)
8080	1131 (95.5%)
Freq Missing	0

Table 2: Summary of events by tooth number.

Variable	All (N = 63720)	6, 11 (N = 10620)	7, 10 (N = 10620)	8, 9 (N = 10620)	22, 27 (N = 10620)	23, 26 (N = 10620)	24, 25 (N = 10620)
Event							
Censored	61757 (96.9 %)	10568 (99.5%)	10240 (96.4%)	9326 (87.8%)	10610 (99.9%)	10563 (99.5%)	10450 (98.4%)
Fail	1963 (3.1%)	52 (0.5%)	380 (3.6%)	1294 (12.2%)	10 (0.1%)	57 (0.5%)	170 (1.6%)
Event							
Censored	61757 (96.9 %)	10568 (99.5%)	10240 (96.4%)	9326 (87.8%)	10610 (99.9%)	10563 (99.5%)	10450 (98.4%)
Extraction	53 (0.15)	10 (0.1%)	15 (0.1%)	23 (0.2%)	1 (0.0%)	1 (0.0%)	3 (0.0%)
Root canal	1910 (3.0%)	42 (0.4%)	365 (3.4%)	1271 (12.0%)	9 (0.1%)	56 (0.5%)	167 (1.6%)

Note: A tooth was considered 'fail' as soon as a root canal / extraction code was encountered.

Kaplan-Meier analysis of all teeth in the set showed, starting at age 10, a 1 year survival rate of 99.52%, 3 year rate of 98.67%, 5 year rate of 97.59%, and 10 year of 95.20% for all untoward events. The gender plot Kaplan-Meier analysis for females showed a 1 year survival of 99.63%, 3 year survival rate of 99.03%, 5 year survival rate of 98.13%, and 10 year survival rate of 96.14% as seen in Figure 1. For males, the plot shows a 1 year survival rate of 99.44%, 3 year survival rate of 98.38%, 5 year survival rate of 97.14%, and 10 year survival rate of 94.39%. Using a univariate unadjusted CoxPH regression analysis, the hazard ratio of 0.66 for females compared to males indicates a 34% lower hazard rate for females ($p < 0.001$), which was statistically significant.

The Kaplan-Meier analysis for tooth number 8/9 survivability was much lower than any other teeth. A 1 year survival probability of 8/9 was 97.83%, 3 year survival probability was 93.99%, 5 year survival probability was 89.86%, and 10 year survival probability was 82.04%. The univariate unadjusted Cox proportional hazards regression p values were all significant ($p < 0.001$) showing teeth 8/9 had lower survivability probability compared to all teeth examined in this study. Compared to teeth 8/9, hazard ratio showed that teeth 6/11 and 23/26 had a 96% lower hazard rate, teeth 22/27 had a 99% lower hazard rate, and teeth 24/25 had a 88% lower hazard rate. The next highest hazard ratio compared to #8/9 was teeth #7/10 with a 0.28 hazard ratio, indicating a 72% lower hazard rate. Unsurprisingly, the mandibular teeth compared to the maxillary teeth had a low hazard ratio of 0.13, indicating a 87% lower hazard rate.

A multiple Cox proportional hazards regression analysis evaluated the time averaged effect of orthodontic treatment with regard to both untoward events. The comparison of the hazard before vs. after orthodontic treatment showed a hazard ratio of 1.105 (95% CI: .97-1.2, p=.122) indicating no significant increase in the hazard ratio as seen in Table 3. This analysis was broken down to compare the yearly effect of orthodontic treatment from year 0 to 1, 1-2, 2-3, 3-4, and 4+. (Figure 4). This analysis was also carried out comparing the yearly effect of orthodontics with failure as root canal therapy and, separately, failure as being extraction (Table 4 and 5; Figure 5 and 6).

In years 2-3 after initiation of orthodontic therapy, results show a higher risk of untoward event with hazard ratio of 1.376 and p value of 0.015. Furthermore, the Cox regression of the yearly effect of orthodontic treatment with failure being only root canal therapy, showed a hazard ratio of 1.327 with a p value of 0.031. Finally, the cox regression of the yearly effect of orthodontic treatment with failure being only extraction shows p values lower than 0.05 for all years after orthodontic therapy.

