# MALOCCLUSION SEVERITY AND ENAMEL DECALCIFICATION RELATIONSHIPS IN FIXED ORTHODONTIC TREATMENT

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## ABSTRACT

**Objectives:** Orthodontic patients treated with traditional metal braces exhibit an increased risk of forming enamel decalcifications known as white spot lesions (WSLs) on facial surfaces of teeth. This is due to the increased surface area around which plaque can adhere with brackets bonded. It is not currently known whether malocclusion complexity contributes to WSL formation. The Salzmann Index (SI) is a set of criteria that quantifies malocclusion complexity. In Pennsylvania, it is used in patients under 21 years to determine eligibility for orthodontic Medicaid insurance coverage. This study aims to determine if SI score impacts the incidence of WSLs among patients treated with traditional braces.

**Methods:** 200 subjects between 10-18 years who completed $\geq$12 months of orthodontic treatment with metal braces were compared for SI scores and oral hygiene (OH). Pre-treatment OH was obtained from clinical exam forms. Pre- and post- intraoral photos of facial surfaces of upper and lower anterior dentition segments were analyzed. Presence and severity of WSLs, and mid- and post-treatment OH were determined by amount of tooth surface with lesion involvement, and localized vs. generalized gingival swelling, redness, and plaque, respectively. Hygiene and WSL's were scored on 3-point scales. Statistical analysis was performed for each variable using R2 values.

**Results:** There was a significant difference in WSLs pre- versus post-treatment ($p<0.001$). Higher SI score, average overall OH, and pre-treatment WSLs were all significant predictors of post-treatment WSLs ($p=.007$, $p=.014$, $p=.000$, respectively). Salzmann Index score and OH showed moderate level correlation to WSLs ($R2=0.22$ for

both), while pre-treatment WSLs showed low level correlation (R2=0.07). Duration of treatment was not a significant predictor of post-treatment WSLs (p=.654).

**Conclusion:** Findings suggest that patients with higher SI scores may be advised on greater predilection to WSL development regardless of treatment duration. Those with poor pre-treatment OH may benefit from greater reinforcement and monitoring of OH. Placement of orthodontic sealants on facial tooth surfaces prior to bonding fixed appliances should be considered to increase prevention of WSLs.

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# CHAPTER 1

# INTRODUCTION

Specific Aims: The aim of this study is to investigate whether a higher Salzmann Index score is correlated with an increased white spot lesion incidence among patients treated with traditional braces, with consideration of treatment duration, pre-treatment WSLs, and oral hygiene.

Orthodontic patients show higher incidence of white spot lesions than untreated individuals (Gorelick, 1982). Patients treated with traditional braces have been shown to exhibit a higher risk for developing facial enamel decalcifications known as WSLs when compared to those treated with clear aligners (Buschang, 2019). Private practice patients are at elevated risk to develop WSLs with extended length of treatment, but caries risk, oral hygiene, and gingival health all play roles (Brown, 2016). In one study, patients with an unfavorable clinical outcome score, measured via the Discrepancy Index, were shown to be at risk for WSL development during orthodontic treatment (Chapman, 2008). Overall, about 25% of patients that undergo orthodontic treatment develop WSLs, with pre-existing WSLs being the greatest risk factor (Julien, 2013). Despite this, there are no present studies that establish a clear connection between pre-treatment malocclusion severity and rate of WSL development.

The Salzmann Index is a qualifying criterion utilized in Pennsylvania to determine eligibility for orthodontic treatment coverage in patients on medical assistance (Rosner, 2020). It classifies severity of malocclusion by assigning numeric tallies to several criteria that fall under two categories, the first being intra-arch deviations, and the second being

inter-arch deviations. A total score is reported after adding scores from each section. The Salzmann Index is the accepted method of scoring case complexity for Pennsylvania patients.

It is desirable to investigate whether pre-treatment malocclusion severity has an impact on the formation of white spot lesions (WSLs) in patients treated with traditional metal braces. Thus, itis critical to further investigate the relationship between malocclusions and the incidence of WSLs to better predict each patient’s risk prior to bonding.

# CHAPTER 2

# REVIEW OF THE LITERATURE

## 2.1 White Spot Lesions

### *2.1.1 Diagnosis and Etiology*

White spot lesions are chalky white areas of demineralization that appear on the facial surfaces of teeth. They are considered the "first sign of caries-like lesion on enamel that can be detected with the naked eye" and have also been referred to as "subsurface enamel porosity from carious demineralization" that present as "milky white opacity…on smooth surfaces" (Srivastava, 2013). They correspond to loss of mineral at the surface or the subsurface level of the enamel layer of teeth, but do not extend into the dentin. There are multiple etiologies of white spot lesions that can act upon the enamel differently, impacting the characteristics and clinical appearance of the lesions. The cause of white spot lesions and the degree to which they extend into enamel is relevant to their treatment. (Sampson, 2020).

