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Impact of Systemic Pathologies on Increased Risk of Endodontic Disorders

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IMPACT OF SYSTEMIC PATHOLOGIES ON INCREASED RISK OF ENDODONTIC DISORDERS

by

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ABSTRACT

The purpose of this study is to evaluate possible factors that have the potential to contribute to increased risk for endodontic disease. Some of the factors that were analyzed in this study include current diagnosis with systemic disease, particularly diabetes and cardiovascular disease. Association between these factors, treatment outcome, and prognosis have also been analyzed. Since the topic of endodontic medicine and its association with systemic disease is not fully explored in the literature, it is critical to conduct studies to further contribute to this topic. This study analyzed clinical data from patients who received treatment for endodontic disease between January 1 – December 30, 2019 at an endodontic office in Brevard County, Florida. During the spring semester of 2021, collected data was downloaded into SPSS and analyzed to evaluate the association between systemic diseases and endodontic disease. Both descriptive analysis and one-way ANOVA were utilized to test the proposed hypotheses. Results from one-way ANOVA among clinical assessment categories showed no significant difference between means of the systemic disease groups. For the impact of treatment on clinical assessment and prognosis, one-way ANOVA did show significant differences indicating potential impact of systemic disease on treatment outcome.

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INTRODUCTION

The association between systemic diseases and general periodontitis, also known as gingivitis, has been well established in existing literature. However, there is less evidence associating endodontic disorders, such as apical periodontitis, with systemic disease. Limited studies have been done associating the two, and lacking evidence persists. The results of studies carried out both in animal models and humans suggest an association between endodontic variables including apical periodontitis and root canal treatment, diabetes mellitus, coronary heart disease, and other systemic diseases. However, these studies are not conclusive (Seguro et al., 2015). The possible association between smoking habits and endodontic infection has also been investigated, with controversial results (Seguro et al., 2015). In addition, a systematic study conducted by Berlin et al. found limited studies in current literature were done on endodontic pathosis and possible association with cardiovascular disease (Berlin et al., 2017).

The purpose of this research project is to provide an understanding of the association between endodontic disease and systemic diseases. The following question will guide the study's analysis: "What factors are associated with the diagnosis of endodontic disease?"

LITERATURE REVIEW

Endodontic disease consists of infection in the oral cavity, specifically in the pulpal structure of the tooth (fig. 1). The most common pulpal disease includes the condition of apical periodontitis (AP). AP, an inflammatory process around the apex of a root, is primarily a consequence of microbial infection of the pulp space and/or the root canal system (Costa et al., 2019; Segura et al., 2015). This disease is the most frequent inflammatory lesion related to the pulpal structure of the tooth. It is estimated that 30–50% of individuals have AP (Kirkevang et al., 2007). Since this disease is prevalent among many individuals, it is important to understand the causes, promoters, and impacts of AP.

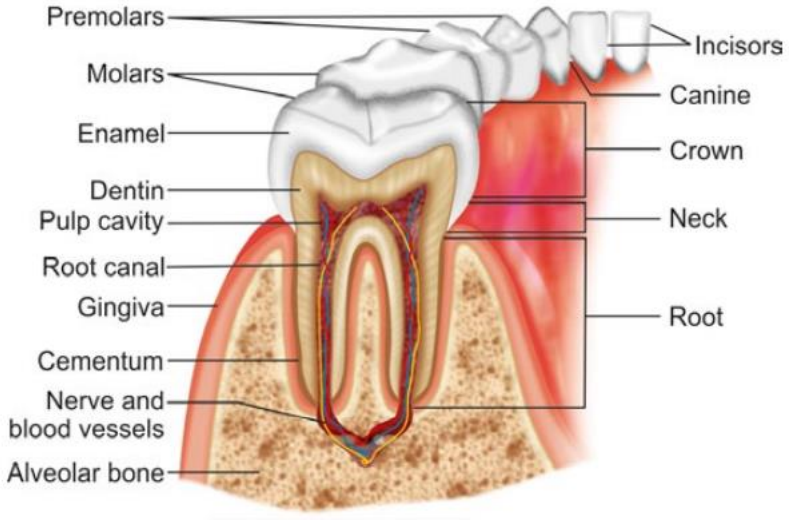

Figure 1: Anatomy of a Tooth. Source: (Phulari, 2014)

Root canal treatment is the therapy generally used to treat teeth with AP. During the root canal procedure, the pulp and existing nerve of the tooth are removed. The canals are then disinfected and sealed to prevent infection or new abscess from forming. However, total reduction in the size of the apical abscess does not always occur in root canaled teeth. (Segura et al., 2015).

This happens when infection has not been completely irradicated, canals are missed, or when there is poor access to the canals. Several other factors may contribute to root canal failure as well. Although root canal treatment does not preserve the pulp, the ultimate goal of the procedure is to prevent and eliminate infection in the root canal system and prevent or cure apical periodontitis (Segura et al., 2015).

