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The effects of chronic stress on oral health and its clinical manifestations and related oral conditions

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THE EFFECTS OF CHRONIC STRESS ON ORAL HEALTH AND ITS CLINICAL MANIFESTATIONS AND RELATED ORAL CONDITIONS

by

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DEDICATION

I would like to dedicate this work to my amazing mother, Phylisa, and in honor of my late father, Michael.

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I want to give a special thank you to my wonderful mentors Dr. Winifred Booker and Dr. Akeadra Bell for your guidance and support. To my advisor, Dr. Davies, thank you for always being there and your continued encouragement throughout this entire process.

THE EFFECTS OF CHRONIC STRESS ON ORAL HEALTH AND ITS ORAL MANIFESTATIONS AND RELATED ORAL CONDITIONS.

KENISHA A. BRANNON

ABSTRACT

Stress occurs within everyone's life, from the onset of life until a person takes their last breath. The National Center for Complementary and Integrative Health describe stress as a physical and emotional reaction to an experience that will occur within one's life as changes occur. Stress is an action that occurs when the body encounters an experience triggered by a stressor, either internally or externally, that brings the body beyond its normal homeostatic threshold. In return the body shuts down to protect itself from overloading and overwhelming itself, from the stressor that is causing this reaction. Stress is a normal feeling, but chronic and long-term stress can lead to many disruptions to an individual's health and disrupt their normal lifestyle.

In 2019 it has been estimated that 70% of primary care visits are related to problems related to stress and lifestyle. Stress can present itself in numerous forms depending on the individual. Stress alters numerous aspects of life, it can be emotionally, physically, psychologically, etc. There are a wide range of health problems that stem from chronic stress; stress can disrupt eating habits, normal body functions, cause mood swings and unwanted behavioral changes, trigger latent diseases and many other problems. One of

the biggest, yet unnoticed changes that stress can cause is how chronic stress leads to a decline in oral health, as an effect of the constant changes going on within the body. The oral cavity is one of the biggest indicators that there are changes going on within a patient.

This literature review will evaluate the various oral conditions that stress can cause within the oral cavity and the resulting impact to one's overall health. Oral health is direly important to overall health. A routine exam of the oral cavity can associate many systemic diseases affecting an individual based on the oral manifestations that are presented. While other symptoms often go unnoticed and get neglected until it is too late, the oral cavity is an early indicator that there is something that is causing a disruption to the body.

The oral manifestations that were focused on for this literature review included some very common cases while others were more circumstantial. The goal was to link the oral manifestations to common oral conditions that stress brought upon the body, including periodontal disease, bruxism, habitual biting of the oral mucosa and geographic tongue.

Bruxism, and periodontal disease yielded the most significant findings and its relation to stress while geographic tongue did lack some critical findings because of the condition being transient in nature and underreported. A reduction in stress can lead to a lower

incidence of these oral conditions and systemic diseases in the population. Numerous research studies were evaluated to access the relation to stress and its effects on oral health, although if this review were to be done again, more data collected over a 5-year span on each condition and manifestation would be supportive.

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LIST OF ABBREVIATIONS

ACTH…… Adrenocorticotrophic Hormone

ADHD……..Attention Deficit Hyperactivity Disorder

APA……..American Psychological Association

BFRB…….Body Focused Repetitive Behavior

BGM…….Benign Migratory Glossitis

BU……Boston University

CRH……Corticotropin Releasing Hormone

DSM-5……Statistic Manual of Mental Disorders

EMG……Electromyogram

GERD…….Gastroesophageal reflux disease

GT……Geographic Tongue

TMD……..Temporomandibular Disorder

TMJ……...Temporomandibular Joint

INTRODUCTION

Stress is defined as a chemical, physical or emotional factor that causes bodily or mental tension (Maheswari & Gnanasundaram, 2010). Stress is a natural process that occurs in humans as a defense mechanism to protect itself from the changes taking place within or around the body. When bodily or mental tension is sensed the amygdala sends signals to the hypothalamus which communicates to the autonomic nervous system that it should trigger the sympathetic nervous system. The adrenal gland is found within the sympathetic nervous system and releases the hormone epinephrine, which allows the body to make necessary adjustments beyond its normal homeostatic threshold to respond to stress and protect the body.

The sympathetic nervous system is known as the fight or flight response; this is characterized by an increase in heart rate, sweat production, blood pressure, dilating of the pupils, rapid breathing, physical alertness and tension; resulting in a person being on edge (*Melinda,* 2021.). Not all these responses will occur, but a variation can be experienced. When the body is experiencing prolonged stress the hypothalamus releases corticotropin-releasing hormone (CRH) triggering the pituitary to release adrenocorticotrophic hormone (ACTH) and in return the adrenal glands will release cortisol which allows the body to stay on constant alert (Harvard Health Publishing, 2020).

Table 1 highlights the effect stress has on the body physiologically, ***Figure 1*** illustrates the homeostatic threshold range compared to the physiological stress being inflicted (Comana, n.d.). The human body is not able to safely handle high levels of cortisol for a prolonged period and when it does, there are negative physiological and psychological effects inflicted upon the body. The focus of this thesis is to analyze the effects that the stress hormone, cortisol, has on oral health and the oral conditions that are brought upon by these oral manifestations of disease. In order to properly explain the effects that stress presents a basic understanding of these common oral conditions need to be explained first.

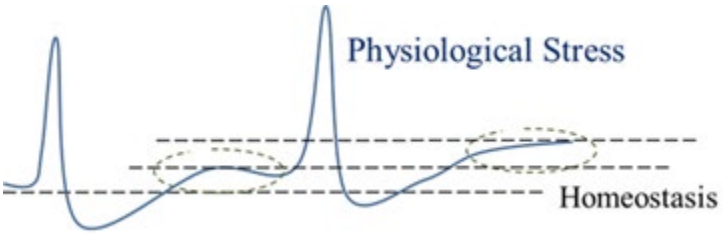

Figure 1: Physiological Stress Effects on Homeostasis. Image illustrates how stress brings the body beyond its normal homeostatic threshold and it needs time to adapt to return back to that homeostasis threshold. Figure adapted from (Comana, n.d.)

Table 1: Physiological Stressors. Table describes the effects that occur when stress is on the body and what the body does to move it past the homeostatic threshold to protect itself (Comana, n.d.).

Events Activated	Events Inhibited
Increased cardiopulmonary responses	Decreased salivary and digestive enzyme secretion, and digestion
Increased vessel dilation in the needed location	Decreased stomach/small intestinal contractility
Increased mobilization of fuels	Reduced pain perception (analgesia)
Increased blood clotting ability	Reduced growth, repair, and maintenance
Increased large intestinal contractility	Decreased reproduction capacity
Increased bladder contractility	Immune function – sustained long-term
Increased immune function – short-term	
Increased sweat rates	

Periodontal Disease

Periodontal disease clinically is a broad range of diseases, in which they attack the gum tissue and the structure that support teeth. Periodontal disease is also referred to as gum disease (Harvard Health, 2011). The Prefix 'Peri' is a Greek word which means around, the root word 'Dontal' or 'Odontal' refers to the word tooth and the suffix '-Itis' medically refers to inflammation/infection. Periodontitis is a chronic inflammatory disease which is classified into 3 stages. The disease is onset by the introduction of biofilms made up of bacterial plaque within the oral cavity (Liccardo et al., 2019).

