The Association of Pulp Stones with Cardiovascular Disease

By

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List of Abbreviations

AHA – American Heart Association

CHD – Coronary Heart Disease

CVD – Cardiovascular Disease

DC/C – Dental Caries/Crown

DC/FR – Dental Caries/Facial Restoration

DC/HR – Dental Caries/Heavy Restoration

DC/MR – Dental Caries/Minimal Restoration

DC/NR – Dental Caries/Non-Restored

HChol – Hypercholesterolemia

HTN – Hypertension

IC/HR –Incipient Caries/Heavy restoration

IC/MR – Incipient Caries/Minimal Restoration

IC/NR – Incipient Caries/Non-Restored

NC/C – Non-Carious/Crown

NC/FR – Non-Carious/Facial Restoration

NC/HR – Non-Carious/Heavy Restoration

NC/MR – Non-Carious/Minimal Restoration

NC/NR – Non-Carious/Non-Restored

NC/NR/MR – Non-Carious/Non-Restored/Minimally Restored

NC/MR – Non-Carious/Minimally Restored

NC/NR – Non-Carious/Non-Restored

SMC – Smooth Muscle Cell

VHD – Valvular Heart Disease

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Definition of Terms

Cardiovascular Disease: The class of diseases that involve the heart or blood vessels (arteries and veins)

Denticle: An alternative term for pulp stone, more usually a calcification filled with epithelial remnants surrounded by odontoblasts

Diffuse Calcification: Calcified deposits that are fine, irregular, and fibrillar. They can begin in the wall of a blood vessel, in connective tissue, surrounding a nerve, or following the course of blood vessels and nerves

Dystrophic Calcification: Inappropriate biomineralization of the pulp in the absence of mineral imbalance

Fibrodentine: Material produced by fibroblast-like cells against dentine prior to differentiation of a new generation of odontoblast-like cells

Hertwig's Epithelial Root Sheath [HERS]: A proliferation of epithelial cells located at the cervical loop of the enamel organ in a developing tooth.

Pulp Stone: A pulpal calcification that develops around a central nidus of pulp tissue which then extends outward in a concentric or radial pattern.

True – Made of dentin and lined by odontoblasts

False – Formed from degenerating cells which mineralize

Free – Stone not related to the pulp space wall, surrounded by soft tissue

Embedded – Stone enclosed within canal wall

Adherent – Less attached to dentin then embedded pulp stones

Round or ovoid - smooth surfaces and concentric laminations

No particular shape - lack lamination and have rough surfaces

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Abstract

Background: Pulp stones develop throughout life and are considered to be an age change or perhaps a response to caries or cavity preparation. The factors involved in the development of pulp stones are still largely unknown but recent research has suggested that their formation may be associated with cardiovascular disease (CVD).

Objective: The aim of this study was to evaluate the association between pulp stone formation and CVD in patients aged 20-75 years.

Methods: The records of 200 UM School of Dentistry patients were selected for this study and divided into two age groups: 20-50 yrs and 51-75 yrs. Fifty patients with CVD and 50 patients without CVD were selected in each age group. Patients selected had at least one

non-carious, non-restored, or minimally restored molar tooth. Data collection included: (1) chart review of the medical history identifying self-reported history of CVD and (2) review of dental radiographs for pulp stone formation in non-carious, non-restored or minimally restored (NC/NR/MR) teeth. Data collection was blinded, with different reviewers performing either the patient's medical history or radiographic review.

Results: In the *20-50 years* age group, 23/50 (46%) of subjects *with CVD* had pulp stones in NC/NR/MR whereas 18/50 (36%) *without CVD* had pulp stones. The difference is not statistically significant. In the *51-75 years* age group, 20/50 (40%) of subjects *without CVD* had pulp stones whereas in the group *with CVD* 19/50 (38%) of subjects had pulp stones. The difference is not statistically significant. A comparison of the prevalence of pulp stones between the two age groups showed no statistically significant differences.

Conclusions: There is no significant difference in pulp stone formation between patients *with CVD* and patients *without CVD* in NC/NR/MR teeth overall nor is there any difference between age groups. In this study, CVD was not a risk indicator of pulp stone formation.

Chapter 1- INTRODUCTION

Significance of Pulp Stones

The mechanism of pulp stone formation is unknown [1, 2]. The current literature indicates that diffuse calcifications may be a result of aging, whereas the origin of pulp stones is still under debate [3-5]. Some studies have suggested that the formation of pulp stones may be associated with certain disease processes such as cardiovascular disease (CVD) [6-8]. The purpose of this study is to investigate whether there are differences in the prevalence of pulpal calcifications, specifically pulp stones, in individuals with and without cardiovascular disease in a dental school patient population. If the results of this study support a positive relationship between CVD and pulp stones, this could be of value during dental radiographic assessment because potential risk for undiagnosed CVD could be

identified. This would be especially important in younger populations to allow early intervention.

Chapter 2 – LITERATURE REVIEW

Cardiovascular Disease and the American Heart Association

According to the American Heart Association (AHA) [9], over 83 percent of people who die of coronary heart disease (CHD) are 65 or older. The AHA also states that the lifetime risk of developing CHD after age 40 is 49% for men and 32% for women. The threshold for increased risk for coronary heart disease in men occurs at age 40 while in women this threshold occurs at age 50. The AHA defines cardiovascular disease not just as one disease but a range of diseases that affect the heart. CVD generally refers to conditions that involve narrowed or blocked blood vessels that can lead to a heart attack, chest pain (angina) or stroke. Other related conditions include infections and disease that affect the heart's muscle, valves or rhythm. The various forms of cardiovascular diseases that are included under the umbrella of cardiovascular disease are: coronary heart disease (myocardial infarction, angina pectoris, atherosclerosis and coronary artery disease), cerebrovascular

accident (stroke), transient ischemic attack (mini stroke), hypertension, and heart failure. Other forms of CVD include: rheumatic fever/rheumatic heart disease, congenital cardiovascular defects, arrhythmias, diseases of the arteries, arterioles and capillaries (atherosclerosis and Kawasaki disease), bacterial endocarditis, cardiomyopathy, valvular heart disease, diseases of pulmonary circulation, diseases of veins and lymphatics, and other diseases of the circulatory system [9].

High cholesterol is considered one of the major controllable risk factors for coronary heart disease, heart attack and stroke [10]. Research over the past decade has linked lipids to inflammation and atherosclerosis. This process occurs when low-density lipoprotein (LDL) levels become elevated in the circulating blood and become retained in the intima of the blood vessel. This retained lipoprotein then undergoes oxidative modification [11, 12] allowing lipid hydroperoxidases, lysophospholipids, carbonyl compounds, and other biologically active moieties to localize in the lipid fraction of atheroma [13]. These modified lipids can induce the expression of adhesion molecules, chemokines, pro-inflammatory cytokines, and other inflammatory mediators in macrophages and vascular wall cells. The result of this inflammatory process is degradation of the arterial extracellular matrix permitting the penetration of the smooth muscle cells (SMC) through the elastic laminae and collagenous matrix of the growing plaque. Ultimately, when the plaque ruptures, the tissue factor induced by inflammatory mediators triggers a thrombus to form causing acute complications of atherosclerosis [14]. The result of narrow and hardened arteries increases the risk of thrombus formation which could lead to a myocardial infarction or stroke. Elevated levels of circulating cholesterol have also been

demonstrated in the dental pulp leading to the formation of pulpal arterial calcifications or pulp stone formation in teeth [15, 16].

Pulp Stone Background

A frequent finding [17] that receives little attention, pulp stones develop throughout life and throughout the pulp tissue [18] and are largely regarded as being a normal either a consequence of aging [4], a result of caries [19], or a result of irritation from extensive restorative treatment [20, 21]. The etiologic factors involved in the development of pulp stones are still largely unknown [1] and the only currently accepted clinical significance they have is blocking canals during endodontic treatment [22]. It has, however, been suggested that pulp stone formation is associated with coronary atherosclerosis [6-8].

Types and Formation of Pulp Stones

Pulp stones may exist as freely floating calcifications within the pulp chamber or may be attached to or embedded into the dentinal wall. Two types of pulp stone have been described: (1) Denticles possessing a central core filled with epithelial remnants surrounded peripherally by tubular dentine made by odontoblasts and (2) stones possessing central cores of tubular and atubular dentine surrounded by calcified tissues [23]. Pulp stones can also be classified based on their location and structure within the pulp as: true, false, free, embedded, adherent, round/ovoid, and no particular shape [24] (see definition of terms). Other forms of calcification within the pulp of a tooth are: fibrodentine, diffuse calcifications and dystrophic calcifications (see definition of terms). Pulp stones can also be subdivided into those with distinct concentric laminations and those without distinct laminations. Laminated pulp stones are not usually associated with

smaller pulp stones, whereas non-laminated stones are rougher and may have smaller stones attached to their surfaces [25].

Prevalence of Pulp Stones

Many large epidemiological studies have investigated the prevalence of pulp stones in both primary and permanent teeth [5, 17, 21, 26-32]. Table 1 shows the pulp stone prevalence data from large scale surveys of permanent teeth in different populations.

Investigator	Methodology	Sample (n)	Age of Subjects (yrs)	Prevalence (%)
Hill (1934)	Histology	132 teeth	10-70 yrs	10-30 yrs (66%), 31-50 yrs (80%), 51-70 yrs (90%)
Sayegh & Reed (1968)	Histology	591 teeth	10-63 yrs	31.6% teeth
Hillmann & Geurtse (1997)	Histology	332 teeth	11-72 yrs	11-30 yrs (14.9%), 31-51 yrs (44.4%), 52-72 yrs (65.1%)
Hamasha & Darwazeh (1998)	Radiography	4,573 teeth, 814 subjects	18-69 yrs	22.4% teeth, 51.4% subjects
Tamse *et al.* (1982)	Radiography	1,380 teeth, 300 subjects	20-40 yrs	20.7% teeth, 41.6% subjects
Chandler *et al.* (2003)	Radiography	445 teeth, 121 subjects	18-25 yrs	9.9% teeth, 4% subjects
Sener *et al.* (2008)	Radiography	15,326 teeth, 536 subjects	13-65 yrs	4.8% teeth, 38% subjects
Rozylo et al. (1999)	Radiography	880 teeth	18-56 yrs	25.7% teeth
Perminder & Singh (1985)	Radiography	2,452 teeth	unknown	18% teeth
Baghdady *et al.* (1988)	Radiography	6,228 teeth	12-13 yrs	19.2% teeth
Ranjitkar *et al.* (2002)	Radiography	3,296 teeth, 217 subjects	17-35 yrs	10.1% teeth, 46.1% subjects

Table 1: Pulp stone prevalence in radiographic and histologic studies

When investigating pulp stone prevalence in teeth two methods are commonly used: histology and radiography. Although pulp stone prevalence seems to vary between studies and populations, one consistent finding the literature shows is that histological studies

estimate a higher prevalence then radiographic studies [5, 17, 19], because smaller pulp stones and diffuse calcifications cannot be identified by radiographically [17]. Pulp stones tend to be more common in molars, heavily restored and carious teeth [19-21]. Most histologic studies show that, with advancing age, diffuse calcifications become more common whereas the prevalence of pulp stones remains constant throughout life [5, 33]. Though the literature shows a wide range of values for prevalence, diffuse pulpal calcifications appear to be consistent with advancing age [3-5, 24, 34]. Whether through histologic or radiographic studies, the prevalence of pulp stones is prominent throughout different populations and age groups; however the difference in frequencies between the groups remains unclear. Very few of these studies examine the medical histories of these patients to determine if any systemic diseases were present which may have contributed to the development of pulp stones [6-8, 20].

Etiology of Pulp Stones

The mechanism of pulp stone development is not fully understood. Two possible mechanisms have been proposed: (1) Initial calcification of isolated pulp tissue components, which may occur anytime and anywhere in the pulp tissue and (2) Epithelio-mesenchymal interactions during odontogenesis, which may occur only in the furcation areas and near the root sheath [18]. The first mechanism occurs when cell components (collagen, ground substance, necrotic cell remnants) serve as a nidus to which calcified materials adhere or deposit. The second proposed mechanism occurs when epithelial strands detach from the enamel organ during tooth development. These strands become isolated in the dental papilla where they interact with the papilla mesenchyme, resulting in the physiologically normal differentiation of odontoblasts around the strands [18].

A few histologic studies have shown that a high frequency of cell islands, considered to be of epithelial origin (possibly Hertwig's Epithelial Root Sheath [HERS]) are observed together with pulp stone formation in teeth that had been subjected to orthodontic intrusion[35, 36]. This infers that HERS may induce pulp stone formation. However, when orthodontic movement is applied to teeth with incomplete root formation, fragmentation of the root sheath may occur causing the islands to form. Some studies suggest that true pulp stone formation may occur only during root formation in the radicular pulp and furcation areas of multi-rooted teeth suggesting that the response of the pulp tissue to a stimulus may be age-dependent [23]. Other studies have found that dentine or dentine-like tissue could be made by inducing fibroblasts in the pulp [37].

Pulp stones have also been investigated by scanning electron microscopy [38] and immunohistochemistry [39, 40] to determine their chemical composition. The two major mineral elements found in pulp stones are calcium and phosphorus. The average concentrations of these two elements are 32.1% calcium and 14.7% phosphorous with the rest of the composition being fluorine, sodium, and magnesium [38]. Trace elements of potassium, chlorine, manganese, zinc, and iron are also found. The major organic component of a pulp stone has been identified as collagen type I which is evenly distributed throughout the stone [40]. Osteopontin, a non-collagenous protein, is found in the periphery of a pulp stone suggesting that it plays a role in the calcification of pulp stones whereas osteonectin and osteocalcin haven't been observed [40]. Some researchers have investigated osteopontin in pulp stones by immunohistochemistry to determine whether there is any correlation between this non-collagenous protein and other atherosclerotic plaques and stones found in the body. It was found that osteopontin has similar

immunostaining to atherosclerotic plaques and urinary stones [39, 41]. These findings suggest that the calcification process involved in pulp stones may be similar to other conditions or systemic diseases such as CVD.

As teeth age, the size of the pulpal chamber is reduced due to the deposition of secondary and tertiary dentin [3] and the increase in collagenous bundles and progressive deposition of calcified masses [4]. Blood vessels start to calcify and decrease in number along with nerves in the coronal pulp while collagen bundles of vascular and neural sheaths become the loci for calcification [3]. A common finding as teeth age is the presence of diffuse calcifications [5, 19, 33], fat deposits [34] and increased amounts of collagen [5].

Available reports on of pulp stones with advancing age show no correlation [20, 24, 33]; diffuse calcifications, on the other hand, do show an association with advancing age [4, 5, 17, 24, 33]. These data suggest that diffuse calcifications are a natural component of aging, but pulp stone formation is not and thus may be a manifestation of another disease or condition.

Pathogenesis of Pulp Stones

Calcifications have been shown to be more likely in carious [19, 20] and heavily restored teeth [20, 21, 31] suggesting that, under pathological conditions, the process of pulp stone formation increases, while under normal conditions pulp calcifications are a physiological process. No definitive association has been found between periodontal disease and pulpal calcifications (discrete and diffuse) [42].

There are reports of pulp stones in patients with genetic disorders such as tumoral calcinosis [43], dentin dysplasia, dentinogenesis imperfecta, Van der Woude syndrome [44],

osteogenesis imperfecta type I [45] , Saethre-Chotzen syndrome [46], elfin facies syndrome [47], familial expansile osteolysis [48], Ehlers Danlos syndrome type I [49], Marfan syndrome [50] and otodental syndrome [51]. These genetic disorders, although rare, show a high prevalence of pulp stone formation but the causative factors of this relationship are unknown.

Recent studies have suggested a correlation between cardiovascular disease and pulp stone formation [6-8]. A significant correlation between coronary atherosclerosis and increased pulp stone prevalence has been shown in patients aged 40-60 [7]. Radiographic studies on the effects of aging in the dental pulp found that dental pulp shrinkage is statistically greater in individuals with calcification-related diseases (atherosclerosis, hypertension, kidney stones, gout, gallstones, and arthritis) than in individuals without those diseases [52, 53] suggesting that the higher rate of root canal closure and pulpal calcifications could be related to calcification-related diseases such as cardiovascular disease.

The earliest researchers to look at a relationship between pulp stone formation and systemic diseases dates back to 1933 [54] when Stafne and Szabo investigated various systemic disturbances and the prevalence of pulp stone formation to see if an association could be established. They found that although pulp stones were not significantly higher in patients with atherosclerosis (53%) than normal patients (46%), it was suggested that changes in pulp blood vessels may predispose to the formation of calcifications in the pulp. More recently, research examining the effects of systemic diseases and pulp stone formation has shown a statistically significant correlation between CVD and pulp stones in patients 20-55 years when compared to patients without CVD [6, 8]. New evidence has also

linked high glucose levels with increased osteopontin production, leading to pathologic pulpal calcifications in diabetic rats [55]. These findings suggest that systemic conditions such as CVD and diabetes that cause atherosclerosis in large vessels could similarly cause atherosclerosis and calcifications in small vessels and thus pulp stones. Other studies contradict this suggestion [20, 21, 31]. Animal studies where atherosclerosis was induced to examine the effects on the pulp have showed no observable differences in pulpal calcifications between normal and atherosclerotic animals suggesting systemic atherosclerosis does not directly affect the pulp and thus pulp stone formation [56].

To date, there seems to be conflicting evidence that supports the hypothesis that systemic diseases such as CVD can cause pulpal changes/calcifications within teeth. There does seem to be agreement that caries, large restorations, and genetic disorders do play a role in pulpal calcifications either from local irritation caused by bacteria or a genetic predisposition. In order to find if a true association between CVD and pulp stones exists, more stringent inclusion criteria is needed to factor out these potential confounders which could mask the effect of CVD on the pulpal tissues. Future studies that look for an association between CVD and pulp stones should focus on patients without genetic disorders having teeth that are non-carious, minimally restored, or non-restored to evaluate the true effect of CVD.

Previous Studies of Association between CVD and Pulp Stone Formation

Recent studies that support the hypothesis that the formation of pulp stones is more prevalent in patients with cardiovascular disease than patients without cardiovascular disease are by Moura and Paiva [7], Edds [6] and Nayak [8].

Moura and Paiva conducted a study on 50 Brazilian patients aged 40-60 years with (25 patients) and without (25 patients) coronary atherosclerosis. This was performed through a periapical radiographic examination of teeth looking for free pulpal calcifications in the pulp chamber. Diagnosis of atherosclerosis was confirmed by clinical examination, laboratory tests, and angiocoronariography. A total of 570 teeth were available and pulpal denticles were recorded and related to both the total number of teeth and to each subject within the group. Their findings were that patients in the atherosclerotic group had significantly more teeth with denticles than the control group, 92% (23/25) vs. 40% (10/25), respectively. When compared on a per tooth basis, significantly more teeth in the group with atherosclerosis had denticles than the control group, 53% (174/327) vs. 16% (39/342); respectively. This evidence suggests an association between pulpal calcifications and atherosclerotic disease. This study, however, had a small sample population (n=50), was not blinded, and the caries and restoration status of the teeth were not considered. By having a small sample population, even slight differences in pulp stone prevalence could affect statistical significance. By not blinding the study, bias could have easily altered the results giving a false correlation. Also, by not accounting for the caries or restoration status of teeth, the true effect of CVD could be masked by local inflammatory mediators irritating pulpal tissue caused from bacteria or large restorations.

Edds conducted a pilot study on dental patients from the University of Louisville School of Dentistry proposing that calcifications of the dental pulp, specifically pulp stones, has the

same pathogenesis as calcified atheromas found elsewhere in the body. In this study, 55 patients aged from 20-55 years with non-carious or minimally restored teeth were evaluated through a medical history interview regarding their cardiovascular disease status as well as that of their parents and siblings. The patient's periapical radiographs were then evaluated blind by one of the examiners to determine the presence or absence of pulp stones. Their results demonstrated a significant relationship between pre-existing cardiovascular disease and pulp stone formation; 74% (14/19) of patients with reported history of CVD had pulp stone formation while only 39% (14/36) of patients without a history of CVD had pulp stone formation. No correlation could be found between family history of CVD and pulp stone formation. This study also had a small sample population (n=55) which was unevenly distributed between patients with and without CVD. There were only a total of 19 patients with CVD representing only 34.5% of the total patient population. This uneven distribution of patients could affect pulp stone prevalence and significance of their findings. Larger, evenly distributed patient populations are necessary to properly look at association and significance.

Nayak conducted a study on dental patients from the KVG Dental College and Hospital, India, and also proposed that calcifications of the dental pulp, specifically pulp stones, has the same pathogenesis as calcified atheromas found elsewhere in the body. Nayak's study consisted of 150 total patients divided into 5 groups each consisting of 30 patients: (1) CVD, (2) type 2 diabetes mellitus, (3), type 1 diabetes mellitus, autoimmune thyroiditis, Sjogren's syndrome, SLE, and multiple sclerosis, (4) dental-wear defects and (5) control group. They found that 93% (28/30) of patients and 15.86% of teeth contained pulp stones in *patients with CVD* compared to 50% (15/30) of patients and 2.83% of teeth in

patients *without CVD*. These findings, similar to Edds, suggest that patients with CVD have a significantly increased prevalence of pulp stone formation when compared to healthy patients. This study was not blinded and had a small sample population of patients with CVD (n=30) which could affect the prevalence and overall significance. Opposed to looking at multiple diseases in smaller numbers, this study should have focused on one disease and increased the number of patients to obtain more concrete conclusions.

The shortcomings of these studies could lead to inaccurate conclusions. There are also relatively few studies that look at the association between CVD and pulp stones which also creates controversy when different findings conflict. More research is needed to close this gap in knowledge. Our study avoids these shortcomings and may be more able to assess if any true association exists between CVD and pulp stone formation.

Chapter 3 – STUDY AIMS

Purpose

The purpose of this study is to investigate whether there are differences in the prevalence of pulpal calcifications, specifically pulp stones, in individuals with and without

cardiovascular disease in a dental school patient population. This study will consist of dental chart and medical history reviews observing for the presence or absence of cardiovascular disease in individuals through their medical histories and then reviewing the patient's dental periapical and bitewing radiographs for the presence of pulp stones in non-carious, non-restored, or minimally restored teeth. This study is unique because it could provide valuable information for screening patients for cardiovascular disease, especially in younger populations (20-50 years) because early intervention could be optimal for preventing progression of this disease.

This study will evaluate 200 patients from UM School of Dentistry that will address the following aims and objectives for this project. Overall, we will analyze patient characteristics and teeth in which pulps stones have been identified. Overall pulp stone prevalence will be addressed and prevalence between age groups. Specifically, we will look to see if there is a correlation between CVD, specific types of CVD, and restoration status of teeth and pulp stone prevalence. Comparison of pulp stone prevalence within and between age groups will be assessed to identify any additional associations. Finally, additional covariates will be assessed to see if they have any impact on pulp stone formation.

Aims

1) What are the patient characteristics for Age, Gender, CVD diagnosis, restoration and caries status in this study population?

2) What is the distribution of pulp stones in this study population?

3) What is the overall prevalence of pulp stones in this study population?

4) Is there an association between the prevalence of CVD and the presence of pulp stones in patients' ages 20-75 years in teeth that are non-carious, non-restored, or minimally restored?

5) Is there an association between the prevalence of CVD and the presence of pulp stones within and between the age groups 20-50 years and 51-75 years in teeth that are non-carious, non-restored or minimally restored?

6) Is there an association between the prevalence in pulp stones in non-carious, non-restored, or minimally teeth between patients with specific types of CVD such as hypertension, valvular heart disease, and hypercholesterolemia and those without CVD in the 20-50 years and 51-75 years age groups?

7) Are there any additional covariates such as age, gender, diabetes, arthritis, tobacco use, or alcohol use that could affect the prevalence of pulp stones in teeth?

8) Is there an association between the prevalence in pulp stones in patients teeth based on caries status and the restoration status?

Hypothesis

The formation of pulp stones is more prevalent in patients with cardiovascular disease than in patients without cardiovascular disease, suggesting that the same disease process and factors causing atherosclerosis in large blood vessels accelerate the calcifications in pulpal tissues.

Chapter 4 – MATERIALS AND METHODS

Study Design

The design for this project consisted of a cross-sectional study evaluating two different groups: patients with CVD and patients without CVD. Once these groups were identified, medical history and dental radiographic records reviews were performed to collect data that would be statistically analyzed identifying any association between the prevalence of pulp stones and CVD (Figure 1). The data for patients were gathered through two methods: (1) a chart review of the medical history section in the patients' dental chart, identifying self-reported or medically documented history of CVD and identification of medications taken for cardiovascular-related diseases and (2) reviewing patient's dental radiographs (periapical and bitewing radiographs) for pulp stone formation in non-carious, non-restored, or minimally restored teeth. The controls for this study were patients without self-reported or medically documented history of CVD. Their radiographs were also

evaluated for pulp stone formation in non-carious, non-restored, or minimally restored teeth.

The first 200 patients' aged 20-75 years who met the inclusion criteria were divided into two separate age groups of 100 patients each; 20-50 years and 51-75 years. Each age group was then divided again into 50 patients with CVD and 50 patients without CVD. These separate age groups 20-50 years and 51-75 years were chosen because men and women acquire an increased risk for CVD at 40 and 50 years; respectively. Dividing these age groups allow for analysis in the younger age group determining whether a true association between CVD and pulp stones exists without age being a factor.

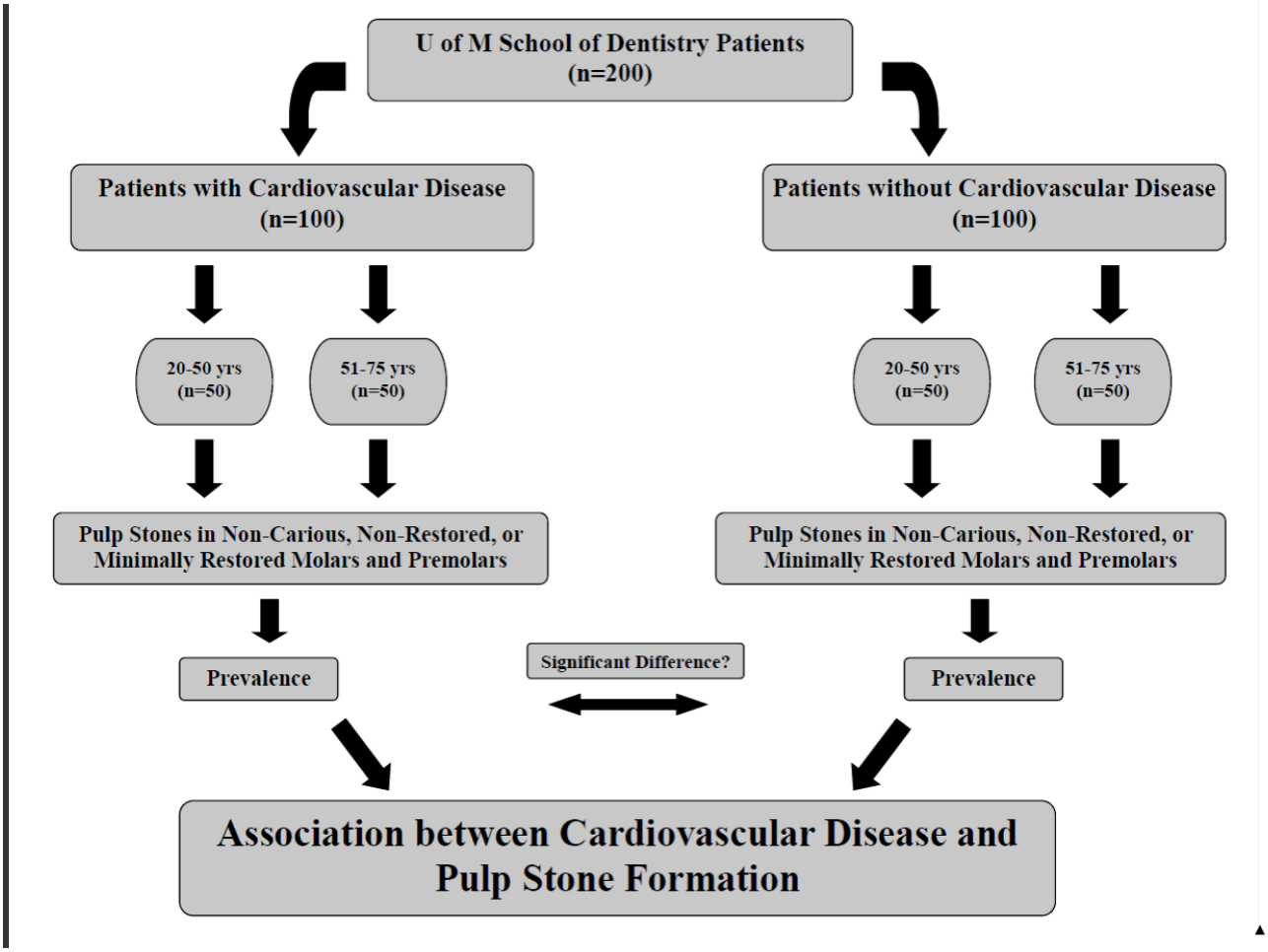

Figure 1: Flowchart of methodological approach to study

Power Analysis

A power analysis was performed based on two studies evaluating the correlation between cardiovascular disease and pulp stone formation; Edds (2005) and Moura (1987). Edds research consisted of 55 patients aged 20-55 years with at least one tooth that was fully erupted, minimally restored, non-carious molar, free from radiographically observable

periodontal disease. In the second study, Moura studied 50 patients aged 40-60 years divided into two groups of 25 patients each. One group consisted of patients with confirmed diagnosis of coronary atherosclerosis and the other group without coronary atherosclerosis. These two papers were chosen because they showed a positive association between cardiovascular disease and pulp stone formation. Using these studies [6, 7], a power analysis using a significance level of 0.050 and a power of 80% indicated that 200 patients would be sufficient for this project. Hence, two groups of individuals were evaluated: 100 patients with cardiovascular disease and 100 patients without cardiovascular disease.

Masking the Study

When selecting patients who met the inclusion criteria for this study, two separate master keys were made. Each master key contained columns for the patient's study ID (1-200), dental chart number, and study ID allocation date. In order to keep track of the patient's CVD diagnosis, a separate column was created on one master key containing CVD diagnosis (yes or no) (Appendix A) but was omitted on the other (Appendix B). This kept count of how many patients were still required for each CVD group. At the bottom of the master key in the comments section, tallies of how many patients with and without CVD were totaled. The master key in which the CVD diagnosis was omitted contained two separate columns identifying whether the medical history and dental radiograph reviews were completed (yes or no) (Appendix B). This was done so that during data collection the radiographic reviewer would not know the CVD diagnosis of the patient. Each patient was assigned a study ID number which was entered on both master keys and their CVD diagnosis (yes or no) was entered only on the one master key (Appendix A). After all of the patients were

selected for the study, the master key containing the CVD diagnosis was kept in a secure, locked file cabinet. The other master key containing the patient's study ID, dental chart number, and the columns for completed medical and dental radiographic reviews was used for data collection. In order to prevent bias during the data collection portion of the study, data collection was masked, with different reviewers performing either the patient's medical history or radiographic review. Fourth year dental student Erik De Young and second year dental student Tom Guinall collected medical history review data while Drs. Jeffrey Dzingle and Lauren Johnson collected the dental radiographic review data for this project. Erik De Young also participated in collecting radiographic data for this project but only on charts he did not already complete medical history review. To keep track on the master key of whom collected data on each patient chart, examiners were assigned different shapes in which they would draw around the "yes" selection in the portion of the medical or dental radiographic review they completed. Erik DeYoung was assigned a rectangle "▭", Tom Guinall was assigned a diamond "◊", Dr. Lauren Johnson was assigned a triangle "Δ", and Dr. Jeffrey Dzingle was assigned circle "O". If any questions arose about data collection on any particular patient it was easy to identify who recorded the information.

Study Variables

Medical History and CVD Diagnosis

Medical histories were evaluated based on the self-reported or medically documented history of CVD. This included the different forms or definitions of CVD on the medical history in the dental treatment chart including: hypertension, myocardial infarction,

atherosclerosis, coronary artery disease, angina or chest pain, heart surgery, congestive heart failure, valvular heart disease, arrhythmia, cardiomyopathy, rheumatic heart disease, heart murmur, mitral valve prolapsed, hypercholesterolemia, cerebrovascular disease, and transient ischemic attack. Patients that document "other" possible forms of CVD were also identified on the medical history data collection forms. Lists of cardio-protective drugs were also documented based on patient self-report.

Age, Gender, and Other Diseases/Conditions

Age of patient, gender of patient, and other diseases or conditions that may affect the formation of calcifications in the body were evaluated. This included calcification-related diseases such as: arthritis, kidney disease, diabetes, gout, metabolic diseases, connective tissue disorders, and peripheral vascular disease. Tobacco use and alcohol consumption were also included as "other conditions" because they can influence CVD.

Pulp Stone Identification

Identification of pulp stones in this study consisted of examining bitewing and periapical radiographs for radiopaque objects in either the pulp chamber or pulp canal. The definition of a pulp stone was 'any distinct radiopaque object, free or attached, identifiable in the pulp chamber or pulp canal in any maxillary or mandibular molar or pre-molar tooth'. Calibration for radiographic assessment of pulp stones was performed by discussing radiographs with documented pulp stones and defining the radiographic characteristics of pulp stones. A Training and Calibration Protocol manual was created for assessment and identification of radiographic variables for data collection in this study (Appendix F). The

kappa statistic was used to determine the inter-observer agreement of radiographic pulp stone formation, radiographic periodontal disease status, restorations status and radiographic dental caries detection. For calibration of examiners for the variables described above, all examiners had to have performed the specified measurements on at least 2 patient charts. After data were collected, it was entered into a Microsoft Access data base for error correction and cleaning and analyzed using SPSS Version 18. Inter-observer agreement between Dr. Dzingle and Erik De Young was 95.7% while inter-observer agreement between Drs. Dzingle and Johnson was 94.8%.

Study Source Population

The individuals selected for this cross-sectional study were patients at The University of Michigan School of Dentistry. The dental school provides complete dental care to many different kinds of medically compromised, social-economic, racial, and age groups. The dental school currently has around 60,000 active patient records held in "Central Records" in the basement of the school in which approximately 22,000 of these records contain patients between the ages of 20-50 years and approximately 39,000 between the ages of 20-75. Dental records contain the patient's medical and dental histories, radiographs, treatment plans, treatment history, periodontal charts, consents and referrals. Dental charts are audited yearly by the student dentists to ensure proper maintenance, updating, and documentation of treatment plans, radiographs and medical histories. The students are required to fill out chart audits forms for each of their patients and submit them to their clinic coordinator who reviews them. Bitewing radiographs are taken yearly at recall visits for caries detection and full –mouth series containing periapical radiographs are taken approximately every 5 years.

Inclusion Criteria

A total of 200 patients' ages 20-75 years were divided into two separate age groups of 100 patients each; 20-50 years and 51-75 years. Each age group was then divided again into 50 patients with CVD and 50 patients without CVD. The first 200 consecutive patients that met the inclusion criteria were selected. Inclusion criteria for selecting patient records for chart review and data abstraction were records of dentate individuals 20-75 years of age who accessed the School of Dentistry since 2006. Patients must have had at least one molar tooth that is fully erupted, non-carious, non-restored or minimally restored. The definition of a non-carious tooth is one having no caries or incipient caries (caries in enamel only). The definition of a minimally restored tooth is one with restorations in enamel or superficial dentin (1/3 or less dentin thickness). Teeth having caries (caries into dentin) or heavy restorations (restorations covering more than one surface, facially restored teeth, or restorations deeper than 1/3rd dentin thickness) containing pulp stones were also included in this study but in a separate category identifying the extent of caries or restorations. This information was used in assessing the overall prevalence of pulp stones in the two study groups. To select patients who met the inclusion criteria, an excel spreadsheet was created containing patient information on active patients in the School of Dentistry from 2006-present. Patient name, dental chart number, and age were used to select patients for each age group. Charts were signed out from central records in the order they appeared on the excel spreadsheets and evaluated individually by Dr. Dzingle identifying if they met the inclusion criteria for CVD and teeth. If the patient chart did not meet inclusion criteria, it was returned to central records to be re-filed. If the patient chart

met inclusion criteria, the chart number was recorded on both Master Keys (Appendices A & B) and retained for future data collection.