AP can be influenced by a number of factors including age, social class, education, and use of dental services. Since cavities frequently lead to AP, these variables may be associated with the presence of both AP and dental cavities (Kirkevang et al., 2003). The cause of AP is related to the outcome of untreated dental cavities when the root canal system is infected by oral microbiota. An infection of the coronal pulp may spread apically, and cause necrosis of the pulpal tissues, and eventually reach the apex of the root (Qian et al., 2019). As AP progresses in the oral cavity, root canal infection can become symptomatic and evolve to severe spreading and sometimes life-threatening abscesses (Qian et al., 2019). The amount and interactions of various inflammatory stimuli can influence and change the state and progression of the disease. Medical symptoms related to AP include soft tissues swelling which indicates periapical abscess, and pain to percussion and palpation. (Cotti et al., 2011). If AP is left untreated, bacterial elements invade the periapical area and cause local bone destruction.

Systemic diseases are those that affect the whole body simultaneously. These disorders are not restricted to a particular organ or part of the body; therefore, they can affect the body as a whole or affect several tissues and organs at once. For example, diabetes and cardiovascular disease are both types of systemic diseases that have the potential to increase the risk of AP.

Diabetes as a Risk Factor for Apical Periodontitis

Diabetes mellitus affects millions of people each year. In 2011, studies showed approximately 366 million patients were affected by this metabolic disease (Lima et al., 2013). Diabetes mellitus is characterized by hyperglycemia, resulting in wound healing complications as well as systemic and oral symptoms, which have a direct effect on dental pulp (Lima et al., 2013). There are two different types of diabetes mellitus. Type 1 diabetes mellitus typically presents itself early in life. It is classified by poor insulin production and requires daily insulin injection. Type 2 diabetes mellitus is the resistance to insulin and is commonly referred to as adult-onset diabetes. (Arheiam & Omar, 2014). Dental pulp from patients with diabetes presents limited circulation, weakened immune response, and increased risk of developing pulpal infection. Diabetes mellitus also causes changes to the way in which cells function. It causes up-regulation of inflammatory cytokines from monocytes and polymorphonuclear leukocytes while also causing down-regulation of growth factors from macrophages. This causes chronic inflammation, gradual tissue breakdown, and reduces the tissues' ability to repair (Segura et al., 2015). Not only does diabetes affect immune cell function, but it also reduces salivary flow, pH, buffer capacity, and it may increase glucose, magnesium, and calcium levels (Arheiam & Omar, 2014). High glucose levels can inhibit macrophage function resulting in an inflammatory state that weakens the healing process (Lima et al., 2013). Understanding how diabetes affects systemic and oral health has an enduring importance, because it may lead to systemic complications and increase the risk of oral diseases with a significant effect on pulp and periapical tissue. Evidence suggests that there could be a common component between apical periodontitis and diabetes mellitus, but more research is necessary to conclusively associate the two diseases (Flor et al., 2020).

Cardiovascular Disease as a Risk Factor for Apical Periodontitis

Cardiovascular disease contributes to 31% of deaths worldwide, making it the leading cause of death globally ("Cardiovascular Diseases," 2017). A statistically significant increased risk of cardiovascular disease in patients with periodontitis is shown by observational studies and meta-analyses. Patients with periodontal disease share many of the same risk factors as patients with cardiovascular disease. These risk factors include age, gender (predominantly male), lower socioeconomic status, stress, and smoking (Paquette et al., 2007). Although periodontal disease shares similar risk factors with coronary heart disease, only a few studies have investigated the association between pulpal inflammation and coronary heart disease.

Caplan et. al published the Veterans Affairs Dental Longitudinal Study, in which 708 participants were recruited. They were all males with mean age of 47.4 years. The study entailed comprehensive medical and dental examinations, which included radiographs of the patients. 35% of all participants had at least one periapical lesion and 23.4% of them were subsequently diagnosed with coronary heart disease. The authors concluded that the mechanisms that link endodontic disease to coronary heart disease might be similar to the theory of an association between periodontal disease and cardiovascular disease. This theory concludes that the localized inflammatory response to bacterial infection leads to the release of cytokines into systematic circulation resulting in negative vascular effects (Caplan et al., 2006). Although there was no causal evidence in the study, it addressed a potential link between endodontic inflammatory disease and adverse systemic health outcomes. Additionally, researchers believe that there could

be a connection between apical periodontitis and cardiovascular disease, however, this causal relationship has yet to be proven (Garg & Chaman, 2016).

Smoking as a Risk Factor for Apical Periodontitis

There has been a sharp increase in smoking in the United States over the past decade. This can be attributed to the use of e-cigarettes and nicotine vape. Tobacco smoking affects multiple organ systems resulting in different tobacco-related diseases. Smoking releases inflammatory cells, such as cytokines and acute phase proteins, into the system which has a large effect on overall health (Yanbaeva et al., 2007). Also, smoking may impact peri-radicular tissues by reducing blood supply and restricting the arrival of nutrients and oxygen. Therefore, it may contribute to early necrosis of the pulp tissue, since pulp and peri-radicular tissues are less able to combat bacterial infections (Pinto et al., 2020). Smoking appears to be one of the most significant factors in the progression of marginal periodontitis, oral cancer, oral mucosal lesions, and coronal caries (Duncan et al., 2006). However, there is little evidence directly associating smoking and apical periodontitis. It is suggested that smoking may be a significant risk factor in inflammation of the marginal periodontium. Therefore, it has been hypothesized that it would have a similar effect on the apical periodontium (Duncan et. al 2006). This theorized relationship between smoking and apical periodontitis presents a gap in the literature. More testing and supporting evidence should be concluded before making a clear association between the two.