Periodontal disease is a progressive disease and can be aggressive in its final stages. The first stage of the disease is known as gingivitis. As the first stage of periodontal disease, gingivitis causes irritation, redness and swelling of the gingiva as well as bad breath, tender and receding gums (Mayo Clinic n.d.). Unlike the other stages of periodontal disease this stage is 100% reversible. If left untreated gingivitis not only progresses into the advanced stages of the disease, early or moderate periodontitis but further progresses into other infections or abscesses within the mouth (US National Library of Medicine-MedlinePlus, n.d.)

The more advanced stages of periodontal disease are not reversible and continue to eat away at the bone until there is complete bone loss. Early and advanced periodontitis

clinically presents with redness, swelling, bleeding gums, loose teeth, deep gum pockets and in some cases, teeth have fallen out if they have not been surgically removed. The deeper the gum pocket in a patient suffering from periodontitis the more severe the disease state. ***Figure 2***, and ***Figure 3*** show advanced stages of the disease. Infectious causing disease and bacteria are continuously eating away at the gums and if periodontitis is left untreated that infection then goes on and spreads into the bloodstream and can cause sepsis and most notably cardiovascular disease which also linked to periodontal disease (Carrizales-Sepúlveda et al., 2018).

Figure 2: Advanced Stages of Periodontitis Photograph taken of a patient in advanced stages of periodontal disease with exposed roots. Adapted from Moharamzadeh, K. (2018).

Figure 3: Clinical Case Study of Advanced Periodontitis This photograph was taken of a patient with severe gum attrition and bone loss. Adapted from Moharamzadeh, K. (2018).

One of the leading causes of disease in the oral cavity is due to periodontal disease. The CDC claims that half of Americans 30 years or older have periodontitis (*Periodontal Disease Fact Sheet | Perio.Org*, n.d.). There is a strong correlation with poor oral hygiene and other systemic diseases, not just periodontitis, including diabetes and endocarditis (Hegde & Awan, 2019). There are numerous risk factors for this oral condition which include poor oral health hygiene, smoking, pregnancy, obesity, genetics, drug use, and most importantly stress and other conditions that weaken one's natural immunity (*Periodontitis - Symptoms and Causes - Mayo Clinic*, n.d.).

It is known that stress is a major risk factor for numerous systemic diseases, and chronic stress increases the prevalence of those diseases. Prolonged stress is associated with the pathogenesis of periodontal disease due to the psychosocial behavioral factor it

plays (Storto Soares et al., 2020). Stress systemically affects one's wellbeing, when prolonged it can alter an individual's mental health and behaviors which, in turn, can have negative impacts on their physical health. Poor mental health leads to neglect in oral hygiene, which leads to the facilitation of bacterial invasion. The prolonged high cortisol levels have altered and overwhelmed the body's natural immune response and the body is not able to process and fight off an infection as successfully as it should.

When the body is experiencing chronic stress, not only are an individual's behaviors and emotional state altering their health. Their immune system function becomes diminished as well and an individual has an increased disease susceptibility. Having high levels of cortisol is linked to elevated oral inflammatory load and bactericidal load which is linked to periodontal disease (Gomaa, 2019). An individual who is experiencing high levels of stress has a lowered immune response compared to someone who is not (Storto Soares et al., 2020).

There have been numerous studies conducted that link stress to adverse effects on oral health status; stress affects behaviors and in return affects oral health. One study examined the relationship between stress and oral health behaviors. Patients in this study were to take an important medical examination and, in the weeks, leading up to the exam were experiencing large amounts of stress. Patients were given a routine oral examination while they were studying for the exam and another oral examination 4-

weeks post exam to determine whether there was a change in their oral health behavior while under immense stress. Indeed, students had higher levels of plaque while experiencing stress. It is assumed that while the students were under stress there was neglect in one's oral health or a change in behaviors that lead to the increase in plaque levels. Plaque buildup leads to inflammation and gingivitis and when neglected over time can become periodontal disease (Gomaa, 2010).

Geographic Tongue

Geographic tongue (GT) is also known as benign migratory glossitis (BMG). Geographic tongue is a noninfectious, harmless inflammatory disorder that affects the tongue epithelium, mainly the papillae see ***Figure 4***. BMG gets its name because it occurs on the glottis, lesions appear in a geographic pattern, is transient in nature meaning the spots do not last long and migrate to different locations on the glottis and it is non-cancerous. When an individual is having a flare up, the normal pinkish-white papillae that normally appear on the tongue are missing and instead the tongue presents itself with red patches that appear all over the tongue and appear to form a map like shape (*Geographic Tongue - Symptoms and Causes*, n.d.). The map-like shape patches are small lesions and are transient in nature, once they heal, they move onto another region of the tongue. A clinical diagnosis for a patient presenting with GT is made by looking at the lesions. The transient nature of the oral condition can be seen visually in ***Figure 5***,

the patients' outbreak of the condition has occurred over a 3-month time frame. The patient also suffers from multiple chronic diseases.

Figure 4: Geographic Tongue. White plaques on the tongue of a black woman with severe cutaneous plaque psoriasis. A histologic specimen would appear similar to geographic tongue. Reproduced with permission from (Mayeaux, Jr., n.d.)

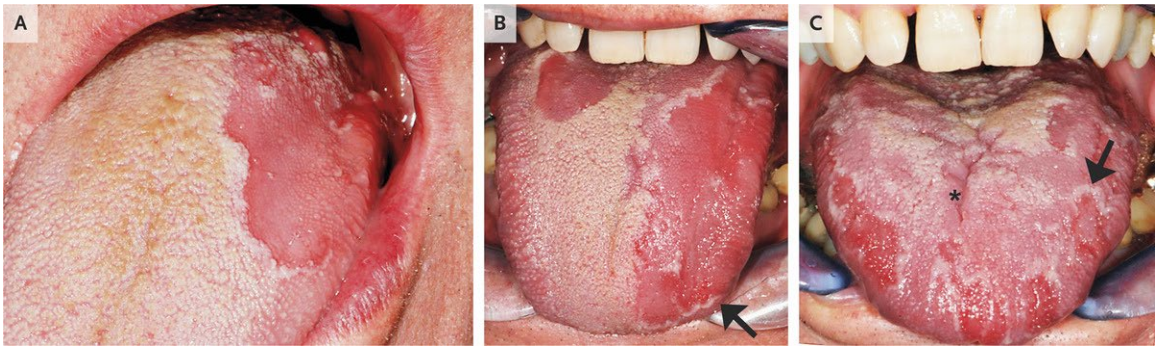

Figure 5: 3-Month Transition with Geographic Tongue A 73-year-old man was referred by his primary care physician, who noted a “weird” red lesion that had been moving across the dorsum of the man's tongue for approximately 3 months. The patient was a former smoker with essential hypertension, hypercholesterolemia, and hyperuricemia. Figure from (Varoni & Decani, 2016).

