Cracked Tooth Prevalence among Extracted Teeth: A Retrospective Study from Academic Dental Clinics

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Abstract

Background: This study was aimed to determine the prevalence of cracks among extracted teeth.

Methods: This retrospective study examined electronic dental record of 40,870 extracted permanent premolars and molars from 20,408 patients (of age 18 and older) of the Virginia Commonwealth University School of Dentistry (VCU SOD) faculty clinics, resident clinics and pre-doc clinics between 2010 and 2016.

Results/Conclusion: A total of 3,228 teeth (prevalence: 7.9%) were identified as cracked tooth. The percentage of extracted teeth with crack has been increasing over time, especially after a template note improved electronic data collection. The prevalence of cracked teeth varied according to tooth type (p < .0001). The mandibular molars showed highest prevalence (16% after the template note use). Age 18 - 35 had the higher prevalence (8.41%) than 36 - 65 (7.56%).

Practical Implications: Clinicians should be aware that cracked tooth is one of the most prevalent reasons for tooth extraction. Using a structured note can facilitate diagnosis. Early diagnosis and prevention may result in reducing tooth extraction of cracked teeth.

Keywords: Cracked Tooth; Extractions

Introduction

Cracked teeth have posed a significant and complicated challenge in dentistry for years. Restoring the cracked tooth has always been somewhat of a dilemma due to the unpredictability of the long-term prognosis. As the population ages and more people are retaining their natural dentition for longer periods of time, this problem will likely increase often with vague symptoms [1]. The impact of cracked teeth would be better understood if we knew how often this condition led to tooth loss. Learning about the characteristics of teeth that are extracted due to the diagnosis of a crack or fracture could provide insight into possible risk factors or trends.

Understanding the various factors related to the prognosis of cracked teeth would allow dental professionals better treatment planning.

Terminology related to tooth cracks or fractures has not been well established. Researchers and clinicians have used a plethora of terms: cuspal fracture odontalgia, incomplete tooth fracture [1], greenstick fracture [2], cracked tooth syndrome [3,4], vertical root fracture [5,6], fracture necrosis [7] and cracked teeth [8-10]. In 2008 the American Association of Endodontists dedicated an issue of Colleagues for Excellence towards the challenges encountered with cracked teeth titled "Cracking the Cracked Tooth Code" [11]. This publication defined five different types of longitudinal tooth fractures: craze lines, fractured cusps, cracked teeth, split teeth and vertical root fractures.

A number of factors are likely to cause tooth cracks. The human dentition is subject to numerous forces during functional and parafunctional habits. Nocturnal bruxism can elicit much greater occlusal force on the teeth thus may result in tooth cracks [12]. Removal of

tooth structure during restorative care can weaken a tooth's overall strength. Hiatt discussed factors such as parafunctional habits, eccentric interferences, the wedging effect of cusp/fossa relations in posterior teeth, the lack of protection of transverse ridges in mandibular molars, and the lever principle of greater forces located more posteriorly near the fulcrum of the temporo-mandibular joint (TMJ) may predispose a tooth to fracture [14]. Hiatt also noted that lack of a cuspal coverage restoration increases the likelihood of a crack developing in posterior teeth that are endodontically treated [13].

Both Cameron and Hiatt found the mandibular second molar to be the most common cracked tooth [3,13]. Seo, however found that the maxillary first molar was the most common cracked tooth [10].

Diagnosing a tooth crack is often a multi-step process. Many patients present with a complaint of diffuse pain, discomfort with chewing, and/or sensitivity to cold and sweets [8,10]. Signs of tooth crack include a combination of radiographic findings, periodontal probings, mobility, sinus tract presence, treatment history, and endodontic diagnostic testing methods, i.e. cold, hot, percussion, palpation, bite test [11]. Staining with methylene blue dye and transillumination have also been identified as techniques to help visualize the presence of cracks. Seo., *et al*. found the most common clinical feature of cracked teeth was pain to the bite test [10]. In a more recent study from the National Dental Practice-Based Research Network, symptomatic cracked teeth were most often found in molars with a distal crack that blocked transilluminated light in patients with clenching or grinding habits [14].