A quantitative questionnaire, published by the National Center for Health Statistics, surveyed both males and females over the age of 16 about their oral health related to cigarette smoking. When asked, “In the past 12 months, did a dentist, hygienist or other dental professional have a direct conversation with you about the benefits of giving up cigarettes or other types of

tobacco to improve dental health?", 404 candidates answered "Yes" while 2,951 answered "No". Four candidates responded with "Don't know" (Oral Health, 2020). This indicates the lack of emphasis on smoking as a potential risk factor for endodontic disease. Smoking is growing rapidly throughout the developing world and is one of the biggest threats to world health. Since it can cause respiratory illness, systemic inflammation, and cardiovascular disease among other problems, it is important for all health care providers to be aware of its spread and do their best to eliminate it. It is also important for us to study the effects it may have on not only periodontal health but endodontic health as well.

Relevance and Need for Further Research

Many studies have surfaced about the prevalence of systemic disease and its association with a different disease of the oral cavity known as periodontal disease, also called gingivitis or gum infection. Over the last 20 years, there has been a focus on periodontal medicine concentrating on the relationship between periodontal disease and systemic diseases (Segura et al. 2015). Periodontal disease has been proven through several studies to have an association with systemic health. Periodontal disease has mainly been associated with diabetes, coronary heart disease, respiratory disease, and many other systemic diseases. Although there has been an increase in studies regarding periodontal medicine, there have been few studies considering endodontic medicine and its impact on systemic disease. Endodontic medicine should be developed following the same course as periodontal medicine. The association between endodontic and systemic diseases should also be evaluated (Segura et al. 2015). Given the relevance of a possible association between systemic disease and endodontic disorders, an investigation on the presence of such association needs further investigation. There is little research proving or otherwise

refuting the existence of a correlation specifically between endodontic disease and systemic disease, thus creating a gap in current knowledge.

Research Aim and Hypotheses

The primary aim of this study is to evaluate the relationship between risk factors, such as systemic disease, and factors associated with endodontic disease. The following hypotheses guided this study:

Hypothesis $_0$: Patients with systemic disease will not have an increased risk of developing endodontic disease.

Hypothesis $_1$: Patients with systemic disease will have an increased risk of developing endodontic disease.

Secondary Hypotheses

Hypothesis $_1$: Patients with diabetes will have an increased risk of developing endodontic disease.

Hypothesis $_2$: Patients with cardiovascular disease will have an increased risk of developing endodontic disease.

Hypothesis $_3$: Patients with systemic disease will have an increased risk of having necrotic pulp status at initial diagnosis.

Hypothesis $_4$: Patients who have systemic disease will experience more sensitivity to cold temperature at initial diagnosis.

Hypothesis $_5$: Patients who have systemic disease will experience more sensitivity to palpation and percussion at initial diagnosis.

Hypothesis $_6$: Patients with systemic disease will have poor prognosis, and need for retreatment, after root canal treatment compared with patients without systemic disease.

METHODS

Study Design

This study analyzed clinical data of patients who received endodontic treatment utilizing retrospective research design. During this research, deidentified clinical data has been provided on patients who have received treatment at an endodontic office in Brevard County, Florida. An agreement was established with this clinic to allow research collaboration. The study was submitted and approved by the IRB at The University of Central Florida, and data collection and analysis took place during Spring 2021. Deidentified clinical data was collected for patients who have received endodontic treatment in order to analyze their medical history including existing diagnosis with systemic disease and association with endodontic disease and treatment outcome. Patients fill out medical history forms upon entering the office. These forms include information related to medical history, pain history, previous medical conditions and disorders, status of the tooth in question, and current symptoms. In addition, clinical data including clinical assessment, treatment, and prognoses have been analyzed for these patients. The patient subjects include all patients who received treatment for endodontic disease between January 2019 and December 2019 at the dental clinic. Collected deidentified clinical data was downloaded into SPSS statistical package for further analysis and is stored in a password protected computer.

Sampling

The target population for this study included all patients that suffered from endodontic disease and received root canal treatment in Florida. The selected sample for this study consisted of patients who visited the selected endodontic office with complications pertaining to pulpal

disease and were treated by the endodontist who practices at this location. The sample population included all males and females who suffered from endodontic complications and were treated from January 2019 to December 2019.

Data Analysis

Analyzed data included patient medical history forms as well as clinical multi-tooth testing information collected by the doctor and assistant during the initial visit. The multi-tooth testing information included tooth number, response to palpation, percussion, and response to cold testing. Pulpal diagnosis, periapical diagnosis, endodontic prognosis, periodontal prognosis, and recommended treatment were also documented. This compiled deidentified clinical data provided by the endodontics office was transferred into a password protected computer for SPSS data analysis.

RESULTS

Deidentified data provided by the endodontic office included 1,290 dental clinic visits in the year of 2019. Among those clinical visits, 67 visits involved patients who had already been treated for endodontic disease previously that year on a different tooth number. After receiving the deidentified data, the information was organized into SPSS. Descriptive analysis included sample demographics, clinical assessment, recommended treatment, endodontic prognosis, and periodontic prognosis. Further analysis included one-way ANOVA evaluation.

Sample Demographics

Sample demographics included age, gender, and medical history of cardiovascular disease and diabetes (table 1).