Geographic tongue affects about 1-3% of the adult population and is more prevalent in females compared to their male counter parts. The etiology of geographic tongue is unknown, but similar to most conditions it is seen as a comorbidity with other diseases. Geographic tongue is thought to be linked to stress and co-occurs with other disorders (Huamei et al., 2015).

BMG is commonly found in patients who suffer from emotional stress, psoriasis, dermatitis, diabetes mellitus, burning mouth syndrome, and patients undergoing hormonal disturbances. GT does physically appear to present itself like other oral conditions. Common differential diagnoses include oral candidiasis, ulcers, cell cancers and leukoplakia. Each condition can visually mimic the other and appear similar on the tongue, although geographic tongue has a better prognosis compared to the other

conditions. Treatments exist to target the discomfort that presents with having GT but there are no treatments that currently exist to assist in clearing up an episodic flare up.

One study conducted found that patients with GT have higher salivary levels of calprotectin and IL-8 compared to those without GT. In conclusion the study supported that as an inflammatory disease, GT leads to an activation of neutrophils and the production of calprotectin within saliva which may play a role in its pathogenesis (Garsjö et al., 2020). However, more research and studies need to be conducted to help develop better treatments and to determine what exactly causes these episodes. It is known that most patients who suffer from GT, the associated patches that show up on their tongue are under the influence of stress or having a psoriasis flare up. Due to this association these lesions can be worsened if they are experiencing high levels of stress. Stress is a common trigger for psoriasis flares and a key treatment is to manage stress levels, so it is possible that the better stress is managed the lower the incidence of GT as well (*Life with Psoriasis*, n.d.).

Bruxism and TMJ Myofascial Pain Syndrome

The medical term for teeth grinding and clenching, is coined as bruxism. An individual who bruxes does so unintentionally, it is an unconscious act and can occur while one is asleep or awake (Hopkins Medicine, n.d-a.). The term ‘bruxism’ was originally given by

Bertrand Frohman in the 1900s, years later Sigmund Freud had a theory of his own where he linked bruxism to having a significant role on one's psychosexual development and the behavior of the individual (James, 2020). Bruxism is linked to one's behavior and their neurological development. Bruxism does not discriminate with age but is more commonly seen in young children and adults who recently experience a sudden lifestyle change, trauma or have high levels of stress. Bruxism is a common sleeping disorder and affects about 10% of adults and up to 15% of children (Cleveland Clinic, n.d.-b). While some individuals who brux are asymptomatic, others do go on to develop symptoms. Bruxism does not last indefinitely, there are treatments available that allow bruxing to halt, and for others they naturally tend to outgrow the condition overtime without treatment.

There are numerous symptoms of bruxism some of which include headaches, loose teeth, wear and attrition of teeth, cheek biting, tongue indentations, lock jaw, pain in jaw when eating or not, TMJ issues, exposed dentin, and tooth sensitivity. ***Figure 6*** illustrates attrition of one's teeth and exposed dentin due to bruxism.

Bruxism is typically diagnosed by a dentist during a routine visit, when the attrition of one's teeth is discovered. Physicians can also diagnose bruxism when physically examining a patient's oral cavity during a visit. Typically, an individual does not self-diagnose themselves with bruxism because it is an unconscious act hence, they do not

know that they suffer from this condition. Majority of the time if a patient is not initially diagnosed with bruxism from a dentist, they find out they suffer from the condition after they exhibit pain from the symptoms it causes.

Stress is commonly linked to awake bruxism and sleep bruxism, it is often discovered that in stressful situations or life periods the incidence of bruxsim is increased. For a definitive diagnosis of bruxism, the muscle activity of an individual is recorded while they are sleeping, the device that does so is called an electromyogram (EMG). The EMG records electrical activity of the temporalis and masseter muscles and sends the data to be analyzed to determine the force and duration of the muscle activity while an individual is sleeping so clinicians can properly diagnose bruxism (Kato et al., 2011).

Figure 6: Attrition, Erosion, and Abrasion Loss of enamel, dentin, or restoration via tooth-to-tooth contact. Image from (Javier et al., 2012)

Just like the other oral conditions previously described, bruxism is also a comorbidity. Many individuals who suffer from bruxism are also generally afflicted with other disorders or neurological diseases (Brannon et al., 2021). Common comorbidities associated with bruxism include sleeping disorders, depression, gastroesophageal reflux disease (GERD), Attention Deficit Hyperactivity Disorder (ADHD), hypertension, tension headaches, temporomandibular disorder (TMD), encephalopathy, epilepsy, psychological stress, personality traits, and anxiety.

Many systematic reviews have proven that emotions act as a trigger for bruxism (Provini et al., 2020). Oral health professionals also link that having too much stress causes bruxism (*Bruxism*, n.d.). Besides stress being the primary cause for bruxism other risk factors include smoking, drug use, anxiety/anxious behaviors, genetic predispositions, medications specifically those that affect neurotransmitters and dementia.

Bruxism has not only had oral effects on the body but systemic effects as well. The effects of bruxism within the oral cavity include but are not limited to cheek biting, temporomandibular disorder, chipped teeth, hypertrophy of the masseter muscles, mandibular tori, and hypersensitivity of teeth. The temporomandibular joint is a synovial joint that allows the mandible to move up and down. The mandible and joints must be properly aligned to allow for chewing, talking, yawning, and swallowing to take

place properly without discomfort. When the joints are not properly aligned then those functions cannot occur, or if they do occur, they are extremely discomfortable.

A temporomandibular disorder occurs when the jaw muscles of the two TMJs are misaligned. TMD impacts the jaw muscles, temporomandibular joints and nerves associated with chronic facial pain. The National Institute of Dental and Craniofacial Research classifies TMD into myofascial pain, degenerative joint disease and internal derangement of the joint (*Temporomandibular Disorder (TMD)*, n.d.). How exactly does Bruxism relate to TMD? Well, bruxism can also cause hypertrophy of the masticatory muscles. When an individual bruxes they are causing frequent trauma to the masseter muscles and that in return causes an enlargement of the facial muscles (Nissani, 2001). Long time exhaustion of these muscles aid in the development of TMD, there is a strong correlation between bruxism and TMD.

There are treatments available to aid in the resolution of bruxism, some treatments consist of conservative approaches while others are more invasive. Treatments include ortho appliances that will prevent the teeth from clenching with the intention of breaking the habit of clenching, as well as stress management and behavioral changes. The more invasive approach concerning treatments of bruxism include injections of botulinum toxin to release tension within the jaw, as well as an even more invasive

approach; reconstructive jaw surgery to realign the jawbone to prevent further grinding. However, bruxism is treatable, and has a great prognosis when caught early.