For cracked teeth, treatment options would range from extractions to full crowns with root canal treatment. Ehrmann suggested treatment of cracked teeth by placing an orthodontic band prior to crowning them, then re-evaluating 2 - 4 weeks later. If at the time of reassessment, the tooth was found to be symptomatic, he recommended nonsurgical root canal therapy in addition to the placement of a full coverage crown [4]. Krell and Rivera found that 20% of cracked teeth with reversible pulpitis treated with a full coverage crown required nonsurgical root canal therapy within 6 months due to development of irreversible pulpitis or pulpal necrosis [8].

The current knowledge regarding cracked teeth's prognosis remains limited. Tan found that among 49 patients with cracked teeth, an 85.5% survival rate at 2 years [9]. The survival rate decreased with the presence of the tooth being in a terminal location, multiple cracks or probing depths. Berman and Kuttler described fracture necrosis showing that teeth with pulpal necrosis and mesial-distal cracks ultimately required extraction [7].

Aim of the Study

The aim of this study was to describe the cracked tooth prevalence, characteristics, and their relationship among extracted teeth in a dental school setting.

Materials and Methods

The VCU Institutional Review Board registered the study as exempt from review as it was a secondary data analysis of existing chart data (IRB #: HM20006705). In order to be included in the study, all of the following inclusion criteria had to be met: patients over the age of 18, having a permanent first or second premolar or first or second molar extracted at the Virginia Commonwealth University School of Dentistry (VCU SOD) within the predoctoral, postdoctoral, or faculty practice clinics between January 1, 2010 and December 31, 2016. Eligibility also required the presence of an electronic health record (EHR) clinical note (axiUm) on or before the extraction date. Extractions were defined by the presence of the ADA CDT codes D7140: extraction of an erupted or exposed root, or D7210: surgical removal of erupted tooth requiring elevation of mucoperiosteal flap and removal of bone and/or sectioning of tooth.

The EHR was queried to first identify patients having molars and premolars extracted over a period of seven years, from January 1, 2010 through December 31, 2016. After the removal of records not meeting all inclusion criteria and duplicates, a total of 60,363 teeth remained as potentially eligible. Using this list, all of the unique chart numbers were extracted, along with date of a patient's last extraction.

A second EHR query was used to aggregate all of the clinical chart notes for these patients on or before the latest extraction date. After verification of the inclusion criteria, there were 20,408 patients and 40,870 extracted teeth eligible for the study. The SAS database was de-identified as per IRB guidelines.

The computer algorithm to identify cracked teeth was developed using a 2-month period of the clinical records which were hand searched for notes in the chart. Briefly, the chart notes were imported as blocks of text that were then broken into "sentences" of text- where a "sentence" was defined by a line-feed character or by a block of text ending with a period and a space. In order to determine whether a particular extracted tooth was cracked, these sentences were searched. Only the sentences from chart notes on or before the date of extraction were searched. The search was done in two steps. First, the tooth number from the extraction file was used to identify a chart note sentence that referred to that tooth. That is if tooth #14 was extracted, then "#14" was searched in all the sentences from the chart notes of that patient. If a sentence did not refer to the extracted tooth, it was not searched further.

In step 2, if a sentence did refer to the extracted tooth, then the sentence was searched for the following Yes-words (including fragments of words): "crack", "split", "broke", "fx", "vrf", or "fract." Secondly, the following No-words (including fragments of words) were searched: "clasp", "bracket", "appliance", "amalgam", "porcelain", "retainer", "denture", "partial", "deliver", "forcep", or "elevat." The extracted tooth was marked as Cracked=Yes if any Yes-words were found and none of the No-words were found. Extracted teeth phrases without Yes-words or with any of the No-words were marked as Cracked = No. For example, the sentence "fractured DO amalgam #19 with caries" was not counted as cracked tooth. The pilot study calculated the accuracy, sensitivity, and specificity of the computer algorithm to a manual review of the clinical notes by the authors. The sensitivity was calculated to be 99.4%. The specificity was found to be 84.6%, and the overall accuracy of the computer algorithm was 96%.

Patient and tooth characteristics

Patient age at the time of tooth extraction was calculated by using the patient's date of birth and the extraction date. For the purposes of analysis, these ages were grouped into four categories: 18 to 35 years, 36 to 50 years, 51 to 65 years, and 66 years and older. Teeth were categorized into 8 tooth types (maxillary first premolar, maxillary second premolar, mandibular first premolar, mandibular second premolar, maxillary first molar, maxillary second molar, mandibular first molar and mandibular second molar).