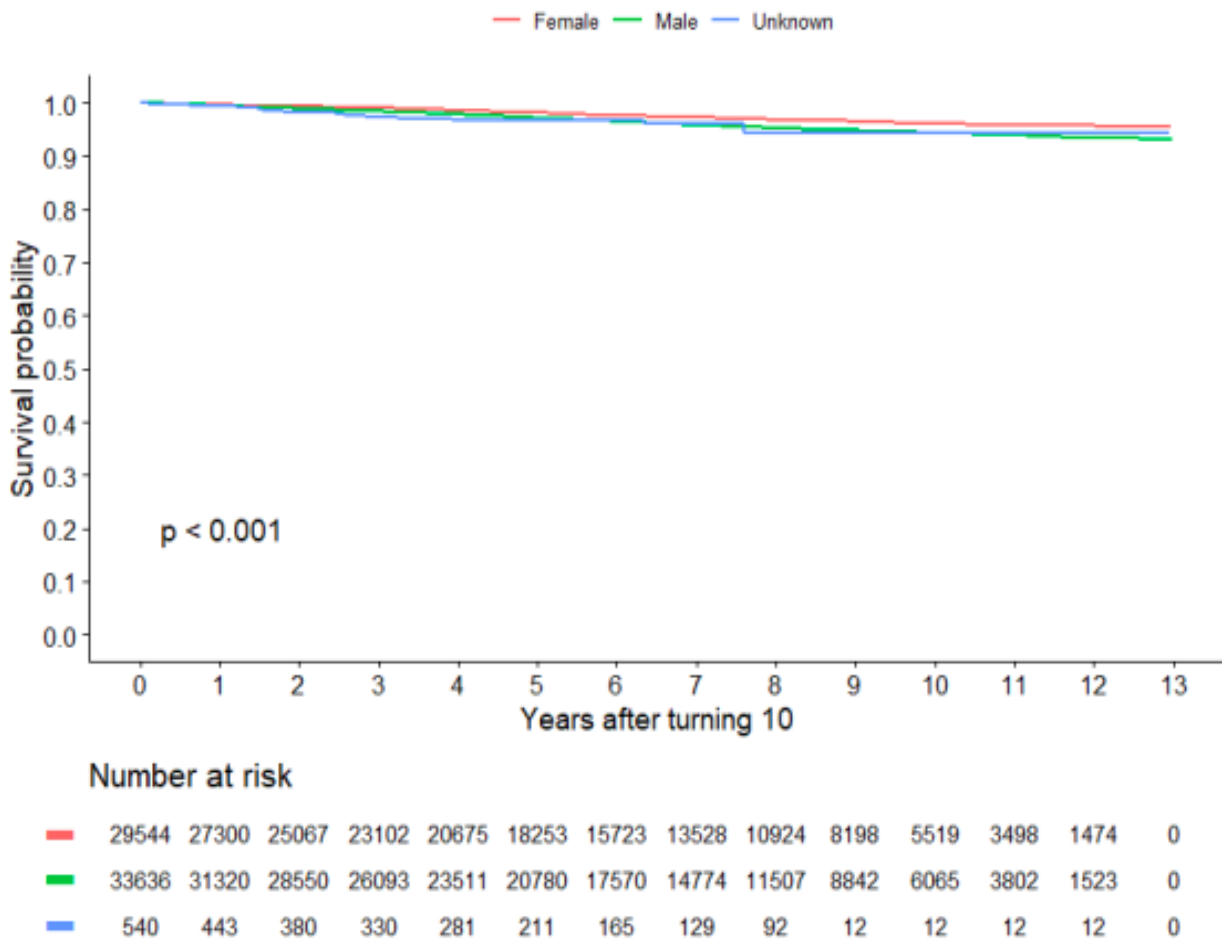

Figure 1: Survival Probability Comparing Gender

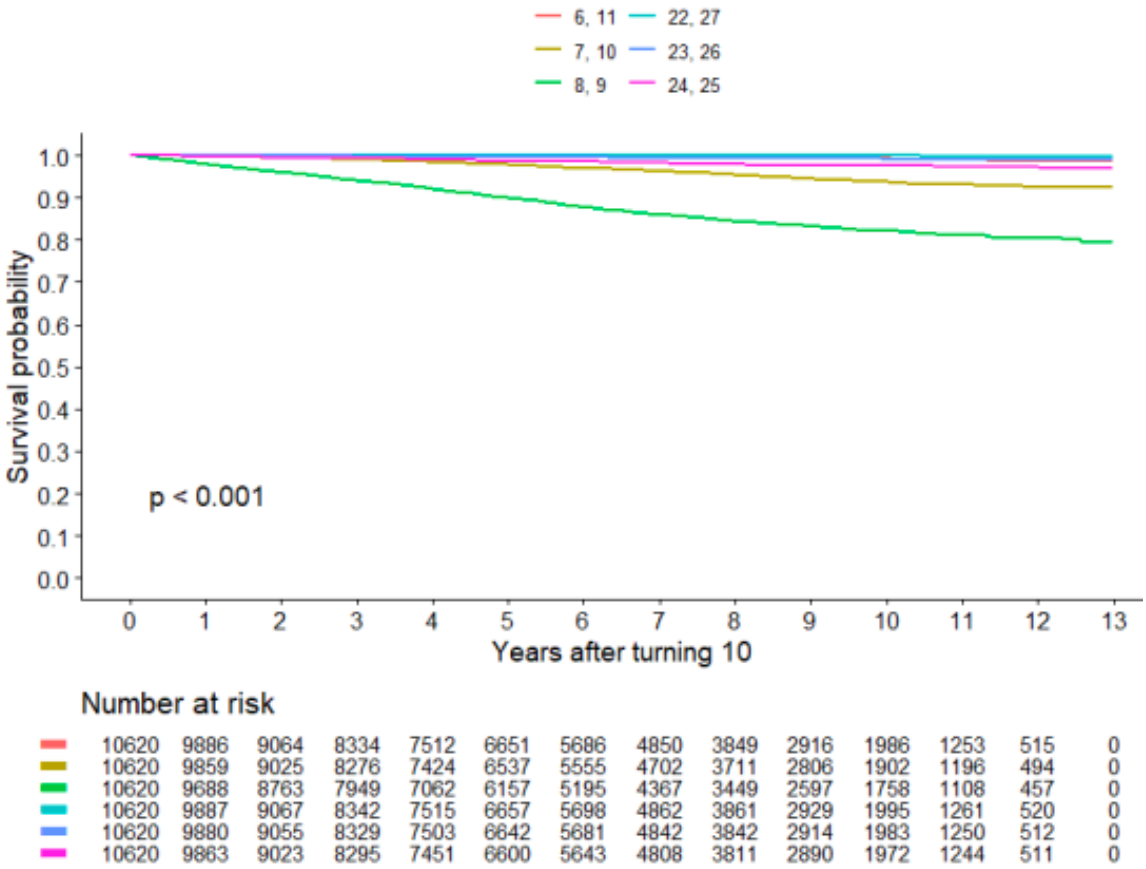

Figure 2: Survival Probability Comparing Tooth Number

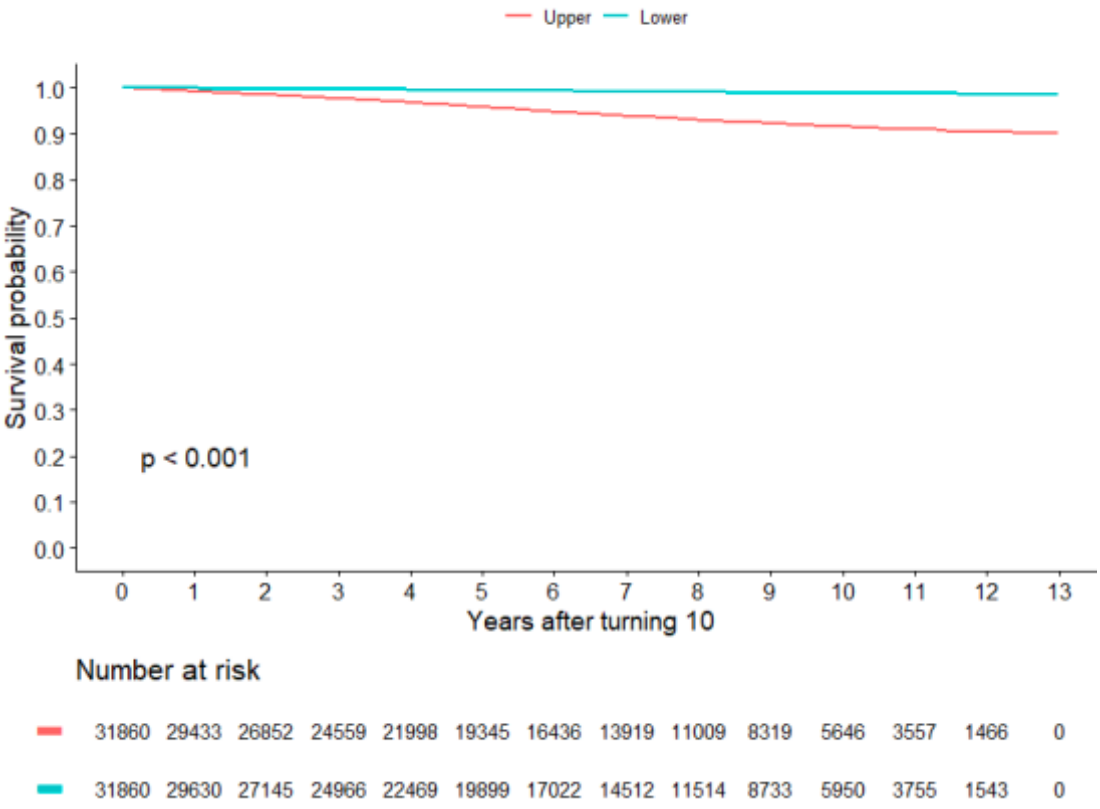

Figure 3: Survival Probability between Upper and Lower Jaw

Table 3: Yearly effect of orthodontic treatment (failure: extraction without any prior root canal procedures / root canal without any prior extraction)

Comparison	Hazard Ratio	95% Lower Confidence Limit for Hazard Ratio	95% Upper Confidence Limit for Hazard Ratio	Pr > ChiSq
Tooth #22, 27 vs #8, 9	0.007	0.004	0.013	<.0001
Tooth #23, 26 vs #8, 9	0.041	0.031	0.055	<.0001
Tooth #24, 25 vs #8, 9	0.124	0.103	0.148	<.0001
Tooth #6, 11 vs #8, 9	0.038	0.028	0.051	<.0001
Tooth #7, 10 vs #8, 9	0.280	0.249	0.314	<.0001
Female vs Male	0.650	0.588	0.720	<.0001
Unknown vs Male	1.159	0.719	1.869	0.5445
0-<1 years after orthodontic treatment	0.971	0.743	1.270	0.8321
1-<2 years after orthodontic treatment	0.954	0.720	1.264	0.7431
2-<3 years after orthodontic treatment	1.376	1.064	1.779	0.0151
3-<4 years after orthodontic treatment	1.219	0.885	1.679	0.2246
4+ years after orthodontic treatment	1.102	0.871	1.393	0.4197