Etiology of white spot lesions can be systemic or local. The classic WSLs observed following orthodontic treatment appear due to four main local factors: bacterial plaque, fermentable carbohydrates, the tooth surface itself, and time (Srivastava, 2013). Caries can also have a genetic link, making some individuals more prone than others. A genome-wide association study of dental caries in diverse populations found associations in or near genes with roles in inflammation, which can influence host susceptibility to oral microorganisms that play roles in the process of caries development (Alotaibi, 2021). Some WSLs are a

result of systemic factors. Fluorosis is a condition that results when one is exposed to elevated levels of fluoride during the process of enamel mineralization. It is known that fluoride can be therapeutic or harmful in different contexts depending on the amount administered and the health status of the patient (Watts, 2001). In controlled amounts it is beneficial in reversing incipient lesions, preventing their progression to cavitation. In excess amounts and upon ingestion into the body, systemic fluoride elevation impacts developing teeth by rendering the enamel under-mineralized and more porous. Clinically, the teeth may present with chalky white spot lesions, or with brown lesions, or pitted lesions. The severity of fluorosis can be staged according to the clinical manifestation. It can often be distinguished from plaque-induced white spot lesions in that fluorosis can present as horizontal, linear, or small opaque scattered and irregular lesions on the facial surfaces of incisors and canines.

Traumatic hypomineralization is a type of white spot lesion that can manifest in a permanent tooth upon its predecessor being mechanically or chemically subjected to trauma. These are observed only on the successor teeth of primary teeth that underwent said trauma. This is due to inflammation that occurs around the apex of the primary tooth, which can disrupt the enamel mineralization of the successor (Almuallem, 2018). Diagnosis usually involves collecting a detailed history of primary tooth trauma from the patient/patient's guardian and observing a white lesion only on the successor tooth of the affected primary tooth. The lesion is most likely to present within the incisal third of the tooth and appear well defined (Deveci, 2018). They are hypomineralized at the subsurface level rather than at the most superficial surface (Torres, 2015).

Demineralization lesions of enamel are induced by plaque, which can accumulate due to poor hygiene practices, plaque accumulation around orthodontic treatment with braces, or both. In their early form, white spot lesions exhibit sound superficial enamel, but underneath, the subsurface region is porous. The loss of mineral content allows air or water to enter as a result. This is why enamel with white spot lesions produces a lower refractive index than that of intact sound enamel (Cazzolla, 2018). When they are observed in orthodontic patients following debonding, they often present around where the bracket used to be bonded. One study referenced around 26% of patients treated in a private practice setting developing lesions following orthodontic treatment (Buschang, 2019). Other studies report up to 70% (Mizrahi, 1982). This is of great concern due to the detrimental effect of WSLs on esthetics, and the risk they pose being that they signify incipient decay.

Molar-incisor hypomineralization refers to white spot lesions that result due to systemic etiology and present on first molars or incisors (Torres, 2011). When the enamel is examined, it exhibits a porous nature and elevated carbon composition, with decreased levels of calcium and phosphate. This causes the enamel to present with either creamy-white or yellow-brown opaque lesions and renders it more prone to fracture. Unlike previous examples of white spot lesions, molar-incisor hypomineralization lesions occur at the dentin-enamel junction rather than at the outermost layer of enamel. This contributes to a higher rate of enamel loss, sensitivity, and severity of decay. The overall etiology is not completely characterized, but it is accepted that interruption of normal amelogenesis leads to the clinical result. This can occur due to poor nutrition, lack of oxygen during development, antibiotic use in children younger than three years, and illness (Deveci,

2018). It is critical to collect a detailed health history and any illnesses the patient may have experienced before birth. This allows greater certainty when generating a differential diagnosis for lesions involving enamel that may be present upon clinical examination, which enhances one's ability to determine a patient's risk of WSL increase or incidence with orthodontic treatment.

### *2.1.2 Risk Factors*

Patient demographics, income, educational status, oral hygiene regimen, use of fluoride toothpaste, and professional toothbrush use have all been investigated in the context of WSL formation during orthodontic treatment, with the following conclusions. Treatment with fixed braces increases WSL formation (Buschang, 2019). Prevalence of WSLs is higher among those whose treatment duration exceeds seventeen months. Patients with unhealthy diets exhibit increased WSL prevalence. Subjects of younger ages with high sugar diets during orthodontic treatment are most prone to developing WSLs (Jiang, 2015).