Data Collection

Data were collected on data collection forms detailing the patient's medical and dental radiographic history (Appendices C, D, and E). Medical and dental review data collection forms were kept separate during data collection to prevent the radiographic reviewer from knowing the CVD diagnosis of the patient being evaluated. When data collection forms were completed, they were filed into a "data collection" tub containing hanging folders for the medical and dental review forms. When both sections of the medical and dental radiographic reviews were checked off on the master key, the medical and dental radiographic data collection forms were removed from the "data collection" tub, stapled together, and then placed into hanging folders in a "data entry" tub where they were stored until they were entered into the Microsoft Access database. Data were then entered, using double data entry, into a Microsoft Access database specifically designed to verify if data were entered accurately.

Both bitewing and periapical radiographs were evaluated from the patient's dental chart to identify pulp stone formation. Radiographs being evaluated were the most current. Diagnosis of pulp stone formation was based on visual inspection of dental periapical or bitewing radiographs. A Clinical Operations Procedures Manual was created for data collection so that any observer collecting data either on the medical review or dental radiographic review could use for reference in case a question arose. This manual

contained pertinent information regarding clinical protocol, procedures, definitions and identification markers for variables being analyzed in this study (Appendix G).

Data Entry, Management, and Quality Control

Microsoft Access was used to create a data entry program and database in which to enter all of the information collected on the medical history review and dental radiographic review forms. The database contained: 1) All screens for double data entry with built-in filters and checks of valid values, 2) The underlying tables with the individual data entered for both double data entry with entries, 3) Comparison programs that compared and identified discrepancies between the two entries of the same data, 4) Programs for entering and posting of data entry correction, 5) Cleaning rules and an option to print such rules, 6) Functions to print all structures for all the tables.

Each data collection form had one or more analogous data entry screens, designed to closely resemble the hard copy form in order to assure accuracy of data entry. An underlying table was created for each data collection form, and the data were stored in those tables, all within the database application.

Initially, the data entry screens were proofread and tested by entering fictitional data to test for functionality and cursor advancement. It was also verified that each data point entered in the data entry screen was correctly linked to the correct corresponding field in the underlying table. Subsequently, they were tested by entering real data from copies of data collection forms. The key with the linkage between the subject identifier and the identity of the subject was kept by Dr. Dzingle under lock at all times when not in use.

Data quality control provisions were implemented from data entry through data analysis procedures. The data entry programs were designed to reject illogical or out-of-range values, accommodate inherent skip patterns, and had features to provide pre-recorded entries for fixed-value fields to reduce the likelihood of errors in data entry. The program was designed to compare the two tables with data entered two different times and discrepancies were listed in an output file that was used for data entry error correction. This file showed the field (variable) name and the two values entered during the first and second round of data entry. These error correction tables were separate from the raw data entered in the actual electronic forms. Corrections could be done in the error correction table and then electronically inserted to their respective items in the data table after the corrections have been verified according to the original data collection forms by Dr. Dzingle. Additionally, data verification was conducted; additional logic checks and cleaning procedures to assure data quality prior to data analysis were also preformed. Regular and periodic inspection of frequency distributions, value ranges, and cross-tabulations of selected variables and review the reports were performed during the course of the project to verify accuracy of data entry and to provide early opportunities for clarification of questions and correction of errors and omissions.

The database was sent via electronic mail as a password-protected file from Dr. Dzingle to Dr. Taylor. Data was transformed into SPSS data files via Excel spreadsheets. The database with all the data, any saved Excel spreadsheets, and the SPSS datasets and program and output files resided on password-protected computers in Dr. Taylor's secure dry laboratory space and on Dr. Dzingle's password-protected computer. The files were backed up in

folders that were sent via password protected e-mail to dedicated space in Dr. Dzingle's umich e-mail account.

Only authorized project personnel were allowed access to project data. Laptop and desktop computers used for the project were password protected.

All personnel involved with the data management and statistical analysis team verbally pledged to keep data confidential, assuring that they will not transfer any information gained from the study to individuals not connected to the study. All data collection forms carried a study identification number only, no other identifiers were known to Dr. Taylor or the data management and analysis team. The copies of data collection forms were kept under lock at all times when not in use. In case of electronic transfer via the Internet, the password would be revealed separately from the message accompanying the files. In case of surface-mail of CD-ROMS or other storage media, the password would not be mailed together with the media. The passwords would be revealed by telephone or electronic mail without any detailed description of the file name, just referring to "the password you need".

A Microsoft Access Procedures Manual (Appendix H) was developed with instructions in how to utilize the comprehensive database, from opening the application and identifying the data entry screen that corresponds to any given data collection form, to how to enter data twice and compare the entries and correct any entry errors. Also, instructions were provided regarding how to back up and password-protect the database. All necessary hands-on training and demonstration for use of the database was provided to Dr. Dzingle as needed by Dr. Taylor and his team. A Microsoft Access Codebook (Appendix I) and SPSS Data Analysis variable definitions (Appendix J) were created for variable definitions in both Microsoft Access and SPSS Data analysis programs.

Statistical Analysis

The statistical analysis consisted of several stages. The first stage conducted a univariate analyses on the variables of interest to determine distributions and to evaluate the need for transformations and possible categorical specifications of the variables. The next stage conducted a bivariate analysis to assess the crude association between the CVD and prevalence of pulp stones. The third stage conducted a stratified analysis to evaluate third variables, as potential confounders or effect modifiers that may affect the bivariate or crude association between CVD and prevalence of pulp stones. If the stratified analysis resulted in any statistically significant findings, then the last stage would be to conduct a multivariate logistic regression analysis to simultaneously control for multiple covariates that may influence the formation of pulp stones, and/or act as confounders or effect modifiers of the association between CVD and pulp stones. The coefficients estimated in each of the bivariate, stratified and multivariate logistic regression analyses were expressed as an odds ratio with 95% confidence intervals. Statistical analysis for between-group comparisons was based on a chi-squared test of association, while analysis for between-group comparisons adjusted for other factors was based on logistic regression. Poisson regression was used to assess whether restorations or caries were predictors of pulp stone formation in teeth. Statistical significance was defined as a p-value less than 0.05.

Chapter 5- RESULTS

Aim 1

What are the patient characteristics for Age and Gender, CVD diagnosis, Restoration and Caries status in this study population?

Age and Gender

Table 2 shows the CVD characteristics of all age groups along with other potential diseases/ conditions that could affect CVD. In this table, the patient population analyzed for pulp stones is presented in three age groups: 20-75 years, 20-50 years, and 51-75 years. The age group *20-75 years* contained the total patient population of 200 patients which was then divided equally into age groups of *20-50 years* (n=100) and *51-75 years* (n=100). The average age for the total patients (n=200) in the 20-75 years age group was 51.0 years. When dividing this group into males (n=91) and females (n=109), the average age for males was 52.1 years while the average age for females was 50.1 years. The age group *20-50 years* (n=100) was divided into male (n=40) and female (n=60) groups. Overall, the average age for this group was 41.4 years while the average age for males was 41.2 years, and the average age for the females was 41.6 years. The age group *51-75 years* (n=100) was divided into male (n=51) and female (n=49) groups. Overall, the average age for this group was

60.6 years while the average age for males was 63.1 years, and the average age for females was 58.1 years.

CVD Diagnosis

Table 2 presents the distribution of types of CVD and other diseases and conditions for 200 patients who were analyzed, 100 with CVD and 100 without CVD. The 3 major sections of the table contain the results for patients ages 20-50, 51-75, and the entire group, ages 20-75.

In the *20-50 yrs age group*, there were a total of 40 male and 60 female patients. Out of the 40 male patients, 58% (23/40) had CVD disease while out of the 60 female patients, 45% (27/60) had CVD. In the *51-75 yrs age group*, there were a total of 51 male and 49 female patients. Out of the 51 male patients, 45% (23/51) had CVD disease while out of the 49 female patients, 55% (27/49) had CVD.

Hypertension, valvular heart disease, and hypercholesterolemia were the most prevalent types of CVD or CVD risk factors in this study accounting for 28%, 12%, and 10% of the patients aged *20-75 yrs*, respectively. When evaluating the *20-50 yrs* age group, hypertension, valvular heart disease, and hypercholesterolemia were also the most prevalent accounting for 21%, 16%, and 9% of the patients with CVD, respectively. When evaluating the *51-75 yrs* age group, hypertension, valvular heart disease, and hypercholesterolemia were again the most prevalent accounting for 35%, 8%, and 10% of the patients with CVD, respectively.

When identifying other diseases or conditions that could affect CVD or influence pulpal calcifications in teeth, diabetes and arthritis were the most prevalent accounting for 10% and 19% of the patients of both age groups combined, respectively (Table 1).

Restoration Status of Teeth

Table 3 shows the characteristic of the patient's dentition by age and CVD diagnosis. Overall, for the age group *20-50 years*, a total of 100 *patients* and 1,470 *teeth* were examined for their restoration status. Among the 1,470 *teeth* examined radiographically, 755 were non-restored, 372 were heavily restored, 272 were minimally restored, 47 were crowned, and 28 had facial restorations as shown in Figure 2. To translate what the total number of teeth in each restorative category represented, average percentages of teeth per patient was calculated. Among the 100 *patients* examined radiographically, on average, each patient had 51% non-restored teeth, 26% heavily restored teeth, 19% minimally restored teeth, 3% crowned teeth, and 2% facially restored teeth as shown in Figure 2. When comparing the CVD present group to the CVD absent group, both groups had similar patterns for the distribution of total number of restorations in each category and similar percentages of teeth found per patient as shown in Figure 2.

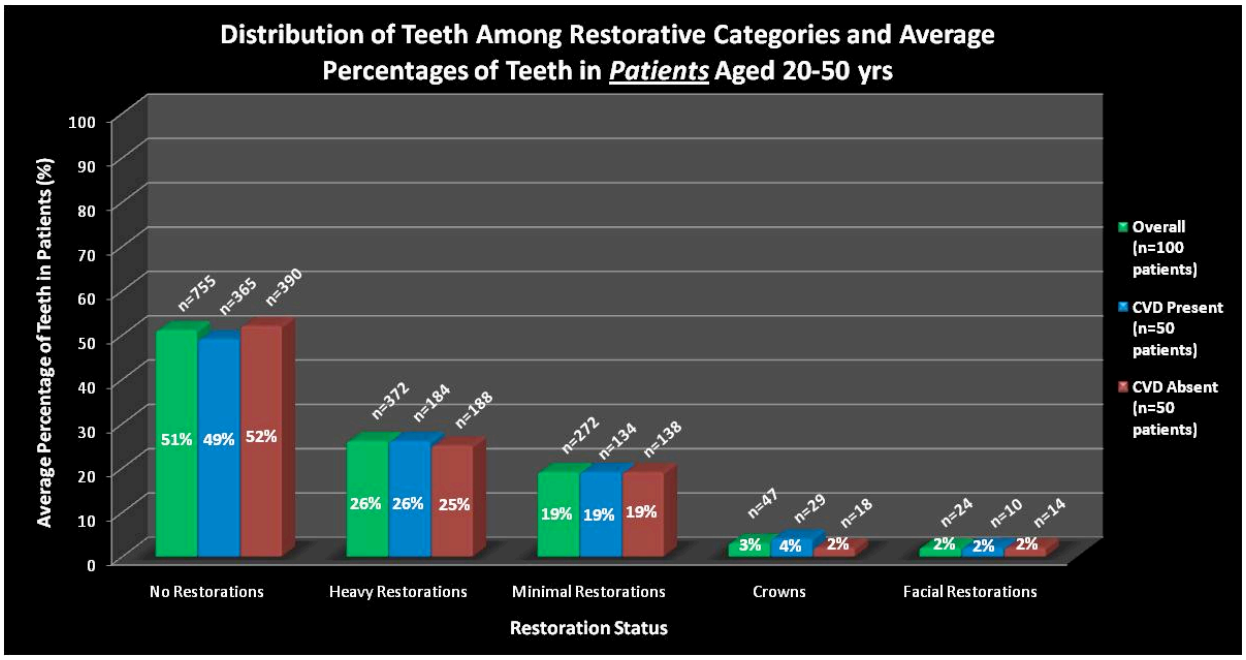

Figure 2. Comparison of restoration status of teeth overall, when CVD is present, and when CVD is absent in patients aged 20-50 yrs

Overall, for the age group *51-75 years*, a total of 100 *patients* and 1,415 *teeth* were examined for their restoration status. Among the 1,415 *teeth* examined radiographically, 520 teeth were non-restored, 413 teeth were heavily restored, 240 teeth were crowned, 218 teeth were minimally restored, and 24 teeth had facial restorations as shown in Figure 3. To translate what the total number of teeth in each restorative category represented, average percentages of teeth per patient was calculated. Among the 100 *patients* examined radiographically, on average, each patient had 36% non-restored teeth, 29% heavily restored teeth, 18% crowned, 16% minimally restored teeth, and 2% facially restored teeth as shown in Figure 3. When comparing the CVD present group to the CVD absent group, both groups had similar patterns for the distribution of total number of restorations in each category and similar percentages of teeth found per patient as shown in Figure 3.

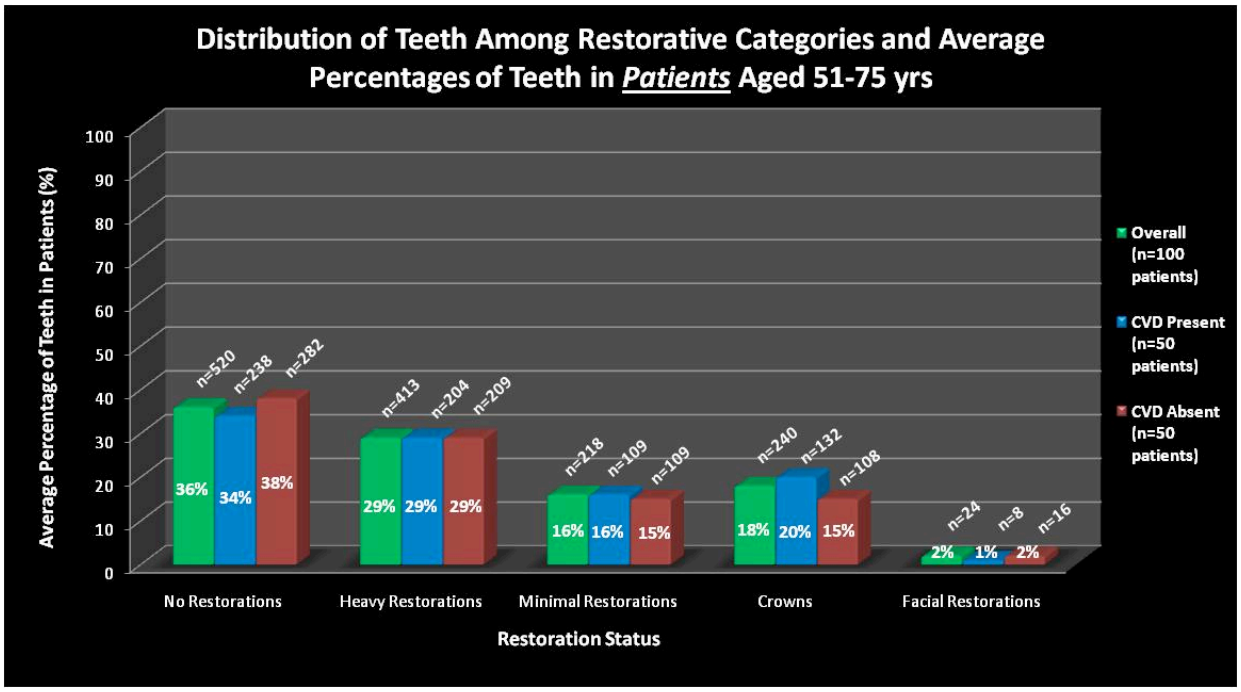

Figure 3. Comparison of restoration status of teeth overall, when CVD is present, and when CVD is absent in patients aged 51-75 yrs

However, when comparing the *20-50 yrs* age group with the *51-75 yrs* age group it was found the older age group had a statistically significantly higher percentage of teeth per *patient* with crown restorations (18%, n=240) than the younger age group (3%, n=47) as shown in Figure 4 (Chi-Square, $P < 0.001$). It was also found that the younger age group had a statistically significantly higher percentage of teeth per *patient* with no restorations (51%, n=755) when compared to the elder age group (36%, n=520), (Chi-Square, P= .013).

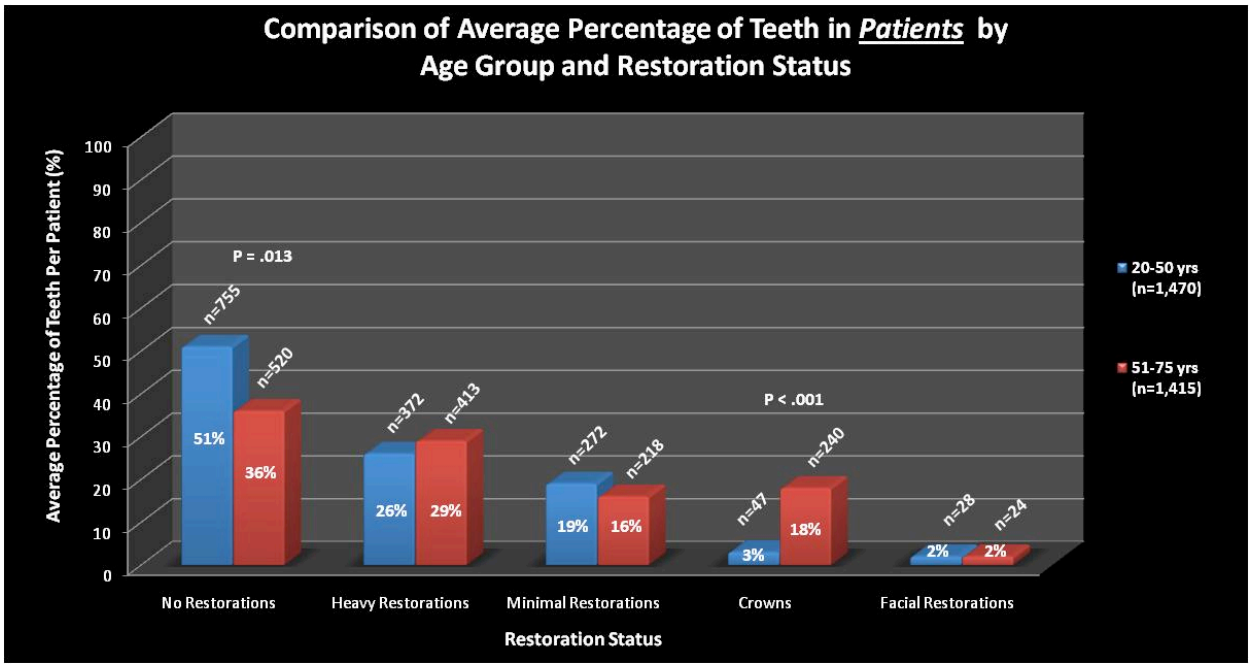

Figure 4. Comparison of restoration status between age groups

Caries Status of Teeth

Table 3 shows the characteristic of the patient's caries status by age and CVD diagnosis. Overall, for the age group *20-50 years*, a total of 100 *patients* and 1,470 *teeth* were examined for their caries status. Among the 1,470 *teeth* examined radiographically, 1,350 teeth were non-carious, 75 teeth were incipient carious, and 45 teeth had dental caries as shown in Figure 5. To translate what the total number of teeth in each caries category represented, average percentages of teeth per *patient* was calculated. Among the 100 *patients* examined radiographically, on average, each patient contained 91% non-carious teeth, 5% incipient carious teeth, and 3% dentinal carious teeth. When comparing the CVD present group to the CVD absent group, both groups had similar patterns for the distribution of total number of restorations in each category and similar percentages of teeth found per *patient* as shown in Figure 5.

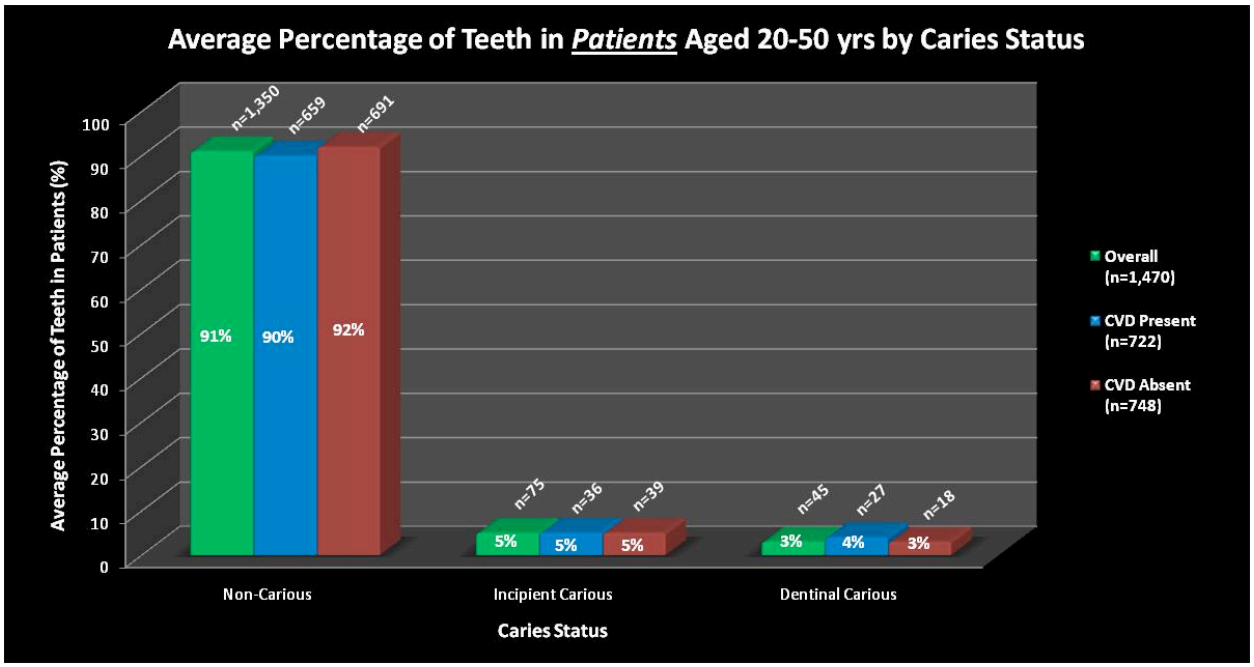

Figure 5. Comparison of caries status of teeth overall, when CVD is present, and when CVD is absent in patients aged 20-50 yrs

Overall, for the age group *51-75 years*, a total of 100 *patients* and 1,415 *teeth* were examined for their caries status. Among the 1,415 *teeth* examined radiographically, 1,352 were non-carious, 2 were incipient carious, and 61 had dental caries. To translate what the total number of teeth in each caries category represented, average percentages of teeth per *patient* was calculated. Among the 100 *patients* examined radiographically, on average, each patient contained 95% non-carious teeth, 0% incipient carious teeth, and 4% dentinal carious teeth. When comparing the *CVD present* group to the *CVD absent* group, both groups had similar patterns for the distribution of total number of restorations in each category and similar percentages of teeth found per *patient* as shown in Figure 6.

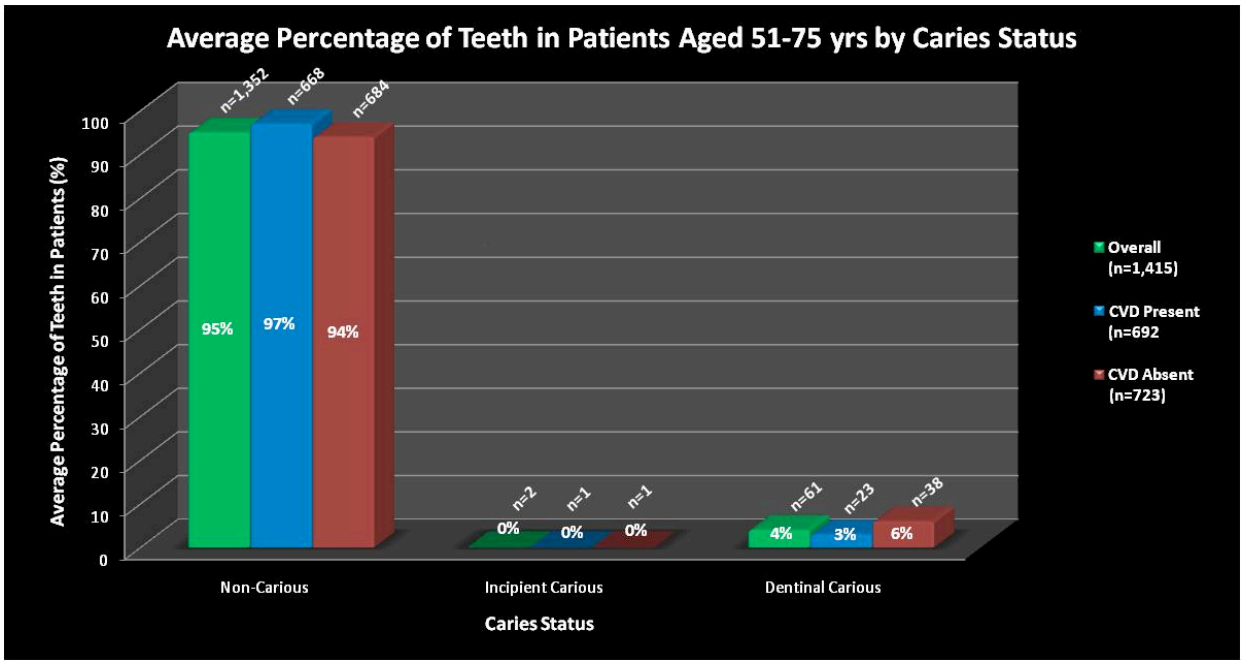

Figure 6. Comparison of caries status of teeth overall, when CVD is present, and when CVD is absent in patients aged 51-75 yrs

Aim 2

What is the distribution of pulp stones in this study population?

Pulp Stone Distribution by Gender and Tooth Type

Table 4 shows pulp stone distribution and prevalence in patient's teeth by age group, tooth type, and gender. A total of 200 patients aged 20-75 yrs were evaluated in this study, 91

male and 109 female. Among these patients, a total of 352 teeth with pulp stones were identified which were distributed between maxillary and mandibular molars and pre-molars as shown in Figure 7.

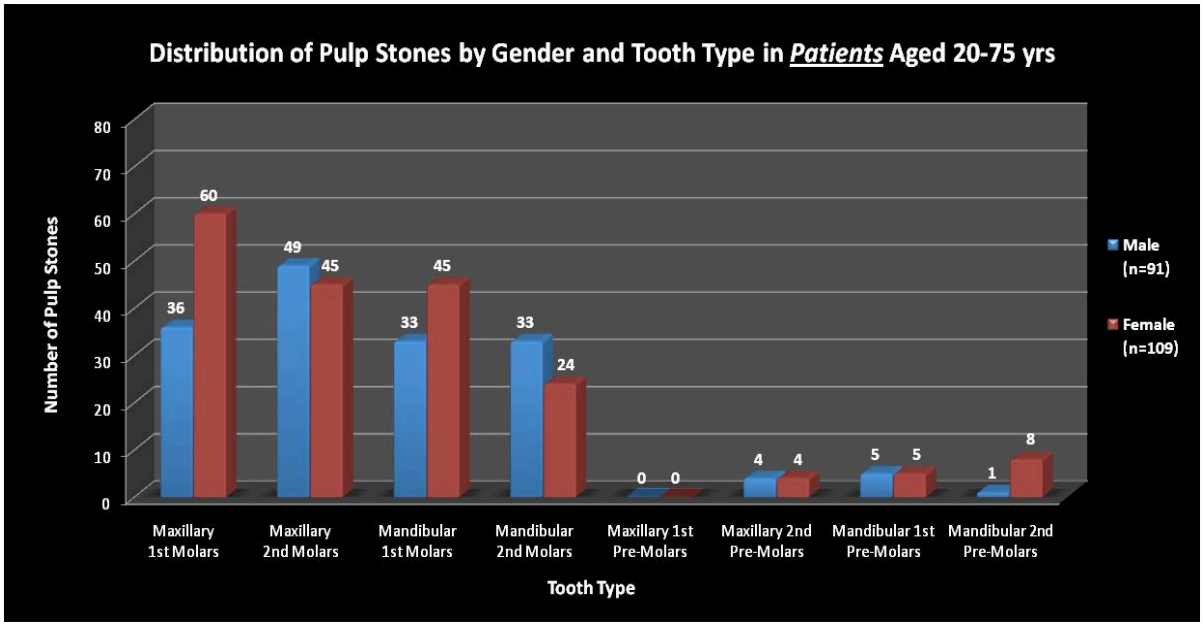

Figure 7: Distribution of pulp stones by gender and tooth type in patients aged 20-75 yrs

Female patients (n=109) contained pulp stones in 191 total teeth while male patients (n=91) contained pulp stones in 161 total teeth. Maxillary molars in both gender groups (males = 85 teeth, females = 105 teeth) accounted for 54.0% (190/352) of the total teeth containing pulp stones followed by mandibular molars (males = 66 teeth, females = 69 teeth) at 38.3% (135/352). Mandibular pre-molars accounted 5.4% of teeth containing pulp stones while maxillary pre-molars were the least common teeth to contain pulp stones at 2.3% (8/352).

Pulp Stone Distribution by Age Group and Tooth Type

Table 4 also shows pulp stone distribution and prevalence by age group and tooth type. The 200 patients were then evenly divided into two age groups, 20-50 yrs and 51-75 yrs, of 100 patients each which then evaluated the distribution and percent contribution of pulp stones within these teeth types. Among the 352 pulp stones identified in this study, 167 pulp stones were found in the 20-50 yrs age group and 185 pulp stones were found in the *51-75 yrs* age group as shown in Table 4. The majority of these pulp stones were located in maxillary and mandibular molars in each age group while maxillary and mandibular pre-molars contained the least amount in each age group as shown in Figure 8.

Percent Contribution of Pulp Stones in Teeth Types

The percent contribution of pulp stones found in the maxillary and mandibular molars to the total pulp stone count for the *20-50 yrs* age group was 57% (96/167) and 38% (94/185), respectively; while the percent contribution for these same teeth in the *51-75 yrs* age group was 51% (64/167) and 38% (71/185), respectively. The percent contribution of pulp stones found in the maxillary and mandibular pre-molars to the total pulp stone count for the *20-50 yrs* age group was 1% (1/167) and 3% (5/167), respectively; while the percent contribution for these same teeth in the *51-75 yrs* age group was 3% (6/185) and 8% (14/185), respectively as shown in Figure 8.

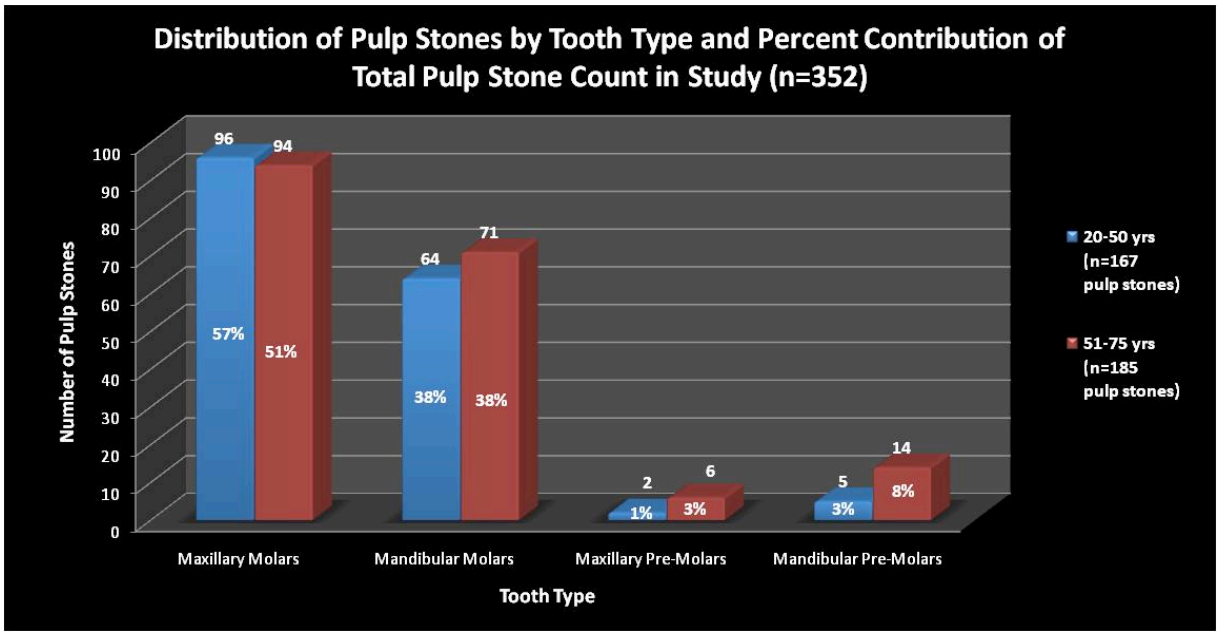

Figure 8: Distribution and percent contribution of pulp stones between age groups

Pulp Stone Distribution by Caries and Restoration Status

Table 5 shows pulp stone distribution and prevalence in *patients* and *teeth* by caries and restoration status. When analyzing the distribution of pulp stones between the two age groups (20-50 yrs and 51-75 yrs), it was found that the majority of pulp stones were identified into three different subcategories of teeth: non-carious/heavily restored, non-carious/minimally restored, and non-carious/non-restored as shown in Figures 9 and 10.