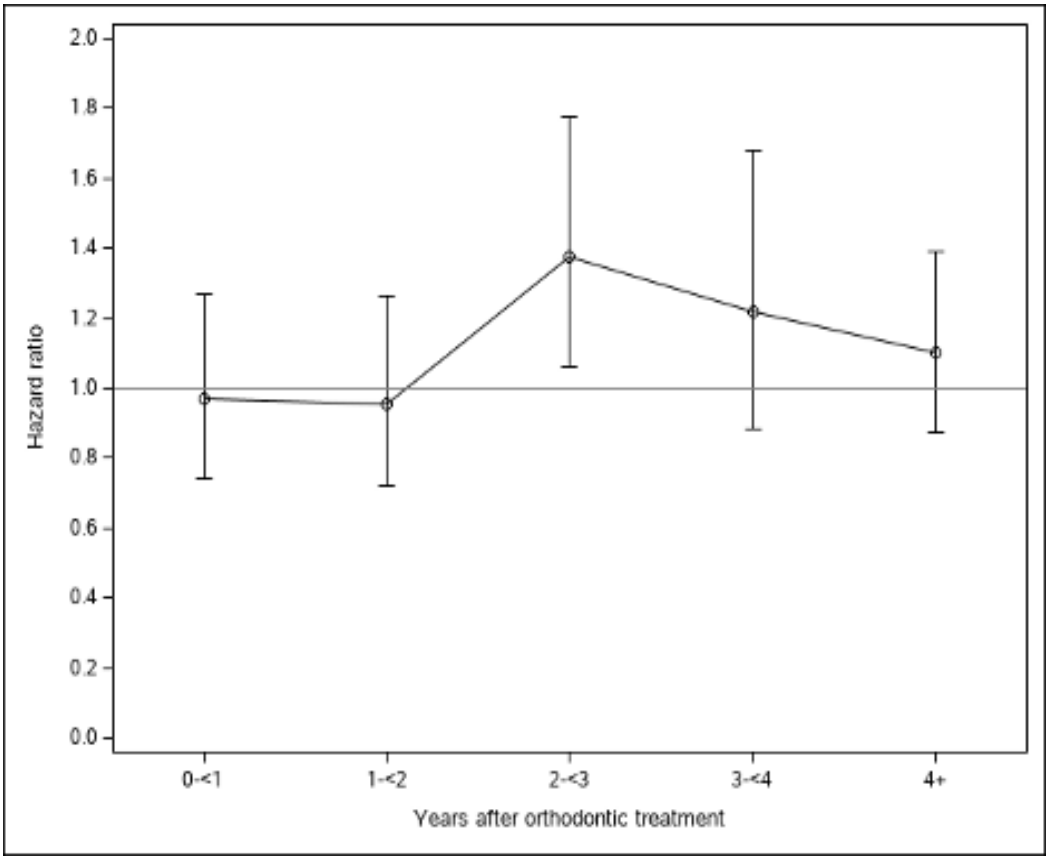

Figure 4: Hazard Ratio Yearly Effect of Orthodontic Treatment with Root Canal Therapy and Extraction

Table 4: Yearly effect of orthodontic treatment (failure: root canal without any prior extraction)

Comparison	Hazard Ratio	95% Lower Confidence Limit for Hazard Ratio	95% Upper Confidence Limit for Hazard Ratio	Pr > ChiSq
Tooth #22, 27 vs #8, 9	0.007	0.003	0.013	<.0001
Tooth #23, 26 vs #8, 9	0.041	0.031	0.055	<.0001
Tooth #24, 25 vs #8, 9	0.124	0.103	0.149	<.0001
Tooth #6, 11 vs #8, 9	0.031	0.022	0.043	<.0001
Tooth #7, 10 vs #8, 9	0.273	0.243	0.307	<.0001
Female vs Male	0.658	0.595	0.728	<.0001
Unknown vs Male	1.197	0.745	1.925	0.4576
0-<1 years after orthodontic treatment	0.892	0.677	1.174	0.4145
1-<2 years after orthodontic treatment	0.912	0.683	1.218	0.5332
2-<3 years after orthodontic treatment	1.327	1.027	1.717	0.0308
3-<4 years after orthodontic treatment	1.163	0.842	1.607	0.3584
4+ years after orthodontic treatment	1.017	0.810	1.277	0.8826