Results were summarized with counts and percentages or with means and standard error, as appropriate. Associations were first tested using likelihood-ratio chi-square analysis and summarized using 95% confidence intervals. Then a multi-variable logistic regression was used to test for the associations with all the patient and tooth characteristics jointly. Tukey's multiple comparison procedure was used to further identify differences. All statistical analyses were performed using SAS software (JMP pro 11, SAS Institute Inc., Cary NC). Statistical significance was declared at alpha = 0.05.

Results

Descriptions of the patients and extracted teeth are presented first. Next, the individual associations between tooth characteristics and cracked teeth are reviewed. Finally, the joint associations are described.

Characteristics of the patients

The 20,408 patients who had teeth extracted were equally male (n = 10,192) and female (n = 10,173), with a small number of unidentified gender (n = 41). The average age was 45.2 years (SD = 16.45, range = 18 to 101). Patients in the 18 - 35 years age range (n = 11,384) comprise 28% of the sample, 26% in the 36 - 50 years age range (n = 10,605), 31% in the 51 - 65 years age range (n = 12,490) and 16% were in the 66 years or older age range (n = 2,626). Sixty-two percent of patients had a single tooth extracted (n = 12,583) and an additional 19% had two teeth extracted (n = 3861). Approximately 2% of the sample (n = 392) had 10 or more extractions.

Characteristics of the extracted teeth

The bars in figure 1 show the number of extractions per month over the 7-year course of the study. Two trends are shown in the smooth line in the figure. First, there was an overall increase in extractions corresponding to a general trend of an increasing number of patients. The number of extractions increased from 4,138 in 2010 to 7,106 in 2016. Secondly, the 12-month variations in extractions largely correspond to the two time frames when the clinics are open less often: in December-January and in June-July.
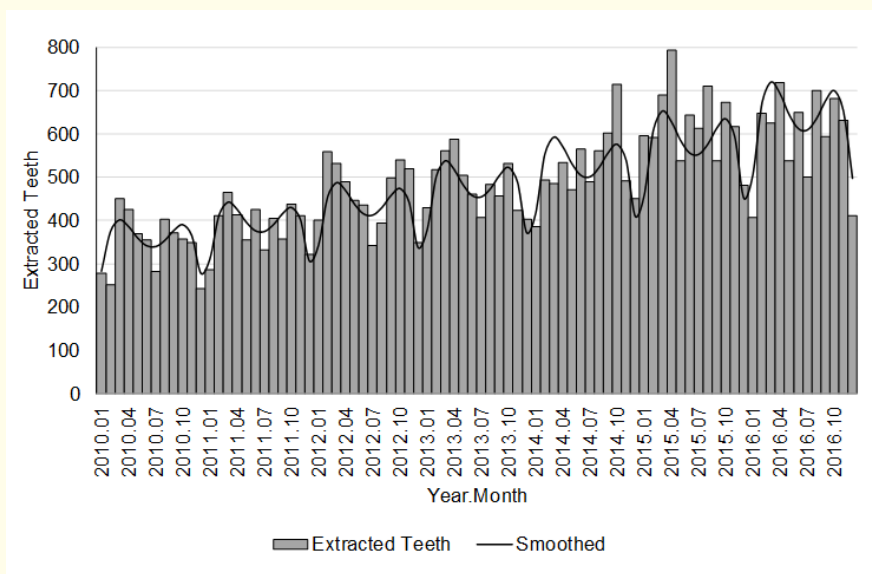
Figure 1: Number of extracted teeth per month.

In the 40,870 extracted teeth eligible for the study, the most common tooth type was the mandibular second molar (17%) and the least common was the mandibular first premolar (7%) (See the "Extracted Teeth" columns in table 1).

Prevalence of cracked teeth

There were 3,228 teeth identified as cracked in the 40,870 extracted teeth-an overall prevalence of 7.90% (the "Cracked" columns in table 1).