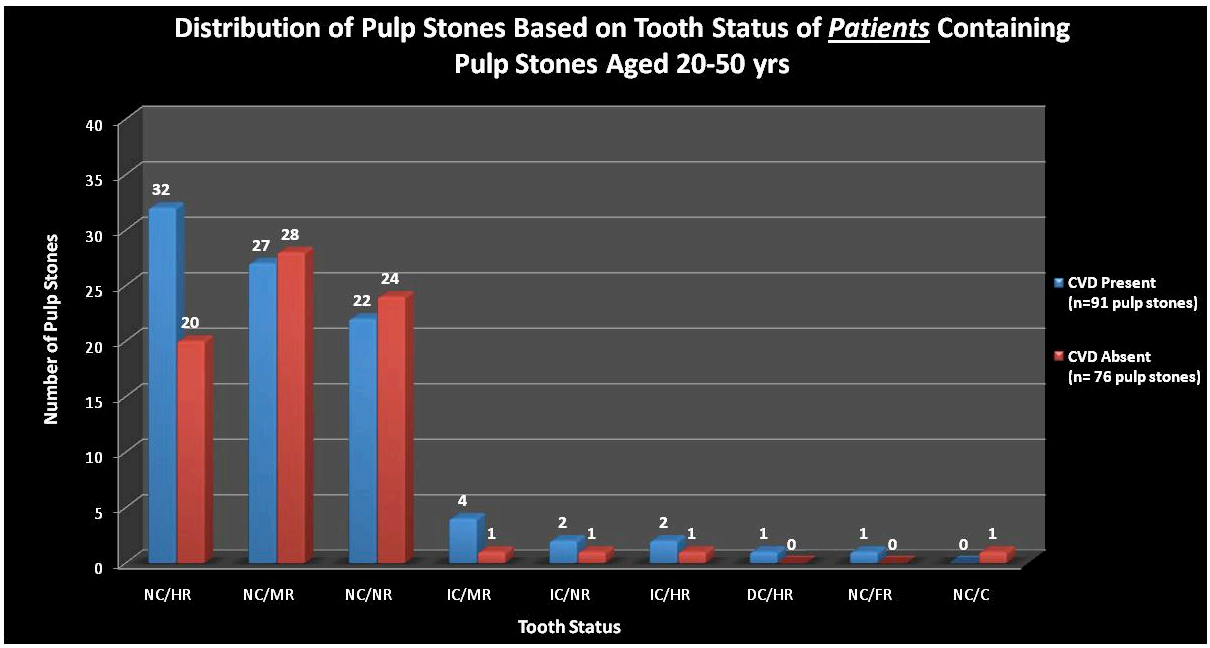

Figure 9. Distribution of pulp stones in patients aged 20-50 yrs

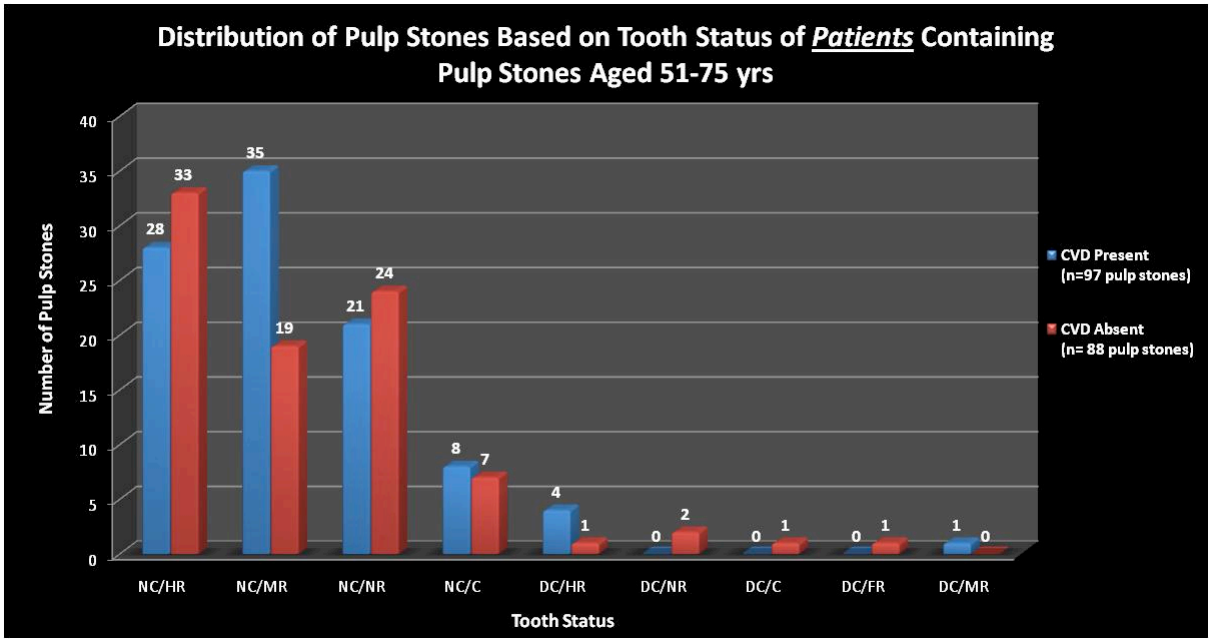

Figure 10. Distribution of pulp stones in patients aged 51-75 yrs

These three subcategories of teeth accounted for approximately 91.6% (153/167) of the total pulp stones identified in the *20-50 yrs* age group and 86.5% (160/185) in the *51-75 yrs* age group. When combining *both age groups*, these three subcategories of teeth accounted for 88.9% (313/352) of the total pulps stones identified in this study. For the remaining caries and restorative categories between the age groups, only non-carious/ crown and dentinal carious/heavy restorations were greater in the older age group.

Aim 3

What is the overall prevalence of pulp stones in this study population 20-75 years?

Overall Pulp Stone Prevalence

Table 4 shows pulp stone prevalence in *patients* by age group, tooth type, and gender. The overall prevalence of pulp stones in the *patients* in the study population aged *20-75 years*

was **53%** (106/200), while the average percentage of teeth per *patient* containing pulp stones was **12.3%** as shown in Figure 11.

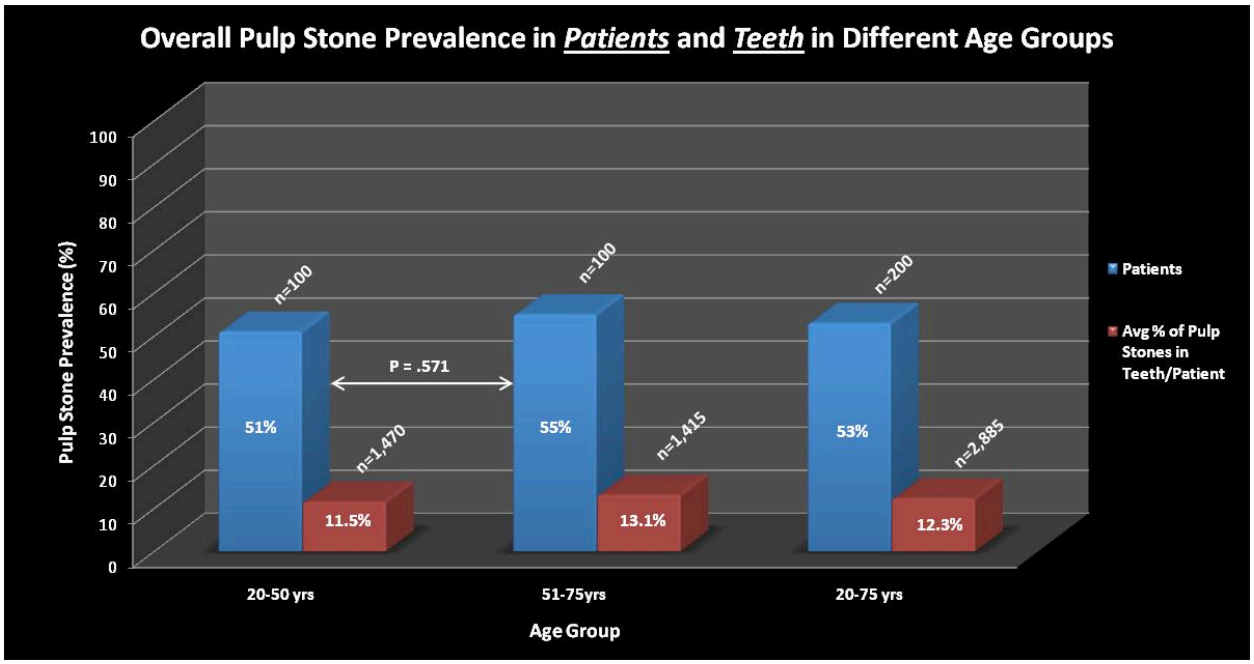

Figure 11. Overall pulp stone prevalence in patients and teeth between age groups

The overall prevalence of pulp stones in the *patients* in the study population aged *20-50 years* was **51%** (51/100), while the average percentage of teeth per *patient* containing pulp stones **11.5%**. The overall prevalence of pulp stones in the *patients* in the study population aged *51-75 years* was **55%** (51/100), while the average percentage of teeth per *patient* containing pulp stones **13.1%** as shown in Table 5 and Figure 11. When comparing the individual age groups *20-50 years* and *51-75 years* (**51%** vs. **55%**) for the prevalence of pulp stones, no statistically significant differences were found (Chi-Square, P = .571).

Pulp Stone Prevalence by Age Group and Gender

When comparing the overall (20-75 yrs) pulp stone prevalence by gender only, 53.8% (49/91) of males and 52.3% (57/109) of females contained teeth with pulp stones; these differences were not statistically significant as shown in Figure 12.

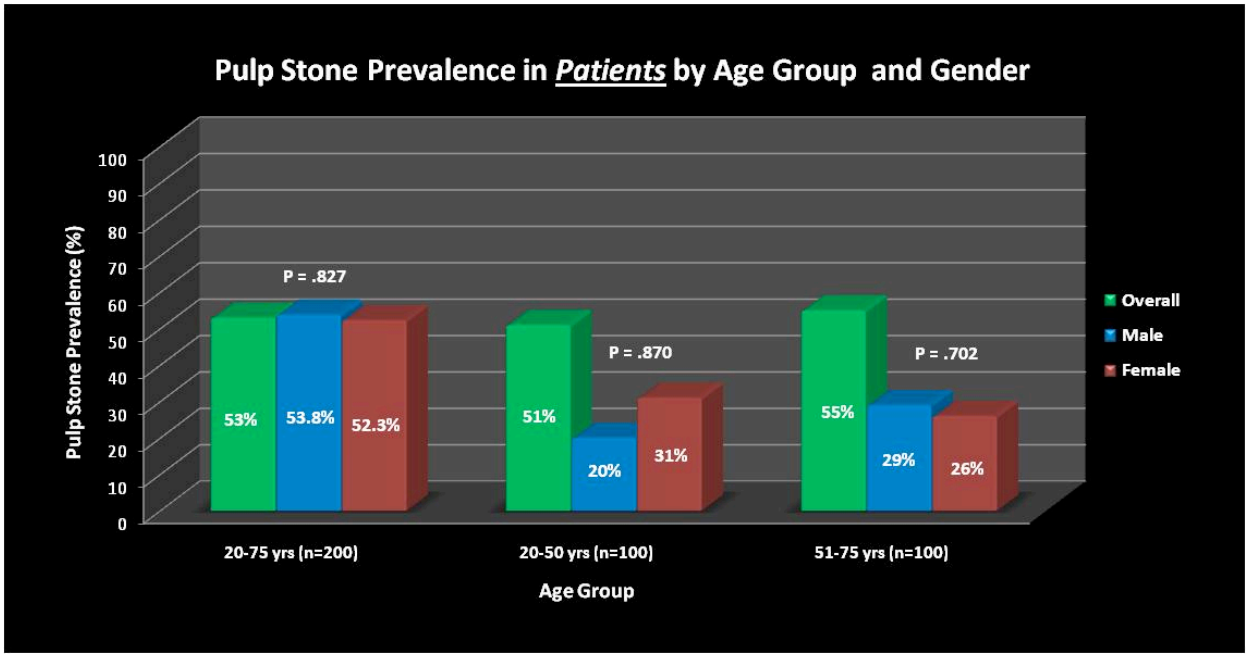

Figure 12: Pulp stone prevalence in patients by age and gender

When comparing pulp stone prevalence by age group and gender, 20% (20/100) of males and 31% (31/100) of females aged *20-50 yrs* contained teeth with pulp stones, while 29% (29/100) of males and 26% (26/100) of females aged *51-75 yrs* contained teeth with pulp stones; these differences were not statistically significant as shown in Figure 12.

Pulp Stone Prevalence by Age Group, Gender and Tooth Type

When evaluating the pulp stone prevalence by age group and tooth type in patients aged *20-50 yrs*, 42% (42/100) of *patients* contained pulp stones in maxillary molars while 30% (30/100) of *patients* contained pulp stones in mandibular molars as shown in Figure 13.

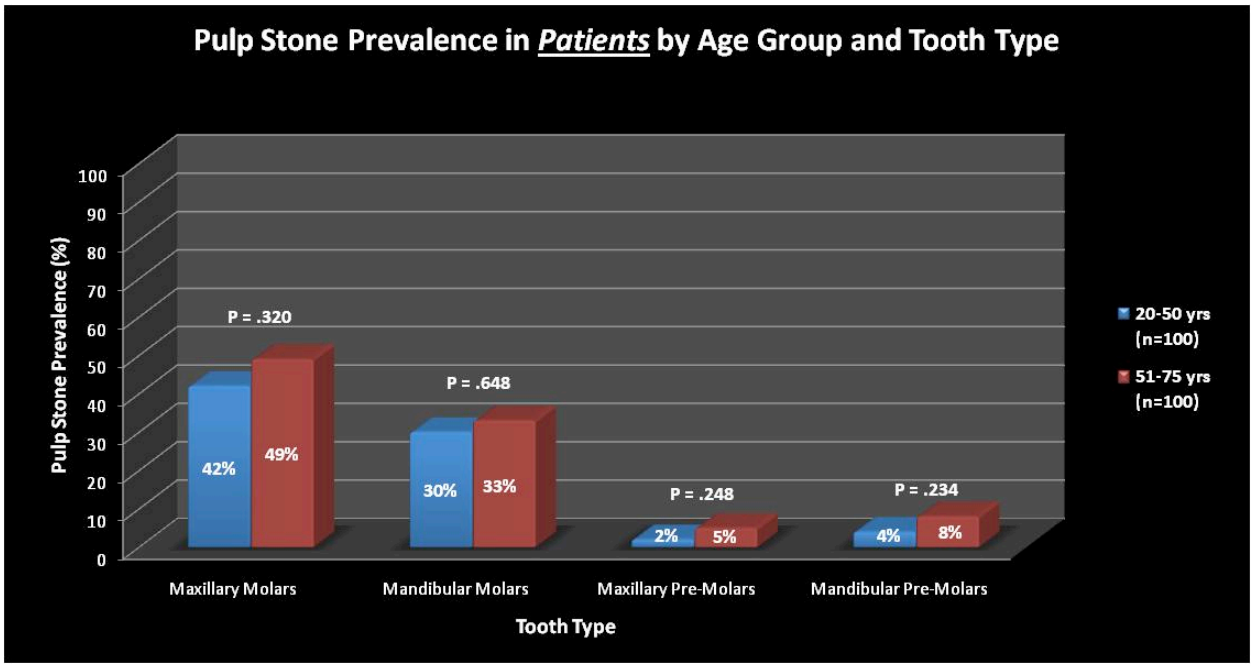

Figure 13: Pulp stone prevalence in patients by age and tooth type

When evaluating the pulp stone prevalence in patients aged *51-75 yrs*, 49% (49/100) of *patients* contained pulp stones in maxillary while 33% (33/100) of *patients* contained pulp stones in mandibular molars. When comparing both age groups by tooth types, no statistically significant differences were found in pulp stone prevalence in any tooth type as shown in Figure 13.

When evaluating individual age groups and teeth types, females in the *20-50 yrs* age group had a greater pulp stone prevalence in maxillary (45.0% vs. 37.5%) and mandibular (33.3% vs. 25.05) molars than males; these differences were not statistically significant as shown in Figure 14.

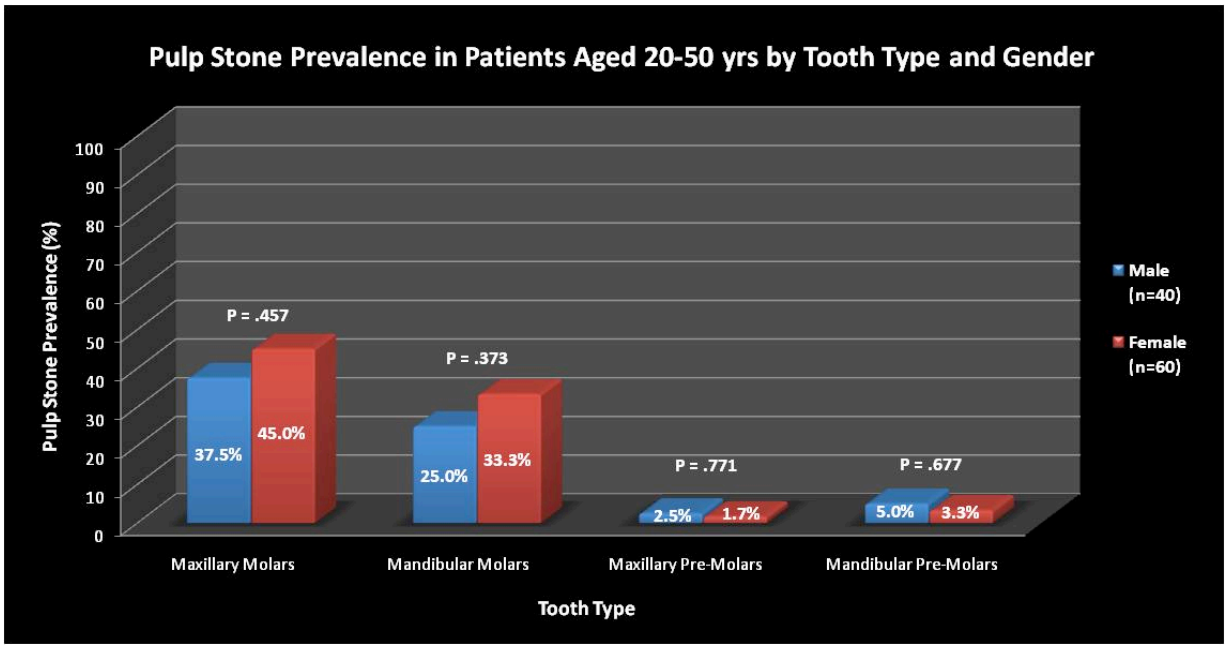

Figure 14: Pulp stone prevalence in patients aged 20-50 yrs by tooth type and gender

However, this was reversed in the *50-75 yrs* age group where males had a greater pulp stone prevalence in maxillary (51.0% vs. 46.9%) and mandibular (37.3% vs. 28.6%) molars than females; these differences were not statistically significant as shown in Figure 15.

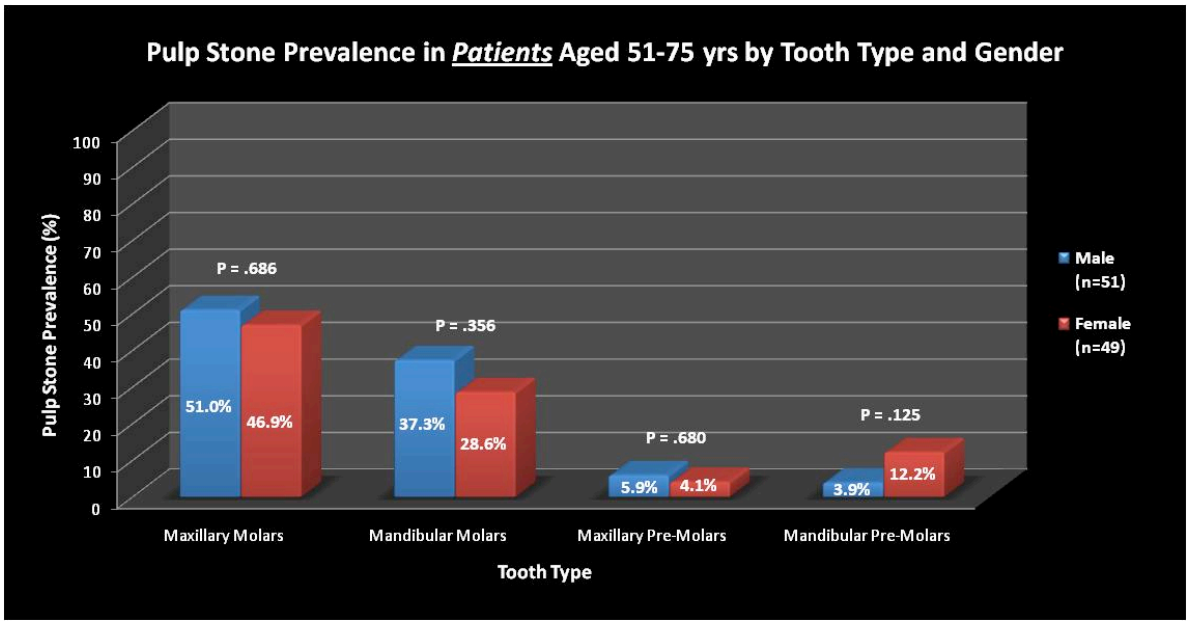

Figure 15: Pulp stone prevalence in patients aged 51-75 yrs by tooth type and gender

Pulp Stone Prevalence by Restorative and Caries Status

When evaluating the overall of pulp stone prevalence by restorative and caries status in *patients* aged 20-75 yrs, 40% (80/200) of patients contained at least one non-carious, non-restored, or minimally tooth with a pulp stone. When dividing this same group into non-carious/minimally restored and non-carious/non-restored teeth, the proportion of patients with a pulp stone in these type of teeth was 31.5% (63/200) and 20.5% (41/200), respectively. The proportion of patients having heavily restored teeth with pulp stones was 35% (70/200) as shown in Figure 16.

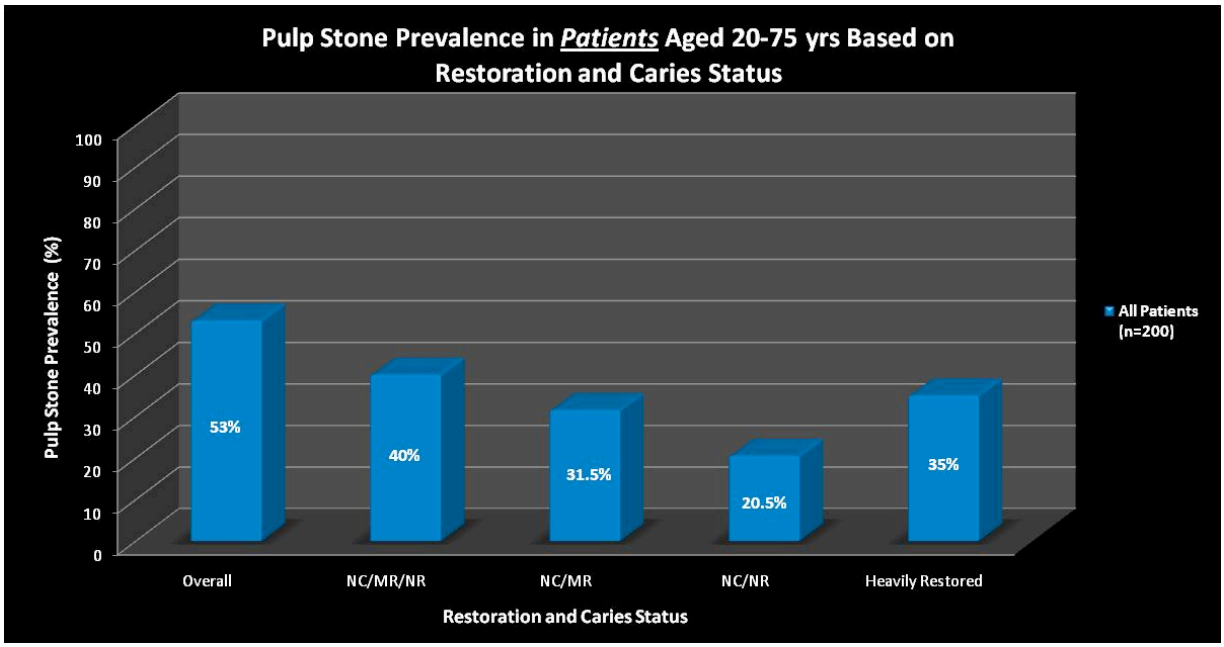

Figure 16. Pulp stone prevalence in patients aged 20-75 yrs by caries and restorative status

When comparing the age groups (20-50 yrs and 51-75 yrs) for pulp stone prevalence by restoration and caries status, no statistically significant differences were found between the groups as shown in Figure 17.

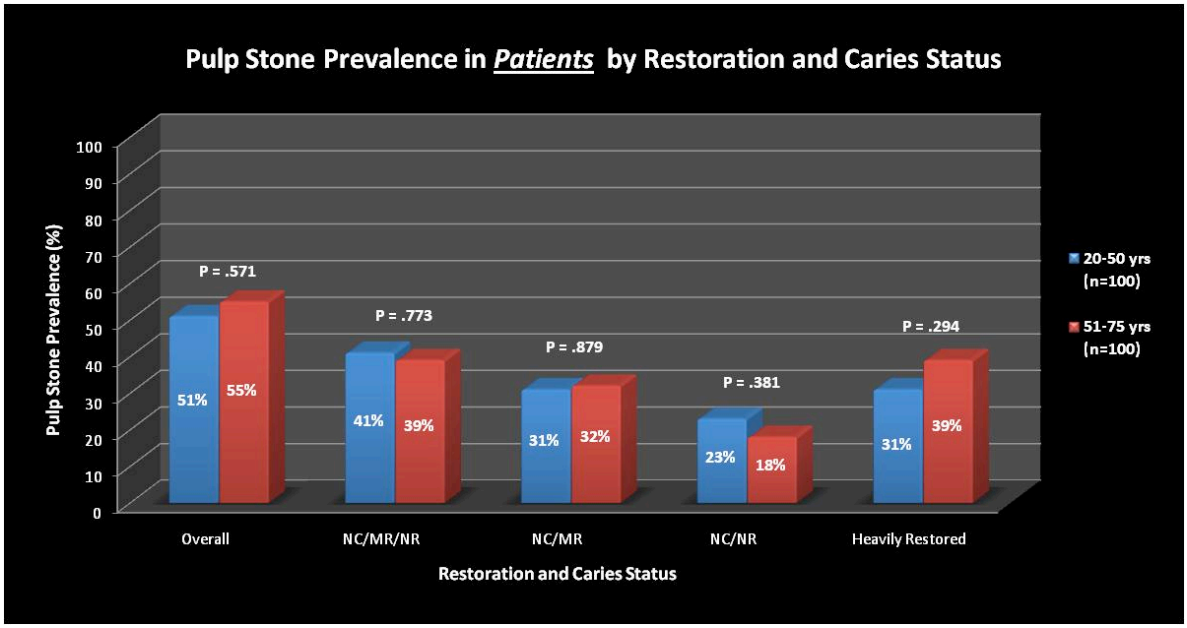

Figure 17. Comparison of pulp stone prevalence between age groups by caries and restorative status

Aim 4

Is there an association between the prevalence of CVD and the presence of pulp stones in patients' ages 20-75 years in teeth that are non-carious, non-restored, or minimally restored?

20-75 years age group

When comparing *patients* within the age group *20-75 years*, more patients *with CVD* had pulp stones overall than those *without CVD*, **56%** (56/100) vs. **50%** (50/100) respectively; however, this difference was not statistically significant as shown in Figure 18 (Chi-Square, P = .395).

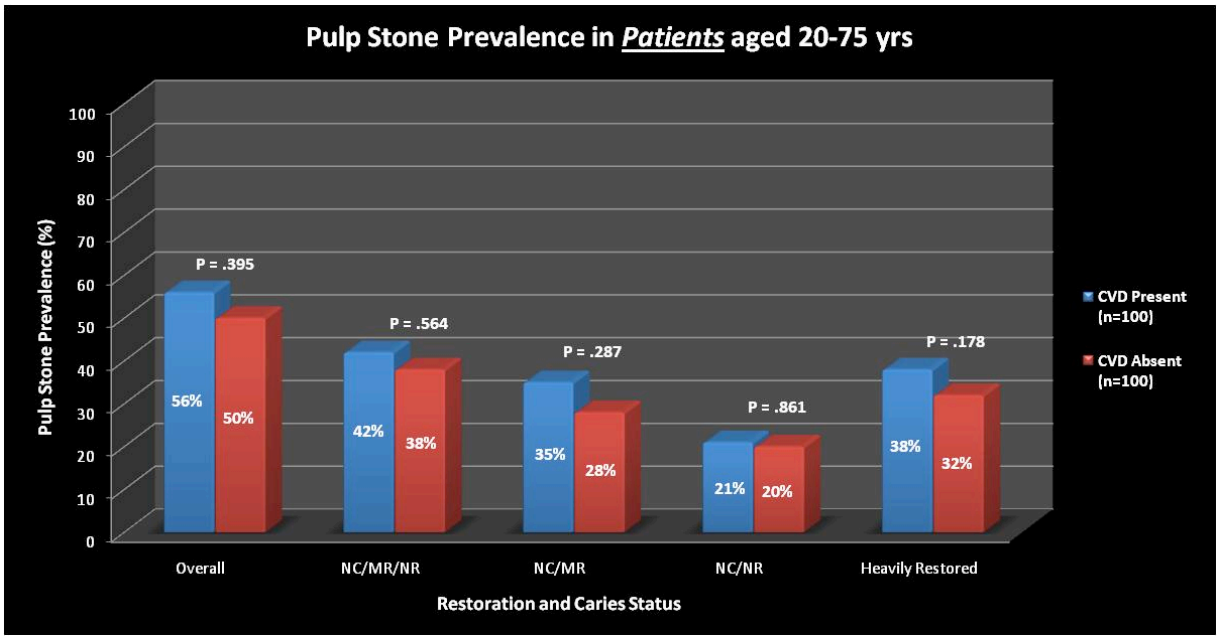

Figure 18. Comparison of pulp stone prevalence between patients ages 20-75 yrs *with CVD* and *without CVD.*

When comparing non-carious, non-restored, or minimally restored teeth in *patients* within this age group, more patients *with CVD* had pulp stones than those *without CVD*, **42%** (42/100) vs. **38%** (38/100) respectively; however, this difference was not statistically

significant (Chi-Square, P = .654). When dividing this same group into non-carious/ minimally restored teeth (35% vs. 28%) and non-carious/non-restored teeth (21% vs. 20%), no statistically significant differences were found in pulp stone prevalence between the CVD groups; (Chi-Square, P = .287 and P = .861) respectively. Finally, when comparing heavily restored teeth (38% vs. 32%) between CVD groups, no statistically significant differences were found in pulp stone prevalence (Chi-Square, P = .178).

Aim 5

Is there an association between the prevalence of CVD and the presence of pulp stones within and between the age groups 20-50 years and 51-75 years in teeth that are non-carious, non-restored or minimally restored?

20-50 years age group with and without CVD

Table 6 shows pulp stone prevalence in patients of different age groups with and without CVD, overall and by specific categories of caries and restoration status. When comparing *patients* within the age group *20-50 years*, more patients *with CVD* had pulp stones overall

than those *with CVD*, **58%** (29/50) vs. **44%** (22/50) respectively; however, this difference was not statistically significant as shown in Figure 19 (Chi-Square, P = .161).

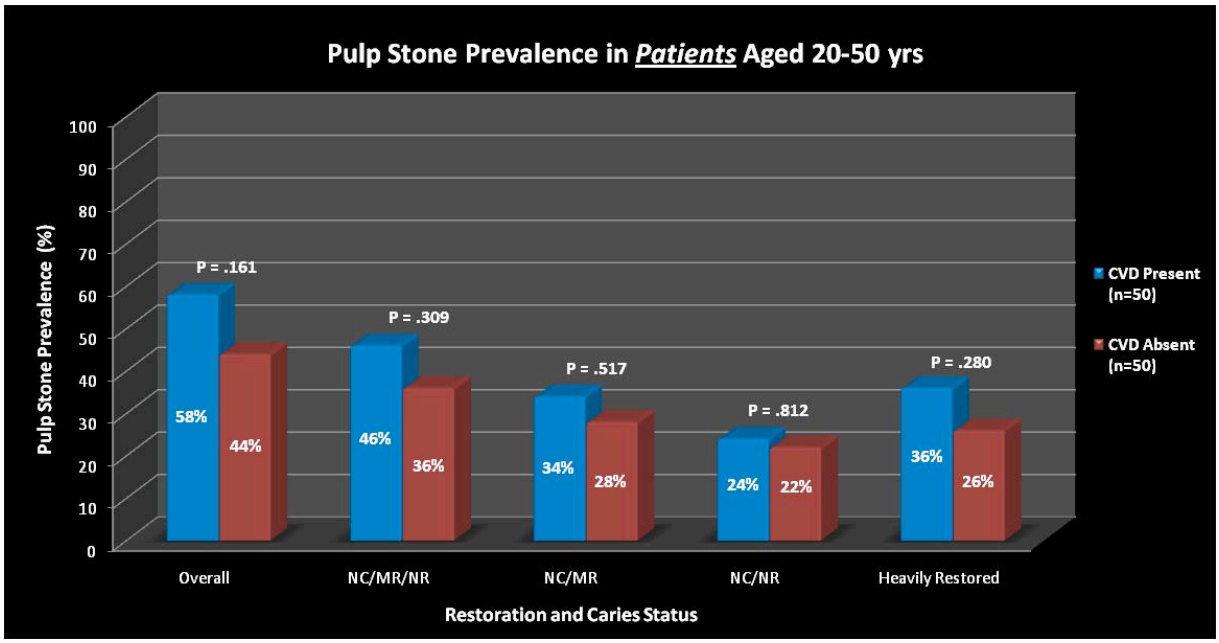

Figure 19. Comparison of pulp stone prevalence between patients ages 20-50 yrs *with CVD* and *without CVD*

When comparing non-carious, non-restored, or minimally restored teeth in *patients* within this age group, more patients *with CVD* had pulp stones than those *without CVD*, **46%** (23/50) vs. **36%** (18/50) respectively; however, this difference was not statistically significant (Chi-Square, P = .309). When dividing this same group into non-carious/ minimally restored teeth (34% vs. 28%) and non-carious/non-restored teeth (24% vs. 22%), no statistically significant differences were found in pulp stone prevalence between the CVD groups; (Chi-Square, P = .517 and P = .812) respectively. Finally, when comparing heavily restored teeth (36% vs. 26%) between CVD groups, no statistically significant differences were found in pulp stone prevalence as shown in Figure 19 (Chi-Square, P = . 280).

51-75 years age group with and without CVD

When comparing *patients* within the age group *51-75 years*, more patients *without CVD* had pulp stones overall than those *with CVD*, **56%** (28/50) vs. **54%** (27/50) respectively; however, this difference was not statistically significant as shown in Figure 20 (Chi-Square, P = .841). When comparing non-carious, non-restored, or minimally restored teeth in *patients* within this age group, more patients *without CVD* had pulp stones than those *with CVD*, **40%** (20/50) vs. **38%** (19/50) respectively; however, this difference was not statistically significant (Chi-Square, P = .838). When dividing this same group of teeth into non-carious/minimally restored teeth (36% vs. 28%) and non-carious/non-restored teeth (18% vs. 18%), no statistically significant differences were found in pulp stone prevalence between the CVD groups; (Chi-Square, P = .391 and P = 1.000) respectively. Finally, when comparing heavily restored teeth (40% vs. 38%) between CVD groups, no statistically significant differences were found in pulp stone prevalence as shown in Figure 20 (Chi-Square, P = .838).