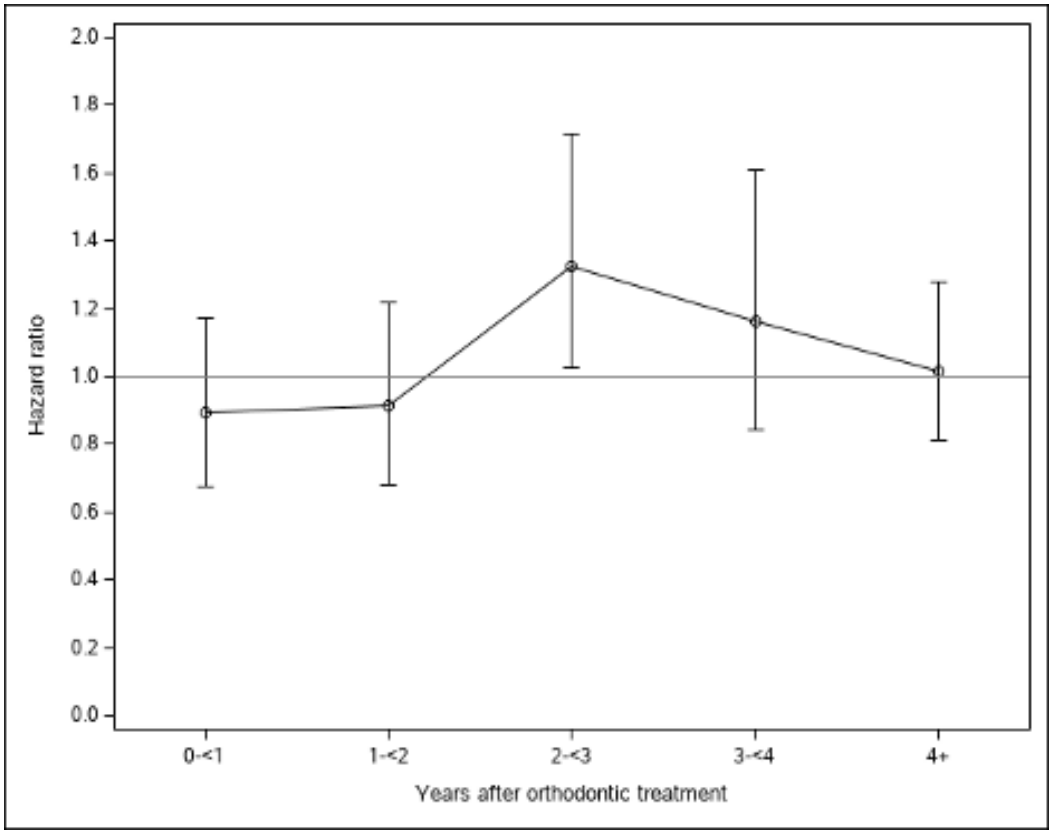

Figure 5: Hazard Ratio Yearly Effect of Orthodontic Therapy and Root Canal Therapy Only.

Table 5: Yearly effect of orthodontic treatment
(failure: extraction without any prior root canal procedures)

Comparison	Hazard Ratio	95% Lower Confidence Limit for Hazard Ratio	95% Upper Confidence Limit for Hazard Ratio	Pr > ChiSq
Tooth #22, 27 vs #8, 9	0.043	0.006	0.324	0.0022
Tooth #23, 26 vs #8, 9	0.043	0.006	0.324	0.0022
Tooth #24, 25 vs #8, 9	0.130	0.039	0.440	0.0010
Tooth #6, 11 vs #8, 9	0.434	0.200	0.943	0.0350
Tooth #7, 10 vs #8, 9	0.652	0.363	1.171	0.1526
Female vs Male	0.433	0.214	0.878	0.0203
Unknown vs Male	0.000	0.000	0.000	<.0001
0-<1 years after orthodontic treatment	7.198	2.817	18.390	<.0001
1-<2 years after orthodontic treatment	4.571	1.260	16.587	0.0208
2-<3 years after orthodontic treatment	5.158	1.364	19.506	0.0156
3-<4 years after orthodontic treatment	5.172	1.386	19.306	0.0145
4+ years after orthodontic treatment	4.503	1.255	16.155	0.0210