Characteristic	Extracted Teeth		Cracked				
	n	%	No (n)	Yes (n)	%Yes	95% CI	P-value
Overall	40870	100.00	37642	3228	7.90	(7.64 to 8.16)	
Tooth type							<.001
Max 1st Premolar	4404	10.78	4018	386	8.76[ab]	(7.93 to 9.60)	
Max 2nd Premolar	4825	11.81	4417	408	8.46[abc]	(7.67 to 9.24)	
Max 1st Molar	5794	14.18	5339	455	7.85[bc]	(7.16 to 8.55)	
Max 2nd Molar	5962	14.59	5548	414	6.94[bc]	(6.30 to 7.59)	
Mand 1st Premolar	2901	7.10	2780	121	4.17[d]	(3.44 to 4.90)	
Mand 2nd Premolar	3763	9.21	3467	296	7.87[bc]	(7.01 to 8.73)	
Mand 1st Molar	6318	15.46	5704	614	9.72[a]	(8.99 to 10.45)	
Mand 2nd Molar	6903	16.89	6369	534	7.74[c]	(7.11 to 8.37)	
Premolar or Molar							0.096
Premolar	15893	38.89	14682	1211	7.62	(7.21 to 8.03)	
Molar	24977	61.11	22960	2017	8.08	(7.74 to 8.41)	
Arch							0.838

Mandibular	19885	48.65	18320	1565	7.87	(7.50 to 8.24)	
Maxillary	20955	51.27	19322	1633	7.79	(7.43 to 8.16)	
Age (years)							0.014
18 - 35	11384	27.85	10427	957	8.41[a]	(7.9 to 8.92)	
36 - 50	10495	25.68	9673	822	7.83[b]	(7.3 to 8.35)	
51 - 65	12490	30.56	11575	915	7.33[b]	(6.9 to 7.78)	
66+	6501	15.91	5967	534	8.21[ab]	(7.5 to 8.88)	
Gender							0.502
Female	19883	48.65	18294	1589	7.99	(7.61 to 8.37)	
Male	20941	51.24	19305	1636	7.81	(7.45 to 8.18)	
Not identified	46	0.11	43	3	6.52		
Year							<.0001
2010	4138	10.12	3942	196	4.74[bc]	(4.09 to 5.38)	
2011	4625	11.32	4405	220	4.76[b]	(4.14 to 5.37)	
2012	5502	13.46	5320	182	3.31[d]	(2.84 to 3.78)	
2013	5766	14.11	5561	205	3.56[cd]	(3.08 to 4.03)	
2014-pre template	1900	4.65	1844	56	2.95[d]	(2.19 to 3.71)	
2014-post template	4349	10.64	3822	527	12.12[a]	(11.15 to 13.09)	
2015	7483	18.31	6549	934	12.48[a]	(11.73 to 13.23)	
2016	7106	17.39	6198	908	12.78[a]	(12.00 to 13.55)	
Provider							<.0001
Faculty	4512	11.04	4303	209	4.63[c]	(4.02 to 5.25)	
Resident	10969	26.84	10384	585	5.33[b]	(4.91 to 5.75)	
Student	25388	62.12	22954	2434	9.59[a]	(9.23 to 9.95)	

Table 1: *Characteristics of extracted teeth and crack prevalence.*

Abbreviations: Max: Maxilla; Mand: Mandible; CI: Confidence Interval.

Notes: Premolars and molars extracted in adult patients from 2010 to 2016. P-values calculated by logistic regression.

%Yes superscripts identify significantly different groups; Groups with the same superscript are not significantly different (alpha < 0.05).

Relationships between teeth characteristics and cracked teeth

The percentages of cracked teeth were compared using a chi-square test of homogeneity. The prevalence of cracked teeth varied between the eight tooth types (p < 0.001). Tukey's multiple-comparison procedure identified the groups of tooth types with significantly different cracked prevalence. The superscripts next to the "%Yes" column values indicate group differences. Groups sharing the same letter are not significantly different. That is, the mandibular first molar group had the highest prevalence (9.72%), which was significantly higher than all the other tooth types except the two maxillary premolar groups. The mandibular first premolar teeth had the lowest prevalence (4.17%), which was significantly lower than all other tooth types.