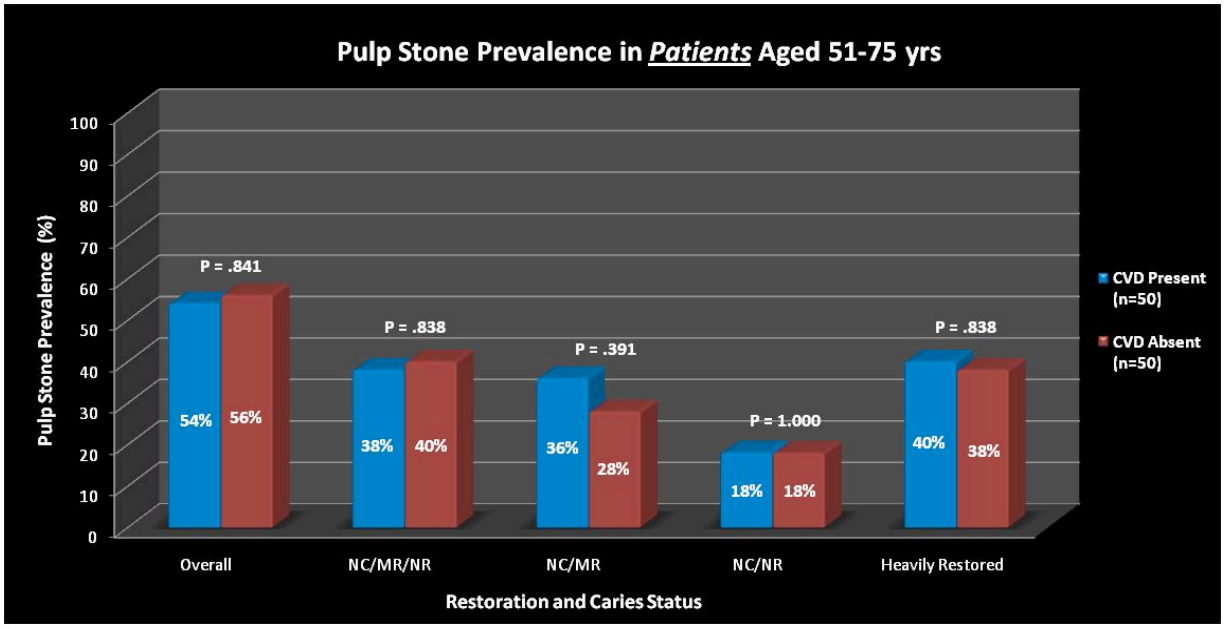

Figure 20. Comparison of pulp stone prevalence between patients ages 51-75 yrs *with CVD* and *without CVD*

Comparing younger (20-50 yrs) vs. older (51-75 yrs) age groups with CVD

When comparing *patients with CVD* between the age groups *20-50 yrs* and *51-75 years*, more patients in the younger age group (20-50 yrs) had pulp stones overall than those in the older age group, **58%** (29/50) vs. **54%** (27/50) respectively; however, this difference was not statistically significant as shown in Figure 21 (Chi-Square, P = .687). When comparing non-carious, non-restored, or minimally restored teeth in *patients with CVD*, more patients in the younger age group (20-50 yrs) had pulp stones than those in the older age group, **46%** (23/50) vs. **38%** (19/50) respectively; however, this difference was not statistically significant (Chi-Square, P = .418). When dividing this same group of teeth into non-carious/minimally restored (34% vs. 36%) and non-carious/non-restored (24% vs. 18%) teeth, no statistically significant differences were found in pulp stone prevalence between the age groups; (Chi-Square, P = .834 and P = .461) respectively. Finally, when comparing heavily restored teeth (36% vs. 40%) between age groups, no statistically significant differences were found in pulp stone prevalence as shown in Figure 21 (Chi-Square, P = .680).

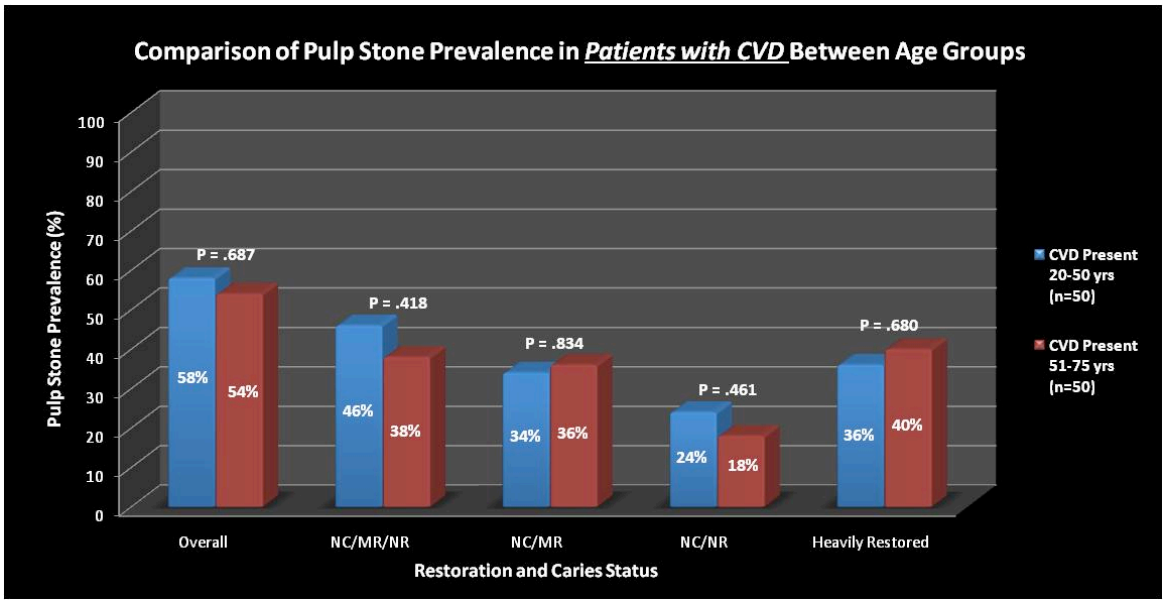

Figure 21. Comparison of pulp stone prevalence between age groups of patients with CVD

Aim 6

Is there an association between the prevalence in pulp stones in non-carious, non-restored, or minimally teeth between patients with specific types of CVD such as hypertension, valvular heart disease, and hypercholesterolemia and those without CVD in the 20-50 years and 51-75 years age groups?

Hypertension: 20-50 years age group

Table 7 shows pulp stone prevalence in patients of different age groups with and without HTN, overall and by restoration and caries status. When comparing *patients* within the age group *20-50 years*, more patients *with HTN* had pulp stones overall than those *without CVD*, **62%** (13/21) vs. **44%** (22/50) respectively; however, this difference was not statistically significant as shown in Figure 22 (Chi-Square, P = .168).

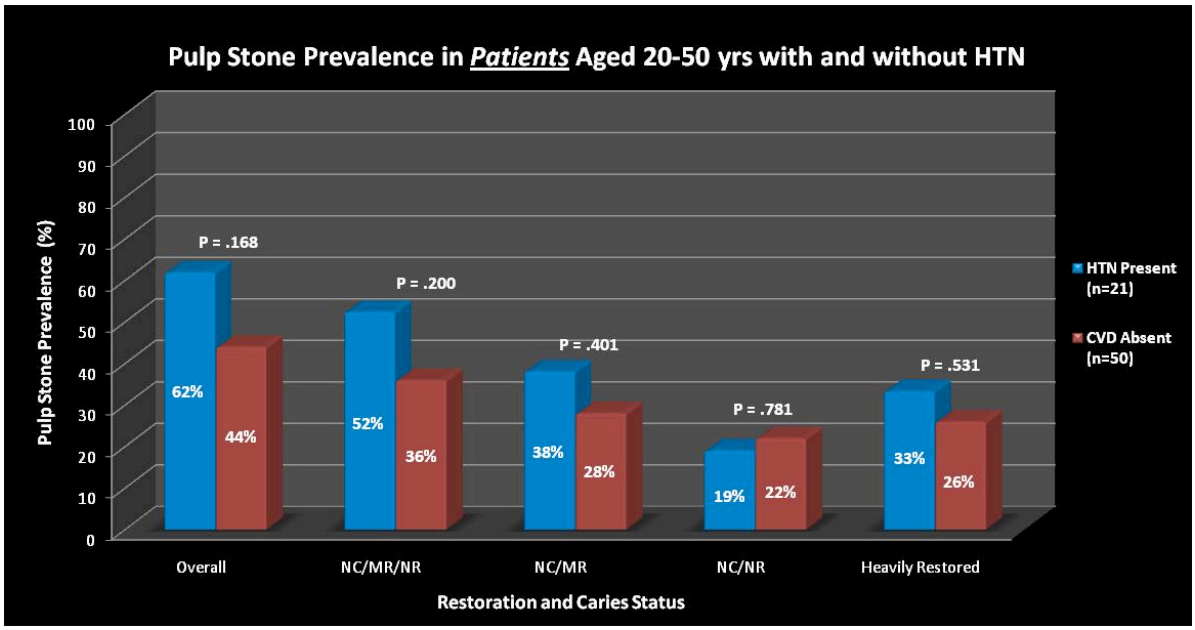

Figure 22. Comparison of pulp stone prevalence between patients ages 20-50 yrs *with HTN* and *without CVD*

When comparing non-carious, non-restored, or minimally restored teeth in *patients* within this age group, more patients *with HTN* had pulp stones than those *without CVD*, **52%** (11/21) vs. **36%** (18/50) respectively; however, this difference was not statistically significant (Chi-Square, P = .200). When dividing this same group into non-carious/ minimally restored teeth (38% vs. 28%) and non-carious/non-restored teeth (19% vs. 22%), no statistically significant differences were found in pulp stone prevalence between the CVD groups; (Chi-Square, P = .401 and P = .781) respectively. Finally, when comparing heavily restored teeth (33% vs. 26%) between CVD groups, no statistically significant differences were found in pulp stone prevalence as shown in Figure 22 (Chi-Square, P = . 531).

Hypertension: 51-75 years age group

When comparing *patients* within the age group *51-75 years*, more patients *with HTN* had pulp stones overall than those *without CVD*, **60%** (21/35) vs. **56%** (28/50) respectively; however, this difference was not statistically significant (Chi-Square, P = .713). When comparing non-carious, non-restored, or minimally restored teeth in *patients* within this age group, more patients *with* HTN had pulp stones than those *without CVD*, **43%** (15/35) vs. **40%** (20/50) respectively; however, this difference was not statistically significant (Chi-Square, P = .792). When dividing this same group into non-carious/minimally restored teeth (43% vs. 28%) and non-carious/non-restored teeth (17% vs. 18%), no statistically significant differences were found in pulp stone prevalence between the CVD groups; (Chi-Square, P = .155 and P = .919) respectively. Finally, when comparing heavily restored teeth (43% vs. 38%) between CVD groups, no statistically significant differences were found in pulp stone prevalence as shown in Figure 23 (Chi-Square, P = .653).

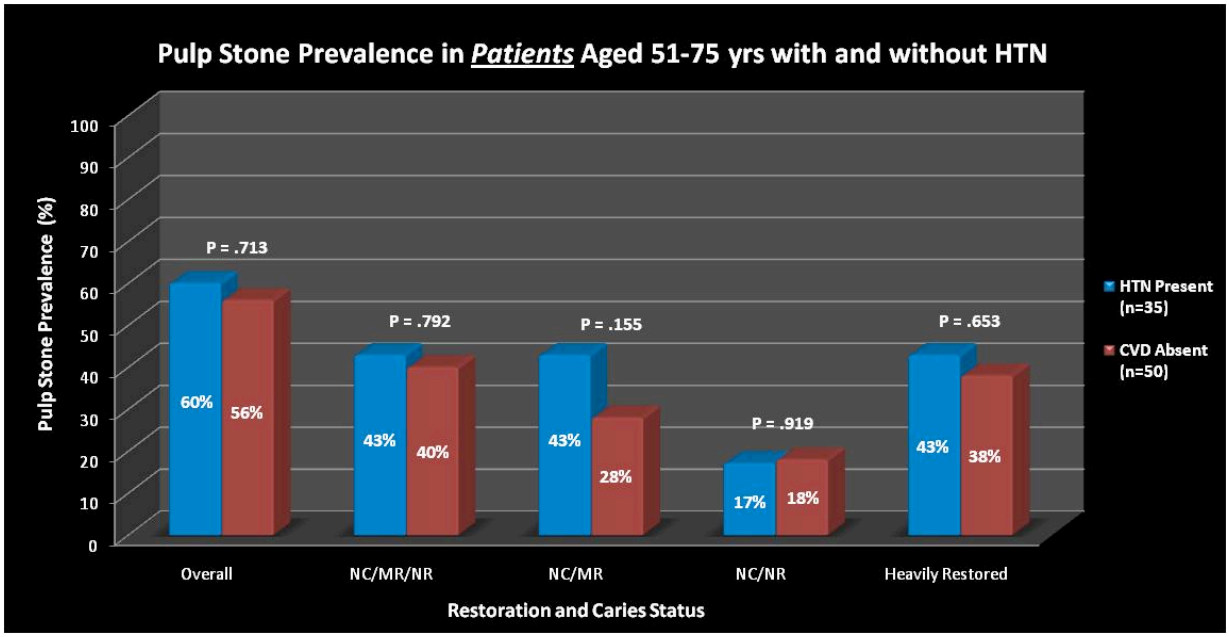

Figure 23. Comparison of pulp stone prevalence between patients ages 51-75 yrs *with HTN* and *without CVD*

Comparing younger (20-50 yrs) vs. older (51-75 yrs) age groups with HTN

When comparing *patients with HTN* between the age groups *20-50 yrs* and *51-75 years*, a slightly higher proportion of patients in the younger age group (20-50 yrs) had pulp stones overall than those in the older age group, **62%** (13/21) vs. **60%** (21/35) respectively; however, this difference was not statistically significant as shown in Figure 24 (Chi-Square, P = .888). When comparing non-carious, non-restored, or minimally restored teeth in *patients with HTN*, more patients in the younger age group (20-50 yrs) had pulp stones than those in the older age group, **52%** (11/21) vs. **43%** (15/35) respectively; however, this difference was not statistically significant (Chi-Square, P = .489). When dividing this same group of teeth into non-carious/minimally restored (38% vs. 43%) and non-carious/ non-restored (24% vs. 17%) teeth, no statistically significant differences were found in pulp stone prevalence between the age groups; (Chi-Square, P = .726 and P = .857) respectively. Finally, when comparing heavily restored teeth (33% vs. 43%) between age groups, no statistically significant differences were found in pulp stone prevalence as shown in Figure 24 (Chi-Square, P = .480).

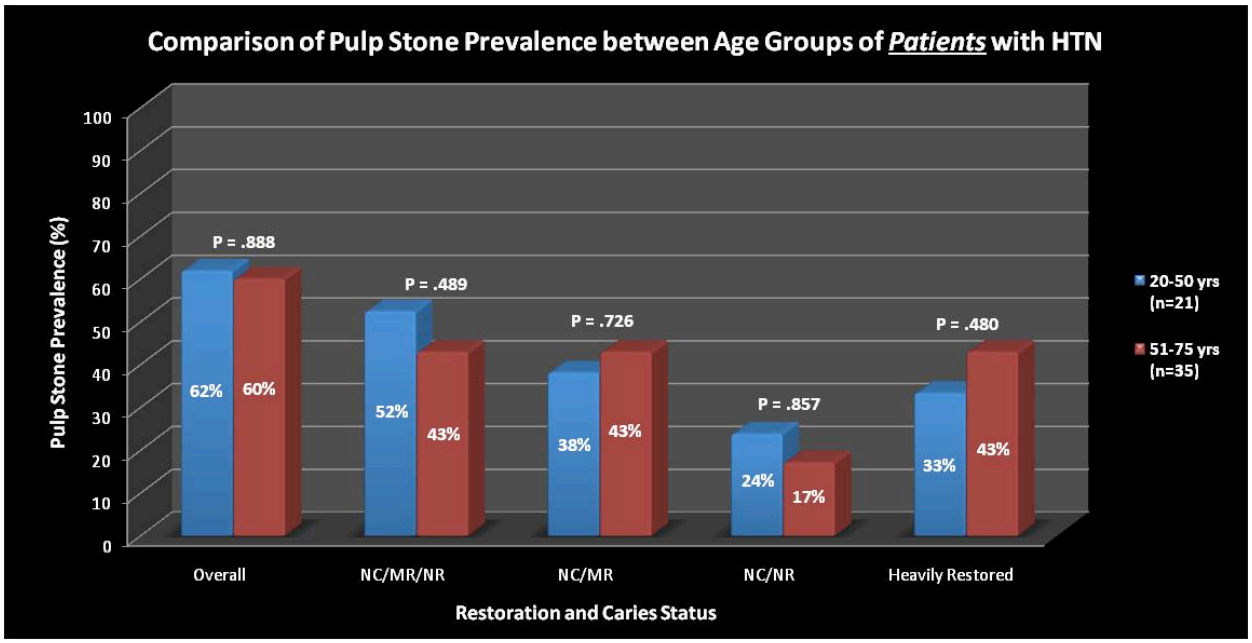

Figure 24. Comparison of pulp stone prevalence between age groups of patients with HTN

Valvular Heart Disease: 20-50 years age group

Table 8 shows pulp stone prevalence in patients of different age groups with and without valvular heart disease (VHD). When comparing *patients* within the age group *20-50 years*, more patients *with VHD* had pulp stones overall than those *without CVD*, **56%** (9/16) vs. **44%** (22/50) respectively; however, this difference was not statistically significant (Chi-Square, P = .393) (Fig. 25). When comparing non-carious, non-restored, or minimally restored teeth in *patients* within this age group, a slightly higher proportion of patients *with VHD* had pulp stones than those *without CVD*, **38%** (6/16) vs. **36%** (18/50) respectively; however, this difference was not statistically significant (Chi-Square, P = .914). When dividing this same group into non-carious/minimally restored teeth (25% vs. 28%) and non-carious/non-restored teeth (31% vs. 22%), no statistically significant differences were

found in pulp stone prevalence between the CVD groups; (Chi-Square, P = .815 and P = . 452) respectively. Finally, when comparing heavily restored teeth between CVD groups, no statistically significant differences were found in pulp stone prevalence (44% vs. 26%) as shown in Figure 25 (Chi-Square, P = .179).

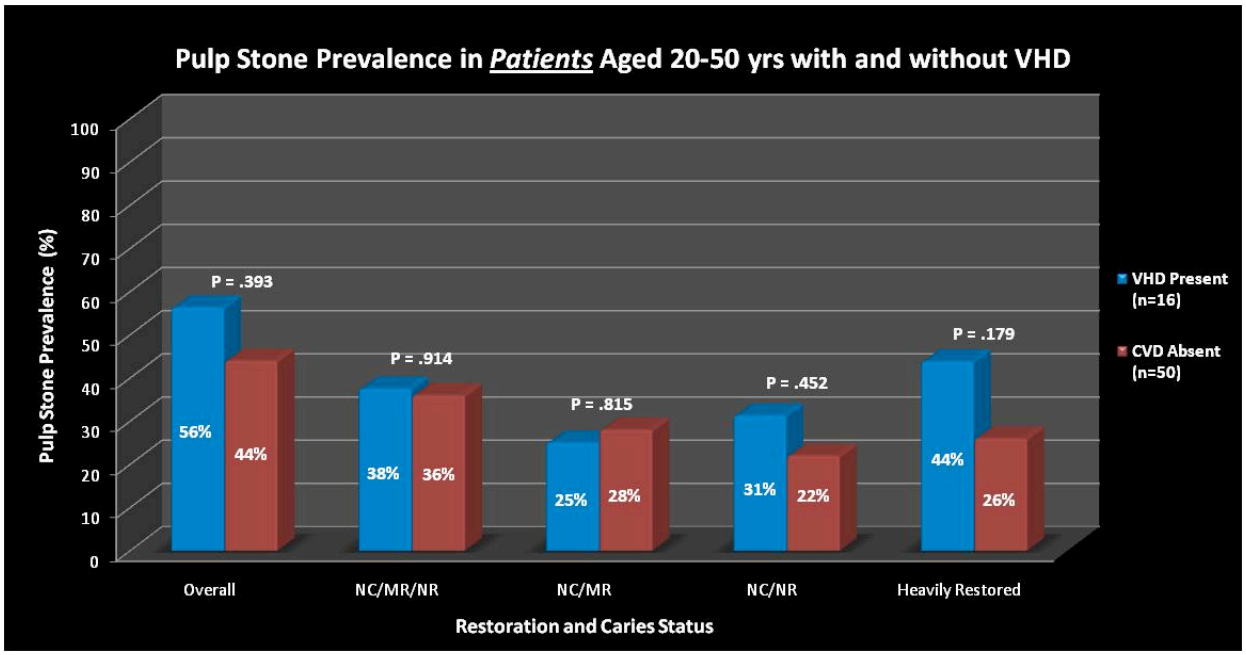

Figure 25. Comparison of pulp stone prevalence between patients ages 20-50 yrs *with VHD* and *without CVD*

Valvular Heart Disease: 51-75 years age group

When comparing *patients* within the age group *51-75 years*, more patients *without CVD* had pulp stones overall than those *with VHD*, **56%** (23/50) vs. **38%** (3/8) respectively; however, this difference was not statistically significant as shown in Figure 26 (Chi-Square, P = .330).

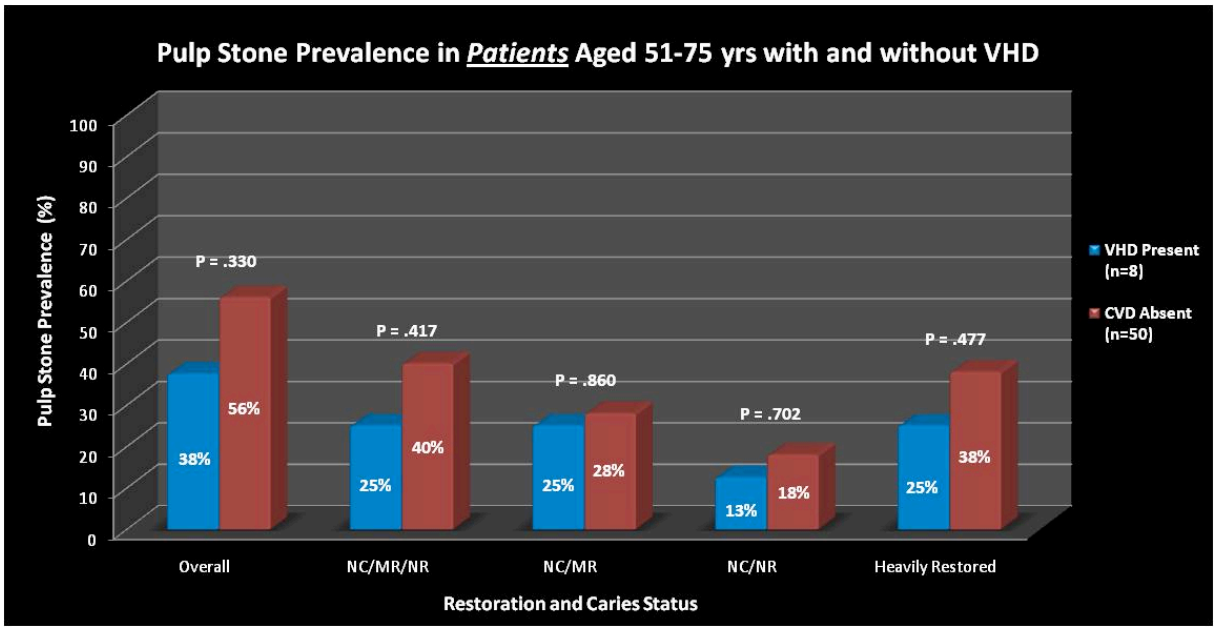

Figure 26. Comparison of pulp stone prevalence between patients ages 51-75 yrs *with VHD* and *without CVD*

When comparing non-carious, non-restored, or minimally restored teeth in *patients* within this age group, more patients *without CVD* had pulp stones than those *with VHD*, **40%** (20/50) vs. **25%** (2/8) respectively; however, this difference was not statistically significant (Chi-Square, P = .417). When dividing this same group into non-carious/ minimally restored teeth (25% vs. 28%) and non-carious/non-restored teeth (13% vs. 18%), no statistically significant differences were found in pulp stone prevalence between the CVD groups; (Chi-Square, P = .860 and P = .702) respectively. Finally, when comparing heavily restored teeth (25% vs. 38%) between CVD groups, no statistically significant differences were found in pulp stone prevalence as shown in Figure 26 (Chi-Square, P = . 477).

Comparing younger (20-50 yrs) vs. older (51-75 yrs) age groups with VHD

When comparing *patients with VHD* between the age groups *20-50 yrs* and *51-75 years*, more patients in the younger age group (20-50 yrs) had pulp stones overall than those in the older age group, **56%** (9/16) vs. **38%** (3/8) respectively; however, this difference was not statistically significant as shown in Figure 27 (Chi-Square, P = .386).

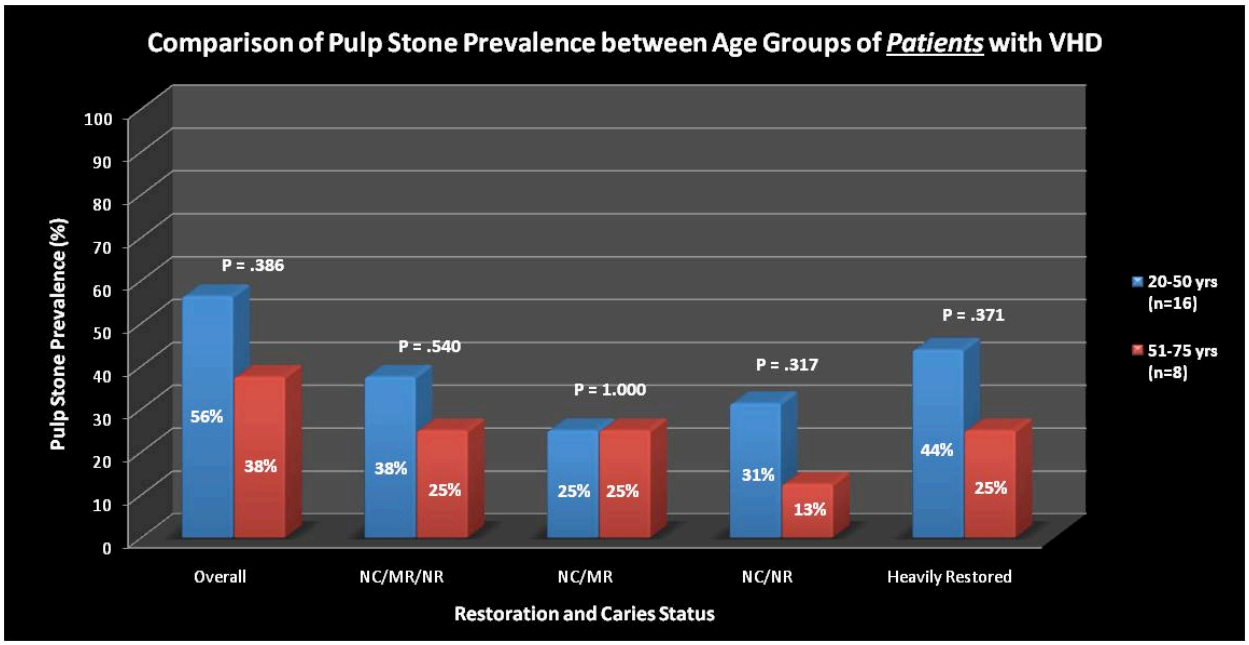

Figure 27. Comparison of pulp stone prevalence between age groups of patients with VHD

When comparing non-carious, non-restored, or minimally restored teeth in *patients with VHD*, more patients in the younger age group (20-50 yrs) had pulp stones than those in the older age group, **38%** (6/16) vs. **25%** (2/8) respectively; however, this difference was not statistically significant (Chi-Square, P = .540). When dividing this same group of teeth into non-carious/minimally restored (25% vs. 25%) and non-carious/non-restored (31% vs. 13%) teeth, no statistically significant differences were found in pulp stone prevalence between the age groups; (Chi-Square, P = 1.000 and P = .317) respectively. Finally, when comparing prevalence of pulp stones in heavily restored teeth between age groups (44%

vs. 25%, respectively), no statistically significant differences were found in pulp stone prevalence as shown in Figure 27 (Chi-Square, P = .371).

Hypercholesterolemia: 20-50 years age group

Table 9 shows pulp stone prevalence in patients of different age groups with and without hypercholesterolemia (Hchol). When comparing *patients* within the age group *20-50 years*, more patients *with HChol* had pulp stones overall than those *without CVD*, **67%** (6/9) vs. **44%** (22/50) respectively; however, this difference was not statistically significant as shown in Figure 28 (Chi-Square, P = .210). When comparing non-carious, non-restored, or minimally restored teeth in *patients* within this age group, more patients *with HChol* had pulp stones than those *without CVD*, **56%** (5/9) vs. **36%** (18/50) respectively; however, this difference was not statistically significant (Chi-Square, P = .268). When dividing this same group into non-carious/minimally restored teeth (44% vs. 28%) and non-carious/ non-restored teeth (44% vs. 22%), no statistically significant differences were found in pulp stone prevalence between the CVD groups; (Chi-Square, P = .324 and P = .155) respectively. Finally, when comparing heavily restored teeth (44% vs. 26%) between CVD groups, no statistically significant differences were found in pulp stone prevalence as shown in Figure 28 (Chi-Square, P = .261).

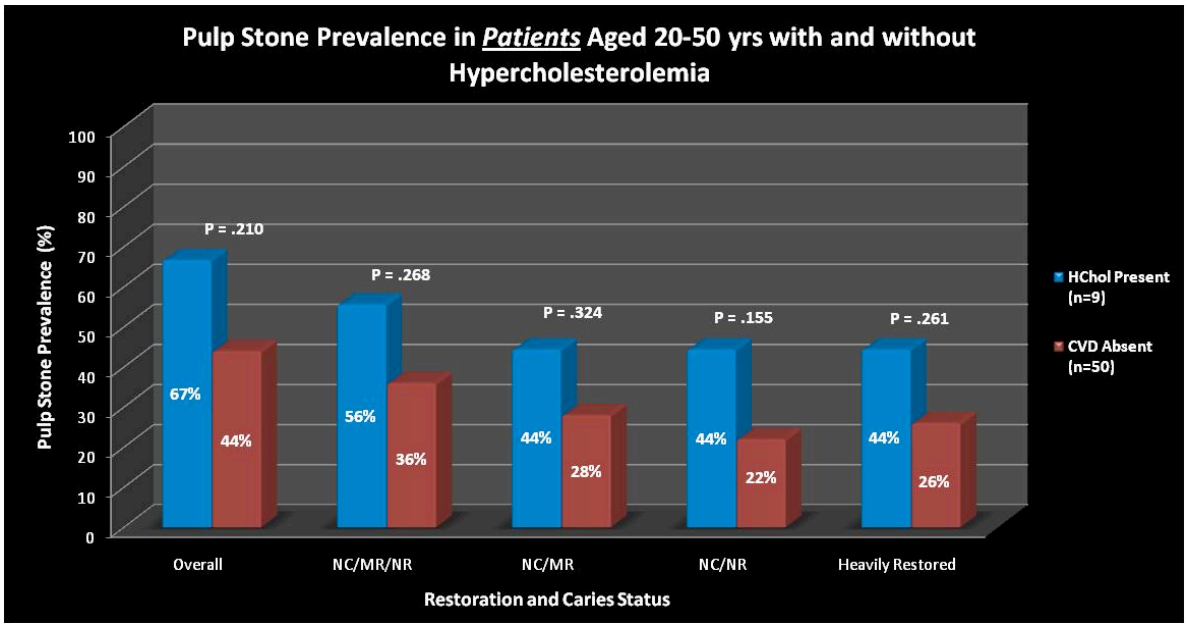

Figure 28. Comparison of pulp stone prevalence between patients ages 20-50 yrs *with HChol* and *without CVD*

Hypercholesterolemia: 51-75 years age group

When comparing *patients* within the age group *51-75 years*, more patients *without CVD* had pulp stones overall than those *with HChol*, **56%** (28/50) vs. **40%** (4/10) respectively; however, this difference was not statistically significant (Chi-Square, P = .355). When comparing non-carious, non-restored, or minimally restored teeth in *patients* within this age group, more patients *without* CVD had pulp stones than those *with HChol*, **40%** (20/50) vs. **10%** (1/10) respectively; however, this difference was not statistically significant (Chi-Square, P = .069). When dividing this same group into non-carious/minimally restored teeth (10% vs. 28%) and non-carious/non-restored teeth (10% vs. 18%), no statistically significant differences were found in pulp stone prevalence between the CVD groups; (Chi-Square, P = .230 and P = .535) respectively. Finally, when comparing heavily restored teeth

(40% vs. 38%) between CVD groups, no statistically significant differences were found in pulp stone prevalence as shown in Figure 29 (Chi-Square, P = .905).

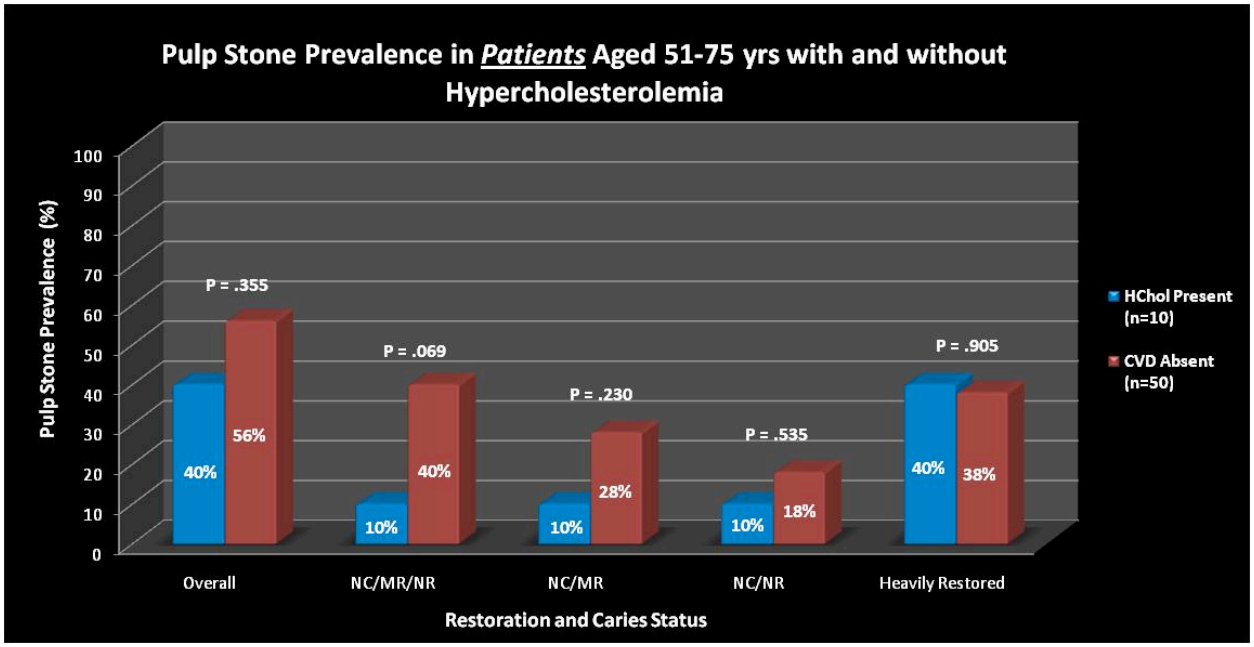

Figure 29. Comparison of pulp stone prevalence between patients ages 51-75 yrs *with HChol* and *without CVD*

Comparing younger (20-50 yrs) vs. older (51-75 yrs) age groups with HChol

When comparing *patients with HChol* between the age groups *20-50 yrs* and *51-75 years*, more patients in the younger age group (20-50 yrs) had pulp stones overall than those in the older age group, **67%** (6/9) vs. **40%** (4/10) respectively; however, this difference was not statistically significant as shown in Figure 30 (Chi-Square, P = .245).