Table 1: Sample Demographics

	N	%
Sample	1290	
Age		
<18	33	3
18-29	119	9
30-49	325	25
50-69	582	45
70-99	231	18
Gender		
Male	620	48
Female	670	52
Medical History		
Diabetes	108	8.4
Cardiovascular Disease (CVD)	401	31

Dental Clinical Assessment

During the initial clinical assessment, there are multiple factors considered when the endodontist evaluates a patient for treatment. These factors include tooth number, percussion, palpation, response to cold testing, pulpal diagnosis, and periapical diagnosis.

The percussion test is done by tapping on the tooth with the end of a mirror. Positive responses indicate sensitivity beyond normal limits and inflammation of the periodontal ligament. During percussion testing, a recording of (WNL) indicates that the patient has a negative or no response, therefore, the patient is within normal limits. A recording of (+) indicates that the patient has a positive response to palpation. The more + signs recorded, the more severe the sensitivity.

During palpation testing, the dentist checks the sensitivity of surrounding gum tissues by gently running a cotton swab across the gums. Similar to percussion testing, no response to this test is recorded by WNL indicating that the patient is within normal limits and does not have pain or sensitivity in the area. A positive response to this test is recorded by an addition sign +. The severity of the response is recorded by adding more + signs.

The cold test is used to detect the vitality of the tooth in question. No response, or no sensitivity to cold testing, indicates that the pulp is non-vital or necrotic. Conversely, if the cold temperature is lingering, or the patient feels sensitivity beyond normal range, this reveals that the patient demonstrates signs of pulpitis. A recording of WNL demonstrates that the patient can feel the cold temperature on the tooth, but they do not have severe or lingering sensitivity, which is a normal sensation.

Pulpal and periapical diagnoses are also recorded during the clinical assessment. A pulpal diagnosis refers to the condition of the pulp or nerve inside the tooth. When necrotic pulp is

recorded, this indicates the death of cells and tissues in the pulp chamber. Pulpitis refers to inflammation of the pulp within the chamber. When a periapical diagnosis of periodontitis is documented, this is characterized as inflammatory gum disease. This leads to the destruction of the tooth-supporting tissues. When an apical abscess is documented, this indicates that a collection of pus, caused by infection, has accumulated at the root of a tooth. Table 2 includes the results of each dental clinical assessments.

Table 2: Dental Clinical Assessment

	N	%
Tooth #		
Molar	860	67
Bicuspid	254	20
Canines	45	3
Incisors	124	10
Other	7	1
Percussion		
WNL*	714	55
+	440	34
++	79	6
+++	11	1
Palpation		
WNL*	936	73
+	272	21
++	31	2
+++	4	0
Response to Cold		
WNL*	142	11
No Sensitivity	514	40
Sensitivity	294	23
Was Not Tested	340	26
Pulpal Diagnosis		
Normal Pulp	45	3
Necrotic Pulp	476	37
Pulpitis	294	30
Prior RCT*	254	20
Periapical Diagnosis		
Normal Tissue	294	3
Periodontitis	788	61
Apical Abscess	143	11

*WNL: Within Normal Limits, *Prior RCT: Prior Root Canal Treatment

Recommended Treatment

Once an accurate determination of the pulp status is achieved during the clinical assessment, the treatment plan is created. Root canal treatment is the most common procedure performed at the endodontic office. A retreatment is performed when a recurrent infection arises in a tooth that has previously been root canal treated. The retreatment is necessary to remove the new infection and preserve the tooth once again. An apicoectomy, or root-end resection, is performed when inflammation or infection persists around the apex of a tooth after a root canal procedure. This surgery is done only after a tooth has had at least one root canal procedure and retreatment has not been successful. Treatment performed on patients from the endodontic office in 2019 is found in figure 2 and table 3.

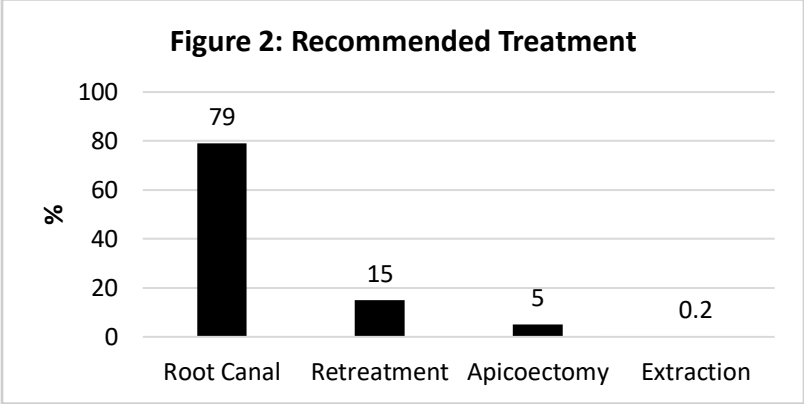

Table 3: Recommended Treatment		
	N	%
Root Canal	1020	79
Retreatment	194	15
Apicoectomy	70	5
Extraction	2	0.2

Endodontic Prognosis

The endodontic prognosis is the endodontist's prediction of the chance of tooth sustainability after treatment. This prognosis is recorded as good, guarded, or poor/hopeless. A good prognosis indicates that the tooth has a high likelihood of being preserved. A guarded prognosis indicates that the chance of tooth sustainability is subpar or questionable. A prognosis of poor or hopeless suggest that the treated tooth will not be sustainable. Results of endodontic prognoses are listed on figure 3 and table 4.