Habitual Biting of the Oral Mucosa (Morsicatio Buccarum)

Another form of minor unconsciously self-induced oral lesions besides bruxism is cheek biting. The biting of the inner cheek (buccal mucosa) can be an accidental occurrence due to many factors, like chewing too quickly, talking too fast or even related to anxiety. Biting of the cheek can be a harmless accident and does not occur often, while other times it is in fact chronic and not as harmless due to the frequent trauma inflicted onto the buccal mucosa.

Chronic cheek biting is known as morsicatio buccarum and is a compulsive behavior that causes an individual to repeatedly bite the inside of their cheek. Morsicatio buccarum is classified as a body-focused repetitive behavior (BFRB) and is found in the Statistic Manual of Mental Disorders (DSM-5) under obsessive-Compulsive and Related Disorders (Traube, n.d.).

According to Frothingham (2018), there are five primary types of cheek biting:

1. Periodic accidental cheek biting.
2. Regular accidental cheek biting, possibly linked to an unalignment of the mouth.

3. Cheek biting while asleep; similar to bruxism can be prevented with a mouth guard.
4. Habitual cheek biting; A habit/ semi-conscious behavior.
5. BFRD; Obsessive cheek biting that is a hard compulsion to cease.

There are numerous reasons for accidental cheek biting, including when not paying attention resulting in a cheek bite or having a tooth deflection where the teeth are deflected towards the cheek inevitably causing indentations.

Depression and anxiety can influence a person to bite their inner cheeks as a coping mechanism, similar to how individuals bite their nails when stressed, anxious or depressed. BFRB are more psychologically related as a compulsion disorder where an individual must bite their cheeks to feel temporary relief from their anxiety and stress. However, cheek biting is more common for people who experience higher levels of stress and anxiety, majority of the time individuals do not notice the damage they are inflicting. While others, when they notice that they have cheek indentations, they have an uncontrollable urge to fix the damage and over time create a repetitive behavior in which they will bite into the buccal mucosa. It is believed that this process is initiated or influenced by emotional stress and can cause an emotional feedback loop that explains the recurring behavior; cheek biting presents with behavioral and emotional components (Frothingham, 2018).

There are some dangers linked to cheek biting arising from the self-inflicted trauma onto the cheek. Mouth sores can form, deep lesions, ulcers and even oral cancer can form. Oral cancer is not an effect of cheek biting, but it can be worsened in a patient who also suffers from cheek biting. Cheek biting is also another comorbidity just like bruxism, geographic tongue, and periodontal disease. Some oral lesions caused by cheek biting can be seen in ***Figure 7***.

Figure 7: Cheek Biting (Morsicatio Buccarum) Damaged buccal mucosa due to cheek bite, occurred over time the white lining is damaged mucosa (Pindborg et al., 1997).

Dentists are typically the health care provider to diagnose this behavior. There are multiple approaches to treatment for patients who bite their cheeks. Similar to patients who brux reconditioning an individual to avoid this behavior using biofeedback is generally a non-invasive treatment option. Other treatments given that are similar to treating bruxism, include targeting the habit using various oral appliances that will prevent one from using their teeth to bite down onto their cheeks as well as a jaw realignment surgery to realign the jaw to prevent the unconscious biting to occur.

Removal of problematic teeth is another form of treatment if the case is extreme like jaw realignment surgery. Hypnosis and meditation are great ways that are noninvasive treatment methods along with therapy to prevent the incidence of cheek biting. The goal of therapy is to teach the individual better ways to cope with stress and whatever else is triggering this habit. Limiting environmental stressors is a great way to prevent cheek biting as well.

OBJECTIVES

The aim of this thesis is to analyze the effects that cortisol, the stress hormone, has on oral health, and the related oral conditions and manifestations that present themselves due to prolonged cortisol levels and stress. Often, individuals are not aware of the systemic effects chronic stress has on the body and how equally importantly oral health is to one's overall health. Prolonged stress impairs the human body from working to its full capacity; stress can cause the body to become compromised and overworked which leads to numerous disorders and diseases of the mouth.

The goal is to further research oral conditions and manifestations within the oral cavity that present itself due to stress and educate others about their prevalence, prevention, and treatment. More research is needed on some of the oral conditions and their underlying effects. However, it is well known that stress is linked to the underlying triggers for some manifestations, specifically geographic tongue, bruxism, periodontal disease and biting of the oral mucosa.

PUBLISHED STUDIES

Stress is constantly connected to the daily life of individuals and in some instances unavoidable. Social, economic, personal, and emotional stressors are always present and there are numerous studies investigating the impact these psychosocial factors have on health status available (Kaur, n.d.; Kononova & Borysenko, 2021; Maheswari & Gnanasundaram, 2010)

Where there is a high incidence of stress there is an equally high association with negative health behaviors, onset of diseases and overall decline in life expectancy (Brondolo, 2018). Stress is a psychosocial risk factor that has a major effect on health. Stressful situations, anxiety, depression and psychological distress all aid in the susceptibility, severity and course of an illness (Brennan et al., 2019). Associating oral and general health conditions will help identify common risk factors that jeopardize health promotion.

Brennan et al. conducted in 2019 to assess the severity that psychological stress plays on oral and general health. The study occurred over a 24-month timeframe, where the individuals were studied. After the study concluded it was found that worsening oral and general health were associated with individuals who had low income, low social support and higher stress levels (Brennan et al., 2019).

It is well known that individuals with low income and those who come from minority populations experience greater stress levels compared to those who do not. Stress may also play a role in health disparities by affecting behavior (Brondolo, 2018). The American Psychological Association says that higher stress levels can lead to mental and physical health effects that affect life expectancy.

Mental and physical health are directly linked to oral behaviors. Oral hygiene, a by-product of oral behavior, plays a critical role in overall oral health. When the body is experiencing intense levels of stress it not only affects the body internally lowering the immune system's defense response and increasing susceptibility to disease and infection it also adversely affects an individual's behaviors as well. In Deinzer et al's (2005) study, the goal was to examine the relationship between stress, oral hygiene behaviors and clinical outcome. The study occurred over a 3-week exam block for medical students and up to 4 weeks following the exam. The exam that the study participants were taking had high stakes attached to it and was known to give med-students high levels of psychological stress during the exam and during their preparation for the exam.

At the conclusion of the study a significant association between stress, plaque, and gingivitis was indicated. Strong evidence presented that oral hygiene behaviors are

adversely affected by stress. Higher rates of gingivitis were associated with exam taking students than the control students 4 weeks after the exam had taken place results shown in ***Figure 8***. It is also well known that persistent gingivitis is a precursor to periodontitis (Lang et al., 2009).