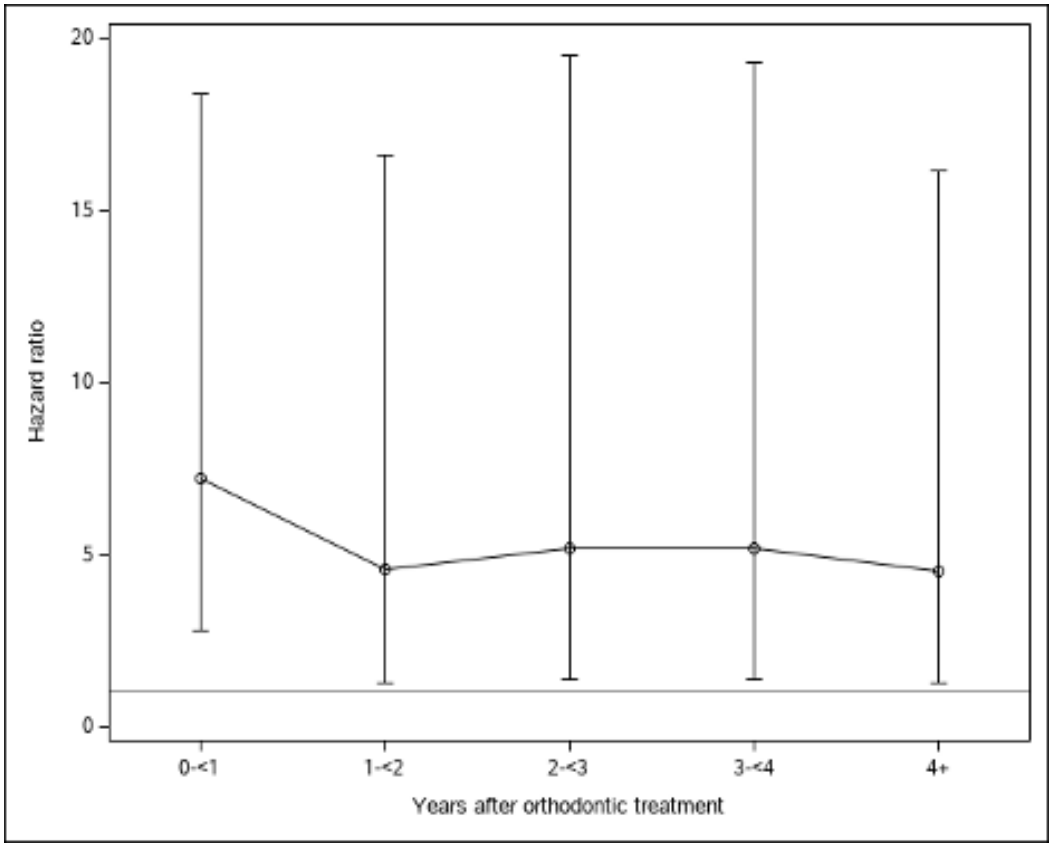

Figure 6. Hazard Ratio Yearly Effect of Orthodontic Therapy and Extraction Only.

DISCUSSION

The primary objective of this study was to evaluate the risk of root canal therapy or extraction after comprehensive orthodontic therapy in the anterior dentition. By utilizing the Delta Dental of Wisconsin insurance database, a substantial number of records were available for analysis, contributing power and meaning to the results.

There has not been a long term, large scale study that seeks to provide insight on real world insurance data that can surmise the association of the cause and effect of orthodontic treatment in regard to an untoward event. However, the limitations of such a large-scale population is that it is difficult to account for various confounding variables such as poor oral hygiene or a history of trauma that may affect treatment outcomes.

Based on the findings of this study, it can be concluded that orthodontic therapy is a relatively safe treatment modality for malocclusion. The greater risk of the adverse events of root canal therapy and extraction after orthodontic treatment are not statistically significant compared to the population without orthodontic treatment.