Molars had somewhat of a higher prevalence of cracks than premolars (8.08% vs. 7.62%), but the difference was not significant (chi-square = 2.77, p = .0959) and there was no evidence for a difference between the prevalence in mandibular teeth and maxillary teeth (7.87% vs. 7.79%, chi-square = 0.04, p = .8384). There is some evidence for a difference depending upon age (chi-square = 8.57, df = 2, p =

0.0137). Those aged 18-35 years of age had a higher prevalence than those aged 36 - 50 years or 51 - 65 years (8.41% vs. 7.83% and 7.33%), but not significantly higher than those aged 66 and older (8.21%). There was no evidence for a gender difference in prevalence (p > 0.5).

A curious and dramatic increase in the prevalence rate after April of 2014 (Figure 2) was seen across time (chi-square = 1084, p < .0001). Upon further inspection, it was observed that the prevalence of cracked teeth throughout 2013 and into the first few months of 2014 averaged 3.3%. And then in May 2014 it was 9.2%. In the last eight months of 2014 the average prevalence was 11.9%. This was attributed to the adoption of a standard clinical note template in the predoctoral clinics that would necessitate entering diagnosis of cracked tooth. Also, there were numerous research projects being done within the VCU SOD regarding diagnosis of cracked teeth that began in 2014.
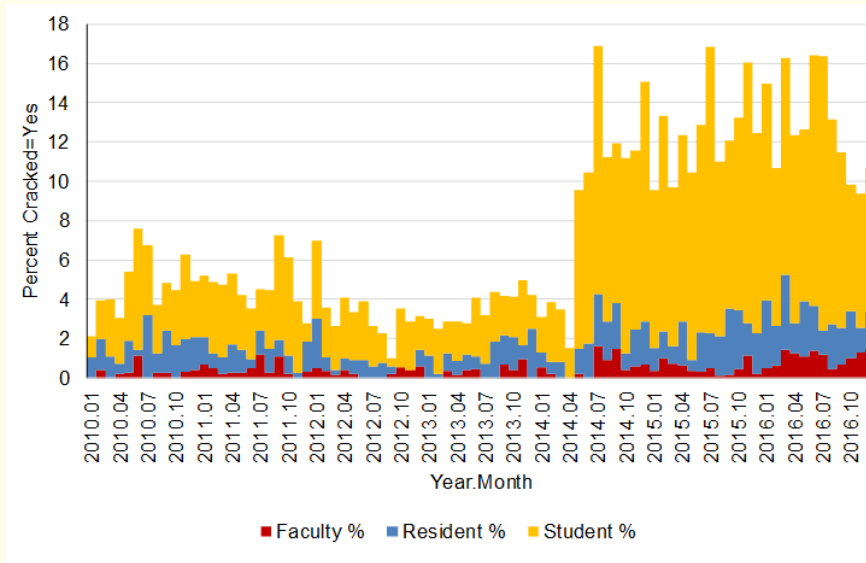
Figure 2: Percentage of cracked teeth per month by provider type.

Figure 2 illustrates the prevalence of cracked teeth reported per month over the course of the study, parsed by provider type. Within each month, the bars are additive such that the final height of the yellow (student) bar is the total prevalence across all three provider group. The faculty and residents indicated the smallest percentage of cracked teeth (3.2% and 3.5%) respectively and these percentages were relatively constant across the pre-template time period. After the template was introduced the prevalence doubled (to 5.8% in faculty and 7.5% in residents). In the pre-template time period, the prevalence of students identifying cracked teeth was nominally higher than faculty or residents (4.1% versus 3.4%). A marked increase in prevalence is then seen among the student provider group during the "post-template" time period (16.1%). When a practitioner uses a more systematic approach, they are more likely to detect cracks and document them. The use of a systematic template triples the odds of identifying a cracked tooth (as compared to 2010, the OR increased to 3.0 in 2016, 95% CI = 2.56 to 3.53).