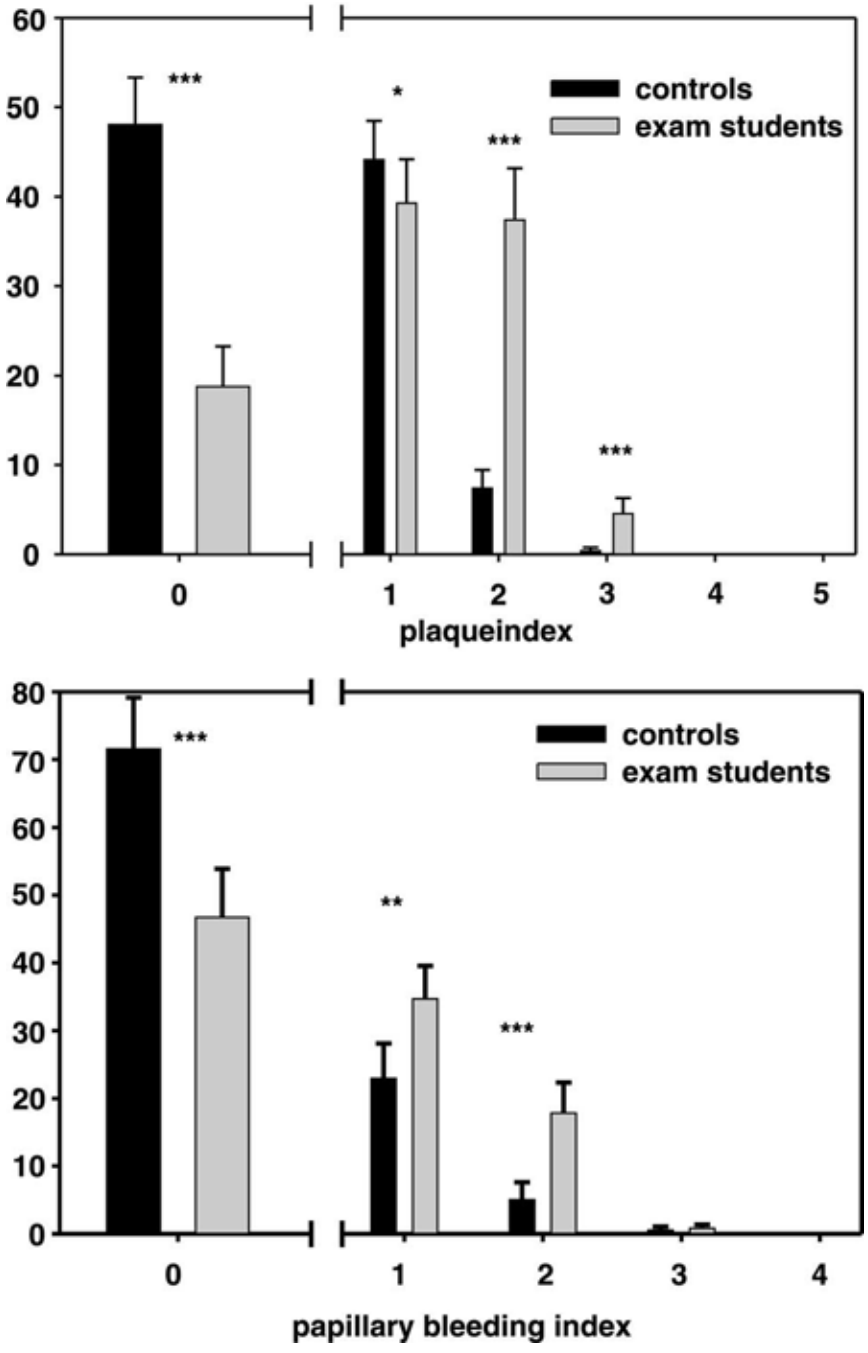

Figure 8: Post Exam Oral Cleaning 4 weeks Post exams oral cleaning report, approximately 10 weeks after professional tooth cleaning. indices of zero indicate absence of plaque or bleeding, respectively. Effect sizes for differences between exam students and controls: *d ≥0.20, **d ≥0.50, ***d ≥0.80.Figure Adapted from (Deinzer et al., 2005)

Salivary alpha amylase is used as a biomarker of chronic stress and stress related oral changes. These biomarkers provide reliable and objective measurements of psychosocial stress and help aid in the assessment of the critical role that stress causes in precipitation of health problems specifically related to mucosal complaints (Vineetha et al., 2014). The study by Vineetha et al., indicated that there was a significantly higher salivary alpha amylase level in the oral mucosal complaint group. Participants of the study were clinically diagnosed to be under high stress or anxiety after a thorough assessment conducted by clinical psychologists. As a result of the salivary alpha amylase activity increasing within patients with chronic psychosocial stress it may be used as a biomarker of chronic stress which has a negative impact over social, mental and physical health of an individual (Vineetha et al., 2014).

Stress and Periodontal Disease

Chronic diseases are accelerating globally and periodontal disease is a component of the global burden; the major risk factor, psychosocial stress (Petersen & Ogawa, 2012). Psychosocial stress plays a role in periodontal disease via biological and behavioral pathways. Frequent and constant exposure to environmental and emotional stressors lead to the wear and tear of the body's biological system and allostatic load. Allosteric load is the cumulative burden that chronic stress has on the individual's life and health outcomes (Guidi et al., 2021). Overriding the body system chronically, causes it to shut

down and allow for conditions that normally are prevented a chance to thrive and cause disease (Sabbah et al., 2018).

Serum cortisol levels are a direct output of the major stress response system and contain properties that allow stress to be investigated and measured (King & Hegadoren, 2002). While investigating the role psychosocial stress influences the periodontium, serum cortisol levels were tested in test subjects to determine if stress was a contributing factor in periodontal disease. 47 test subjects containing males and females were placed into two groups: (Group I) and (Group II). The 16 participants in Group I were diagnosed with chronic periodontitis Group II consisted of 31 stressed subjects. Both groups' stress levels were evaluated using a standard questionnaire, plaque index, gingival index, periodontal disease index and measuring their serum cortisol levels.

Group I showed a statistically significant correlation between 1. Cortisol serum levels and periodontal disease index and 2. Cortisol serum levels and plaque index. Group II indicated a positive correlation between stress, cortisol serum levels, plaque index, gingivitis index and periodontal disease index. In conclusion of the study it is statistically significant that stress may be a contributing factor in periodontal disease (Goyal et al., 2011). ***Tables 2*** and ***3*** indicate the statistically significant correlation between cortisol and plaque index and perinodal disease index in both test groups.

Table 2: Group I Results. Correlation of stress, cortisol serum levels and clinical parameters for group I. (Goyal et al., 2011).

Relationship between	Group I	
	r value	*P* value
Stress and PI	-0.42	0.11
Stress and GI	-0.29	0.27
Stress and PDI	0.06	0.84
Stress and cortisol	0.41	0.12
Cortisol and PI	-0.62	<0.05, s
Cortisol and GI	-0.33	0.21
Cortisol and PDI	-0.57	<0.05, s

PI indicates plaque index; GI, gingival index; PDI, periodontal disease index

Table 3: Group II Results. Correlation of stress, cortisol serum levels and clinical parameters for group II. (Goyal et al., 2011).