As previously mentioned, numerous risks of orthodontic therapy have been described in the literature including periodontal damage, pain, root resorption, temporomandibular problems, caries, speech difficulties and damage to enamel (7). The original study design to explore this topic was a data analysis to evaluate the effect of orthodontic extrusion on palatally impacted canines. Specifically, we sought to investigate if canines with a history of orthodontic extrusion were more likely to experience an untoward outcome such as an extraction or root canal therapy. However, the generated data set only produced a set of 138 teeth that underwent extrusion and furthermore, only 2 teeth had root canal therapy after this orthodontic treatment. After

further review of the literature, maxillary impacted canines demonstrating palatal displacement only occur in 2% of the population. Timely recognition around the ages 10 to 12 years with palpation and radiographic evaluation allows for effective treatment intervention (72). Excessive mesial orientation of the canine may be redirected to a more distal and vertical eruption path through removal of the primary canine when the permanent canine exhibits approximately two-thirds root development. This treatment intervention typically results in normal repositioning of the ectopic permanent canine 85 to 90% of the time (73). These factors caused our sample size to be too small for any meaningful analysis. However, if this study could be done with a larger sample size, it could provide meaningful data that answers our question more thoroughly.

In this current study, it is apparent that the maxillary central incisors are at highest risk of experiencing adverse outcomes. The majority of the adverse outcomes were root canal therapy, making up 1910 of the 1963 adverse outcomes. However, our Cox regression analysis comparing hazard ratios showed orthodontic therapy did not significantly increase the need for root canal therapy immediately. But, the p value was 0.01 for years 2-3 after orthodontic treatment, indicating an increase in root canal therapy during those years. After year 3 of initiation of orthodontic therapy, there was no significant difference in incidence in root canal therapy. This finding was worthy of note because orthodontic treatment can take around 2 years (21). If the incidence of root canal therapy increased with the completion of orthodontic therapy, it may be deduced that orthodontics protect anterior teeth from subsequent trauma in the anterior dentition.

During our literature review, we found that children ages seven to twelve years old have the highest incidence of dental trauma, the leading cause being sports and

fighting (74). De Paula Barros's study on the profile of trauma in the permanent dentition stated that maxillary central incisors were the primary teeth affected in trauma (75). They also stated that males were more affected than females which also was in agreement with our study (75). Furthermore, it has been found that children with malocclusion were at a higher risk of anterior trauma. Arraj et al (76) found that an overjet equal to or greater than 5mm are at significant risk of traumatic dental injury. Data shows a third of children with an untreated class II malocclusion will experience significant trauma to the upper incisors, resulting in a fracture of the tooth and/or devitalization of the pulp (10). Due to these facts, it is unsurprising that our results indicate teeth #8 and #9 are more likely to receive a root canal compared to the others, as well as males having a greater incidence of root canal therapy compared to girls. In essence, corrected malocclusion should not have an elevated risk, however, devitalization of the pulp due to trauma may be not be detected until years after trauma has taken place.

The literature also stated that severe orthodontic root resorption does occur 1-5% of the time and subsequently is more frequent in maxillary incisors (32). Furthermore, the study by Javed(10) shows that orthodontic forces not only change the external aspect of teeth but alter the nerve and blood supply in the pulp dentin complex. These negative alterations to the treated teeth could lead to non-vitality and root canal therapy or extractions (40). This also could explain the incidence of root canals and extractions in our study occurring in the maxillary teeth, specifically teeth #8 and 9.

This study had some limitations. The generalities of our results pertains to one private insurance plan in one state, making our population homogeneous. Additionally, orthodontics is an expensive treatment not fully covered by insurance which limits our

population's diversity in the data set. We also assumed that all 12 studied teeth were present without prior root canal or extraction at age 10, and we also assumed that no one had already started orthodontic treatment before the age of 10.

In conclusion, orthodontic therapy did not show a significant increase in adverse events. It is evident that the survival of teeth #8 and #9 to adverse events is much lower than any other anterior teeth. Also, this study shows that males are at a greater risk to adverse events compared to females. These findings may be explained by the greater incidence of traumatic injuries in children but it may also be explained by the forces of orthodontic therapy. More research is needed to determine which variable has more effect on the incidence of root canal therapy or extractions after orthodontic therapy. Generally, the incidence of these untoward events is small and orthodontic therapy is a safe treatment modality for children and adolescents.

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