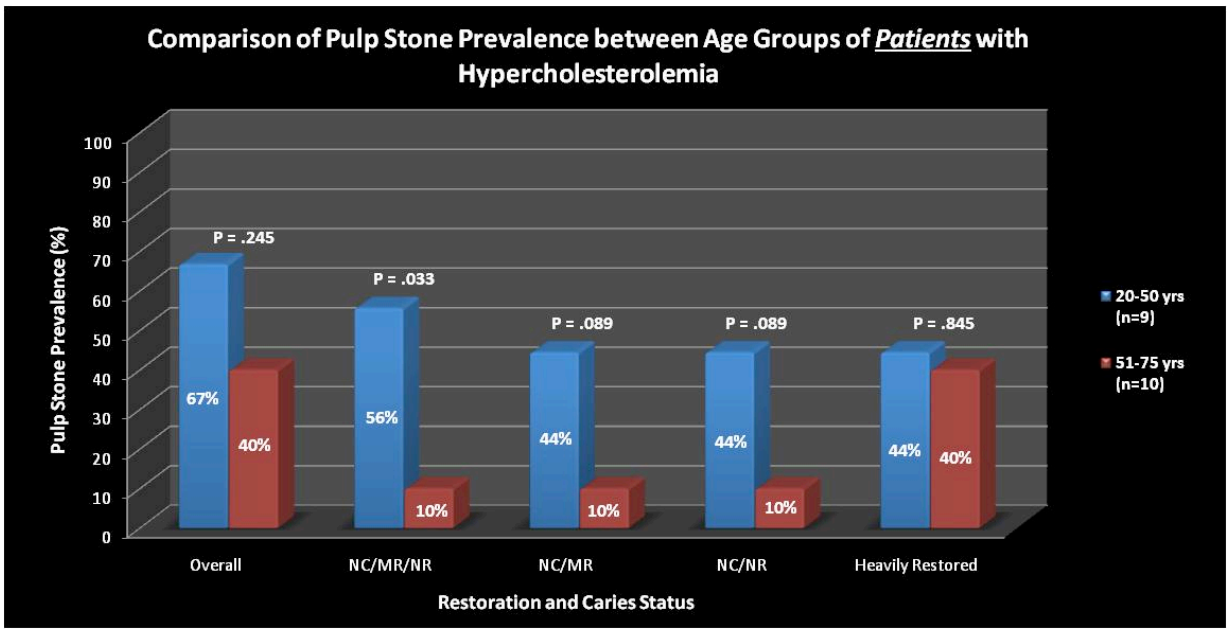

Figure 30. Comparison of pulp stone prevalence between age groups of patients with HChol

When comparing non-carious, non-restored, or minimally restored teeth in *patients with HChol*, more patients in the younger age group (20-50 yrs) had pulp stones than those in the older age group, **56%** (5/9) vs. **10%** (1/10) respectively; this difference was statistically significant (Chi-Square, P = .033). When dividing this same group of teeth into non-carious/minimally restored teeth (44% vs. 10%) and non-carious/non-restored teeth (44% vs. 10%), more patients in the younger age group (20-50 yrs) had pulp stones than those in the older age group; however, these differences were not statistically significant (Chi-Square, P = .089 and P = .089) respectively. Finally, when comparing heavily restored teeth (44% vs. 40%) between age groups, no statistically significant differences were found in pulp stone prevalence as shown in Figure 30 (Chi-Square, P = .845).

Comparison of Pulp Stone Prevalence by Age Group and Selected CVD Categories in Patients with Specific Types of CVD

When comparing non-carious, non-restored, or minimally restored teeth in *patients* with CVD(n=100), HTN (n=56), VHD (n=24), or HChol (n=19); patients in the 20-50 yrs age group tended to have a higher pulp stone prevalence in all CVD categories as shown in Figure 31.

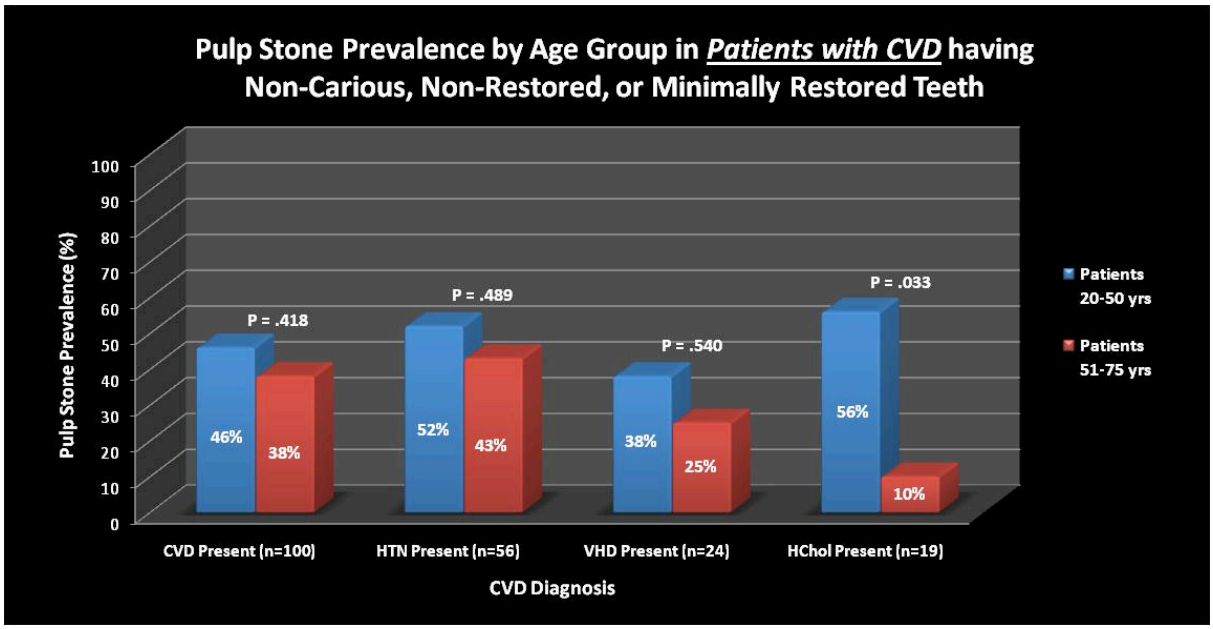

Figure 31. Comparison of pulp stone prevalence in patients with specific types of CVD

Although younger patients (20-50 yrs) tended to have higher pulp stone prevalence than older patients (51-75 yrs), these differences were not statistically significant except for HChol (P = .033).

Aim 7

Are there any additional covariates such as age, age group, gender, diabetes, arthritis, tobacco use, or alcohol use that could affect the prevalence of pulp stones in teeth?

Age (actual), Age Group, Gender, Diabetes, Arthritis, Tobacco Use, and Alcohol Use

Table 10 shows each covariate as a potential confounder to pulp stone formation in *patients with CVD*. When identifying if any of the covariates such as age (actual), age group, gender, diabetes, arthritis, tobacco use, or alcohol use had an influence on pulp stone formation in non-carious, non-restored, or minimally restored teeth in *patients with CVD*; each covariate was analyzed individually and the odds ratio with 95% confidence interval was generated. The odds of *patients with CVD only* to have pulp stones in non-carious, non-restored, or minimally restored teeth was 25.0% greater than *patients without CVD*; however, this was not statistically significant (P = .448, 95% CI .703 – 2.221). When analyzing each individual covariate as a potential confounder to pulp stone formation in *patients with CVD*, patients having CVD and an additional covariate had a 23.3% - 29.1% greater odds of having pulp stones in non-carious, non-restored, or minimally restored teeth than *patients without CVD*, but none of the associations were statistically significant because all of the 95% confidence intervals included 1.0. Since none of the individual covariates had any statistically significant impact on the odds of pulp stone formation in non-carious, non-restored, or

minimally restored teeth in *patients with CVD*, no further multivariate logistic regressions were performed.

Aim 8

Is there an association between the prevalence in pulp stones in patients teeth based on restoration and caries status?

Table 11 shows the average number and percentage of teeth per patient containing pulp stones by restoration and caries status. To compare the restoration and caries status of teeth and pulp stone formation, the Poisson regression model was used. This analysis evaluates the counts of teeth with pulp stones by categories of restoration status and caries status. A total of 352 pulp stones were identified in this study. They were distributed into three main restorative and three caries categories for teeth:

Restorative Category: non-restored, minimally restored, and heavily restored

Caries Category: non-carious, incipient carious, and dentinal carious

Pulp Stone Average by Restoration Status

When analyzing the overall distribution of pulp stones in teeth of *patients* aged 20-75 yrs, heavily restored teeth contained the most pulp stones (n=141 teeth with pulp stones), followed by minimally restored teeth (n=115), and non-restored teeth contained the least (n=96). However, when evaluating the average percentage of pulp stones per *patient* within these restorative categories, it was found that the prevalence of pulp stones was highest in minimally restored teeth (20.4%), followed by heavily restored (12.2%), and non-restored had the lowest prevalence of pulp stones (6.3%). When comparing restorative categories of teeth containing pulp stones, it was found that there were statistically significant

differences (P < .001) in pulp stone prevalence between non-restored and minimally restored teeth (6.3% vs. 20.4%), non-restored and heavily restored teeth (6.3% vs. 12.2%), and minimally restored and heavily restored teeth (12.2% vs. 20.4%); respectively as shown in Table 11. Overall, it was found that the prevalence of pulp stones increased in teeth when restorations were present; however, most teeth on average did not contain pulp stones (61.1%) as shown in Figure 32.

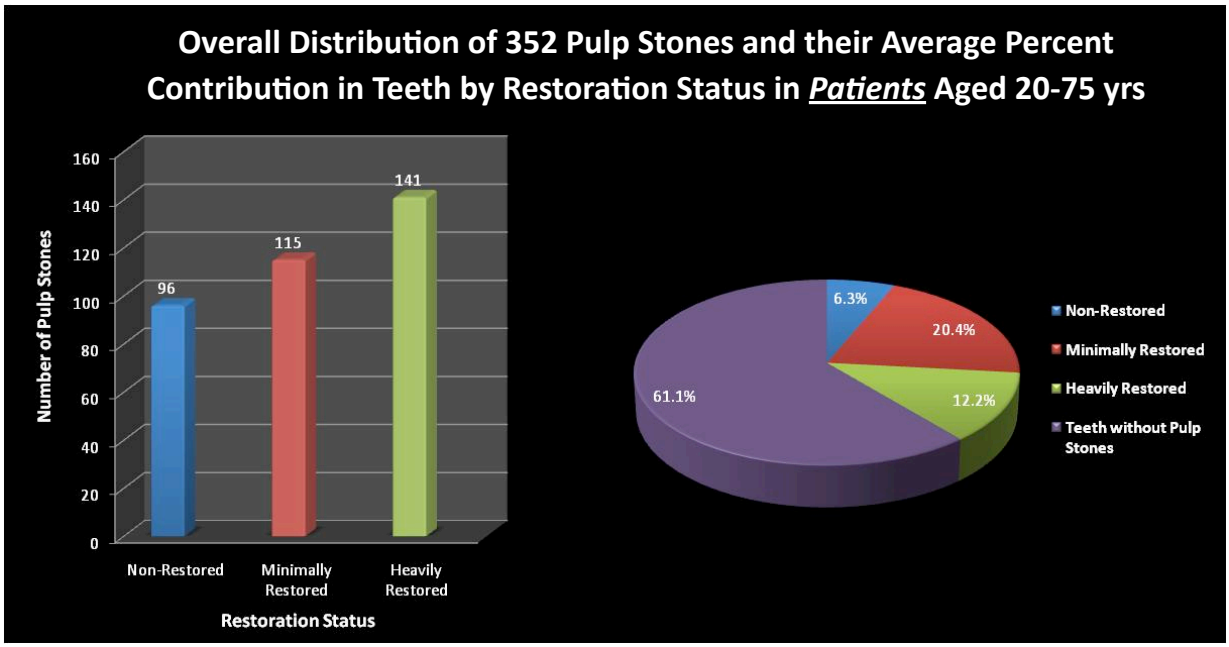

Figure 32. Distribution of pulp stones in patients aged 20-75yrs

Pulp Stone Average by Caries Status

When analyzing the distribution of pulp stones in *teeth* based on caries status in patients aged 20-75 yrs, non-carious contained the most (n=330), while both incipient and dental caries teeth each contain the same amount of pulp stones (n=11). When looking at the average percentage of pulp stones within these carious categories of teeth in *patients*, it was

found that non-carious teeth contained the most pulp stones (12.6%), followed by dentinal caries (2.4%), and incipient caries contained the least (2.3%) as shown in Figure 33.

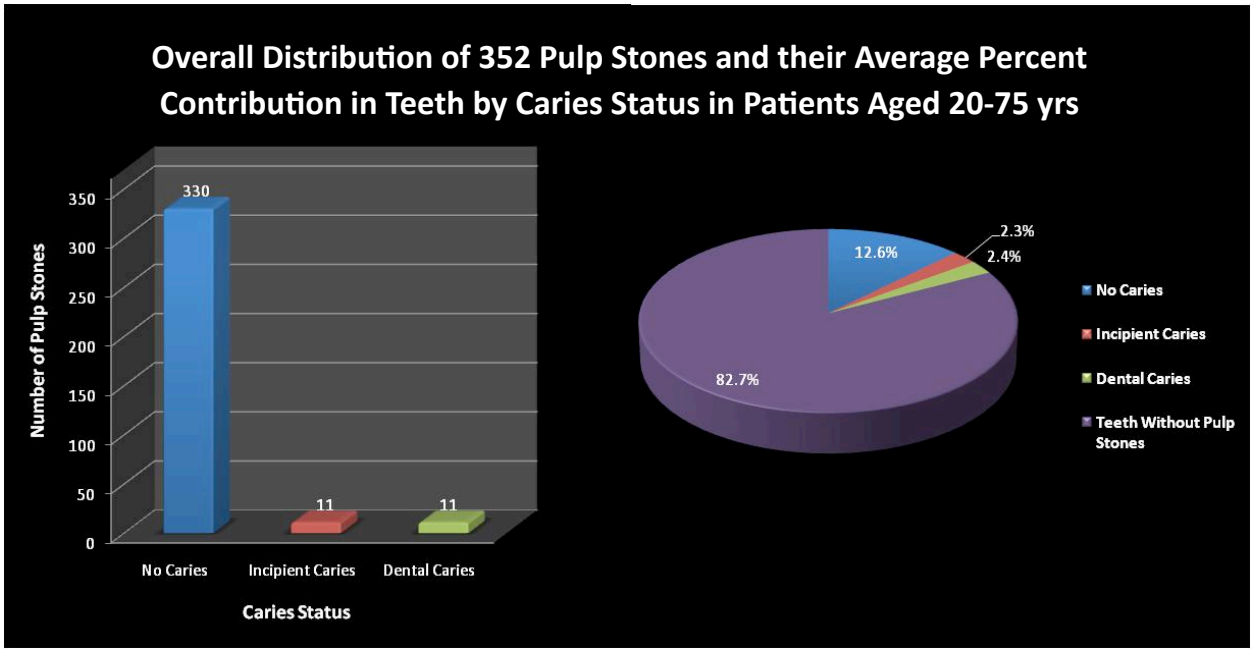

Figure 33. Pulp stone distribution into three main caries categories of teeth and their percent contribution among the categories

When comparing caries categories of teeth containing pulp stones, it was found that there were statistically significant differences in pulp stone prevalence between non-carious and incipient carious teeth (12.6% vs. 2.3%, P = 0.034) and non-carious and dentinal carious teeth and heavily restored teeth (12.6% vs. 2.4%, P = 0.001). When comparing incipient carious and dentinal carious teeth (2.3% vs. 2.4%), no statistically significant differences were found as shown in Table 11 (P = .878). Overall, it was found that the prevalence of pulp stones increased in teeth when caries was absent.

Chapter 6- DISCUSSION

This cross-sectional study evaluated a total of 200 patients divided between two different age groups of patients (20-50 yrs and 51-75 yrs) *with and without CVD* to identify if an association existed in pulp stone formation in non-carious, non-restored, or minimally restored teeth. The central hypothesis was that *patients with CVD* would have a statistically significant higher prevalence of pulp stones in these teeth types then those *patients without CVD*. The significance of a positive association between CVD and pulp stone formation could is that this could support a dental practitioner screening for potential undiagnosed

CVD among their patients. This would be especially important in younger patients (20-50 yrs) because early intervention could potentially limit the burden of this disease and preventative measures could be taken to slow or reverse the disease process.

Research dating from 1933 has evaluated the significance of pulp stone formation in teeth and its potential link to systemic diseases such as CVD [54]. More recently, some research has specifically evaluated if an association exists between pulp stones and patients suffering from coronary atherosclerosis [7]. Current research has focused more broadly on pulp stone prevalence in geographic populations [20, 21, 26, 31] while very little has focused directly on associations between CVD and pulp stone formation [6]. This study specifically focused on investigating an association between CVD or CVD risk factors (hypercholesterolemia) and pulp stone formation in patients overall, in different age groups, and between age groups. This study identified and accounted for other conditions/ diseases that may influence pulp stone formation within teeth or have a positive effect on CVD in patients. Specifically, teeth that were carious or heavily restored were not included in the analysis due to their potential local inflammatory effects on the dental pulp that could influence pulp stone formation [19, 20]. To meet inclusion criteria, patients had to have at least one molar tooth that was non-carious, non-restored, or minimally restored (restorations in enamel or 1/3rd dentin thickness only) so local causes of inflammation on the pulp could be avoided. Also, diseases or conditions such as diabetes, smoking, and alcohol use that could have a adverse effect on CVD pathogenesis were analyzed as well validating they did not influence pulp stone formation. Finally, age, age group of patient, gender, and calcifying conditions such as arthritis were evaluated with CVD identifying if

they had any influence on pulp stone formation within non-carious, non-restored, or minimally restored teeth.

Overall, this study did *not* find a statistically significant difference in pulp stone formation in non-carious, non-restored, or minimally restored teeth between *patients with and without CVD*; 42% vs. 38% respectively. Furthermore, when looking at specific types of CVD such as hypertension and valvular heart disease or CVD risk factors such as hypercholesterolemia, no statistically significant differences were found in pulp stone formation in non-carious, non-restored, or minimally restored teeth when compared to patients *without CVD*. When comparing within and between age groups, 20-50 yrs and 51-75 yrs, no statistically significant differences in pulp stone formation were found either in these teeth types. However, *patients with CVD* in the younger age group (20-50 yrs) did tend to have a higher prevalence of pulp stones than those *without CVD*; 46% vs. 36%, respectively. Also, when looking at specific types of CVD or CVD risk factors, *patients with HTN, VHD, and HChol* in the younger age group (20-50 yrs) also tended to a have higher prevalence of pulp stones in these same teeth types than those *without CVD*. These trends, although not statistically significant, could have potential meaning but even larger sample sizes of patients in this age group would be needed to confirm any significance.

This study's findings are contrary to Edds [6] and Nayak [8] studies where they both found a significant association between pulp stone formation in non-carious/minimally restored teeth and CVD. Overall, we found that more patients *with CVD* (42%) tended to have pulp stones in their teeth than those *without CVD* (38%). We also found that patients in the younger age group (20-50 yrs) *with CVD* (46%) had a higher pulp stone prevalence in non-carious, non-restored, or minimally restored teeth than patients *without CVD* (36%);

although both of these findings were not statistically significant. This was also the same observation when categorizing CVD patients into the most common sub-types of CVD found in this age group: hypertension, valvular heart disease, and hypercholesterolemia. Although the trend showed that patients *with HTN* (52%), *VHD* (38%), and *HChol* (56%) tended to have a higher pulp stone prevalence in non-carious, non-restored, or minimally restored teeth than those *without CVD* (36%); however, no statistical significance was found. This was in part due to even smaller sample sizes within these sub-categories of patients *with CVD*: HTN (n=21), VHD (n=16), HChol (n=9).

Edds study consisted of 50 patients aged 20-55 yrs, 19 patients with CVD and 36 patients without CVD. They found that 74% (14/19) of *patients with CVD* had pulp stones in non-carious/minimally restored teeth while only 39% (14/36) of *patients without CVD* contained pulp stones in these same teeth types. Due to an even smaller sample size of patients (n=50) and uneven distribution of patients within the study (CVD Present; n=19 vs. CVD Absent; n=36), statistical significance may have been influenced by even small differences between pulp stone prevalence in patients. Nayak's study consisted of 150 total patients divided into 5 groups each consisting of 30 patients: (1) CVD, (2) Type 2 DM, (3), Type 1 DM, autoimmune thyroiditis, Sjogren's syndrome, SLE, and multiple sclerosis, (4) dental-wear defects and (5) control group. They found that 93% (28/30) of patients and 15.86% of teeth contained pulp stones in *patients with CVD* compared to 50% (15/30) of patients and 2.83% of teeth in patients *without CVD*. They too, had a small sample size of patients with CVD (n=30) so statistical significance could have been influenced by small differences. Also, the author did not mention anything in their materials and methods

about blinding the groups to eliminate any bias when collecting data; this could have also influenced the outcome of this study and the associations they found.

In the current study, a total of 200 patients were analyzed, *100 patients with CVD* and *100 patients without CVD,* which is 4 times the sample size of Edds [6] pilot study and 1.3 times larger than Nakak's [8] pilot study. In terms of *CVD patients only*, our sample size was 2.6 times greater in the *20-50 yrs* age group and 5.3 times greater for *overall CVD* patients than Edds study, while 1.7 times greater in the *20-50 yrs* age group and 2 times greater for *overall CVD* then Nayak's study. With a larger number of patients in our study, we can draw better conclusions from our data and statistical analysis when comparing to the smaller sample sizes in Edds and Nayak's studies.

In our study, we found that patients in the 51-75 yrs age group *without CVD* (40%) tended to have a higher prevalence of pulp stones in non-carious, non-restored, or minimally restored teeth than those *with CVD* (38%), which is not statistically significant. This was also true when looking at patients with pulp stones in these teeth types *with VHD* (25%) or *HChol* (10%) in this age group. Only patients *with HTN* (43%) had higher pulp stone prevalence than those *without CVD* (40%), which is not statistically significant. These findings are also in part due to even smaller sample sizes within these sub-categories of patients *with CVD*: HTN (n=35), VHD (n=8), HChol (n=10). These findings, which are opposite for the 20-50 yrs age group in this study, could be by chance or more likely attributed to the age related changes of a pulp. Pulp chambers and canals tend to decrease in size with age due to the deposition of secondary and tertiary dentin [4] making identification of pulp stones more difficult. Even in the absence of caries and restorations, these natural calcifications are present in variable size and shape [5]. Patients in the

younger age group had larger pulp chambers and canals so identifying a distinct radiopaque object such as a pulp stone was much easier than the older age group. Diffuse calcifications in the dental pulp from the natural process of aging [3, 4, 33] also become more apparent in the older age group which might also be mistaken as a pulp stone. This was a limitation of this study even with limiting the teeth types to non-carious, non-restored, or minimally restored teeth.

Our findings cannot be directly compared to the Moura & Paiva [7] study where they found a significant association between coronary atherosclerosis, a specific type of CVD, and pulp stone formation. This was due to another limitation in our project when collecting medical history data because the medical histories did not specifically ask whether the patient had coronary atherosclerosis. Instead, it asked whether the patient has ever had a heart attack, angina, or other heart or circulation problems in which the patient would have to explain what type of heart condition they had. Even though these conditions may imply that the patient was suffering from coronary atherosclerosis, it is impossible to know for sure. Also, even if these conditions were considered as a form of coronary atherosclerosis, our study only had a total of three patients who fit this category. The majority of the patients with CVD in our study either had hypertension (n=56), valvular heart disease (n=24), or hypercholesterolemia (n=19). Nonetheless, Moura & Paiva only looked at 50 patients total, 25 patients with coronary atherosclerosis and 25 patients without CVD making the sample size small. Furthermore, they also considered all teeth containing pulp stones instead of only non-carious, non-restored, or minimally restored teeth. Therefore, teeth containing caries or heavy restorations could have influenced pulp stone formation due to local inflammatory mediators caused from bacteria [19, 20] instead of coronary atherosclerosis.

Our findings are in agreement with Sener [20] who looked radiographically at the pulp stone prevalence in 536 Turkish patients, 56 of whom had CVD. Their study evaluated pulp stone prevalence by caries and restoration status of teeth, age, gender and CVD status of patients. Their study did not specifically target patients with CVD but rather included them if present. Also, when analyzing patients with CVD for pulp stone prevalence, they also considered all teeth rather than only non-carious, non-restored, or minimally restored teeth. Once again, by considering all teeth types in their analysis, the true effect of CVD on pulp stone formation in teeth could not be evaluated because teeth containing caries and heavy restorations could cause local inflammatory effects on the pulp affecting pulp stones formation rather than CVD. Although their findings are in agreement with ours, the true effect of CVD of pulp stone formation in their study remains suspect.

The overall prevalence of pulp stones in *patients* in our study was 53% whereas the average percentage of *teeth* containing pulp stones was 12.3%. These findings are in accordance with the range of radiographic prevalence found in *patients* (9.9% - 51.4%) and *teeth* (4% - 22.4%) within the literature [20, 21, 26, 27, 30, 31]. Overall, no differences were found between gender (males = 53.8%, females = 52.3%) or age group (20-50 yrs = 51%, 51-75 yrs = 55%) for pulp stone prevalence; these findings are also in accordance with the literature [20, 21, 26, 27].

The most prevalent tooth type in *patients* in our study to contain pulp stones were maxillary molars (45.5%) followed by mandibular molars (31.5%). Maxillary and mandibular pre-molars were the least likely tooth type in *patients* to contain pulp stones; 3.5% and 6.0% respectively; these findings are also in accordance with the literature [21, 32]. The most probable reason why pre-molars contained the lowest pulp stone prevalence

was because they also contain the smallest pulp chamber and canals making it difficult to identify pulp stones radiographically. Molars generally have much larger pulp chambers which allow for larger detectable calcifications to be seen radiographically. Only through histology could more accurate measurements in pulp stone prevalence and distinction between diffuse calcifications and pulp stones be determined in teeth [5, 17, 19, 33]. This method of identification is also impractical in a clinical setting where tooth extraction is not warranted for functioning and healthy teeth.

Overall, we found that restoration status had a statistically significant influence on pulp stone prevalence. In this study, we found that teeth having any type of restoration had an increased chance of containing a pulp stone; this is in agreement with some literature [20] and contrary to others [30, 32, 57]. We also found that the level of restoration was significantly related to probability that a tooth had a pulp stone, with non-restored teeth (6.3%) having a lower probability than either minimally (20.4%) or heavily restored (12.2%) teeth. However, teeth with minimal restorations had a higher rate of pulp stones than heavy restorations, which seems counterintuitive. A possible explanation for the lower pulp stone occurrence rate in heavily restored teeth when compared to minimally restored teeth is due the decreased ability to properly identify pulp stones in crowned and heavily restored teeth. In this study, there were a total of 287 crowned teeth within the heavily restored category. This meant that there were 287 less teeth to identify pulp stones within this category because of the pulp chambers being completely covered by the crowns. Even though these teeth may have contained pulp stones, they were unidentifiable resulting in a lower pulp stone prevalence. Also, some teeth containing heavy restorations tended to have obliterated pulp chambers making identification of pulp stones difficult, whereas

minimally restored teeth had clearly identifiable pulp chambers in which pulp stones could be easily seen.

Overall, we found that caries status of teeth had a statistically significant influence on pulp stone prevalence with non-carious teeth (12.6%) having the highest pulp stone prevalence, followed by dentinal carious teeth (2.4%), and incipient carious teeth having the lowest prevalence (2.3%). There were no statistically significant differences in pulp stone prevalence between dentinal carious and incipient carious teeth; this is contrary to the literature [19]. The reason why pulp stone prevalence was significantly higher in non-carious teeth when compared to incipient or dentinal carious teeth was due the inclusion criteria required for this study; over 93% of the teeth were non-carious. To meet inclusion criteria, patients had to have at least one molar that was non-carious, non-restored, or minimally restored. Over 1,000 dental charts were individually evaluated in this study to find patients who met the inclusion criteria; many patients who had carious teeth did not meet the inclusion criteria and were excluded from the study. Also, all of the patients selected for this study had to be active patients of the dental school within the last three years. Many of these patients seek regular dental care and have had all of the carious teeth removed or restored back to health, therefore most teeth within this study population were non-carious. Our conclusion that non-carious teeth have a statistically significant higher prevalence of containing pulps stones is biased towards the sample population we chose for this study and therefore cannot be considered valid due to the extremely low number of incipient carious and dentinal carious teeth evaluated.

Conclusions

1) In this study, CVD was *not* a risk indicator for pulp stone formation in non-carious, non-restored, or minimally restored teeth.

2) There was no statistically significant difference in pulp stone formation between *patients with and without CVD* in non-carious, non-restored or minimally restored teeth or between the two age groups.

3) There was no statistically significant difference in pulp stone formation between *patients with and without HTN, VHD, or HChol* in non-carious, non-restored or minimally restored teeth or between the two age groups.

4) Patients 20-50 yrs *with CVD* (46%) were more likely to have pulp stones in non-carious, non-restored, or minimally restored teeth than patients *without CVD* (36%); however this was not statistically significant.

5) Covariates such as age, age group, gender, diabetes, arthritis, tobacco use, and alcohol use did not influence the association of CVD with pulp stone formation in patients in this study.

6) To find the association between CVD and pulp stone formation, *only* teeth that are non-carious and non-restored should be evaluated because local irritation from restorations or bacteria could cause pulp stone formation and mask the true effect CVD has on the pulpal tissue.

Summary

In this study, CVD was *not* a risk indicator for pulp stone formation in non-carious, non-restored, or minimally restored teeth. Although we did not find any statistically significant differences between patients *with and without CVD*, it is suggestive that younger patients (20-50 yrs) *with CVD* have a higher pulp stone prevalence than patients *without CVD*. We also found that restorations, whether minimal or heavy, significantly increase the probability of pulp stone formation in teeth. Future studies trying to identify an association between pulp stone formation and CVD should have larger sample sizes, include non-carious and non-restored teeth *only* and should focus on younger populations (20-50 yrs) where pulp stone prevalence appears to be higher in *patients with CVD*.

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List of Tables

Table 10: Comparison of Pulp Stone Formation in Non-Carious, Non-Restored and Minimally Restored Teeth in Patients with and without CVD having Additional Covariates

Table 11: Average Percentage of Teeth per Patient Containing Pulp Stones by Restoration and Caries Status

Table 1

Investigator	Methodology	Sample (n)	Age of Subjects (yrs)	Prevalence (%)
Hill (1934)	Histology	132 teeth	10-70 yrs	10-30 yrs (66%), 31-50 yrs (80%), 51-70 yrs (90%)
Sayegh & Reed (1968)	Histology	591 teeth	10-63 yrs	31.6% teeth
Hillmann & Geurtse (1997)	Histology	332 teeth	11-72 yrs	11-30 yrs (14.9%), 31-51 yrs (44.4%), 52-72 yrs (65.1%)
Hamasha & Darwazeh (1998)	Radiography	4,573 teeth, 814 subjects	18-69 yrs	22.4% teeth, 51.4% subjects
Tamse *et al.* (1982)	Radiography	1,380 teeth, 300 subjects	20-40 yrs	20.7% teeth, 41.6% subjects
Chandler *et al.* (2003)	Radiography	445 teeth, 121 subjects	18-25 yrs	9.9% teeth, 4% subjects
Sener *et al.* (2008)	Radiography	15,326 teeth, 536 subjects	13-65 yrs	4.8% teeth, 38% subjects
Rozylo et al. (1999)	Radiography	880 teeth	18-56 yrs	25.7% teeth
Perminder & Singh (1985)	Radiography	2,452 teeth	unknown	18% teeth
Baghdady *et al.* (1988)	Radiography	6,228 teeth	12-13 yrs	19.2% teeth
Ranjitkar *et al.* (2002)	Radiography	3,296 teeth, 217 subjects	17-35 yrs	10.1% teeth, 46.1% subjects

Table 2

Patient Characteristics by Age and CVD Diagnosis

CVD Exposures	Age Group 20 -50 yrs						Age Group 51-75 yrs						Age Group 20-75 yrs					
	Total Patients (n=100) Average Age: 41.4 yrs		Male (n=40) Average Age: 41.2 yrs		Female (n=60) Average Age: 41.6 yrs		Total Patients (n=100) Average Age: 60.6 yrs		Male (n=51) Average Age: 63.1 yrs		Female (n=49) Average Age: 58.1 yrs		Total Patients (n=200) Average Age: 51.0 yrs		Male (n=91) Average Age: 52.1 yrs		Female (n=109) Average Age: 50.1 yrs	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
CVD Present	50	50%	23	58%	27	45%	50	50%	23	45%	27	55%	100	50%	46	51%	54	50%
CVD Absent	50	50%	17	43%	33	55%	50	50%	28	55%	22	45%	100	50%	45	49%	55	50%
Angina Pectoris	1	1%	1	3%	0	0%	6	6%	2	4%	4	8%	7	4%	3	3%	4	4%
Myocardial Infarction	0	0%	0	0%	0	0%	3	3%	1	2%	2	4%	3	2%	1	1%	2	2%
Heart Surgery	3	3%	3	8%	0	0%	3	3%	3	6%	0	0%	6	3%	6	7%	0	0%
Hypertension	21	21%	10	25%	11	18%	35	35%	15	29%	20	41%	56	28%	25	27%	31	28%
Congestive Heart Failure	1	1%	0	0%	1	2%	1	1%	0	0%	1	2%	2	1%	0	0%	2	2%
Coronary Heart Disease	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Cardiomyopathy	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Valvular Heart Disease	16	16%	4	10%	12	20%	8	8%	4	8%	4	8%	24	12%	8	9%	16	15%
Congenital Heart Disease	1	1%	1	3%	0	0%	0	0%	0	0%	0	0%	1	1%	1	1%	0	0%
Atherosclerosis	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Hypercholesterolemia	9	9%	6	15%	3	5%	10	10%	6	12%	4	8%	19	10%	12	13%	7	6%
Arrhythmia	7	7%	2	5%	5	8%	7	7%	2	4%	5	10%	14	7%	4	4%	10	9%
Aneurysm	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Cerebrovascular Accident (Stroke)	0	0%	0	0%	0	0%	1	1%	1	2%	0	0%	1	1%	1	1%	0	0%
Transient Ischemic Attack (mini stroke)	1	1%	0	0%	1	2%	1	1%	0	0%	1	2%	2	1%	0	0%	2	2%
Cerebrovascular Disease	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Pulmonary Embolism	1	1%	0	0%	1	2%	0	0%	0	0%	0	0%	1	1%	0	0%	1	1%
Aorta Disease	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Rheumatic Heart Disease/ Rheumatic Fever	0	0%	0	0%	0	0%	2	2%	2	4%	0	0%	2	1%	2	2%	0	0%
Deep Vein Thrombosis	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Other Diseases/Conditions	**Age Group 20 -50 yrs**						**Age Group 51-75 yrs**						**Age Group 20-75 yrs**					
	Total Patients (n=100)		Male (n=40)		Female (n=60)		Total Patients (n=100)		Male (n=51)		Female (n=49)		Total Patients (n=200)		Male (n=91)		Female (n=109)	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Kidney Disease	1	1%	0	0%	1	2%	3	3%	2	4%	1	2%	4	2%	2	2%	2	2%
Diabetes Type I	1	1%	0	0%	1	2%	0	0%	0	0%	0	0%	1	1%	0	0%	1	1%
Diabetes Type II	8	8%	2	5%	6	10%	11	11%	6	12%	5	10%	19	10%	8	9%	11	10%
Gout	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Metabolic Diseases	3	3%	1	3%	2	3%	12	12%	2	4%	10	20%	15	8%	3	3%	12	11%
Connective Tissue Disorders	0	0%	0	0%	0	0%	1	1%	0	0%	1	2%	1	1%	0	0%	1	1%
Peripheral Vascular Disease	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%	0	0%
Arthritis	7	7%	0	0%	7	12%	30	30%	12	24%	18	37%	37	19%	12	13%	25	23%
Tobacco Use Ever	44	44%	16	40%	28	47%	52	52%	33	65%	19	39%	96	48%	49	54%	47	43%
Alcochol Use Ever	45	45%	17	43%	28	47%	46	46%	23	45%	23	47%	91	46%	40	44%	51	47%