Relationship between	Group II (IIa+IIb)	
	r value	*P* value
Stress and PI	0.18	0.34
Stress and GI	0.33	0.07
Stress and PDI	0.002	0.99
Stress and Cortisol	0.10	0.63
Cortisol and PI	0.11	0.55
Cortisol and GI	0.08	0.67
Cortisol and PDI	0.25	0.18

PI indicates plaque index; GI, gingival index; PDI, periodontal disease index

The purpose of Coelho et al., (2020) study was to estimate the association between stress and periodontitis. Out of the 301 individuals that were identified presenting with

stress, 72 were clinically diagnosed with periodontitis. According to the data found, it was concluded that individuals exposed to stress have a 15-36% higher chance of being diagnosed with periodontitis than those who are not exposed to stress. In another study related to stress and periodontal disease, individuals who experience higher levels of perceived stress experience worse oral health related quality of life (Machado et al., 2020). The unhealthy oral behaviors that lead to poor oral health related quality of life may be linked to individuals not properly being able to cope with stressful situations or lack the financial resources to find outlets to better handle the situations. Psychosocial measures of stress associated with financial strain and distress that manifest as depression are significant risk factors for severe periodontal disease in adults (Genco et al., 1999).

Vasiliou et al (2016) used data from a cross-sectional study of 2,412 participants, whose ages ranged from 25-64, the average working age adult, to examine the relationship between current stress and general oral health and oral pain. Those who reported greater stress in their lives reported having poorer oral health and greater oral pain compared to their counterparts who experience less stress. See ***Table 4*** to see the positive and statistically significant data associating stress and oral pain and oral health, with an $\alpha = 0.05$ in Model 1 the association is 0.33 and 0.31.

Table 4: Crude Effects of Perceived and Adjusted Current Stress Index. Model 1 indicated the crude effect of perceived stress while Model 2 indicated the same current stress index but it is adjusted for age and sex of the participants. Adapted from (Vasiliou et al.,2016).

	Model 1	Model 2
Oral Health Outcomes	**Crude Current Stress Beta Coefficient (95 % CI)**	**Adjusted Current Stress and Oral Health Beta Coefficient (95 % CI)**
Pain or discomfort in teeth or gums over past month	0.33 (0.27–0.39)	0.32 (0.26–0.38)
General health of teeth and mouth	0.31 (0.23–0.39)	0.28 (0.19–0.36)

Stress and Bruxism

Chemelo et al., (2020), a systematic review and meta- analysis was conducted to investigate the possible association between bruxism and stress within humans. The review evaluated various observational studies in adult humans who experience stress and those who did not, to confirm the association of stress induced bruxism. After eliminating studies that were identified as being biased and following the preferred reporting items for systemic reviews and Meta-Analyses guidelines, it was concluded that stressed individuals have a higher probability of presenting with bruxism compared to those who are not experiencing stress. Methodology for the search criteria for studies that associate stress and bruxism relationship is found in ***Table 5***

Table 5:Studies Summary. Summary of characteristics and results of the included studies for the meta-analysis (Chemelo et al 2020)

Study design/ Country (Reference)	Participants (Source of sample/sample size)	Age	Stress evaluation	Bruxism evaluation	Statistical analysis	Results
Cross-sectional/Iran (13)	Isfahan Shahid Vatan Pour Airforce Base/($N = 172$) 86: Presence of stress 86: Absence of stress	40 years	12-item General Health Questionnaire (GHQ-12)	12-item General Health Questionnaire (GHQ-12) and clinical examination	Chi-square test; Independent *t*-test and Pearson	Indicated a significant positive association between stress level and bruxism ($p < 0.05$).
Cross-sectional/Turkey (14)	Protective-care facilities in Kocaeli, Turkey and primary school, one elementary school and one high school in Kocaeli, Turkey/($N = 385$) 184: Presence of stress 201: Absence of stress	8–18 years	Questionnaire about stressful life events	Questionnaire about bruxism (diurnal tooth grinding/clenching) and clinical examination	Chi-square, Spearman's correlation and Mann–Whitney *U*-tests	The mean number of oral parafuction (bruxism) was higher in children who reported emotional problems than in children who did not report any problems ($P < 0.05$)
Cross-sectional/Lithuania (15)	Department of Preventive and Pediatric Dentistry, Medical Academy, Kaunas, Lithuania/($N = 200$) 171: Presence of stress 29: Absence of stress	15–19 years	Purpose-designed self-reported questionnaire; regarding stress experience; describe stress intensity and allocate into 10 stress intensity levels.	Questionnaire about systemic conditions (stress, GERD, bruxism)	ANOVA and chi-square test	Stress have an association with oral health status. The prevalence of bruxism increases with higher stress levels. The percentage of stress distribution among respondents with bruxism was detected statistically ($X^2 = 12.157$; $p = 0.002$)
Cross-sectional/Brazil (16)	Brazilian Navy/($N = 486$) 103: Presence of stress 383: Absence of stress	19–48 years	Stress symptoms inventory (SSI)	Extra and intraoral physical examination: Presence of wear facets using the Ordinal Wear Severity Scale Occlusal. Self-report of grinding bruxism sounds; painful sensitivity upon touching the masticatory muscles.	Chi-square test	The statistical analysis of the correlation between stress and bruxism was significant ($P > 0.05$).
Cross-sectional/Brazil (17)	Brazilian Police Officers/($N = 394$) 180: Presence of stress 214: Absence of stress	Mean age: 35.5	Stress symptoms inventory (SSI)	Presence of wear facets on the anterior and/or posterior teeth. Score in accordance with the ordinal scale of wear severity. Grinding bruxism sounds; painful sensitivity upon touching the masticatory muscles.	Chi-square test	Emotional stress was associated with bruxism, independently of the type of work done by the police officer. The prevalence association between emotional stress in police officers and bruxism was statistically significant ($P = 0.0004$).
Cross-sectional/Israel (18)	Israel Air Force/($N = 57$) 35: Presence of stress 22: Absence of stress	25.8 years ± 4.3 SD	Psychological questionnaires to assess two factors: Magnitude of workplace stress and Coping style.	Dental examination: tooth wear visually	Chi-square t- test, ANOVA following by *post hoc* comparisons.	The results of the questionnaires among pilots revealed a stress level of 3.84 (SD 0.54), whereas among non-pilots the stress level was 3.59 (SD 0.48). Association between work environment stressful demand and bruxism was clearly more noticeable among pilots (69%) than among non-pilots (27%).