Figure 3: Endodontic Prognosis

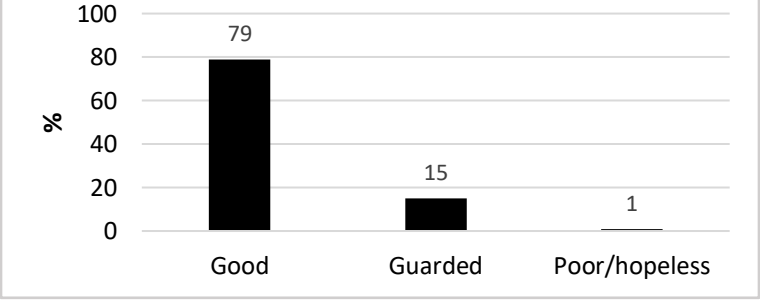

Table 4: Endodontic Prognosis		
	N	**%**
Good	1115	79
Guarded	194	15
Poor/ Hopeless	10	1

Periodontic Prognosis

Periodontic prognoses are predictions of the condition of the supporting structures around the tooth and roots after treatment. These prognoses are recorded similar to the endodontic prognoses and can be viewed in figure 4 and table 5.

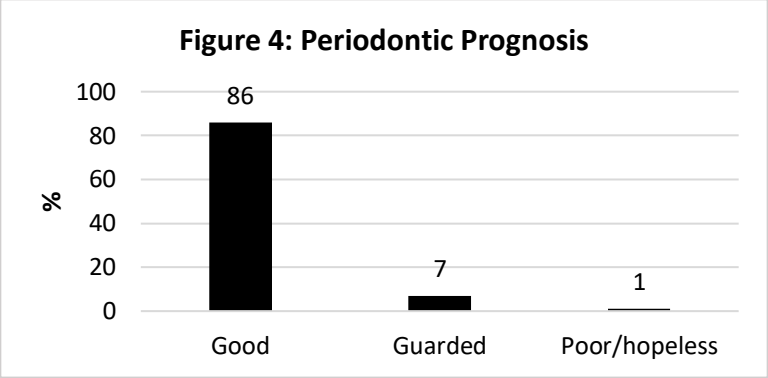

Table 5: Periodontic Prognosis		
	N	**%**
Good	1112	86
Guarded	96	7
Poor/ Hopeless	9	1

Statistical Analysis: One-Way ANOVA and Crosstabulation

One-way ANOVA was also utilized to determine statistically significant differences between the means of the independent groups. This was coupled with Crosstabulation that allows mapping the frequency distribution of two categorical variables in a contingency table. The purpose of crosstabulation is to determine if two variables are related. One-way ANOVA analysis was performed to assess the following:

1. Impact of systemic disease on clinical outcome, treatment, and prognosis.
2. Association between treatment and clinical outcome and prognosis.

1. Impact of Systemic Disease on Clinical Outcome, Treatment, and Prognosis

One-way ANOVA was utilized to analyze the association between systemic disease and all clinical multitooth testing, endodontic and periodontic prognoses, and recommended treatment (table 6). Further analysis comparing frequency of these variables among different systemic disease categories are explained below:

Table 6: Systemic Disease One-Way ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Percussion	Between Groups	1.045	3	0.348	0.417	0.741
	Within Groups	1075.052	1286	0.836		
	Total	1076.097	1289			
Palpation	Between Groups	0.980	3	0.327	0.437	0.727
	Within Groups	1075.052	1286	0.836		
	Total	961.969	1286	0.748		
Cold Temperature	Between Groups	962.949	1289		2.085	0.100
	Within Groups	1253.297	1286	0.975		
	Total	1259.392	1289			
Pulpal Diagnosis	Between Groups	5.054	3	1.685	0.452	0.716
	Within Groups	4792.779	1286	3.727		
	Total	4797.833	1289			
Periapical Diagnosis	Between Groups	2.881	3	0.960	0.552	0.647
	Within Groups	2236.707	1286	1.739		
	Total	2239.588	1289			
Endodontic Prognosis	Between Groups	6.941	3	2.314	1.422	0.235
	Within Groups	2092.008	1286	1.627		
	Total	2098.949	1289			
Periodontic Prognosis	Between Groups	7.188	3	2.396	1.593	0.189
	Within Groups	1934.595	1286	1.504		
	Total	1941.784	1289			
Treatment	Between Groups	1.367	3	0.456	1.479	0.219
	Within Groups	394.975	1282	0.308		
	Total	396.342	1285			

Impact of Systemic Disease on Percussion

The impact of systemic disease on percussion showed no statistical significance ($F(3, 1286) = 0.417$, $p > 0.05$). Those without systemic disease showed the highest percentage within normal limits in the percussion clinical test. However, the majority of patients with systemic disease also tested within normal limits to percussion (table 7).

Table 7: Systemic Disease & Percussion (%)					
	WNL	**+**	**++**	**+++**	**NA**
Diabetes	57	33	7	0	3
CVD	61	28	5	2	3
Diabetes & CVD	51	41	6	0	1
None	54	36	7	0	4

Impact of Systemic Disease on Palpation

The impact of systemic disease on palpation showed similar results to those seen in percussion testing (table 8). No significant difference was found ($F(3, 1286) = 0.427$, $p > 0.05$).