Multi-variable logistic regression

Note that all of the previously described differences according to teeth, patient and provider characteristics have been univariate analysis. That is, each characteristic was considered individually. A multi-variable logistic regression was used to consider all of the char-

acteristics together. The results of the joint analysis indicated that tooth type (p < .001), age (p = 0.042), year (p < .001) and provider (p < .001) all remained statistically significant and, after adjusting for other factors, gender became significant (p = 0.030). Males have a lower prevalence of cracked teeth (OR = 0.92, 95% CI = 0.86 to 0.99). Compared to 18 - 35 year olds, 36 - 50 year olds have a nominally lower prevalence of cracked teeth (OR = 0.94, 95% CI = 0.85 to 1.04) and 51 - 65 year olds have a significantly lower prevalence of cracked teeth (OR = 0.88, 95% CI = 0.80 to 0.97). Compared to maxillary first premolars, the following tooth types have significantly lower prevalence: maxillary first molars (OR = 0.86, 95% CI = 0.74 to 0.99), maxillary second molars (OR = 0.74, 95% CI = 0.63 to 0.85), mandibular first molars (OR = 0.47, 95% CI = 0.37 to 0.57) and mandibular second molars (OR = 0.84, OR = 0.73 to 0.96).

Discussion

The present study reports the cracked tooth prevalence of 7.9% among extracted teeth: slightly higher than a previous study. Osaghae and Azodo reported a prevalence of split teeth requiring extraction to be 5% out of a sample of 670 extracted teeth [15]. Our number is also higher than Bader., *et al.*'s reported prevalence of 4.4% documented complete crown fractures based on 74,503 HMO plan enrollees [16].

The present study reports females having a higher prevalence of cracked teeth-7.99% in females vs. 7.81% in males (p = 0.0280). This may be due to females more often seeking dental care [17]. In contrast, some studies argued that males likely develop more cracks because of more advanced development of their masticatory muscles [18-20]. Other studies did not find any gender-related differences [10,21].

In this study, the most commonly extracted cracked teeth were mandibular first molars, followed by maxillary first and second premolars while mandibular first premolars were found least. However, after adjusting for gender and age, maxillary premolars are most prone to cracks. Literature varies a lot in what tooth type is most prevalent or prone to cracks. Hiatt found that mandibular second molars followed by mandibular first molars among 100 teeth were most commonly involved with incomplete fracture [13]. Seo., *et al.* found the maxillary first molars followed by the mandibular first molars among 107 teeth were most commonly involved with cracks [10].

The adoption of using template in 2014 significantly increased the reported prevalence of cracked teeth diagnoses. The required field in axiUm™ (Electronic Health Record) prompted clinicians to describe teeth being extracted more thoroughly (i.e. examining for fractures in order to fill in a drop down questionnaire) thus resulting in more diagnoses of cracked teeth. A more systematic approach such as using templates likely increases detecting and documenting cracks compared to rough, informal methods or depending solely on clinicians.

Limitations of this study are found in the lack of a standard protocol for diagnosing and documenting cracks. Each clinician forms their individual methods for diagnosing and documenting a cracked tooth. The patients that were seen only for extractions (i.e. they were not established patients of record within any of the clinics) had only short diagnostic descriptions within their EHR. This could be attributed to patients presenting with grossly carious teeth, obviously being non-restorable. In such cases, the clinician may have then only noted "non-restorable" as the reason for extraction. This could have led to an errantly low reported prevalence or inaccuracy in diagnosing cracked teeth. Unusual misspellings beyond what we used may have underestimated the prevalence. Lastly, it should be noted that the cracked tooth prevalence in the population would be lower than that of the current study because this study examined extracted teeth, not per patient.

Future studies can use a prospective study design standardizing diagnostic measures by calibrated clinicians then the reported prevalence would be more accurate. The diagnostic process would include thorough dental history, vitality testing, tooth slooth, bite testing, inspection for cracks using transillumination and staining under high magnification. Using a well-structured template will help ensure a clinician to gather all necessary information and document diagnosis. Appendix A shows an example template for treatment note. Areas with * are to be entered by a clinician.

Once a clinician early identifies a cracked tooth or risk factors, a series of prevention and treatment options can be considered. These include correcting malocclusions that attribute to destructive occlusal wear and fabricating an occlusal guard.

Conclusion

Clinicians should be aware that cracked tooth is one of the most prevalent reasons for tooth extraction. Early diagnosis and prevention may result in reducing tooth extraction of cracked teeth. Using a systematic approach (templates) would improve diagnosing cracks and preventing/treating the involved teeth.

Supplemental Data

The data used to support this study's findings are available upon request from the corresponding author.

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Disclosure

None of the authors reported any disclosures.

Conflicts of Interest

Authors have to no conflicts of interest.

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