The study by Monaco et al. in 2002 was initiated to test the hypothesis that anxiety states and stress affect the development of bruxism in children. Eighty-six children with ages ranging from 1 to 7 years old were evaluated to determine if there is a significant difference between anxiety scores of bruxers compared to non-bruxers. The results indicate that a bruxer child has a 16x greater probability to be anxious than a non bruxer child. Stress and anxiety are both emotional responses but stress has an identifiable trigger and anxiety is present without a trigger or stressor, both have identical symptoms (*What's the Difference between Stress and Anxiety?*, 2020.).

1784 employees who worked at the Finnish Broadcasting Company were mailed a self-adminstered questionnaire to analyze whether perceived bruxism was associated with stress, age, gender, work role and occupational health care (Ahlberg et al., 2002). The questionnaire covered questions regarding demographics, total stress experience, the use of health servies provided by the company and perceived bruxism. Of the 1339 participants, it was concluded that frequent bruxism is significantly positively associated with experiencing severe stress and may reveal ongoing stress in normal work life.

The study by Cavallo et al. t aimed to correlate the relationship of bruxism and stress and its effects on the quality of life of college-age students. Sleep and awake bruxism were both investigated and its correlation with perceived stress in a group of 278 students. Results were based on students' responses to a socio-demographic test and

the perceiverd stress scale. There was a 37.7% prevalence for awake bruxism and a 31.8% prevalence for sleep bruxism. University students showed both higher bruxism and stress levels compared to the general population with males having a positive correlation between the stress and bruxism events (Cavallo et al., 2016).

Stress is commonly linked to awake bruxism and sleep bruxism. It is often discovered that in stressful situations or stressful life periods the incidence of bruxism is increased. Electromyographic activity is measured to determine how much rhythmic masseter muscle activity is occurring while an individual is sleeping so clinicians can properly diagnose bruxism (Kato et al., 2011).

Stress and Geographic Tongue

A benign yet common oral condition, geographic tongue, is generally asymptomatic and transient but can present with symptoms and occur chronically depending on the individual. Geographic tongue is often associated with other systemic diseases such as allergies, stress, hormonal variations and psoriasis (Nandini et al., 2016). Jainkittivong & Langlais (2005) confirm the various systemic diseases that are associated with geographic tongue.

Hooman et al. (2010) tested 60 patients with geographic tongue and 60 patients without geographic tongue to determine if stress was related to the etiology of the condition. Based on the results of the study there is an association between stress and geographic tongue. Knowing the etiology can lead to better prevention strategies. Decreasing stress in geographic patients does lead to the healing of the lesions (Hooman et al., 2010).

Stress and Morsicatio Buccarum

Sewerin*'s study entitled A Clinical and Epidemiologic Study Morsicatio Buccarum/Labiorum,* included 8,589 individuals ages 5-47 years old, each participant attended the Royal Dental College, Copenhagen. Of the 8,589 study participants 42 were diagnosed with morsicatio buccarum. Morsicatio buccarum was more common in individuals between the ages of 15-19 years old. 93% of the patients with morsicatio buccarum were aware of their condition and habit and indicated that the condition has persisted for years prior to the study being conducted. Several cases may be linked to personal problems and mental stress and "intellectual" work may predispose individuals to the habit (Sewerin, 1971).

Stress and Covid-19

When stress is experienced, oral health often gets neglected and the frequency of visiting the dentist is low. During the COVID-19 pandemic dental healthcare providers

noticed the prevalence of stress related oral health conditions increased. Covid-19 caused a lot of uncertainty and added a lot of stress into people's lives. Due to the pandemic schools and businesses were forced to close, leading to many losing their jobs and sources of income. As the virus spread many were placed on restrictions to keep others from becoming sick and unintentionally split up families across the world (*Impact of COVID-19 on People's Livelihoods, Their Health and Our Food Systems*, 2020; *The Covid-19 Effects on Societies and Economies | News*, n.d.). The added stress from the pandemic was well observed, dentists reported that there was an increase in the prevalence of teeth grinding, clenching, chipped teeth, cracked teeth and temporomandibular joint disorder symptoms. Conditions all associated with stress (*HPI Poll: Dentists See Increased Prevalence of Stress-Related Oral Health Conditions*, 2021.) Results seen in ***Figure 9***.

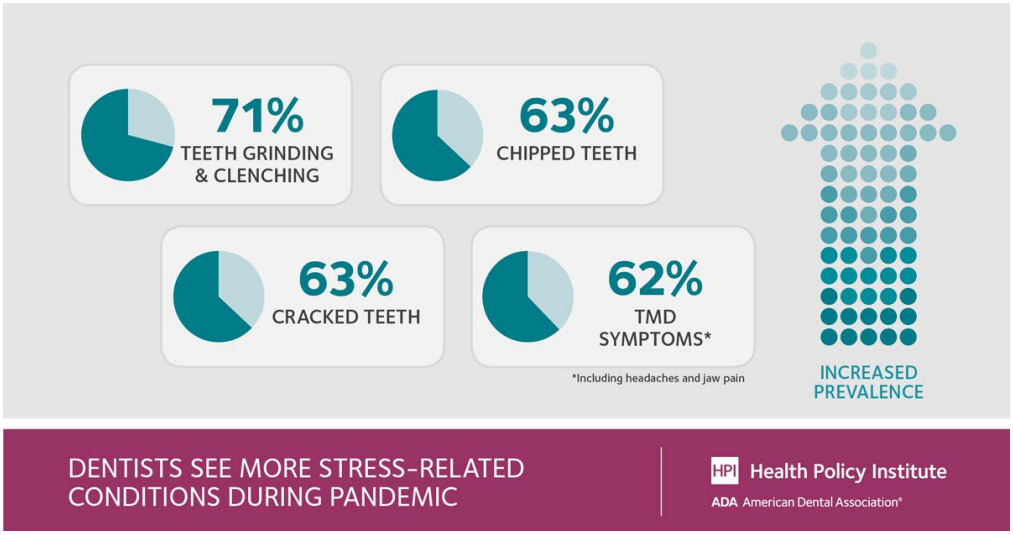

Figure 9: Stress-Related Conditions During Covid-19 Pandemic. Related oral conditions influenced by stress during the Covid-19 Pandemic in 2020. Adapted from (*HPI Poll: Dentists See Increased Prevalence of Stress-Related Oral Health Conditions*, 2021.).

DISCUSSION

Further research on stress and its relation to oral conditions should be imperative due to the increasing numbers of individuals experiencing stress, especially in 2020 due to the Covid-19 Pandemic. As health professionals see a rise in the number of patients being diagnosed and treated for anxiety and depression it is imperative that more researchers and physicians educate individuals on the role stress plays systemically and the manifestations that are seen orally.

According to the American Psychological Association (APA) two in three adults say they experienced an increase in stress over the course of the pandemic. Half of the adults interviewed reported that stress has negatively affected their behaviors and relationships (APA, 2020.). Many oral conditions are exacerbated by stress which include periodontal disease, cold sores, dry mouth, geographic tongue, ulcers, bruxism, and cheek biting to name a few.