Table 8: Systemic Disease & Palpation (%)					
	WNL	**+**	**++**	**+++**	**NA**
Diabetes	57	40	0	0	3
CVD	73	22	2	0	3
Diabetes & CVD	65	28	4	1	1
None	74	19	3	0	4

Impact of Systemic Disease on Response to Cold

Those with both cardiovascular disease and diabetes represented the largest group who displayed no response to cold assessment (table 9). However, no significant difference was found for cold assessment ($F(3,1286) = 2.085$, $p > 0.05$).

Table 7: Systemic Disease & Response to Cold (%)				
	WNL	**No Response**	**Sensitivity**	**Did Not Test**
Diabetes	17	47	23	13
CVD	12	43	19	26
Diabetes & CVD	8	54	17	22
None	11	37	25	27

Impact of Systemic Disease on Pulpal Diagnosis

The impact of systemic disease on pulpal diagnosis showed no significant difference ($F(3, 1286) = 0.452$, $p > 0.05$). Those with and without systemic disease had the largest percentage of patients with necrotic pulp status (table 10).

Table 8: Systemic Disease & Pulpal Diagnosis (%)										
	Normal Pulp	**Necrotic Pulp**	**Symptomatic Irreversible Pulpitis**	**Asymptomatic Irreversible Pulpitis**	**NA**	**Prior RCT**	**Previously Initiated**	**Reversible Pulpitis**	**Uncertain Diagnosis**	**Pulpless**
Diabetes	0	50	13	17	3	12	0	3	0	0
CVD	5	39	15	9	7	20	2	0	3	0
Diabetes & CVD	4	47	10	6	3	21	5	0	4	0
None	3	35	24	9	5	20	2	1	3	0

Impact of Systemic Disease on Periapical Diagnosis

Similar to pulpal diagnosis, periapical diagnosis indicated that there was no significant difference ($F(3, 1286) = 0.552$, $p > 0.05$). Most with and without systemic disease indicated symptomatic apical periodontitis (table 11).

Table 9: Systemic Disease & Periapical Diagnosis (%)						
	Normal Apical Tissue	**Chronic Apical Abscess**	**Symptomatic Apical Periodontitis**	**Asymptomatic Apical Periodontitis**	**NA**	**Acute Apical Abscess**
Diabetes	30	7	47	7	3	7
CVD	25	7	39	20	6	3
Diabetes & CVD	17	6	56	15	3	3
None	22	7	42	19	5	5

Impact of Systemic Disease on Endodontic Prognosis

Endodontic prognosis showed no significant difference ($F(3,1286) = 1.422$, $p > 0.05$). All systemic disease categories had the highest percentage of good endodontic prognosis (table 12).

Table 10: Systemic Disease & Endodontic Prognosis (%)						
	Excellent	**Good**	**Guarded**	Poor	**Hopeless**	**NA**
Diabetes	7	80	7	0	3	3
CVD	0	75	18	0	0	6
Diabetes & CVD	0	86	10	0	1	3
None	0	79	15	1	0	5

Impact of Systemic Disease on Periodontic Prognosis

Similar to endodontic prognosis, periodontic prognosis showed no significant difference ($F(3,1286) = 1.593$, $p > 0.05$). The majority of those with and without systemic disease showed good periodontic prognosis (table 13).

Table 11: Systemic Disease & Periodontic Prognosis (%)						
	Excellent	**Good**	**Guarded**	Poor	**Hopeless**	**NA**
Diabetes	7	80	7	0	3	3
CVD	1	83	10	0	0	6
Diabetes & CVD	0	95	1	0	1	3
None	0	87	7	1	0	5

Impact of Systemic Disease on Treatment

There was no significant difference on the impact of systemic disease on treatment ($F(3, 1282) = 1.479$, $p > 0.05$). Most patients in each systemic disease category received root canal treatment (table 14).

Table 12: Systemic Disease & Treatment (%)					
	Incomplete	**Root Canal**	**Retreatment**	**Apicoectomy**	**Extraction**
Diabetes	3	83	13	0	0
CVD	0	78	14	8	0
Diabetes & CVD	0	81	13	5	1
None	0	80	16	4	0

2. Association between Treatment and Clinical Outcome and Prognosis

One-way ANOVA was utilized to analyze association between treatment and all outcome of clinical multitooth testing, endodontic and periodontic prognoses, and recommended treatment (table 15). Further analysis comparing frequency of these variables among different treatment categories are explained below:

Table 13: Treatment One-Way ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Palpation	Between Groups	19.268	4	4.817	6.742	0.000
	Within Groups	915.220	1281	0.714		
	Total	934.488	1285			
Percussion	Between Groups	4.148	4	1.037	1.267	0.281
	Within Groups	1048.692	1281	0.819		
	Total	1052.840	1285			
Cold Temperature	Between Groups	169.064	4	42.266	49.863	0.000
	Within Groups	1085.822	1281	0.848		
	Total	1254.866	1285			
Pulpal Diagnosis	Between Groups	1625.637	4	406.409	164.741	0.000
	Within Groups	3160.177	1281	2.467		
	Total	4785.813	1285			

Periapical Diagnosis	Between Groups	75.607	4	18.902	11.254	0.000
	Within Groups	2151.492	1281	1.680		
	Total	2227.099	1285			
Endodontic Prognosis	Between Groups	400.186	4	100.047	77.248	0.000
	Within Groups	1659.064	1281	1.295		
	Total	2059.250	1285			
Periodontic Prognosis	Between Groups	74.148	4	18.537	13.007	0.000
	Within Groups	1825.601	1281	1.425		
	Total	1899.749	1285			

Treatment and Palpation

Patients who received any type of treatment had a majority of palpation testing within normal limits. All patients who received extractions at the endodontic office tested within normal limits to palpation (table 16). This difference was statistically significant in one-way ANOVA ($F(4, 1281) = 6.742$, $p < 0.05$).