Table 3

Distribution and Tooth Prevalence of Patient's Dentition by Restoration and Caries Status and CVD Diagnosis

Caries and Restoration Characteristics of Teeth	Overall Patients 20-50 yrs (n=100)		Patients 20-50 yrs with CVD Present (n=50)		Patients 20-50 yrs with CVD Absent (n=50)		Overall Patients 51-75 yrs (n=100)		Patients 51-75 yrs with CVD Present (n=50)		Patients 51-75 yrs with CVD Absent (n=50)		Overall Patients 20-75 yrs (n=200)	
	Number of Teeth (Teeth/Group)	Tooth Prevalence (Avg % of Teeth/Patient) n=16	Number of Teeth (Teeth/Group)	Tooth Prevalence (Avg % of Teeth/Patient) n=16	Number of Teeth (Teeth/Group)	Tooth Prevalence (Avg % of Teeth/Patient) n=16	Number of Teeth (Teeth/Group)	Tooth Prevalence (Avg % of Teeth/Patient) n=16	Number of Teeth (Teeth/Group)	Tooth Prevalence (Avg % of Teeth/Patient) n=16	Number of Teeth (Teeth/Group)	Tooth Prevalence (Avg % of Teeth/Patient) n=16	Number of Teeth (Teeth/Group)	Tooth Prevalence (Avg % of Teeth/Patient) n=16
Total Teeth	1,470	(Tooth Retention Rate) 91.5%	722	(Tooth Retention Rate) 90.3%	748	(Tooth Retention Rate) 93.5%	1,415	(Tooth Retention Rate) 88.4%	691	(Tooth Retention Rate) 86.5%	724	(Tooth Retention Rate) 90.4%	2,885	(Tooth Retention Rate) 90.2%
Restoration Status														
Non-Restored Teeth	755	50.5%	365	49.3%	390	51.7%	520	36.2%	238	33.9%	282	38.4%	1,275	43.3%
Heavily Restored Teeth	372	25.7%	184	26.4%	188	25.0%	413	29.0%	204	28.6%	209	29.4%	785	27.3%
Minimally Restored Teeth	272	18.8%	134	18.7%	138	18.9%	218	15.5%	109	16.3%	109	14.7%	490	17.2%
Crowned Teeth	47	3.1%	29	3.9%	18	2.3%	240	17.6%	132	20.0%	108	15.2%	287	10.4%
Facially Restored Teeth	24	1.9%	10	1.6%	14	2.1%	24	1.7%	8	1.2%	16	2.2%	48	1.8%
Caries Status														
Non-Carious Teeth	1,350	91.2%	659	90.2%	691	92.3%	1,352	95.4%	668	96.6%	684	94.2%	2,702	93.3%
Incipient Carious Teeth	75	5.3%	36	5.4%	39	5.2%	2	0.1%	1	0.1%	1	0.1%	77	2.7%
Dentinal Cariuos Teeth	45	3.5%	27	4.4%	18	2.5%	61	4.5%	23	3.4%	38	5.6%	106	4.0%

Table 4

Pulp Stone Distribution and Prevalence in Patient's Teeth by Age Group, Tooth Type and Gender

Characteristics of Tooth Types	Patients Aged 20-50 yrs								Patients Aged 51-75 yrs								Patients Aged 20-75 yrs							
	Overall (n=100)		Male (n=40)		Female (n=60)		Difference between Gender Groups		Overall (n=100)		Male (n=51)		Female (n=49)		Difference between Gender Groups		Overall (n=200)		Male (n=91)		Female (n=109)		Difference between Gender Groups	
	Number of Teeth with Pulp Stones	Pulp Stone Prevalence (% of Patients)	Number of Teeth with Pulp Stones	Pulp Stone Prevalence (% of Patients)	Number of Teeth with Pulp Stones	Pulp Stone Prevalence (% of Patients)	Chi-Square P- Value (<.05)		Number of Teeth with Pulp Stones	Pulp Stone Prevalence (% of Patients)	Number of Teeth with Pulp Stones	Pulp Stone Prevalence (% of Patients)	Number of Teeth with Pulp Stones	Pulp Stone Prevalence (% of Patients)	Chi-Square P-Value (<.05)		Number of Teeth with Pulp Stones	Pulp Stone Prevalence (% of Patients)	Number of Teeth with Pulp Stones	Pulp Stone Prevalence (% of Patients)	Number of Teeth with Pulp Stones	Pulp Stone Prevalence (% of Patients)	Chi-Square P-Value (<.05)	
Total Teeth	167	51%	59	50.0%	108	51.7%	0.870	0.827	185	55%	102	56.9%	83	53.1%	0.702	0.827	352	53.0%	161	53.8%	191	52.3%	0.827	0.827
Maxillary Molars (Total)	96	42%	35	37.5%	61	45.0%	0.457	0.908	94	49%	50	51.0%	44	46.9%	0.686	0.908	190	45.5%	85	45.1%	105	45.9%	0.908	0.908
Maxillary 1st Molars	58	39%	21	35.0%	37	41.7%	0.503	0.139	38	29%	15	23.5%	23	34.7%	0.219	0.139	96	34.0%	36	28.6%	60	38.5%	0.139	0.139
Maxillary 2nd Molars	38	24%	14	20.0%	24	26.7%	0.444	0.392	56	38%	35	45.1%	21	30.6%	0.136	0.392	94	31.0%	49	34.1%	45	28.4%	0.392	0.392
Mandibular Molars (Total)	64	30%	21	25.0%	43	33.3%	0.373	0.518	71	33%	45	37.3%	26	28.6%	0.356	0.518	135	31.5%	66	31.9%	69	31.2%	0.518	0.518
Mandibular 1st Molars	41	27%	12	20.0%	29	31.7%	0.198	0.496	37	26%	21	27.5%	16	24.5%	0.736	0.496	78	26.5%	33	24.2%	45	28.4%	0.496	0.496
Mandibular 2nd Molars	23	16%	9	17.5%	14	15.0%	0.738	0.059	34	21%	24	29.4%	10	12.2%	0.035	0.059	57	18.5%	33	24.2%	24	13.8%	0.059	0.059
Maxillary Pre-Molars (Total)	2	2%	1	2.5%	1	1.7%	0.771	0.529	6	5%	3	5.9%	3	4.1%	0.680	0.529	8	3.5%	4	4.4%	4	2.8%	0.529	0.529
Maxillary 1st Pre-Molars	0	0%	0	0.0%	0	0.0%	N/A	N/A	0	0%	0	0.0%	0	0.0%	N/A	N/A	0	0.0%	0	0.0%	0	0.0%	N/A	N/A
Maxillary 2nd Pre-Molars	2	2%	1	2.5%	1	1.7%	0.771	0.529	6	5%	3	5.9%	3	4.1%	0.680	0.529	8	3.5%	4	4.4%	4	2.8%	0.529	0.529
Mandibular Pre-Molars (Total)	5	4%	2	5.0%	3	3.3%	0.677	0.383	14	8%	4	3.9%	10	12.2%	0.125	0.383	19	6.0%	6	4.4%	13	7.3%	0.383	0.383
Mandibular 1st Pre-Molars	5	4%	2	5.0%	3	3.3%	0.677	0.529	5	3%	3	3.9%	2	2.0%	0.582	0.529	10	3.5%	5	4.4%	5	2.8%	0.529	0.529
Mandibular 2nd Pre-Molars	0	0%	0	0.0%	0	0.0%	N/A	N/A	9	7%	1	2.0%	8	12.2%	0.044	0.091	9	3.5%	1	1.1%	8	5.5%	0.091	0.091

Table 5

Pulp Stone Distribution and Prevalence in *Patients* and *Teeth* by Caries and Restoration Status

Caries and Restoration Characteristics of Teeth	Patients Aged 20-50 yrs (n=100)			Patients Aged 51-75 yrs (n=100)			Patients Aged 20-75 yrs (n=200)		
	Number of Pulp Stones Identified in Teeth	Pulp Stone Prevalence Patients (% of Patients)	Pulp Stone Prevalence Teeth (Avg % of Teeth/Patient)	Number of Pulp Stones Identified in Teeth	Pulp Stone Prevalence Patients (% of Patients)	Pulp Stone Prevalence Teeth (Avg % of Teeth/Patient)	Number of Pulp Stones Identified in Teeth	Pulp Stone Prevalence Patients (% of Patients)	Pulp Stone Prevalence Teeth (Avg % of Teeth/Patient)
Overall	167	51.0%	11.5%	185	55.0%	13.1%	352	53.0%	12.3%
Non-Carious/Heavily Restored	52	28.0%	12.7%	61	35.0%	13.4%	113	31.5%	13.1%
Non-Carious/Minimally Restored	55	30.0%	18.4%	54	32.0%	22.9%	109	31.0%	20.7%
Non-Carious/Non-Restored	46	22.0%	6.8%	45	18.0%	6.3%	91	20.0%	6.5%
Non-Carious/Facially Restored	1	1.0%	1.0%	0	0.0%	0.0%	1	0.5%	0.5%
Non-Carious/Crowned	1	1.0%	0.5%	15	12.0%	5.4%	16	6.5%	2.9%
Incipient Carious/Heavily Restored	3	3.0%	2.5%	0	0.0%	0.0%	3	1.5%	1.3%
Incipient Carious/Minimally Restored	5	3.0%	2.3%	0	0.0%	0.0%	5	1.5%	1.1%
Incipient Carious/Non-Restored	3	3.0%	2.5%	0	0.0%	0.0%	3	1.5%	1.3%
Dentinal Carious/Heavily Restored	1	1.0%	1.0%	5	4.0%	3.0%	6	2.5%	2.0%
Dentinal Carious/Minimally Restored	0	0.0%	0%	1	1.0%	1.0%	1	0.5%	0.5%
Dentinal Carious/Non-Restored	0	0.0%	0%	2	2.0%	2.0%	2	1.0%	1.0%
Dentinal Carious/Facially Restored	0	0.0%	0%	1	1.0%	1.0%	1	0.5%	0.5%
Dentinal Carious/Crowned	0	0.0%	0%	1	1.0%	0.5%	1	0.5%	0.3%

Table 6

Pulp Stone Prevalence In Patients of Different Age Groups with and without CVD

Caries and Restoration Characteristics of Teeth	Patients Aged 20-50 yrs					Patients Aged 51-75 yrs					Comparing Age Groups with CVD				
	CVD Present (n=50)		CVD Absent (n=50)		Difference between CVD Groups	CVD Present (n=50)		CVD Absent (n=50)		Difference between CVD Groups	20-50 yrs CVD Present (n=50)		51-75 yrs CVD Present (n=50)		Difference between Age Groups
	Number of Patients with Pulp Stones	Pulp Stone Prevalence (% of Patients)	Number of Patients with Pulp Stones	Pulp Stone Prevalence (% Patients)	Chi-Square P-value (<.05)	Number of Patients with Pulp Stones	Pulp Stone Prevalence (% of Patients)	Number of Patients with Pulp Stones	Pulp Stone Prevalence (% Patients)	Chi-Square P-value (<.05)	Number of Patients with Pulp Stones	Pulp Stone Prevalence (% of Patients)	Number of Patients with Pulp Stones	Pulp Stone Prevalence (% Patients)	Chi-Square P-value (<.05)
Overall	29	58%	22	44%	0.161	27	54%	28	56%	0.841	29	58%	27	54%	0.687
Non-Carious, Non-Restored and Minimally Restored Teeth	23	46%	18	36%	0.309	19	38%	20	40%	0.838	23	46%	19	38%	0.418
Non-Carious/Minimally Restored Teeth	17	34%	14	28%	0.517	18	36%	14	28%	0.391	17	34%	18	36%	0.834
Non-Carious/Non-Restored Teeth	12	24%	11	22%	0.812	9	18%	9	18%	1.000	12	24%	9	18%	0.461
Heavily Restored Teeth (Including Facially Restored and Crowned)	18	36%	13	26%	0.280	20	40%	19	38%	0.838	18	36%	20	40%	0.680

Table 7

Pulp Stone Prevalence In Patients of Different Age Groups with and without Hypertension

Caries and Restoration Characteristics of Teeth	Patients Aged 20-50 yrs					Patients Aged 51-75 yrs					Comparing Age Groups with HTN				
	HTN Present (n=21)		CVD Absent (n=50)		Difference between CVD Groups	HTN Present (n=35)		CVD Absent (n=50)		Difference between CVD Groups	20-50 yrs HTN Present (n=21)		51-75 yrs HTN Present (n=35)		Difference between Age Groups
	Number of Patients with Pulp Stones	Pulp Stone Prevalence (% of Patients)	Number of Patients with Pulp Stones	Pulp Stone Prevalence (% Patients)	Chi-Square P-value (< .05)	Number of Patients with Pulp Stones	Pulp Stone Prevalence (% of Patients)	Number of Patients with Pulp Stones	Pulp Stone Prevalence (% Patients)	Chi-Square P-value (< .05)	Number of Patients with Pulp Stones	Pulp Stone Prevalence (% of Patients)	Number of Patients with Pulp Stones	Pulp Stone Prevalence (% Patients)	Chi-Square P-value (< .05)
Overall	13	61.9%	22	44%	0.168	21	60.0%	28	56%	0.713	13	61.9%	21	60.0%	0.888
Non-Carious, Non-Restored and Minimally Restored Teeth	11	52.4%	18	36%	0.200	15	42.9%	20	40%	0.792	11	52.4%	15	42.9%	0.489
Non-Carious/Minimally Restored Teeth	8	38.1%	14	28%	0.401	15	42.9%	14	28%	0.155	8	38.1%	15	42.9%	0.726
Non-Carious/Non-Restored Teeth	4	19.0%	11	22%	0.781	6	17.1%	9	18%	0.919	4	19.0%	6	17.1%	0.857
Heavily Restored Teeth (Including Facially Restored and Crowned)	7	33.3%	13	26%	0.531	15	42.9%	19	38%	0.653	7	33.3%	15	42.9%	0.480

Table 8

Pulp Stone Prevalence In Patients of Different Age Groups with and without Valvular Heart Disease

Caries and Restoration Characteristics of Teeth	Patients Aged 20-50 yrs					Patients Aged 51-75 yrs					Comparing Age Groups with VHD				
	VHD Present (n=16)		CVD Absent (n=50)		Difference between CVD Groups	VHD Present (n=8)		CVD Absent (n=50)		Difference between CVD Groups	20-50 yrs VHD Present (n=16)		51-75 yrs VHD Present (n=8)		Difference between Age Groups
	Number of Patients with Pulp Stones	Pulp Stone Prevalence (% of Patients)	Number of Patients with Pulp Stones	Pulp Stone Prevalence (% Patients)	Chi-Square P-value (< .05)	Number of Patients with Pulp Stones	Pulp Stone Prevalence (% of Patients)	Number of Patients with Pulp Stones	Pulp Stone Prevalence (% Patients)	Chi-Square P-value (< .05)	Number of Patients with Pulp Stones	Pulp Stone Prevalence (% of Patients)	Number of Patients with Pulp Stones	Pulp Stone Prevalence (% Patients)	Chi-Square P-value (< .05)
Overall	9	56.3%	22	44%	0.393	3	37.5%	28	56%	0.330	9	56.3%	3	37.5%	0.386
Non-Carious, Non-Restored and Minimally Restored Teeth	6	37.5%	18	36%	0.914	2	25.0%	20	40%	0.417	6	37.5%	2	25.0%	0.540
Non-Carious/Minimally Restored Teeth	4	25.0%	14	28%	0.815	2	25.0%	14	28%	0.860	4	25.0%	2	25.0%	1.000
Non-Carious/Non-Restored Teeth	5	31.3%	11	22%	0.452	1	12.5%	9	18%	0.702	5	31.3%	1	12.5%	0.317
Heavily Restored Teeth (Including Facially Restored and Crowned)	7	43.8%	13	26%	0.179	2	25.0%	19	38%	0.477	7	43.8%	2	25.0%	0.371

Table 9

Pulp Stone Prevalence In Patients of Different Age Groups with and without Hypercholesterolemia

Caries and Restoration Characteristics of Teeth	Patients Aged 20-50 yrs					Patients Aged 51-75 yrs					Comparing Age Groups with Hchol				
	HChol Present (n=9)		CVD Absent (n=50)		Difference between CVD Groups	HChol Present (n=10)		CVD Absent (n=50)		Difference between CVD Groups	20-50 yrs HChol Present (n=9)		51-75 yrs HChol Present (n=10)		Difference between Age Groups
	Number of Patients with Pulp Stones	Pulp Stone Prevalence (% of Patients)	Number of Patients with Pulp Stones	Pulp Stone Prevalence (% Patients)	Chi-Square P-value (<.05)	Number of Patients with Pulp Stones	Pulp Stone Prevalence (% of Patients)	Number of Patients with Pulp Stones	Pulp Stone Prevalence (% Patients)	Chi-Square P-value (<.05)	Number of Patients with Pulp Stones	Pulp Stone Prevalence (% of Patients)	Number of Patients with Pulp Stones	Pulp Stone Prevalence (% Patients)	Chi-Square P-value (<.05)
Overall	6	66.7%	22	44%	0.210	4	40.0%	28	56%	0.355	6	66.7%	4	40.0%	0.245
Non-Carious, Non-Restored and Minimally Restored Teeth	5	55.6%	18	36%	0.268	1	10.0%	20	40%	0.069	5	55.6%	1	10.0%	0.033
Non-Carious/Minimally Restored Teeth	4	44.4%	14	28%	0.324	1	10.0%	14	28%	0.230	4	44.4%	1	10.0%	0.089
Non-Carious/Non-Restored Teeth	4	44.4%	11	22%	0.155	1	10.0%	9	18%	0.535	4	44.4%	1	10.0%	0.089
Heavily Restored Teeth (Including Facially Restored and Crowned)	4	44.4%	13	26%	0.261	4	40.0%	19	38%	0.905	4	44.4%	4	40.0%	0.845

Table 10

Table 11

Comparison of Pulp Stone Formation in Non-Carious, Non-Restored, or Minimally Restored Teeth in *Patients with and without CVD* having Additional Covariates				
Covariates	**Odds Ratio**	**95% Confidence Interval for Odds Ratio**		**Binary Logistic Regression P -Value (P < .05)**
		Lower	**Upper**	
CVD Present Only	1.250	0.703	2.221	0.448
CVD Present and Age (actual)	1.263	0.709	2.250	0.427
CVD Present and Age Group (20-50 yrs vs 51-75 yrs)	1.256	0.706	2.234	0.438
CVD Present and Gender (Male vs Female)	1.253	0.703	2.234	0.443
CVD Present and Diabetes Present	1.291	0.722	2.311	0.389
CVD Present and Arthritis Present	1.252	0.704	2.225	0.445
CVD Present and Tobacco Use	1.233	0.688	2.210	0.481
CVD Present and Alcohol Use	1.250	0.677	2.306	0.476

Average Number and Percentage of Teeth Per Patient Containing Pulp Stones by Restoration and Caries Status				
Patients Aged 20-75 yrs (n=200)	Average Number of Teeth per Patient (16 Possible Teeth/Patient)	Pulp Stone Prevalence (Average % of Pulp Stones/Patient)	Comparison of Restroration and Caries Status	Poisson P -Value (P < .05)
Restoration Status				
Non-Restored	6.4	6.3%	Non-Restored vs. Minimally Restored	< .001
Minimally Restored	2.5	20.4%	Non-Restored vs. Heavily Restored	< .001
Heavily Restored	5.6	12.2%	Minimally Restored vs. Heavily Restored	< .001
Caries Status				
Non-Carious	13.5	12.6%	Non-Carious vs. Incipient Carious	0.034
Incipient Carious	0.4	2.3%	Non-Carious vs. Dentinal Carious	0.001
Dentinal Carious	0.5	2.4%	Incipient Carious vs. Dentinal Carious	0.878

List of Appendices

Appendix A: Master Key with CVD diagnosis
Appendix B: Master Key without CVD diagnosis
Appendix C: Medical History and Medication data collection form
Appendix D: Radiographic Survey data collection form
Appendix E: Tobacco and Alcohol data collection form
Appendix F: Training and Calibration Protocol for IRB- Health Application
Appendix G: Clinical Operations Procedures Manual
Appendix H: Microsoft Access Procedures Manual
Appendix I: Microsoft Access Codebook
Appendix J: SPSS Data Analysis variable definitions

Appendix A

ASSOCIATION OF PULP STONES AND CARDIOVASCULAR DISEASE

Jeffrey N. Dzingle D.D.S.

MASTER KEY

CONFIDENTIAL

#	Study ID (Study ID:_ _ _)	Dental Chart Number	Date Study ID Allocated	CVD Diagnosis?
1	001			YES NO
2	002			YES NO
3	003			YES NO
4	004			YES NO
5	005			YES NO
6	006			YES NO
7	007			YES NO
8	008			YES NO
9	009			YES NO
10	010			YES NO
11	011			YES NO
12	012			YES NO
13	013			YES NO
14	014			YES NO
15	015			YES NO
16	016			YES NO
17	017			YES NO
18	018			YES NO
19	019			YES NO
20	020			YES NO
21	021			YES NO
22	022			YES NO
23	023			YES NO
24	024			YES NO
25	025			YES NO

COMMENTS: _____

_____

Appendix B

ASSOCIATION OF PULP STONES AND CARDIOVASCULAR DISEASE

Jeffrey N. Dzingle D.D.S.

MASTER KEY

CONFIDENTIAL

#	Medical Review Completed?	Dental Review Completed?	Study ID (Study ID:_ _ _)	Dental Chart Number	Date Study ID Allocated	Refer to comments?
1	YES NO	YES NO	001			YES NO
2	YES NO	YES NO	002			YES NO
3	YES NO	YES NO	003			YES NO
4	YES NO	YES NO	004			YES NO
5	YES NO	YES NO	005			YES NO
6	YES NO	YES NO	006			YES NO
7	YES NO	YES NO	007			YES NO
8	YES NO	YES NO	008			YES NO
9	YES NO	YES NO	009			YES NO
10	YES NO	YES NO	010			YES NO
11	YES NO	YES NO	011			YES NO
12	YES NO	YES NO	012			YES NO
13	YES NO	YES NO	013			YES NO
14	YES NO	YES NO	014			YES NO
15	YES NO	YES NO	015			YES NO
16	YES NO	YES NO	016			YES NO
17	YES NO	YES NO	017			YES NO
18	YES NO	YES NO	018			YES NO
19	YES NO	YES NO	019			YES NO
20	YES NO	YES NO	020			YES NO
21	YES NO	YES NO	021			YES NO
22	YES NO	YES NO	022			YES NO
23	YES NO	YES NO	023			YES NO
24	YES NO	YES NO	024			YES NO
25	YES NO	YES NO	025			YES NO

COMMENTS:

Appendix C

Study ID: __ __ __ **Medical History Review**

Entry 1Date:_____ Enterer1ID:_____ Entry2Date:_____ Enterer2ID:_____

1a. **Gender:** 1. Male 2. Female

1b. **Age: ____ Yrs.**

2b. **Cardiovascular Disease**	**Present**	**Absent**	**Not Known**	**Missing**
2b1. Angina Pectoris	1. Yes	2. No	3. NK	4. M
2b2. Myocardial Infarction	1. Yes	2. No	3. NK	4. M
2b3. Heart Surgery	1. Yes	2. No	3. NK	4. M
2b4. Hypertension	1. Yes	2. No	3. NK	4. M
2b5. Congestive Heart Failure	1. Yes	2. No	3. NK	4. M
2b6. Coronary Artery Disease	1. Yes	2. No	3. NK	4. M
2b7. Cardiomyopathy (heart muscle disease)	1. Yes	2. No	3. NK	4. M
2b8. Valvular Heart Diseases	1. Yes	2. No	3. NK	4. M
2b9. Congenital Heart Disease	1. Yes	2. No	3. NK	4. M
2b10. Atherosclerosis	1. Yes	2. No	3. NK	4. M
2b11. Hypercholesterolemia	1. Yes	2. No	3. NK	4. M
2b12. Arrhythmia	1. Yes	2. No	3. NK	4. M
2b13. Aneurysm	1. Yes	2. No	3. NK	4. M
2b14. Cerebrovascular Accident (stroke)	1. Yes	2. No	3. NK	4. M
2b15. Transient Ischemic Attack (mini stroke)	1. Yes	2. No	3. NK	4. M
2b16. Cerebrovascular Disease	1. Yes	2. No	3. NK	4. M
2b17. Disease of Pulmonary Circulation (pulmonary embolism)	1. Yes	2. No	3. NK	4. M
2b18. Aorta Disease and Marfan Syndrome	1. Yes	2. No	3. NK	4. M
2b19. Rheumatic Heart Disease/ Rheumatic Fever	1. Yes	2. No	3. NK	4. M
2b20. Deep Vein Thrombosis	1. Yes	2. No	3. NK	4. M
3c. **Other Diseases/Conditions**	**Present**	**Absent**	**Not Known**	**Missing**
3c1. Kidney Disease	1. Yes	2. No	3. NK	4. M
3c2. Diabetes Type I	1. Yes	2. No	3. NK	4. M
3c3. Diabetes Type II	1. Yes	2. No	3. NK	4. M
3c4. Gout	1. Yes	2. No	3. NK	4. M
3c5. Metabolic Diseases	1. Yes	2. No	3. NK	4. M
3c6. Connective Tissue Disorders	1. Yes	2. No	3. NK	4. M
3c7. Peripheral Vascular Disease (vasculitis, Kawasaki, Wegener)	1. Yes	2. No	3. NK	4. M
3c8. Arthritis	1. Yes	2. No	3. NK	4. M

Study ID: __ __ __ **Medical History Review**

Entry 1Date:_____ Enterer1ID:_____ Entry2Date:_____ Enterer2ID:_____

Medication Review Table	
Medications	**Currently Taking? Yes/No**
4a1.	4a2. 1. Yes 2. No
4b1.	4b2. 1. Yes 2. No
4c1.	4c2. 1. Yes 2. No
4d1.	4d2. 1. Yes 2. No
4e1.	4e2. 1. Yes 2. No
4f1.	4f2. 1. Yes 2. No
4g1.	4g2. 1. Yes 2. No
4h1.	4h2. 1. Yes 2. No
4i1.	4i2. 1. Yes 2. No
4j1.	4j2. 1. Yes 2. No
4k1.	4k2. 1. Yes 2. No
4l1.	4l2. 1. Yes 2. No
4m1.	4m2. 1. Yes 2. No
4n1.	4n2. 1. Yes 2. No
4o1.	4o2. 1. Yes 2. No
4p1.	4p2. 1. Yes 2. No
4q1.	4q2. 1. Yes 2. No
4r1.	4r2. 1. Yes 2. No
4s1.	4s2. 1. Yes 2. No
4t1.	4t2. 1. Yes 2. No

Appendix D

Study ID: __ __ __ Dental Radiograph Review

Entry1Date: _____ Enterer1ID:_____ Entry2Date: _____ Enterer2ID: _____

1a. **Gender:** 1. Male 2. Female 1b. **Age:** ____		1c. **X-Rays:**	12c1. **PA** 1. Yes 2. No	12c2. **BWX** 1. Yes 2. No	12c3. **PAN** 1. Yes 2. No
2a. **Dentition**	**Tooth #**	**Present**		**Absent**	**Not Known**
2a1. Maxillary Right 2nd Molar	2	1. Yes		2. No	3. NK
2a2. Maxillary Right 1st Molar	3	1. Yes		2. No	3. NK
2a3. Maxillary Right 2nd Pre-Molar	4	1. Yes		2. No	3. NK
2a4. Maxillary Right 1st Pre-Molar	5	1. Yes		2. No	3. NK
2a5. Maxillary Left 1st Pre-Molar	12	1. Yes		2. No	3. NK
2a6. Maxillary Left 2nd Pre-Molar	13	1. Yes		2. No	3. NK
2a7. Maxillary Left 1st Molar	14	1. Yes		2. No	3. NK
2a8. Maxillary Left 2nd Molar	15	1. Yes		2. No	3. NK
2a9. Mandibular Left 2nd Molar	18	1. Yes		2. No	3. NK
2a10. Mandibular Left 1st Molar	19	1. Yes		2. No	3. NK
2a11. Mandibular Left 2nd Pre-Molar	20	1. Yes		2. No	3. NK
2a12. Mandibular Left 1st Pre-Molar	21	1. Yes		2. No	3. NK
2a13. Mandibular Right 1st Pre-Molar	28	1. Yes		2. No	3. NK
2a14. Mandibular Right 2nd Pre-Molar	29	1. Yes		2. No	3. NK
2a15. Mandibular Right 1st Molar	30	1. Yes		2. No	3. NK
2a16. Mandibular Right 2nd Molar	31	1. Yes		2. No	3. NK
3a. **Pulp Stones**	**Tooth #**	**Present**		**Absent**	**Not Known**
3a1. Maxillary Right 2nd Molar	2	1. Yes		2. No	3. NK
3a2. Maxillary Right 1st Molar	3	1. Yes		2. No	3. NK
3a3. Maxillary Right 2nd Pre-Molar	4	1. Yes		2. No	3. NK
3a4. Maxillary Right 1st Pre-Molar	5	1. Yes		2. No	3. NK
3a5. Maxillary Left 1st Pre-Molar	12	1. Yes		2. No	3. NK
3a6. Maxillary Left 2nd Pre-Molar	13	1. Yes		2. No	3. NK
3a7. Maxillary Left 1st Molar	14	1. Yes		2. No	3. NK
3a8. Maxillary Left 2nd Molar	15	1. Yes		2. No	3. NK
3a9. Mandibular Left 2nd Molar	18	1. Yes		2. No	3. NK
3a10. Mandibular Left 1st Molar	19	1. Yes		2. No	3. NK
3a11. Mandibular Left 2nd Pre-Molar	20	1. Yes		2. No	3. NK
3a12. Mandibular Left 1st Pre-Molar	21	1. Yes		2. No	3. NK
3a13. Mandibular Right 1st Pre-Molar	28	1. Yes		2. No	3. NK
3a14. Mandibular Right 2nd Pre-Molar	29	1. Yes		2. No	3. NK
3a15. Mandibular Right 1st Molar	30	1. Yes		2. No	3. NK
3a16. Mandibular Right 2nd Molar	31	1. Yes		2. No	3. NK

Study ID: __ __ __ Dental Radiograph Review

Entry1Date: _____ Enterer1ID:_____ Entry2Date: _____ Enterer2ID: _____

4a. **Pulpal Obliteration/Calcification**	**Tooth #**	**Present**	**Absent**	**Not Known**
4a1. Maxillary Right 2nd Molar	2	1. Yes	2. No	3. NK
4a2. Maxillary Right 1st Molar	3	1. Yes	2. No	3. NK
4a3. Maxillary Right 2nd Pre-Molar	4	1. Yes	2. No	3. NK
4a4. Maxillary Right 1st Pre-Molar	5	1. Yes	2. No	3. NK
4a5. Maxillary Left 1st Pre-Molar	12	1. Yes	2. No	3. NK
4a6. Maxillary Left 2nd Pre-Molar	13	1. Yes	2. No	3. NK
4a7. Maxillary Left 1st Molar	14	1. Yes	2. No	3. NK
4a8. Maxillary Left 2nd Molar	15	1. Yes	2. No	3. NK
4a9. Mandibular Left 2nd Molar	18	1. Yes	2. No	3. NK
4a10. Mandibular Left 1st Molar	19	1. Yes	2. No	3. NK
4a11. Mandibular Left 2nd Pre-Molar	20	1. Yes	2. No	3. NK
4a12. Mandibular Left 1st Pre-Molar	21	1. Yes	2. No	3. NK
4a13. Mandibular Right 1st Pre-Molar	28	1. Yes	2. No	3. NK
4a14. Mandibular Right 2nd Pre-Molar	29	1. Yes	2. No	3. NK
4a15. Mandibular Right 1st Molar	30	1. Yes	2. No	3. NK
4a16. Mandibular Right 2nd Molar	31	1. Yes	2. No	3. NK
5a. **Periapical Disease**	**Tooth #**	**Present**	**Absent**	**Not Known**
5a1. Maxillary Right 2nd Molar	2	1. Yes	2. No	3. NK
5a2. Maxillary Right 1st Molar	3	1. Yes	2. No	3. NK
5a3. Maxillary Right 2nd Pre-Molar	4	1. Yes	2. No	3. NK
5a4. Maxillary Right 1st Pre-Molar	5	1. Yes	2. No	3. NK
5a5. Maxillary Left 1st Pre-Molar	12	1. Yes	2. No	3. NK
5a6. Maxillary Left 2nd Pre-Molar	13	1. Yes	2. No	3. NK
5a7. Maxillary Left 1st Molar	14	1. Yes	2. No	3. NK
5a8. Maxillary Left 2nd Molar	15	1. Yes	2. No	3. NK
5a9. Mandibular Left 2nd Molar	18	1. Yes	2. No	3. NK
5a10. Mandibular Left 1st Molar	19	1. Yes	2. No	3. NK
5a11. Mandibular Left 2nd Pre-Molar	20	1. Yes	2. No	3. NK
5a12. Mandibular Left 1st Pre-Molar	21	1. Yes	2. No	3. NK
5a13. Mandibular Right 1st Pre-Molar	28	1. Yes	2. No	3. NK
5a14. Mandibular Right 2nd Pre-Molar	29	1. Yes	2. No	3. NK
5a15. Mandibular Right 1st Molar	30	1. Yes	2. No	3. NK
5a16. Mandibular Right 2nd Molar	31	1. Yes	2. No	3. NK

Study ID: __ __ __ Dental Radiograph Review

Entry1Date: _____ Enterer1ID:_____ Entry2Date: _____ Enterer2ID: _____

6a. **Caries**	**Tooth #**	**No Caries**	**Incipient Caries**	**Dentinal Caries**	**Not Known**
6a1. Maxillary Right 2nd Molar	2	1. NC	2. IC	3. DC	4. NK
6a2. Maxillary Right 1st Molar	3	1. NC	2. IC	3. DC	4. NK
6a3. Maxillary Right 2nd Pre-Molar	4	1. NC	2. IC	3. DC	4. NK
6a4. Maxillary Right 1st Pre-Molar	5	1. NC	2. IC	3. DC	4. NK
6a5. Maxillary Left 1st Pre-Molar	12	1. NC	2. IC	3. DC	4. NK
6a6. Maxillary Left 2nd Pre-Molar	13	1. NC	2. IC	3. DC	4. NK
6a7. Maxillary Left 1st Molar	14	1. NC	2. IC	3. DC	4. NK
6a8. Maxillary Left 2nd Molar	15	1. NC	2. IC	3. DC	4. NK
6a9. Mandibular Left 2nd Molar	18	1. NC	2. IC	3. DC	4. NK
6a10. Mandibular Left 1st Molar	19	1. NC	2. IC	3. DC	4. NK
6a11. Mandibular Left 2nd Pre-Molar	20	1. NC	2. IC	3. DC	4. NK
6a12. Mandibular Left 1st Pre-Molar	21	1. NC	2. IC	3. DC	4. NK
6a13. Mandibular Right 1st Pre-Molar	28	1. NC	2. IC	3. DC	4. NK
6a14. Mandibular Right 2nd Pre-Molar	29	1. NC	2. IC	3. DC	4. NK
6a15. Mandibular Right 1st Molar	30	1. NC	2. IC	3. DC	4. NK
6a16. Mandibular Right 2nd Molar	31	1. NC	2. IC	3. DC	4. NK
7a. **Root Canal Therapy**	**Tooth #**	**Present**	**Absent**	**Not Known**	
7a1. Maxillary Right 2nd Molar	2	1. Yes	2. No	3. NK	
7a2. Maxillary Right 1st Molar	3	1. Yes	2. No	3. NK	
7a3. Maxillary Right 2nd Pre-Molar	4	1. Yes	2. No	3. NK	
7a4. Maxillary Right 1st Pre-Molar	5	1. Yes	2. No	3. NK	
7a5. Maxillary Left 1st Pre-Molar	12	1. Yes	2. No	3. NK	
7a6. Maxillary Left 2nd Pre-Molar	13	1. Yes	2. No	3. NK	
7a7. Maxillary Left 1st Molar	14	1. Yes	2. No	3. NK	
7a8. Maxillary Left 2nd Molar	15	1. Yes	2. No	3. NK	
7a9. Mandibular Left 2nd Molar	18	1. Yes	2. No	3. NK	
7a10. Mandibular Left 1st Molar	19	1. Yes	2. No	3. NK	
7a11. Mandibular Left 2nd Pre-Molar	20	1. Yes	2. No	3. NK	
7a12. Mandibular Left 1st Pre-Molar	21	1. Yes	2. No	3. NK	
7a13. Mandibular Right 1st Pre-Molar	28	1. Yes	2. No	3. NK	
7a14. Mandibular Right 2nd Pre-Molar	29	1. Yes	2. No	3. NK	
7a15. Mandibular Right 1st Molar	30	1. Yes	2. No	3. NK	
7a16. Mandibular Right 2nd Molar	31	1. Yes	2. No	3. NK	