Stress is the principal factor that promotes the initiation of tobacco use (Torres & O'Dell, 2016). In 2021 cigarette smoking is currently the leading cause of preventable diseases in the United States (CDCTobaccoFree, 2021). As the incidence of stress continues to rise, there will also be an increase in cigarette smokers and tobacco users as well. Borojevic (2012) credits smoking to being a well-established risk factor for periodontal

disease. The effects of stress not only directly affect systemic health and oral behaviors but also indirectly causes and exacerbates oral diseases. More education on the effects stress has on the human body is needed to bring awareness to the alarming conditions it causes. ***Figure 10*** illustrates the direct and indirect pathways that psychosocial stress inflicts on behavioral changes and how it leads to periodontal disease (Reners & Brecx, 2007).

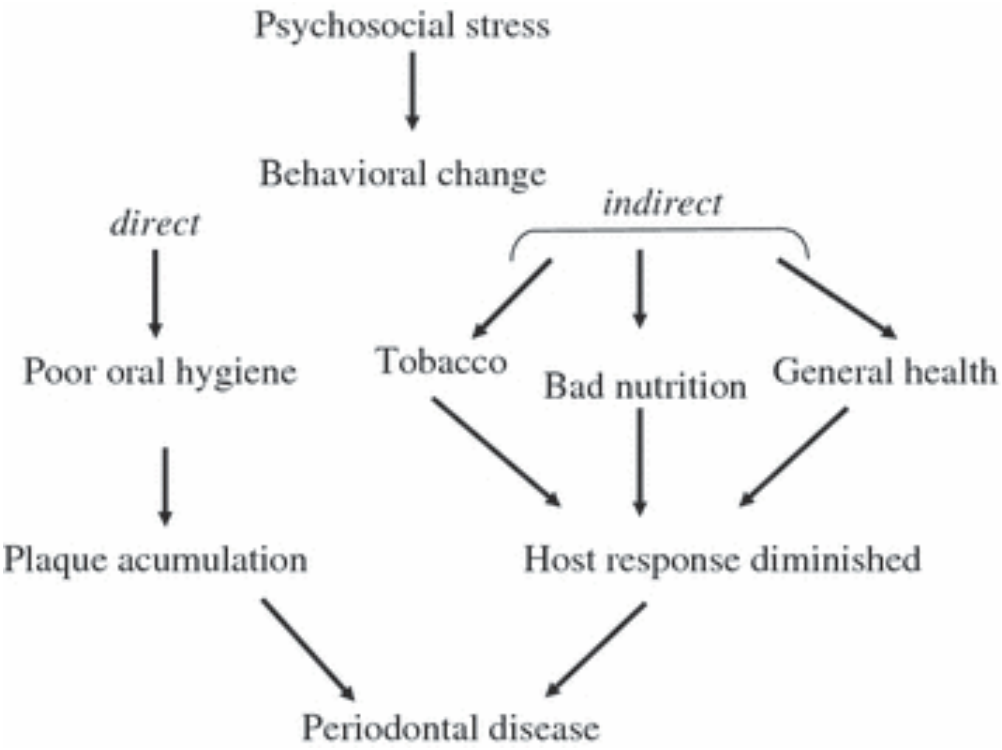

Figure 10: Psychosocial Stress Diagram Pathway that psychological stress plays on behavioral changes and its related direct and indirect behaviors that cause periodontal disease (Reners & Brecx, 2007).

The incidence on the progression of periodontal disease in *Relationship of Stress, Distress, and Inadequate Coping Behaviors to Periodontal Disease* was believed to be linked to inadequate coping behaviors related to stress. It was suggested that further research be conducted to establish the time course of stress, distress, and inadequate coping skills with respect to the onset and progression of periodontal disease, and the mechanisms that explain this association (Genco et al., 1999).

Stress should be included as a factor in models of patient compliance (Deinzer et al., 2005). Using stress as a factor in patient compliance and an indicator it will help to target intervention to specific levels of risk and will help in integrating oral and general health promotion (Sabbah et al., 2018).

Stress and anxiety may originate within the workplace, at home, within the community, but it can also be related to certain professions and have effects on individual behaviors. Many have anxiety towards certain professions, and it affects their perspective of life, one of these professions that bring anxiety to people is dentistry. Bell et al. (2012) conducted a study analyzing dental anxiety and the oral health outcomes associated with it. Individuals with high dental anxiety are associated with poor oral outcomes. More studies show that dental anxiety is a public health challenge and can progress into lower self-motivation concerning their oral health behaviors (Nermo et al., 2019).

Within the last 20 years there has been an increase in the number of studies regarding bruxism and its relation to stress. However, in the future there needs to be more research directed to achieve a better distinction between the relationship regarding sleep-bruxism and stress (Manfredini, 2021). Most studies successfully linked stress for being the primary risk factor for causing sleep bruxism but in Cavallo et al. (2016) the female university students included in the study had higher bruxism stress and bruxism levels compared to the general population. Although females presented with higher stress levels there was only a positive correlation for the male students between stress and bruxism. Further studies should be done to see if there is a link between female stress and its effects on bruxism compared to male stress levels and its effects on bruxism. Observing if gender also plays a role in the progression of the oral condition in the presence of stress should be evaluated as well.

Finding research in the early 2000's relating stress to various oral conditions presented difficult to find, oral hygiene behavior studies were rarely studied in certain contexts (Deinzer et al., 2005). Previously, studies assessing the effects of stress on the body and stress affecting oral behaviors were not done often, but as the prevalence of stress is increasing in the world more of these studies need to be conducted. However, there were few studies conducted that did have associations between stress and oral health but received mixed support (Armfield et al., 2013).

Shareef & Ettefagh (2021) present that some believe that geographic tongue is an oral manifestation of psoriasis, while others do not. There is a need for more research to be collected on psoriasis and geographic tongue to validate or void this association. Although, there is growing knowledge about the influence of psychosocial factors on health, and its influence on TMD and other oral habits (Knibbe & Lobbezoo, 2020).

When conducting research for this thesis trying to find articles, journals and case studies that related stress to specific oral and systemic diseases, the search did not yield a decent number of useful results. MeSH terms used in the search included but are not limited to: Oral Disease, Stress, Bruxism, Geographic Tongue, Cancer, Ulcers, Anxiety, Covid-19, Oral Hygiene and Cheek Biting. Finding scholarly examples solely on how chronic stress affects the oral cavity was difficult. Focusing the research on stress in general and then separately the various oral conditions presented within the thesis honing in specifically on their etiology gained more progress on finding scholarly information to use within this thesis.

Advancements in research, case studies and articles looking at the effect of stress and serum cortisol levels on oral health will likely ease the burden of those individuals who suffer with the oral manifestations and conditions describe in this thesis. Since dentistry and health care are constantly evolving, these advanced studies will lead to greater public awareness about the importance of preventing and treating psychosocial stress.

Ultimately, this research will also shine a light on how oral health and systemic health work simultaneously to maintain a healthy lifestyle.

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