Table 14: Treatment & Palpation (%)

	WNL	**+**	**++**	+++	**NA**
Incomplete	75	0	25	0	0
Root Canal	74	20	2	0	3
Retreatment	70	22	2	1	5
Apicoectomy	53	32	2	0	14
Extraction	100	0	0	0	0

Treatment and Percussion

The impact of treatment on percussion showed no significant difference in one-way ANOVA ($F(3, 1286) = 1.267$, $p > 0.05$). All who were treated with an extraction indicated percussion assessment within normal limits. However, most patients with an incomplete root canal, meaning that the root canal was unable to be performed after the endodontist opened the canal due

to a crack or other untreatable finding, received a "+" outcome to percussion testing. All other treatments had a majority of percussion testing within normal limits (table 17).

Table 15: Treatment & Percussion (%)					
	WNL	**+**	**++**	+++	**NA**
Incomplete	25	75	0	0	0
Root Canal	54	36	7	1	2
Retreatment	63	27	4	1	5
Apicoectomy	61	23	3	0	14
Extraction	100	0	0	0	0

Treatment and Response to Cold

There was a significant difference on the impact of treatment on response to cold assessment ($F(4, 1281) = 49.863$, $p < 0.05$). Those treated with an apicoectomy or retreatment had a majority of response within "did not test". This is due to the need to test cold sensitivity in those cases because the pulp has been removed previously. A majority of those who had root canal treatment or incomplete treatment indicated no response to cold assessment (table 18). This indicates necrotic pulp or periodontitis.

Table 16: Treatment & Response to Cold (%)				
	WNL	**No Response**	**Sensitivity**	**Did Not Test**
Incomplete	25	75	0	0
Root Canal	13	44	28	15
Retreatment	5	25	2	68
Apicoectomy	5	21	2	73
Extraction	0	50	0	50

Treatment and Pulpal Diagnosis

There was a significant difference on the impact of treatment on pulpal diagnosis ($F(4, 1281) = 164.741$, $p < 0.05$). A majority of those with retreatments and apicoectomy treatments have experienced prior root canal treatment. Most of those who received root canal treatment, extraction, and incomplete root canal treatment had necrotic pulp, indicating tooth unsustainability (table 19).

Table 17: Treatment & Pulpal Diagnosis

	Normal Pulp	Necrotic Pulp	Symptomatic Irreversible Pulpitis	Asymptomatic Irreversible Pulpitis	NA	Prior RCT	Previously Initiated	Reversible Pulpitis	Uncertain Diagnosis	Pulpless
Incomplete	0	50	25	0	0	25	0	0	0	0
Root Canal	4	46	26	11	4	2	3	1	4	0
Retreatment	1	1	0	0	7	92	1	0	0	0
Apicoectomy	0	2	0	2	14	83	0	0	0	0
Extraction	0	50	0	0	0	50	0	0	0	0

Treatment and Periapical Diagnosis

There was a statistically significant difference on the impact of treatment on periapical diagnosis ($F(4, 1281) = 11.254$, $p < 0.05$). Those who received extractions had a majority of chronic apical abscess and acute apical abscess diagnoses. All other treatments had a majority of diagnoses as symptomatic apical periodontitis (table 20).

Table 18: Treatment & Periapical Diagnosis (%)

	Normal Apical Tissue	Chronic Apical Abscess	Symptomatic Apical Periodontitis	Asymptomatic Apical Periodontitis	NA	Acute Apical Abscess
Incomplete	25	0	75	0	0	0
Root Canal	27	5	44	15	4	5
Retreatment	6	11	37	36	8	3
Apicoectomy	8	18	32	26	15	2
Extraction	0	50	0	0	0	50

Treatment and Endodontic Prognosis

There was a significant difference on the impact of treatment on endodontic prognosis ($F(4, 1281) = 77.248$, $p < 0.05$). 100% of those who received extractions had a hopeless endodontic prognosis (table 21).

Table 19: Treatment & Endodontic Prognosis (%)						
	Excellent	**Good**	**Guarded**	**Poor**	**Hopeless**	**NA**
Incomplete	0	75	0	0	25	0
Root Canal	0	91	5	0	0	4
Retreatment	1	31	59	2	0	8
Apicoectomy	0	34	50	2	0	14
Extraction	0	0	0	0	100	0

Treatment and Periodontic Prognosis

There was a significant difference on the impact of treatment on periodontic prognosis ($F(4, 1281) = 13.007$, $p < 0.05$). Similar to endodontic prognosis, those who had extraction treatment received a periodontic prognosis of hopeless. All other treatments had a majority of good prognoses (table 22).