Study ID: __ __ __ Dental Radiograph Review

Entry1Date: _____ Enterer1ID:_____ Entry2Date: _____ Enterer2ID: _____

8a. **Restorations**	**Tooth #**	**No Restoration**	**Minimal**	**Heavy**	**Facial**	**Crown**	**Not Known**
8a1. Maxillary Right 2nd Molar	2	1. NR	2. M	3. H	4. F	5. C	6. NK
8a2. Maxillary Right 1st Molar	3	1. NR	2. M	3. H	4. F	5. C	6. NK
8a3. Maxillary Right 2nd Pre-Molar	4	1. NR	2. M	3. H	4. F	5. C	6. NK
8a4. Maxillary Right 1st Pre-Molar	5	1. NR	2. M	3. H	4. F	5. C	6. NK
8a5. Maxillary Left 1st Pre-Molar	12	1. NR	2. M	3. H	4. F	5. C	6. NK
8a6. Maxillary Left 2nd Pre-Molar	13	1. NR	2. M	3. H	4. F	5. C	6. NK
8a7. Maxillary Left 1st Molar	14	1. NR	2. M	3. H	4. F	5. C	6. NK
8a8. Maxillary Left 2nd Molar	15	1. NR	2. M	3. H	4. F	5. C	6. NK
8a9. Mandibular Left 2nd Molar	18	1. NR	2. M	3. H	4. F	5. C	6. NK
8a10. Mandibular Left 1st Molar	19	1. NR	2. M	3. H	4. F	5. C	6. NK
8a11. Mandibular Left 2nd Pre-Molar	20	1. NR	2. M	3. H	4. F	5. C	6. NK
8a12. Mandibular Left 1st Pre-Molar	21	1. NR	2. M	3. H	4. F	5. C	6. NK
8a13. Mandibular Right 1st Pre-Molar	28	1. NR	2. M	3. H	4. F	5. C	6. NK
8a14. Mandibular Right 2nd Pre-Molar	29	1. NR	2. M	3. H	4. F	5. C	6. NK
8a15. Mandibular Right 1st Molar	30	1. NR	2. M	3. H	4. F	5. C	6. NK
8a16. Mandibular Right 2nd Molar	31	1. NR	2. M	3. H	4. F	5. C	6. NK
9a. **Periodontal Disease**	**Tooth #**	**None**	**Type II**	**Type III**	**Type IV**	**Not Known**	
9a1. Maxillary Right 2nd Molar	2	1. None	2. II	3. III	4. IV	5. NK	
9a2. Maxillary Right 1st Molar	3	1. None	2. II	3. III	4. IV	5. NK	
9a3. Maxillary Right 2nd Pre-Molar	4	1. None	2. II	3. III	4. IV	5. NK	
9a4. Maxillary Right 1st Pre-Molar	5	1. None	2. II	3. III	4. IV	5. NK	
9a5. Maxillary Left 1st Pre-Molar	12	1. None	2. II	3. III	4. IV	5. NK	
9a6. Maxillary Left 2nd Pre-Molar	13	1. None	2. II	3. III	4. IV	5. NK	
9a7. Maxillary Left 1st Molar	14	1. None	2. II	3. III	4. IV	5. NK	
9a8. Maxillary Left 2nd Molar	15	1. None	2. II	3. III	4. IV	5. NK	
9a9. Mandibular Left 2nd Molar	18	1. None	2. II	3. III	4. IV	5. NK	
9a10. Mandibular Left 1st Molar	19	1. None	2. II	3. III	4. IV	5. NK	
9a11. Mandibular Left 2nd Pre-Molar	20	1. None	2. II	3. III	4. IV	5. NK	
9a12. Mandibular Left 1st Pre-Molar	21	1. None	2. II	3. III	4. IV	5. NK	
9a13. Mandibular Right 1st Pre-Molar	28	1. None	2. II	3. III	4. IV	5. NK	
9a14. Mandibular Right 2nd Pre-Molar	29	1. None	2. II	3. III	4. IV	5. NK	
9a15. Mandibular Right 1st Molar	30	1. None	2. II	3. III	4. IV	5. NK	
9a16. Mandibular Right 2nd Molar	31	1. None	2. II	3. III	4. IV	5. NK	

Study ID: __ __ __ Dental Radiograph Review

Entry1Date:_____ Enterer1ID:_____ Entry2Date: _____ Enterer2ID: _____

10a. **Attrition (Flattened Occlusal Plane)**	**Tooth #**	**Normal**	**Flattened Occlusal Plane**	**Not Known**
10a1. Maxillary Right 2nd Molar	2	1. N	2. FOP	3. NK
10a2. Maxillary Right 1st Molar	3	1. N	2. FOP	3. NK
10a3. Maxillary Right 2nd Pre-Molar	4	1. N	2. FOP	3. NK
10a4. Maxillary Right 1st Pre-Molar	5	1. N	2. FOP	3. NK
10a5. Maxillary Left 1st Pre-Molar	12	1. N	2. FOP	3. NK
10a6. Maxillary Left 2nd Pre-Molar	13	1. N	2. FOP	3. NK
10a7. Maxillary Left 1st Molar	14	1. N	2. FOP	3. NK
10a8. Maxillary Left 2nd Molar	15	1. N	2. FOP	3. NK
10a9. Mandibular Left 2nd Molar	18	1. N	2. FOP	3. NK
10a10. Mandibular Left 1st Molar	19	1. N	2. FOP	3. NK
10a11. Mandibular Left 2nd Pre-Molar	20	1. N	2. FOP	3. NK
10a12. Mandibular Left 1st Pre-Molar	21	1. N	2. FOP	3. NK
10a13. Mand. Right 1st Pre-Molar	28	1. N	2. FOP	3. NK
10a14. Mand. Right 2nd Pre-Molar	29	1. N	2. FOP	3. NK
10a15. Mandibular Right 1st Molar	30	1. N	2. FOP	3. NK
10a16. Mandibular Right 2nd Molar	31	1. N	2. FOP	3. NK

Appendix E

Patient ID	Dental Chart Number	Tobacco Use Ever: 1 = Yes, 0 = No	Tobacco Use Current: 1 = Yes, 0 = No	Alcohol Use: 1 = Yes, 0 = No	Number of Alcohol Drinks/Week
1					
2					
7					
8					
10					
14					
16					
19					
21					
23					
25					
27					
28					
29					
31					
33					
34					
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86					

Appendix F

TRAINING AND CALIBRATION PROTOCOL FOR IRB-HEALTH APPLICATION

Introduction

The purpose of the training and calibration sessions will be to prepare a team of clinical examiners for making consistent and repeatable assessments of radiographic pulp stone formation, radiographic periodontal disease status, and radiographic dental caries detection. Another component of this exercise will be the orientation and familarization of the clinicians to data entry on data collection forms. This exercise is crucial in aiding to minimize measurement error and its' attending bias in radiographic interpretation. This team of clinical examiners will participate in studies investigating the association between pulp stone formation and cardiovascular disease. The specific aims of this exercise are to:

1. Train all clinical examiners participating in studies of association between pulp stone formation and CVD in the retrospective cross-sectional radiographic assessment of pulp stone formation and medical chart review identifying CVD.

2. Determine the level of inter-examiner reproducibility between the examiners to be calibrated with respect to assessments of radiographic pulp stone formation, radiographic periodontal disease status, and radiographic dental caries detection.

3. Orient the clinicians to proper documentation in data collection forms.

Subjects

Dr. Dzingle will select the first 100 consecutive patients who have non-carious, non-restored, or minimally restored teeth aged 20-75 years with cardiovascular disease dividing them equally between 20-50 years and 51-75 years age groups from central records. Dr. Dzingle will also select the first 100 consecutive patients that have non-carious, non-restored, or minimally restored minimally restored teeth aged 20-75 years without cardiovascular disease dividing them equally between 20-50 years and 51-75 years age groups from central records.

Inclusion criteria for selecting patient records for chart review and data abstraction will be records of dentate individuals 20-75 years of age who accessed the School of Dentistry since 2006. Patients must have at least one molar tooth that is fully erupted, non-carious, non-restored, or minimally restored. Two groups of individuals will be evaluated: 100 patients with cardiovascular disease and 100 patients without cardiovascular disease.

The exclusion criteria are as follows: (a) edentulous patients; (b) posterior teeth with large and/or deep restorations and/or caries; (c) patients below the age of 20 years or over the age of 75 yrs; (d) no dental

bitewing or periapical radiographs of posterior teeth (e) radiographically observable periodontal disease; (f) retained deciduous teeth; (g) un-erupted teeth; (h) incomplete medical history form

This retrospective cross-sectional study is a chart review only and has been waived for informed consent.

Training and Practice Session

The first session will be a discussion of the project protocol, procedures, including measurements, and other aspects of the study to achieve a common understanding of concepts and examination criteria. This session will include a lecture and discussion of the measurements to be calibrated and assessment of radiographs. Following this discussion session, Dr. Dzingle will demonstrate the clinical application of the various measurements and radiographic descriptors. After the clinical demonstration, examiners will perform the radiographic measurements for periodontal status, dental caries and pulp stone formation from a few selected charts. Each examiner will review and describe the patient's periapical and bitewing radiographs for teeth with pulp stone formation, caries, restorations and periodontal disease. This will be an opportunity for the standard examiner to review the general principles of the measurements and radiographic description with each of the examiners to be calibrated.

Calibration Session

Following the training and practice component, the examiners will be calibrated to Dr. Dzingle to assess inter-examiner agreement with the standard examiner(s) for measurements of pulp stone formation, periodontal and caries status.

In general the method of calibration will be as follows: Assessing inter-examiner agreement between 2 examiners will employ the following procedure. The standard examiner will perform a radiographic examination of one of the randomly chosen dental charts. The standard examiner will assess the patient's bitewing and periapical radiographs for the described criteria. Following this, examiner #1 will perform the same radiographic assessment of the patient's periapical and bitewing radiographs then examiner #2 will follow and perform the same radiographic assessment. The standard examiner, upon completion of his radiographic assessment of the first patient chart will begin radiographic assessment of a second randomly chosen patient chart. The procedure as described for the first patient chart is repeated for the second chart and all remaining patient charts until all examiners have performed the specified measurements on at least 2 patient charts.

Specific examination and Radiographic Assessment

Periodontal Status: Examiners will perform measurements for horizontal bone loss with a millimeter ruler measuring from the CEJ to the crest of the boney ridge. Classifications of periodontal status will be dictated by the ADA Classifications:

- **Type II (Early Periodontitis) -** Alveolar bone level is 3 to 4 mm from the CEJ area
- **Type III (Moderate Periodontitis) -** Alveolar bone level is 4 to 6 mm from the CEJ area
- **Type IV (Advanced Periodontitis) -** Alveolar bone level is 6 mm or more from the CEJ area

Dental Caries Status: Caries status will be assessed for non-restored and restored coronal surfaces using bitewing and periapical radiographs. Teeth that are non-carious or minimally restored will be defined as teeth with restorations in enamel or superficial dentin (1/3 or less of dentin thickness) or teeth having no decay or incipient caries (caries within enamel only).

Pulp Stone Identification: Identification of pulp stones in this study will consists of examining bitewing and periapical radiographs for radiopaque objects in either the pulp chamber or pulp canal. The definition of a pulp stone will be any distinct radiopaque object, free or attached, identifiable in the pulp chamber or pulp canal in any maxillary or mandibular molar or pre-molar.

Statistical analyses

Examiners will be compared to Dr. Dzingle on a site basis for radiographic assessment of periodontal status, caries status, and pulp stone formation status. The Kappa statistic will be used to assess the inter-examiner agreement.

Appendix G

Association of Pulp Stones with Cardiovascular Disease

CLINICAL OPERATIONS PROCEDURES MANUAL

Retrospective Cross-Sectional Study
University of Michigan School of Dentistry
Jeffrey N. Dzingle D.D.S.: Principal Investigator
IRB HUM00036278
2009-2011

PSCVD CLINICAL OPERATIONS PROCEDURES MANUAL: TABLE OF CONTENTS

1.1 INTRODUCTION

The purpose of this study is to investigate whether there are differences in the prevalence of pulpal calcifications, specifically pulp stones, in individuals who do and do not have cardiovascular disease in a dental school patient population. This study will consist of dental chart and medical history reviews observing for the presence or absence of cardiovascular disease in individuals through their medical histories and then reviewing the patient's dental periapical and bitewing radiographs for the presence of pulpal calcifications.

This study is unique because it could provide valuable information for screening patients for cardiovascular disease, especially in younger populations (20-50 years) because early intervention could be optimal for preventing progression of this disease. According to the American Heart Association, over 83 percent of people who die of coronary heart disease are 65 or older. Also, according to the American Heart Association, the lifetime risk of developing CHD after age 40 is 49% for men and 32% for women. The incidence of CHD in women lags behind men by 10 years for total CHD. This study will test the feasibility of screening patients in the future for possible undiagnosed cardiovascular disease by observing for the presence of pulp stones.

1.2 OBJECTIVES AND STUDY DESIGN

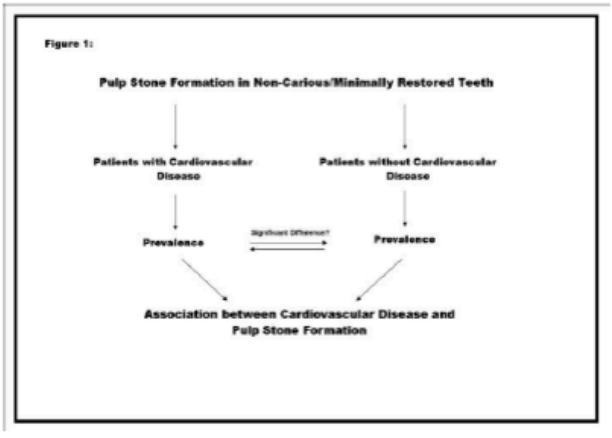
The Specific Aims of this project are:

(1) To determine if there is an association between the prevalence of CVD and the presence of pulp stones in people ages 20-75 years with teeth that are non-carious or minimally restored having restorations only in enamel or superficial dentin.

(2) To determine if there is an association between the prevalence of CVD and the presence of pulp stones in people ages 20-50 years with teeth that are non-carious or minimally restored having restorations only in enamel or superficial dentin. This separate aim is specified within the age range of 20-75 years because the American heart association states the threshold for increased risk for coronary heart disease in men occurs at age 40 while in women this threshold occurs at age 50. Analyzing this age range to investigate if an association exists would be valuable because CVD onset could be diagnosed early and preventive measures taken in this younger population. After the age of 50 years, the increased prevalence of CVD is expected so preventive measures may not have as much of an impact on the outcome of the patient's disease process or treatment.

Significance:

The formation of pulp stones still very much remains a question. There are many suggestions on the etiology, formation, types and prevalence of pulp stones making them a very dynamic phenomenon to be studied. From the current body of literature, diffuse pulpal calcifications may be a natural process of aging, whereas pulp stone formation is still under debate. The formation of pulp stones may be associated with certain disease processes such as cardiovascular disease. Identifying an association between cardiovascular disease and pulp stone formation may be of valuable use in screening patients for CVD during routine dental radiographic evaluation, especially in younger populations, because early intervention may reduce the chance of progression of the disease process. This proposed study could contribute to the body of evidence that supports the association between cardiovascular disease and pulp stone formation and could influence clinical policy regarding screening patients with pulp stones as a risk factor for CVD. Figure 1 provides a schematic model of the focus of this research.



Hypothesis:

The formation of pulp stones is more prevalent in patients with cardiovascular disease than patients without cardiovascular disease, suggesting that the same disease process and factors causing atherosclerosis in large blood vessels accelerate the calcifications in pulpal tissues.

Study Design:

The general approach for this project will be through a "cross-sectional looking at two different groups: patients with CVD and patients without CVD. The approach to this project will identify these two groups and conduct dental records reviews to find differences in prevalence of pulp stones that may be associated with CVD. The data for patients will be gathered through two methods: (1) a chart review of the medical history section in the patients' dental chart looking for self-reported or medically documented history of CVD and identification of medications taken for cardiovascular-related diseases and (2) reviewing patient's dental radiographs (periapical and bitewing radiographs) for pulp stones formation in minimally restored and non-carious teeth. The controls for this study will be patients without self-reported or medically documented history of CVD. Their radiographs will also be evaluated for pulp stone formation in non-carious, non-restored, or minimally restored teeth. Once the data are collected from each group, they will be analyzed to determine if an association between pulp stone formation and CVD exists. The age groups for this study will include individual's ages 20-75 years. We will also conduct separate analysis of individuals between the ages of 20-50 because men and women acquire an increased risk for CVD at 40 and 50 years respectively. Younger populations age 20-40 are also included because although age as a risk factor typically occurs between 40-50 years CVD may also develop at younger ages as well, especially in individuals who have a family history of CVD. Analyzing this age range would be valuable because CVD onset could be diagnosed early and preventive measures taken in this younger population. After the age of 50 years, the increased prevalence of CVD is expected so preventive measures may not have as much of an impact on the outcome of the patient's disease process or treatment.

A power analysis was performed based off two studies looking at the correlation between cardiovascular disease and pulp stone formation, Edds (2005) and Moura (1987). Using these two studies, a power analysis was performed with a significance level of 0.050 and a power of 80% which resulted in a sample size of 200 patients for this project. Two groups of individuals will be evaluated: 100 patients with cardiovascular disease and 100 patients without cardiovascular disease.

1.3 STUDY SCHEDULE

The project is designed to take 24 months for completion. The following is a general time table for project activities:

Project Month 1 to 12: Preparatory period involving protocol and manual development, examiner training and calibration, power analysis, data entry program development and testing, development of electronic record systems for project management, development of data management system, data collection forms, equipment and supply purchasing.

Project Month 13 to 17: Patient medical chart review and dental radiographic examination. We estimate that this portion of the project will require approximately 4 months to complete for the 300 chart reviews.

Project Month 18 to 24: Chart review closeout, data management (data cleaning, preparatory programming for analysis, analysis file creation), data analysis, report and manuscript preparation.

2. ORGANIZATION

2.1 Investigators

Taylor, George W., DMD, DrPH, Principal Investigator, Associate Professor, Cariology, Restorative Sciences and Endodontics

Dzingle, Jeffrey N., D.D.S., Co-Investigator, Endodontic Resident, Cariology, Restorative Sciences and Endodontics

2.2. Coordinators

2.2.1 Project Manager And Coordinator:

Taylor, George W., DMD, DrPH

2.2.2 Data Coordinator:

2.3. Data Safety And Monitoring Board

Taylor, George W., DMD, DrPH

Committee Chair: Dr. George W. Taylor, Associate Professor, Cariology, Restorative Sciences and Endodontics

1. **Chart Review Methodology:** Dr. Jeffrey N. Dzingle, Endodontic Resident, Cariology, Restorative Sciences and Endodontics
2. **Librarian:** Mark MacEachern, Liaison Services Librarian, Health Sciences Library, University Library
3. **Biostatistics:** Thomas Braun, Associate Professor in the Department of Biostatistics.
4. **Ethics:** Graham Rex Holland, Professor, Cariology, Restorative Sciences and Endodontics

3. Policy Matters

3.1. Informed Consent

This retrospective cross-sectional study is a chart review only and has been waived for informed consent.

3.2. Blinding and Breaking the Code

Dr. Taylor and Dr. Dzingle will select the first 100 consecutive patients who have at least one non-carious, non-restored, or minimally restored molar tooth aged 20-75 years with cardiovascular disease and the first 100 consecutive patients that have at least one non-carious, non-restored, or minimally restored and non-carious molar tooth aged 20-75 years without cardiovascular disease from central records. Medical and radiographic evaluation will be blinded by using two different examiners, Dr. Dzingle and Erik DeYoung (fourth year dental student), one for medical and dental history review and one for dental radiographic evaluation for every chart.

In maintaining patient anonymity, data collection forms will be kept in a secure, locked file cabinet at the School of Dentistry. No patients will be interviewed or examined during this study so risk to them is minimal. All data collection forms will be coded so no patient information will be identifiable. Subjects will be identified by a study ID number, protecting their identity. There will be no data linked to subjects' identity by name or other identifier or code in the data collected. A separate file linking the subjects' identity by anonymous study identification number will be created and used to facilitate data collection and verification for accuracy. This file will be password protected and used on a password protected computer. This linking file will be destroyed after all of the data are verified as accurate and complete. As described previously, computers and study-related files will be password protected and accessible only to the study team.

At the end of the project, which will take approximately 1 year, or upon verification of the accuracy of all data collected, master paper logs containing the patient's chart number and study ID number will be shredded and electronic files deleted to destroy any possible linkage of patient information the research data set.

The necessity for collecting data linked to subjects' identities is due to the need to select individuals for whom the retrospective data will be collected, namely: medical and dental treatment charts. The data from these different sources will need to be verified and linked to create an analysis database. For quality assessment of the data captured and data cleaning, it will be necessary to retain the subjects' identifiers to allow for return to the original data sources to correct errors or resolve questions related to data capture.

Data collection forms will be designed by Dr. Taylor and Dr. Dzingle at University of Michigan School of Dentistry. Anonymous study identification numbers will be created for all participants' to designate data captured on paper forms from the dental charts and radiographs. Patient data will consist of limited data sets in all electronic files created for this study for data analysis.

3.3. Project Termination

The identifiers will be retained until it is confirmed that the data are accurate, i.e. the verification checks in our double data entry program reveal no errors and the univariate analysis confirm that all values for datapoints are valid or explained. It is anticipated that the identifiers will be retained until no later than May 31, 2011.

3.4. Participant Identification

Patient identification codes will have an assigned numeric portion consisting of 4-digits: the first digit identifying which group (CVD or non-CVD) the participant belongs to and the next three digits would identify what number they are in the group.

All data entry will be completed in records or on forms that contain subject identification codes only, and not any other information that could allow data managers and analysts to identify patients. This identification code will protect participant's identity from anyone outside the study and provide blinding for data analysis, but would allow examiner's to identify patients with CVD and pulp stones.

4. PATIENT RECRUITMENT

4.1. Patient Recruitment Sources

The University of Michigan School of Dentistry has been providing dental care to patients since 1875 and treats thousands of patients yearly. The dental school provides complete dental care to all different medically compromised, social-economic, racial, and age groups. The dental school currently has around 60,000 active patient records held in "Central Records" in the basement of the school in which approximately 22,000 of these records contain patients between the ages of 20-50 years and approximately 39,000 between the ages of 20-75. The School of Dentistry has four undergraduate clinics and eight graduate programs which all communicate through a computer referral system. Dental records contain the patient's medical and dental histories, radiographs, treatment plans, treatment history, periodontal charts, consents and referrals. Dental charts are audited yearly by the student dentists to ensure proper maintenance, updating, and documentation of treatment plans, radiographs and medical histories. The students are required to fill out charts audits forms for each of their patients and submit them to their clinic coordinator who reviews them. Bitewing radiographs are usually taken yearly at recall visits for caries detection and full –mouth series containing periapical radiographs are taken approximately every 5 years. Assessment of frequency of radiographic exposure is also part of the chart audit process and is documented on the forms.

Dr. Taylor and Dr. Dzingle will select the first 100 consecutive patients who have at least one non-carious, non-restored, or minimally restored molar tooth aged 20-75 years with cardiovascular disease and the first 100 consecutive patients that have at least one non-carious, non-restored, or minimally restored molar tooth aged 20-75 years without cardiovascular disease.

4.2. Mechanism of Recruitment

Dr. Taylor and Dr. Dzingle will select the first 100 consecutive patients who have at least one non-carious, non-restored, or minimally restored molar tooth aged 20-75 years with cardiovascular disease and the first 100 consecutive patients that have at least one non-carious, non-restored, or minimally restored molar tooth aged 20-75 years without cardiovascular disease from central records at the School of Dentistry.

5. PATIENT EVALUATION, ASSIGNMENT, TREATMENT, FOLLOW-UP AND ADVERSE EVENTS

Eligibility and Exclusion Criteria

Inclusion criteria for selecting patient records for chart review and data abstraction will be records of dentate individuals 20-75 years of age who accessed the School of Dentistry since 2006. Patients must have at least one tooth that is fully erupted, minimally restored, non-carious molar, free from radiographically observable periodontal disease. Two groups of individuals will be evaluated: 100 patients with cardiovascular disease and 100 patients without cardiovascular disease.

Diagnosis of cardiovascular disease will be based upon review of the medical history questionnaire and student notes entered about patient's medical history and medications used to treat cardiovascular diseases by Tom Guinall and Erik De Young. Atherosclerotic cardiovascular disease will be limited to the choices present on the medical history questionnaire, unless otherwise specified, and will be defined as: hypertension, myocardial infarction, atherosclerosis, coronary artery disease, angina or chest pain, heart surgery, congestive heart failure, valvular heart disease, arrhythmia, cardiomyopathy, rheumatic heart disease, heart murmur, mitral valve prolapsed, hypercholesterolemia, cerebrovascular disease, and transient ischemic attack.

Diagnosis of pulp stone formation will be based on visual inspection of dental radiographs (periapical, bitewing radiographs) by Dr. Jeffrey Dzingle, Dr. Lauren Johnson, and Erik DeYoung. Pulp stones will be identified as any distinct radiopaque object identifiable in the pulp chamber or pulp canal in any maxillary or mandibular molar or pre-molar. Calibration for radiographic assessment of pulp stones will be performed by looking at radiographs with documented pulp stones and discussing the radiographic characteristics of pulp stones.

In the data collection tables for radiographic assessment of pulp stones, inclusion criteria for our study will include teeth that must be non-carious, non-restored or minimally restored molar and pre-molar teeth. The definition of minimally restored teeth are teeth with restorations in enamel or superficial dentin (1/3 or less dentin thickness). The definition of non-carious teeth is teeth having no caries or incipient caries (caries in enamel only). Teeth that have caries or restorations containing pulp stones will also be included but in a separate category identifying the extent of caries or restorations. This information will be used in assessing the overall prevalence of pulp stones in our two study groups.

The exclusion criteria are as follows: (a) edentulous patients; (b) posterior teeth with large and/or deep restorations and/or caries; (c) patients below the age of 20 years or over the age of 75 yrs; (d) no dental bitewing or periapical radiographs of posterior teeth (e) un-erupted teeth; (f) incomplete medical history form

6.0 Chart Review
6.1 Radiographic Survey

Diagnosis of pulp stone formation will be based on visual inspection of dental radiographs (periapical, bitewing radiographs) by Dr. Jeffrey Dzingle, Dr. Lauren Johnson, and Erik DeYoung. Pulp stones will be identified as any distinct radiopaque object identifiable in the pulp chamber or pulp canal in any maxillary or mandibular molar or pre-molar. Calibration for radiographic assessment of pulp stones will be performed by looking at radiographs with documented pulp stones and discussing the radiographic characteristics of pulp stones. There are several different types of pulp stones as follows:

True – Made of dentin and lined by odontoblasts
False – Formed from degenerating cells which mineralize
Free – Stone not related to the pulp space wall, surrounded by soft tissue
Embedded – Stone enclosed within canal wall
Adherent – Less attached to dentin then embedded pulp stones
Round or ovoid - smooth surfaces and concentric laminations

Since we are not looking at these specimens histologically and only radiographically we will **not** be able to determine whether the pulp stone is true or false or whether they are free, embedded, adherent, round or ovoid so all these will be classified with one description as "pulp stone".

In the data collection tables for radiographic assessment of pulp stones, inclusion criteria for our study will include teeth that must be non-carious, non-restored, or minimally restored teeth. The definition of minimally restored teeth are teeth with restorations in enamel or superficial dentin (1/3 or less dentin thickness). The definition of non-carious teeth is teeth having no caries or incipient caries (caries in enamel only). Teeth that have caries or restorations containing pulp stones will also be included but in a separate category identifying the extent of caries or restorations. This information will be used in assessing the overall prevalence of pulp stones in our two study groups.

To determine the level of periodontal status for each patient the American Dental Association Classifications of periodontal disease will be used. It provides the clinician with clinical and radiographic descriptors of the four Case Types:

Case Type I: Gingivitis
Case Type II: Early Periodontitis
Case Type III: Moderate Periodontitis
Case Type IV: Advanced Periodontitis

Since we will only be evaluating radiographs and not the patients we will use the radiographic criteria provided by these classifications.

Case Type II: Early Periodontitis

- Horizontal type of bone loss is most common
- Slight loss of the interdental septum
- Alveolar bone level is 3 to 4 mm from the CEJ area

Case Type III: Moderate Periodontitis

- Horizontal or Vertical bone loss may be present
- Alveolar bone level is 4 to 6 mm from the CEJ area
- Radiographic furcations of Grade I and/or Grade II
- Crown to root ratio is 1:1 (loss of 1/3 of supporting alveolar bone)

Case Type IV: Advanced Periodontitis

- Horizontal and vertical bone loss
- Alveolar bone level is 6 mm or more from the CEJ area
- Radiographic furcations
- Crown to root ratio is 2:1 or more (loss of over 1/3 of the supporting alveolar bone)

6.2 Medical History Survey

Diagnosis of cardiovascular disease will be based upon review of the medical history questionnaire and student notes entered about patient's medical history and medications used to treat cardiovascular diseases by Tom Guinall and Erik De Young. Atherosclerotic cardiovascular disease will be limited to the choices present on the medical history questionnaire, unless otherwise specified, and will be defined as: hypertension, myocardial infarction, atherosclerosis, coronary artery disease, angina or chest pain, heart surgery, congestive heart failure, valvular heart disease, arrhythmia, cardiomyopathy, rheumatic heart disease, heart murmur, mitral valve prolapsed, hypercholesterolemia, cerebrovascular disease, and transient ischemic attack.

According to the American Heart Association the following are considered types of CVD:

- Coronary heart disease
  - -Myocardial infarction (Heart attack)
  - -Angina pectoris or chest pain
  - -Atherosclerosis
  - -Coronary Artery Disease
- Cerebrovascular Accident (Stroke)
- Transient Ischemic Attack (Mini stroke)
- Hypertension (High blood pressure)
- Heart failure

Other forms include:

- Rheumatic fever/rheumatic heart disease
- Congenital cardiovascular defects
- Arrhythmias (disorders of heart rhythm)
- Diseases of the arteries, arterioles and capillarie
  - -Atherosclerosis
  - -Kawasaki disease
- Bacterial endocarditis
- Cardiomyopathy
- Valvular heart disease
- Diseases of pulmonary circulation
- Diseases of veins and lymphatics
- Other diseases of the circulatory system.
- *Hypercholesterolemia (CVD risk factor)

7. DATA COLLECT FORMS AND SUPPLIES

Forms:
Medical History Form
Radiographic Survey Form

Supplies/Equipment/Facilities:
-Light box for radiograph examination
-Data collection forms for medical histories and dental radiographs
-Dental informatics -Software for data entry program design (Microsoft Access)
-SPSS Data Analysis for statistical analysis of data

*See appendix C for Medical History Form
*See appendix D for Radiographic Survey Form

8. DATA MANAGEMENT PROCEDURES

Patient data will consist of limited data sets in all electronic files created for this study for data analysis. Dr. Taylor's team will create a Microsoft Access database for data entry. The database will contain: 1) All screens for double data entry with built-in filters and checks of valid values, 2) The underlying tables with the individual data entered for both double data entry with entries, 3) Comparison programs that will compare and identify discrepancies between the two entries of the same data, 4) Programs for entering and posting of data entry correction, 5) Cleaning rules and an option to print such rules, 6) Functions to print all structures for all the tables.

Each data collection form will have one or more analogous data entry screens database, designed to closely resemble the hard copy form in order to assure accuracy of data entry. An underlying table will be created for each data collection form, and the data are stored in those tables, all within the database application.

Initially, the data entry screens will be proofread and tested by entering made-up data for functionality and cursor advancement. It will also be verified that each data point entered in the data entry screen in correctly linked to the correct corresponding field in the underlying table. Subsequently, they will be tested by entering real data from copies of data collection forms. The key with the linkage between the subject identifier and the identity of the subject will be kept by Dr. Dzingle under lock at all times when not in use.

Data quality control provisions will be implemented from data entry through data analysis procedures. The data entry programs will be designed to reject illogical or out-of-range values, accommodate inherent skip patterns, and have features to provide pre-recorded entries for fixed-value fields to reduce the likelihood of errors in data entry. A program will be designed to compare the two tables with data entered two different times and discrepancies will be listed in an output file that will be used for data entry error correction. This file will show the field (variable) name and the two values entered during the first and second round of data entry. These error correction tables are separate from the raw data entered in the actual electronic forms. Corrections can be done in the error correction table and then electronically inserted to their respective items in the data table after the corrections have been verified according to the original data collection forms by Dr. Dzingle. Additionally, we will conduct data verification, additional logic checks and cleaning procedures to assure data quality prior to data analysis. We will perform regular, periodic inspection of frequency distributions, value ranges, and cross-tabulations of selected variables and review the reports with Dr. Dzingle and Dr. Taylor during the course of the project to verify accuracy of data entry and provide early opportunities for clarification of questions and correction of errors and omissions.

The database will be sent via electronic mail as password-protected file from Dr. Dzingle to Dr. Taylor. Data will be via Excel spreadsheets to transform into SAS data files for analysis. The database with all the data, any saved Excel spreadsheets, and the SAS datasets and program and output files will reside on password-protected computers in Dr. Taylor's secure dry laboratory space and on Dr. Dzingle's password-protected computer. The files will be backed up in dated and password-protected folders/directories to a dedicated space on the School of Dentistry's secure server.

Only authorized project personnel will have access to project data. Laptop and desktop computers used for the project will be password protected. Files containing data collected for the project will be backed up as password protected files at the School of Dentistry.

All personnel involved with the data management and statistical analysis team will sign a pledge of confidentiality form, assuring that they will not transfer any information gained from the study to individuals not connected to the study. All data collection forms will carry a study identification number only, no other identifiers will be known to Dr. Taylor or the data management and analysis team. The copies of data collection forms will be kept under lock at all times when not in use. In case of electronic transfer via the Internet, the password will be revealed separately from the message accompanying the files. In case of surface-mail of CD-ROMS or other storage media, the password will not be mailed together with the media. The passwords are to be revealed by telephone or electronic mail without any detailed description of the file name, just referring to "the password you need".