Table 20: Treatment & Periodontic Prognosis (%)						
	Excellent	**Good**	**Guarded**	**Poor**	**Hopeless**	**NA**
Incomplete	0	75	0	0	25	0
Root Canal	0	89	6	0	0	4
Retreatment	1	78	13	1	0	8
Apicoectomy	0	68	17	2	0	14
Extraction	0	0	0	0	100	0

DISCUSSION

The purpose of this study was to assess the relationship between systemic diseases, particularly cardiovascular disease and diabetes, and the potential impact on endodontic disease. The prediction was that patients with systemic disease will have an increased risk of developing endodontic disease. Descriptive analysis shows that 31% of patients who received treatment had cardiovascular disease and/or hypertension and 8.4% of patients who received treatment had diabetes. This demonstrates that the majority of the patients who received treatment at the endodontic office did not have a history of systemic disease.

Crosstabulation of systemic disease in relation to clinical assessment, prognoses, and recommended treatment were analyzed to assess potential relationship between these variables. Patients evaluated as part of this study received both percussion and palpation testing to determine pulp health. Percussion testing involves tapping the exterior of the tooth and recording sensitivity as expressed by the patient either verbally or through body language. This sensitivity indicates an inflammatory condition in the apex of the tooth. Palpation testing, on the other hand, involves testing of the gums rather than the tooth itself. When performing palpation, the endodontist massages the gums to ascertain tenderness, swelling, fluctuation, or hardness in the underlying tissues. Study results showed 51% of patients with systemic diseases tested within normal limits for percussion, while 54% of patients without systemic disease tested within normal limits. Although there is a difference of 3%, this result was not significantly different. Similarly, 65% of patients with systemic diseases tested within normal limits to palpation while 74% of those without these systemic diseases tested within normal limits to palpation. Although the difference in this case was 9%, this is not a statistically significant difference. Ultimately, this shows that patients

with diabetes and cardiovascular disease had similar testing results to those without systemic disease when it comes to percussion and palpation.

In addition to percussion and palpation testing, cold assessment was also performed on the patients in this study. Cold tests are performed by applying endodontic ice indirectly to the surface of the tooth. Extreme sensitivity by the patient to the cold indicates pulpal disease, while no sensitivity indicates that the pulp is nonvital. Results show that 54% of patients with systemic disease had no response to cold testing while 37% of patients without systemic disease tested no response to cold, indicating necrotic pulp and the need for endodontic treatment. In a majority of cases where an apicoectomy or retreatment was performed, the clinical cold assessment was not performed and the patient's chart stated, "Did not test". This is because cold testing is unnecessary in these situations since the nerve of the tooth has previously been removed. For all other treatments, the majority of cold testing resulted in no response, indicating necrotic pulp or periodontitis. This result was suspected because most cases referred to the office are in relation to nerve necrosis, therefore requiring endodontic or root canal treatment.

All patients in this study were assessed using percussion, palpation, and cold assessment tests. The majority of results for both palpation and percussion showed that patients fell within normal limits and did not need endodontic treatment, while the majority of results from the cold assessment testing indicated the need for endodontic treatment. This shows that cold assessment was a more specific indicator for endodontic treatment than percussion or palpation testing.

The analysis of treatment in comparison to clinical assessment and prognoses was tabulated. Although one-way ANOVA indicated a significant difference in almost all categories, this result was potentially impacted by the fact that the largest group treated were those who came

to the dental office for root canal treatment. Most patients were referred to the endodontic office from a general dentist who had concluded from their own clinical assessment that the patient was in need of root canal therapy. While a general dentist may refer a patient to an endodontist for various reasons, (e.g., extractions, retreatments, apicoectomies) root canal patients are the most prevalent. As shown in table 3, 79% of patients who received treatment had a root canal. Since this group of patients was much larger than the other treatment categories, this may have contributed to the significant differences seen in one-way ANOVA. By looking at the frequency of patients' clinical assessment results, there is was not much difference in these results.

CONCLUSION

Patients at an endodontic office in Brevard County, Florida displayed no statistically significant difference in multi-tooth testing, prognoses, and treatment when comparing those with or without systemic disease. However, the opposite is true when comparing treatment types. Even though one-way ANOVA shows statistically significant differences when comparing treatments, the patients who needed root canal treatment represented the largest group, which impacts the ability to generalize the findings of the impact of treatment on clinical outcome and prognosis. Since there was no significant difference when comparing patients with and without systemic disease on clinical findings, treatment outcomes, and prognoses, a correlation cannot be determined from the results. It is recommended that a similar study be conducted at a non-specialty dental office to ensure that pre-existing endodontic disease determinations do not impact results.

STUDY LIMITATION

The sample in this study included all patients in the past year who have received root canal treatment at the endodontic office located in Brevard County, Florida, therefore, we were unable to focus on a particular target population or age range. The sample was restricted to one endodontic office in Brevard County, Florida. Since one endodontist performs root canals at the dental clinic, we were limited to the number of patients the dentist treated. However, to combat these limitations, deidentified data was collected from patients who received treatment for an entire year, from January 2019 to December 2019, to increase sample size. Since this study was based on secondary data from previous treatment history, this also limits the generalization of the results. Specific questions were unable to be incorporated in this study because the data is being collected after the treatment has been performed.

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