A manual will be developed with instructions in how to utilize the comprehensive database, from opening the application and identifying the data entry screen that corresponds to any given data collection form, to how to enter data twice and compare the entries and correct any entry errors. Also, instruction will be provided regarding how to back up and password-protect the database. All necessary hands-on training and demonstration for use of the database will be provided to Dr. Dzingle as needed by Dr. Taylor and his team. Documentation will be developed in the form of a data dictionary and code book for all variables.

Appendix H

Procedures Manual

Data is collected using an application written in Microsoft Access. Therefore, all usual conventions utilized by Access are appropriate.

I. STARTING THE DATA ENTRY APPLICATION

A. Open the application in Access in one of the following ways:

1. Open Access from the Start menu.

1) Select START
2) Select All Programs
3) Locate Microsoft Office
4) Select Microsoft Office Access 20xx

When Access opens:

5) From the Access tool bar, select File → Open
6) Navigate to the file "DataEntryYYMMDD.mdb" (YYMMDD is the latest version of the application), double click on the name, and the application will open.

OR

2. From the "My Computer" window, navigate to the folder that contains the file "DataEntryYYMMDD.mdb" (YYMMDD is the latest version of the application), Double click on "DataEntryYYMMDD.mdb" and Access will open at the main Access window with the application open.

B. Opening the application presents the main menu. The menu contains a utility button and buttons for each of the visit types. The Utilities are not necessary for entering data. However, they do provide information about the database and may be of interest to the data manager.

II. THE UTILITIES MENU:

The "Utilities" button on aMainMenu presents the Utilities Menu with the following functions:

A. Inventory of Visits: A report showing the number records for each visit type in the first- and second-entry tables. This report may be printed (when the form is displayed on the screen) by selecting "File" > "Print" from the menu bar.

B. Table Structure: Click on the down arrow for a list of the tables. Selecting a table will present a report of the variables in the table. This report may be printed (when the form is displayed on the screen) by selecting "File" > "Print" from the menu bar.

C. Export records to Excel Table: Extracts the data from Access tables to Excel tables in your current directory/

D. Delete All Records: Use this option only if you want to delete ALL records from ALL the tables.

III. GENERAL CONVENTIONS FOR DATA ENTRY:

A. Subject ID is a numerical value.

B. Version will have a default value and the cursor will not tab to it. To change the version value, click on the version field and enter the new value.

C. When the program encounters an error condition, a message will occur on the screen. The EXACT wording of the error message and EXACTLY what operation was being performed (i.e. entering data for the Dental Chart Information and trying to advance to the second input screen") should be noted and reported.

D. The format for date entries is MM/DD/YYYY unless otherwise specified.

E. In cases where only a month and year are requested, if the month is not known, enter "01" for MM and if the day is not known, enter "01" for DD.

F. The general guidelines for answers are:

Most questions will have an answer key specifying the acceptable responses. If there is no answer key, the following conventions should be used.

1 = Yes
2 = No
7 = Answer is missing and it should be missing
8 = Answer is missing and should not be missing
99 = Do not know (DK) the answer for this question

G. When a question is answered, the tab key or enter key will advance the cursor to the next field. In some cases the cursor will skip one or more fields because, based on the answer to a previous question, one or more of the following questions do not require an answer (a "7" may be entered into the skipped fields by the program). Skipped fields may be accessed for editing by using the mouse.

H. The record identification for the Periodontal Exam of the active form will appear at the bottom of the input screen. This should always agree with the form you are inputting.

I. Page notations on the screen form (e.g. "Page 1") are a reference to the page number of the paper form.

J. If you chose the "Print This Screen" button, the printout will consist of one or more pages depending on the length of the screen form. If the form consists of more than one screen (i.e. "Open Screen 2" appears at the bottom of the screen), open Screen 2 and select "Print This Screen" to get the remainder of the form.

IV. DATA ENTRY FOR EACH VISIT TYPE:

On the application's main menu there is a button for each Visit Type which will present another menu with all the options available for data entry and data validation for that visit type. A description of each button follows.

A. First Entry: Presents the screen for the "first" data entry for the first page. The data entry screen contains the form for recording the collected data and the following buttons as applicable:

1. "Print This Screen" button (see General Conventions for Data Entry, III.I).

2. "Open Screen 2" button will open the next screen for the current form when there are multiple screens for a form. Subsequent screens will have buttons to allow you to go back or forward as necessary.

NOTE: When there are multiple screens for a form, to start entering a new record, you must close all of the current screens, return to the "Visit Type Main Menu" and select the appropriate form button again.

B. Second Entry: Presents the screen for "second" data entry. "Second Entry" is similar to the "First Entry" button except there are no "Print" options.

C. Verify Double Entry: Compares the "first" entry table with the "second" entry table and reports the discrepancies between the two tables.

D. Enter Corrections: Presents a screen showing the discrepancies and allows for entry of the correct data in either the first or second table. If no data is in the field in the table, the word "blank" will appear as the value. Enter the correct value replacing the word "blank." If a field has a value in the Error Table and is should be empty, enter "blank" in the Error Table field.. The corrections are not posted to the tables until the "Post Corrections" button is selected. A backup copy of this Error Correction table is created and the file name will be shown when the screen is closed.

E. Post Corrections: Posts the changes made in the "Enter Corrections" form to the appropriate table. If a new Error Table report does not appear automatically after the postings occur (posting is complete when the hourglass cursor returns to its "normal" shape), run "Verify Double Entry" again to ensure that all errors have been corrected. If there are still errors, return to "Enter Corrections."

V. SPECIAL INSTRUCTIONS FOR INDIVIDUAL FORMS:

A. Dental Radiograph Review: Data is collected using an application written in Microsoft Access. Therefore, all usual conventions utilized by Access are appropriate.

B. Medical History Review: Data is collected using an application written in Microsoft Access. Therefore, all usual conventions utilized by Access are appropriate.

Appendix I

Association of Pulp Stones with Cardiovascular Disease

Codebook

Dental Radiographic

Variable Name	Item/Question (As it appears on the form)		Validation Rule
ID	Study ID: __ __ __ __		
DE1	Enterer1ID:		
DE1DATE	Entry1Date:		Between #1/1/2000# And #12/31/2020#
DE2	Enterer2ID:		
DE2DATE	Entry2Date:		Between #1/1/2000# And #12/31/2020#
dr1aGender	1a. **Gender:** 1. Male 2. Female		1 Or 2 Or 3
dr1bAge	1b. **Age:**		
dr12c1PA	12c1. **PA** 1. Yes 2. No		1 Or 2 Or 3
dr12c2BWX	12c2. **BWX** 1. Yes 2. No		1 Or 2 Or 3
dr12c3PAN	12c3. **PAN** 1. Yes 2. No		1 Or 2 Or 3
dr2a12	2a1. Maxillary Right 2nd Molar	2	1 Or 2 Or 3
dr2a23	2a2. Maxillary Right 1st Molar	3	1 Or 2 Or 3
dr2a34	2a4. Maxillary Right 1st Pre-Molar	4	1 Or 2 Or 3
dr2a45	2a5. Maxillary Left 1st Pre-Molar	5	1 Or 2 Or 3
dr2a512	2a5. Maxillary Left 1st Pre-Molar	12	1 Or 2 Or 3
dr2a613	2a6. Maxillary Left 2nd Pre-Molar	13	1 Or 2 Or 3
dr2a714	2a7. Maxillary Left 1st Molar	14	1 Or 2 Or 3
dr2a815	2a8. Maxillary Left 2nd Molar	15	1 Or 2 Or 3
dr2a918	2a9. Mandibular Left 2nd Molar	18	1 Or 2 Or 3
dr2a1019	2a10. Mandibular Left 1st Molar	19	1 Or 2 Or 3
dr2a1120	2a11. Mandibular Left 2nd Pre-Molar	20	1 Or 2 Or 3
dr2a1221	2a12. Mandibular Left 1st Pre-Molar	21	1 Or 2 Or 3
dr2a1328	2a13. Mandibular Right 1st Pre-Molar	28	1 Or 2 Or 3
dr2a1429	2a14. Mandibular Right 2nd Pre-Molar	29	1 Or 2 Or 3
dr2a1530	2a15. Mandibular Right 1st Molar	30	1 Or 2 Or 3
dr2a1631	2a16. Mandibular Right 2nd Molar	31	1 Or 2 Or 3
dr3a12	3a1. Maxillary Right 2nd Molar	2	1 Or 2 Or 3
dr3a23	3a2. Maxillary Right 1st Molar	3	1 Or 2 Or 3
dr3a34	3a3. Maxillary Right 2nd Pre-Molar	4	1 Or 2 Or 3
dr3a45	3a4. Maxillary Right 1st Pre-Molar	5	1 Or 2 Or 3
dr3a512	3a5. Maxillary Left 1st Pre-Molar	12	1 Or 2 Or 3
dr3a613	3a6. Maxillary Left 2nd Pre-Molar	13	1 Or 2 Or 3
dr3a714	3a7. Maxillary Left 1st Molar	14	1 Or 2 Or 3
dr3a815	3a8. Maxillary Left 2nd Molar	15	1 Or 2 Or 3
dr3a918	3a9. Mandibular Left 2nd Molar	18	1 Or 2 Or 3
dr3a1019	3a10. Mandibular Left 1st Molar	19	1 Or 2 Or 3
dr3a1120	3a11. Mandibular Left 2nd Pre-Molar	20	1 Or 2 Or 3
dr3a1221	3a12. Mandibular Left 1st Pre-Molar	21	1 Or 2 Or 3

Dental Radiographic

Variable Name	Item/Question (As it appears on the form)		Validation Rule
dr3a1328	3a13. Mandibular Right 1st Pre-Molar	28	1 Or 2 Or 3
dr3a1429	3a14. Mandibular Right 2nd Pre-Molar	29	1 Or 2 Or 3
dr3a1530	3a15. Mandibular Right 1st Molar	30	1 Or 2 Or 3
dr3a1631	3a16. Mandibular Right 2nd Molar	31	1 Or 2 Or 3
dr4a12	4a1. Maxillary Right 2nd Molar	2	1 Or 2 Or 3
dr4a23	4a2. Maxillary Right 1st Molar	3	1 Or 2 Or 3
dr4a34	4a3. Maxillary Right 2nd Pre-Molar	4	1 Or 2 Or 3
dr4a45	4a4. Maxillary Right 1st Pre-Molar	5	1 Or 2 Or 3
dr4a512	4a5. Maxillary Left 1st Pre-Molar	12	1 Or 2 Or 3
dr4a613	4a6. Maxillary Left 2nd Pre-Molar	13	1 Or 2 Or 3
dr4a714	4a7. Maxillary Left 1st Molar	14	1 Or 2 Or 3
dr4a815	4a8. Maxillary Left 2nd Molar	15	1 Or 2 Or 3
dr4a918	4a9. Mandibular Left 2nd Molar	18	1 Or 2 Or 3
dr4a1019	4a10. Mandibular Left 1st Molar	19	1 Or 2 Or 3
dr4a1120	4a11. Mandibular Left 2nd Pre-Molar	20	1 Or 2 Or 3
dr4a1221	4a12. Mandibular Left 1st Pre-Molar	21	1 Or 2 Or 3
dr4a1328	4a13. Mandibular Right 1st Pre-Molar	28	1 Or 2 Or 3
dr4a1429	4a14. Mandibular Right 2nd Pre-Molar	29	1 Or 2 Or 3
dr4a1530	4a15. Mandibular Right 1st Molar	30	1 Or 2 Or 3
dr4a1631	4a16. Mandibular Right 2nd Molar	31	1 Or 2 Or 3
dr5a12	5a1. Maxillary Right 2nd Molar	2	1 Or 2 Or 3
dr5a23	5a2. Maxillary Right 1st Molar	3	1 Or 2 Or 3
dr5a34	5a3. Maxillary Right 2nd Pre-Molar	4	1 Or 2 Or 3
dr5a45	5a4. Maxillary Right 1st Pre-Molar	5	1 Or 2 Or 3
dr5a512	5a5. Maxillary Left 1st Pre-Molar	12	1 Or 2 Or 3
dr5a613	5a6. Maxillary Left 2nd Pre-Molar	13	1 Or 2 Or 3
dr5a714	5a7. Maxillary Left 1st Molar	14	1 Or 2 Or 3
dr5a815	5a8. Maxillary Left 2nd Molar	15	1 Or 2 Or 3
dr5a918	5a9. Mandibular Left 2nd Molar	18	1 Or 2 Or 3
dr5a1019	5a10. Mandibular Left 1st Molar	19	1 Or 2 Or 3
dr5a1120	5a11. Mandibular Left 2nd Pre-Molar	20	1 Or 2 Or 3
dr5a1221	5a12. Mandibular Left 1st Pre-Molar	21	1 Or 2 Or 3
dr5a1328	5a13. Mandibular Right 1st Pre-Molar	28	1 Or 2 Or 3
dr5a1429	5a14. Mandibular Right 2nd Pre-Molar	29	1 Or 2 Or 3
dr5a1530	5a15. Mandibular Right 1st Molar	30	1 Or 2 Or 3
dr5a1631	5a16. Mandibular Right 2nd Molar	31	1 Or 2 Or 3
dr6a12	6a1. Maxillary Right 2nd Molar	2	1 Or 2 Or 3 Or 4
dr6a23	6a2. Maxillary Right 1st Molar	3	1 Or 2 Or 3 Or 4
dr6a34	6a3. Maxillary Right 2nd Pre-Molar	4	1 Or 2 Or 3 Or 4
dr6a45	6a4. Maxillary Right 1st Pre-Molar	5	1 Or 2 Or 3 Or 4
dr6a512	6a5. Maxillary Left 1st Pre-Molar	12	1 Or 2 Or 3 Or 4
dr6a613	6a6. Maxillary Left 2nd Pre-Molar	13	1 Or 2 Or 3 Or 4
dr6a714	6a7. Maxillary Left 1st Molar	14	1 Or 2 Or 3 Or 4
dr6a815	6a8. Maxillary Left 2nd Molar	15	1 Or 2 Or 3 Or 4

Dental Radiographic

Variable Name	Item/Question (As it appears on the form)		Validation Rule
dr6a918	6a9. Mandibular Left 2nd Molar	18	1 Or 2 Or 3 Or 4
dr6a1019	6a10. Mandibular Left 1st Molar	19	1 Or 2 Or 3 Or 4
dr6a1120	6a11. Mandibular Left 2nd Pre-Molar	20	1 Or 2 Or 3 Or 4
dr6a1221	6a12. Mandibular Left 1st Pre-Molar	21	1 Or 2 Or 3 Or 4
dr6a1328	6a13. Mandibular Right 1st Pre-Molar	28	1 Or 2 Or 3 Or 4
dr6a1429	6a14. Mandibular Right 2nd Pre-Molar	29	1 Or 2 Or 3 Or 4
dr6a1530	6a15. Mandibular Right 1st Molar	30	1 Or 2 Or 3 Or 4
dr6a1631	6a16. Mandibular Right 2nd Molar	31	1 Or 2 Or 3 Or 4
dr7a12	7a1. Maxillary Right 2nd Molar	2	1 Or 2 Or 3
dr7a23	7a2. Maxillary Right 1st Molar	3	1 Or 2 Or 3
dr7a34	7a3. Maxillary Right 2nd Pre-Molar	4	1 Or 2 Or 3
dr7a45	7a4. Maxillary Right 1st Pre-Molar	5	1 Or 2 Or 3
dr7a512	7a5. Maxillary Left 1st Pre-Molar	12	1 Or 2 Or 3
dr7a613	7a6. Maxillary Left 2nd Pre-Molar	13	1 Or 2 Or 3
dr7a714	7a7. Maxillary Left 1st Molar	14	1 Or 2 Or 3
dr7a815	7a8. Maxillary Left 2nd Molar	15	1 Or 2 Or 3
dr7a918	7a9. Mandibular Left 2nd Molar	18	1 Or 2 Or 3
dr7a1019	7a10. Mandibular Left 1st Molar	19	1 Or 2 Or 3
dr7a1120	7a11. Mandibular Left 2nd Pre-Molar	20	1 Or 2 Or 3
dr7a1221	7a12. Mandibular Left 1st Pre-Molar	21	1 Or 2 Or 3
dr7a1328	7a13. Mandibular Right 1st Pre-Molar	28	1 Or 2 Or 3
dr7a1429	7a14. Mandibular Right 2nd Pre-Molar	29	1 Or 2 Or 3
dr7a1530	7a15. Mandibular Right 1st Molar	30	1 Or 2 Or 3
dr7a1631	7a16. Mandibular Right 2nd Molar	31	1 Or 2 Or 3
dr8a12	8a1. Maxillary Right 2nd Molar	2	1 Or 2 Or 3 Or 4 Or 5
dr8a23	8a2. Maxillary Right 1st Molar	3	1 Or 2 Or 3 Or 4 Or 5
dr8a34	8a3. Maxillary Right 2nd Pre-Molar	4	1 Or 2 Or 3 Or 4 Or 5
dr8a45	8a4. Maxillary Right 1st Pre-Molar	5	1 Or 2 Or 3 Or 4 Or 5
dr8a512	8a5. Maxillary Left 1st Pre-Molar	12	1 Or 2 Or 3 Or 4 Or 5
dr8a613	8a6. Maxillary Left 2nd Pre-Molar	13	1 Or 2 Or 3 Or 4 Or 5
dr8a714	8a7. Maxillary Left 1st Molar	14	1 Or 2 Or 3 Or 4 Or 5
dr8a815	8a8. Maxillary Left 2nd Molar	15	1 Or 2 Or 3 Or 4 Or 5
dr8a918	8a9. Mandibular Left 2nd Molar	18	1 Or 2 Or 3 Or 4 Or 5
dr8a1019	8a10. Mandibular Left 1st Molar	19	1 Or 2 Or 3 Or 4 Or 5
dr8a1120	8a11. Mandibular Left 2nd Pre-Molar	20	1 Or 2 Or 3 Or 4 Or 5
dr8a1221	8a12. Mandibular Left 1st Pre-Molar	21	1 Or 2 Or 3 Or 4 Or 5
dr8a1328	8a13. Mandibular Right 1st Pre-Molar	28	1 Or 2 Or 3 Or 4 Or 5
dr8a1429	8a14. Mandibular Right 2nd Pre-Molar	29	1 Or 2 Or 3 Or 4 Or 5
dr8a1530	8a15. Mandibular Right 1st Molar	30	1 Or 2 Or 3 Or 4 Or 5
dr8a1631	8a16. Mandibular Right 2nd Molar	31	1 Or 2 Or 3 Or 4 Or 5
dr9a12	9a1. Maxillary Right 2nd Molar	2	1 Or 2 Or 3 Or 4
dr9a23	9a2. Maxillary Right 1st Molar	3	1 Or 2 Or 3 Or 4
dr9a34	9a3. Maxillary Right 2nd Pre-Molar	4	1 Or 2 Or 3 Or 4
dr9a45	9a4. Maxillary Right 1st Pre-Molar	5	1 Or 2 Or 3 Or 4

Dental Radiographic

Variable Name	Item/Question (As it appears on the form)		Validation Rule
dr9a512	9a5. Maxillary Left 1st Pre-Molar	12	1 Or 2 Or 3 Or 4
dr9a613	9a6. Maxillary Left 2nd Pre-Molar	13	1 Or 2 Or 3 Or 4
dr9a714	9a7. Maxillary Left 1st Molar	14	1 Or 2 Or 3 Or 4
dr9a815	9a8. Maxillary Left 2nd Molar	15	1 Or 2 Or 3 Or 4
dr9a918	9a9. Mandibular Left 2nd Molar	18	1 Or 2 Or 3 Or 4
dr9a1019	9a10. Mandibular Left 1st Molar	19	1 Or 2 Or 3 Or 4
dr9a1120	9a11. Mandibular Left 2nd Pre-Molar	20	1 Or 2 Or 3 Or 4
dr9a1221	9a12. Mandibular Left 1st Pre-Molar	21	1 Or 2 Or 3 Or 4
dr9a1328	9a13. Mandibular Right 1st Pre-Molar	28	1 Or 2 Or 3 Or 4
dr9a1429	9a14. Mandibular Right 2nd Pre-Molar	29	1 Or 2 Or 3 Or 4
dr9a1530	9a15. Mandibular Right 1st Molar	30	1 Or 2 Or 3 Or 4
dr9a1631	9a16. Mandibular Right 2nd Molar	31	1 Or 2 Or 3 Or 4
dr10a12	10a1. Maxillary Right 2nd Molar	2	1 Or 2 Or 3
dr10a23	10a2. Maxillary Right 1st Molar	3	1 Or 2 Or 3
dr10a34	10a3. Maxillary Right 2nd Pre-Molar	4	1 Or 2 Or 3
dr10a45	10a4. Maxillary Right 1st Pre-Molar	5	1 Or 2 Or 3
dr10a512	10a5. Maxillary Left 1st Pre-Molar	12	1 Or 2 Or 3
dr10a613	10a6. Maxillary Left 2nd Pre-Molar	13	1 Or 2 Or 3
dr10a714	10a7. Maxillary Left 1st Molar	14	1 Or 2 Or 3
dr10a815	10a8. Maxillary Left 2nd Molar	15	1 Or 2 Or 3
dr10a918	10a9. Mandibular Left 2nd Molar	18	1 Or 2 Or 3
dr10a1019	10a10. Mandibular Left 1st Molar	19	1 Or 2 Or 3
dr10a1120	10a11. Mandibular Left 2nd Pre-Molar	20	1 Or 2 Or 3
dr10a1221	10a12. Mandibular Left 1st Pre-Molar	21	1 Or 2 Or 3
dr10a1328	10a13. Mand. Right 1st Pre-Molar	28	1 Or 2 Or 3
dr10a1429	10a14. Mand. Right 2nd Pre-Molar	29	1 Or 2 Or 3
dr10a1530	10a15. Mandibular Right 1st Molar	30	1 Or 2 Or 3
dr10a1631	10a16. Mandibular Right 2nd Molar	31	1 Or 2 Or 3
VERSION	Version		
VISITDATE			Between #1/1/2000# And #12/31/2020#

Medical History Review

Variable Name	Item/Question (As it appears on the form)	Validation Rule
ID	Study ID:	
DE1	Enterer1ID:	
DE1DATE	Entry 1Date	Between #1/1/2000# And #12/31/2020#
DE2	Entry2Date:	
DE2DATE	Enterer2ID:	Between #1/1/2000# And #12/31/2020#
mh1aGender	1a. Gender: 1. Male 2. Female	1 Or 2 Or 3 Or 4
mh1bAge	1b. Age:	
mh2b1Ap	2b1. Angina Pectoris	1 Or 2 Or 3 Or 4
mh2b2Mi	2b2. Myocardial Infarction	1 Or 2 Or 3 Or 4
mh2b3Hs	2b3. Heart Surgery	1 Or 2 Or 3 Or 4
mh2b4Hy	2b4. Hypertension	1 Or 2 Or 3 Or 4
mh2b5Chf	2b5. Congestive Heart Failure	1 Or 2 Or 3 Or 4
mh2b6Cad	2b6. Coronary Artery Disease	1 Or 2 Or 3 Or 4
mh2b7Hmd	2b7. Cardiomyopathy (heart muscle disease)	1 Or 2 Or 3 Or 4
mh2b8Vhd	2b8. Valvular Heart Diseases	1 Or 2 Or 3 Or 4
mh2b9Chd	2b9. Congenital Heart Disease	1 Or 2 Or 3 Or 4
mh2b10Ath	2b10. Atherosclerosis	1 Or 2 Or 3 Or 4
mh2b11Hct	2b11. Hypercholesterolemia	1 Or 2 Or 3 Or 4
mh2b12Arr	2b12. Arrhythmia	1 Or 2 Or 3 Or 4
mh2b13Ane	2b13. Aneurysm	1 Or 2 Or 3 Or 4
mh2b14Sto	2b14. Cerebrovascular Accident (stroke)	1 Or 2 Or 3 Or 4
mh2b15Tia	2b15. Transient Ischemic Attack (mini stroke)	1 Or 2 Or 3 Or 4
mh2b16Cvd	2b16. Cerebrovascular Disease	1 Or 2 Or 3 Or 4
mh2b17Puc	2b17. Disease of Pulmonary Circulation (pulmonary embolism)	1 Or 2 Or 3 Or 4
mh2b18Adm	2b18. Aorta Disease and Marfan Syndrome	1 Or 2 Or 3 Or 4
mh2b19Rhd	2b19. Rheumatic Heart Disease/ Rheumatic Fever	1 Or 2 Or 3 Or 4
mh1b20Dvt	2b20. Deep Vein Thrombosis	1 Or 2 Or 3 Or 4
mh3c1Kd	3c1. Kidney Disease	1 Or 2 Or 3 Or 4
mh3c2Ty1	3c2. Diabetes Type I	1 Or 2 Or 3 Or 4
md3c3Ty2	3c3. Diabetes Type II	1 Or 2 Or 3 Or 4
mh3c4Gout	3c4. Gout	1 Or 2 Or 3 Or 4
mh3c5Met	3c5. Metabolic Diseases	1 Or 2 Or 3 Or 4
mh3c6Ctd	3c6. Connective Tissue Disorders	1 Or 2 Or 3 Or 4
mh3c7Pvd	3c7. Peripheral Vascular Disease (vasculitis, Kawasaki, Wegener)	1 Or 2 Or 3 Or 4
mh3c8Art	3c8. Arthritis	1 Or 2 Or 3 Or 4
mhMed4a1	4a1.	
mhMed4a2	4a2. 1. Yes 2. No	1 Or 2 Or 3
mhMed4b1	4b1.	
mhMed4b2	4b2. 1. Yes 2. No	1 Or 2 Or 3
mhMed4c1	4c1.	
mhMed4c2	4c2. 1. Yes 2. No	1 Or 2 Or 3

Medical History Review

Variable Name	Item/Question (As it appears on the form)			Validation Rule
mhMed4d1	4d1.			
mhMed4d2	4d2.	1. Yes	2. No	1 Or 2 Or 3
mhMed4e1	4e1.			
mhMed4e2	4e2.	1. Yes	2. No	1 Or 2 Or 3
mhMed4f1	4f1.			
mhMed4f2	4f2.	1. Yes	2. No	1 Or 2 Or 3
mhMed4g1	4g1.			
mhMed4g2	4g2.	1. Yes	2. No	1 Or 2 Or 3
mhMed4h1	4h1.			
mhMed4h2	4h2.	1. Yes	2. No	1 Or 2 Or 3
mhMed4i1	4i1.			
mhMed4i2	4i2.	1. Yes	2. No	1 Or 2 Or 3
mhMed4j1	4j1.			
mhMed4j2	4j2.	1. Yes	2. No	1 Or 2 Or 3
mhMed4k1	4k1.			
mhMed4k2	4k2.	1. Yes	2. No	1 Or 2 Or 3
mhMed4l1	4l1			
mhMed4l2	4l2.	1. Yes	2. No	1 Or 2 Or 3
mhMed4m1	4m1.			
mhMed4m2	4m2.	1. Yes	2. No	1 Or 2 Or 3
mhMed4n1	4n1.			
mhMed4n2	4n2.	1. Yes	2. No	1 Or 2 Or 3
mhMed4o1	4o1.			
mhMed4o2	4o2.	1. Yes	2. No	1 Or 2 Or 3
mhMed4p1	4p1.			
mhMed4p2	4p2.	1. Yes	2. No	1 Or 2 Or 3
mhMed4q1	4q1.			
mhMed4q2	4q2.	1. Yes	2. No	1 Or 2 Or 3
mhMed4r1	4r1.			
mhMed4r2	4r2.	1. Yes	2. No	1 Or 2 Or 3
mhMed4s1	4s1.			
mhMed4s2	4s2.	1. Yes	2. No	1 Or 2 Or 3
mhMed4t1	4t1.			
mhMed4t2	4t2.	1. Yes	2. No	1 Or 2 Or 3
VERSION	Version			
VISITDATE				Between #1/1/2000# And #12/31/2020#

Appendix J

1. **Ptid:** Patient ID Number
2. **Gender_Female_0_Male_1:** Female = 0, Male =1
3. **Age:** Patient Age (Actual)
4. **Age_Young_0_Age_Old_1:** Age Young (20-50 yrs) = 0, Age Old (51-75 yrs) = 1
5. **PulpStones_NC_NR:** Total pulp stones in non-carious/non-restored teeth in each patient
6. **PulpStones_NC_NR_Present:** Pulp stones present in non-carious/non-restored teeth in each patient: 1 = yes, 0 = no
7. **PulpStones_NC_MR:** Total pulp stones in non-carious/non-restored teeth in each patient
8. **PulpStones_NC_MR_Present:** Pulp stones present in non-carious/minimally-restored teeth in each patient: 1 = yes, 0 = no
9. **PulpStones_IC_NR:** Total pulp stones in incipient-carious/non-restored teeth in each patient
10. **PulpStones_IC_NR_Present:** Pulp stones present in incipient-carious/non-restored teeth in each patient: 1 = yes, 0 = no
11. **PulpStones_IC_MR:** Total pulp stones in incipient-carious/minimally-restored teeth in each patient
12. **PulpStones_IC_MR_Present:** Pulp stones present in incipient-carious/minimally-restored teeth in each patient: 1 = yes, 0 = no
13. **PulpStones_4Types_Total:** Total pulp stones in non-carious/non-restored, incipient carious/non-restored, non-carious/minimally restored, and incipient carious/minimally restored teeth in each patient
14. **PulpStones_4Types_Present:** Pulp stones present in non-carious/non-restored, incipient carious/non-restored, non-carious/minimally restored, and incipient carious/minimally restored teeth in each patient: 1 = yes, 0 = no
15. **AnginaPectoris:** CVD exposure present: 1 = yes, 0 = no
16. **MyocardialInfarction:** CVD exposure present: 1 = yes, 0 = no
17. **HeartSurgery:** CVD exposure present: 1 = yes, 0 = no
18. **Hypertension:** CVD exposure present: 1 = yes, 0 = no
19. **CongestiveHeartFailure:** CVD exposure present: 1 = yes, 0 = no
20. **CoronaryHeartDisease:** CVD exposure present: 1 = yes, 0 = no
21. **Cardiomyopathy:** CVD exposure present: 1 = yes, 0 = no
22. **ValvularHeartDisease:** CVD exposure present: 1 = yes, 0 = no
23. **CongenitalHeartDisease:** CVD exposure present: 1 = yes, 0 = no
24. **Atherosclerosis:** CVD exposure present: 1 = yes, 0 = no

25. **Hypercholesterolemia:** CVD exposure present: 1 = yes, 0 = no
26. **Arrhythmia:** CVD exposure present: 1 = yes, 0 = no
27. **Aneuurysm:** CVD exposure present: 1 = yes, 0 = no
28. **Stroke:** CVD exposure present: 1 = yes, 0 = no
29. **MiniStroke:** CVD exposure present: 1 = yes, 0 = no
30. **CerebrovascularDisease:** CVD exposure present: 1 = yes, 0 = no
31. **PulmmonaryEmbolism:** CVD exposure present: 1 = yes, 0 = no
32. **AortaDisease:** CVD exposure present: 1 = yes, 0 = no
33. **RheumaticHeartDiseaseFever:** CVD exposure present: 1 = yes, 0 = no
34. **DeepVeinThrombosis:** CVD exposure present: 1 = yes, 0 = no
35. **Total_CVD:** Total CVD exposures in each patient
36. **CVD_Present:** CVD present in patient: 1 = yes, 0 =no
37. **Heavy_Restored_Teeth:** Number of heavily restored teeth in each patient
38. **PulpStones_NC_HR:** Number of pulp stones in non-carious/heavily restored teeth in each patient
39. **PulpStones_IC_HR:** Number of pulp stones in incipient-carious/heavily restored teeth in each patient
40. **PulpStones_DC_HR:** Number of pulp stones in dentinal-carious/heavily restored teeth in each patient
41. **PulpStones_Heavy_Restored_Total:** Total number of pulp stones found in heavily restored teeth in each patient
42. **PulpStones_Heavy_Restored_Present:** Pulp stones present in heavily restored teeth including in each patient: 1 =yes, 0 =no
43. **Minmally_Restored_Teeth:** Total number of minimally restored teeth in each patient
44. **PulpStones_Minimally_Restored_Total:** Total number of pulp stones in minimally restored teeth in each patient
45. **PulpStones_Minimally_Restored_Present:** Pulp stones present in minimally restored teeth in each patient: 1 = yes, 0 = no
46. **Non_Restored_Teeth:** Total number of non-restored teeth in each patient
47. **PulpStones_Non_Restored_Total:** Total number of pulp stones in non-restored teeth in each patient
48. **PulpStones_Non_Restored_Present:** Pulp stones present in non-restored restored teeth in each patient: 1 = yes, 0 = no
49. **Non_Caries_Teeth:** Total number of non-carious teeth in each patient
50. **PulpStones_Non_Caries_Total:** Total number of pulp stones in non-carious teeth in each patient

51. PulpStones_Non_Caries_Present: Pulp stones present in non-carious teeth in each patient: 1 = yes, 0 = no

52. Incipient_Caries_Teeth: Total number of incipient carious teeth in each patient

53. PulpStones_Incipient_Caries_Total: Total number of pulp stones in incipient carious teeth in each patient

54. PulpStones_Incipient_Caries_Present: Pulp stones present in incipient carious teeth in each patient: 1 = yes, 0 = no

55. Dental_Caries_Teeth: Total number of dentinal carious teeth in each patient

56. PulpStones_Dental_Caries_Total: Total number of pulp stones dentinal carious teeth in each patient

57. PulpStones_Dental_Caries_Present: Pulp stones present in dentinal carious teeth in each patient: 1 = yes, 0 = no

58. PulpStones_DC_MR: Total pulp stones in dentinal-carious/minimally-restored teeth in each patient

59. PulpStones_DC_NR: Total pulp stones in dentinal-carious/non-restored teeth in each patient

60. Heavy_Restored_Teeth_Present: Heavily restored teeth present in each patient: 1 = yes, 0 = no

61. Minimally_Restored_Teeth_Present: Minimally restored teeth present in each patient: 1 = yes, 0 = no

62. Non_Restored_Teeth_Present: Non-restored teeth present in each patient: 1 = yes, 0 = no

63. Non_Caries_Teeth_Present: Non-carious teeth present in each patient: 1 = yes, 0 = no

64. Incipient_Caries_Teeth_Present: Incipient carious teeth present in each patient: 1 = yes, 0 = no

65. Dental_Caries_Teeth_Present: Dentinal carious teeth present in each patient: 1 = yes, 0 = no

66. Number_Crowns: Total number of crowns in each patient

67. Crowns_Present: Crowned teeth present in each patient: 1 = yes, 0 = no

68. Total_Pulp_Stones: Total number of pulp stones in each patient

69. Pulp_Stones_Present: Pulp stones present in each patient: 1 = yes, 0 =no

70. Total_Teeth: Total number of teeth in each patient

71. NC_NR_Teeth_Total: Total number of non-carious/non-restored teeth in each patient

72. NC_MR_Teeth_Total: Total number of non-carious/non-restored teeth in each patient

73. IC_NR_Teeth_Total: Total number of incipient-carious/non-restored teeth in each patient

74. IC_MR_Teeth_Total: Total number of incipient-carious/minimally-restored teeth in each patient

75. Inclusion_Criteria_Teeth_Total: Total number of non-carious/non-restored, incipient carious/non-restored, non-carious/minimally restored, and incipient carious/minimally restored teeth in each patient

76. NC_NR_IC_NR_Total: Total number of non-carious/non-restored and incipient carious/ non-restored teeth in each patient

77. PulpStones_NC_NR_IC_NR_Total: Total pulp stones in non-carious/non-restored and incipient carious/non-restored teeth in each patient

78. PulpStones_NC_NR_IC_NR_Present: Pulp stones present in non-carious/non-restored and incipient carious/non-restored teeth in each patient: 1 = yes, 0 = no