### *2.1.3 In Orthodontics*

When patients are bonded with fixed orthodontic brackets, the accumulation of plaque around the bracket contributes to increased risk of WSL formation, which is then visible in the shape of the bracket following debonding (Cochrane, 2010). Such outcomes are considered unesthetic and undesirable. WSLs that form following orthodontic treatment have also posed a significant challenge in their management once braces are removed. The quality of evidence regarding WSL treatment is low, and it does not support remineralizing

or camouflaging as successful strategies. Often times, invasive approaches are required in order to eliminate both the esthetic and biologic issues posed by the presence of white spot lesions, depending on their level of involvement in the enamel with respect to proximity to dentin. There remains a need for further studies with longer follow up (Sonesson, 2017).

### *2.1.4 Prevention*

There is mixed evidence of successful interventions for the prevention of WSL formation during orthodontic treatment. Possible preventative measures studied include various forms of fluoride varnish application (including Elmex fluid, Fluor Protector S, fluoride foam) use of various forms of fluoride toothpastes (including Clinpro 5000 or Clinpro topical tooth crème, 1100 or 5000 ppm fluoride toothpaste), bonding of brackets with fluoride-containing resin, use of combination rinse containing sodium fluoride and amine fluoride, and use of fluoride-releasing primer (Opal Seal). Fluoride varnish was only found to reduce WSL prevalence when applied regularly or professionally, but not consistently (Sonesson, 2020)(Jiang, 2013)(Rechmann, 2018)(Kumar Jena, 2015). Studies where it was applied only at the start of treatment did not display a difference versus high quality toothbrushing with fluoride paste (Kirshneck, 2016). High fluoride toothpaste use was shown to decrease WSL development in all studies evaluating its use (Kau, 2019)(Sonesson, 2014). Fluoride-releasing composite did not display preventative effects against WSLs in fixed orthodontic patients (Alabdullah, 2017). Use of fluoride rinse contributed to optimized oral health and reduced WSLs (Van der Kaaij, 2015). Fluoride-releasing primer did not display an impact in WSL prevention (Tufekci, 2014). It can be

concluded that in terms of preventing WSLs, it is best to recommend regular use of high fluoride toothpaste, and regular application of fluoride varnish for the best results, although fluoride varnish alone does not guarantee desired results.

Orthodontic sealants have also been introduced to prevent the formation of WSLs with fixed orthodontic treatment. They do not require patient compliance and allow support of enamel surfaces for an extended time in treatment. Factors of importance in efficacy of sealant use, however, include antibacterial properties, color permanency, acid and brush abrasion resistance, and impact on shear bond strength. One review of orthodontic sealants found that they were significantly effective in WSL prevention (Linjawi, 2020).

### *2.1.5 Treatment*

Icon resin infiltration (ICON) is used to treat fluorosis lesions. It is also often utilized to address poor esthetics associated with severe WSLs, especially those that involve the majority of the tooth surface and extend towards the level of dentin. It aims to prevent further enamel mineral loss via blocking porous sites in the lesion using resin. The resin is low viscosity and light cured. The surface is first etched to allow better penetration of resin (Torres, 2011). Drying agent is then used. This pulls the resin into the lesion via capillary action. Once the microporosites are filled, further loss of mineral will not occur. If this technique does not work, direct or indirect restorations can be completed. However, it is important to note that the severity of the fluorosis may interfere with successful bonding to enamel (Ermis, 2009) (Swift, 2009). To combat this, one can utilize a two-step self-etch technique to enhance bonding. The success of resin infiltration can be assessed by measuring the refractive index of the enamel after the procedure is completed. The

refractive index of normal healthy enamel is 1.65. That of enamel in the region of a white spot lesion ranges from 1.0 to 1.33. Once resin infiltration is completed, the index can be raised to around 1.48 (Denis, 2013).

Treatment of traumatic hypomineralization usually takes multiple attempts. Studies show more success by first performing external bleaching, followed by resin infiltration. As a rule of thumb, treatment of demineralization lesions should be performed with the most conservative approach before resorting to more invasive measures. One can begin with fluoride treatment following removal of braces to remineralize enamel to its sound form via fluoride varnish or toothpaste (Derks, 2004). Casein phosphopeptide amorphous calcium phosphate (CPP-ACP) pastes can also be used. They work by creating an environment rich in calcium and phosphate which, when combined with saliva, flow over the tooth surface and aid in remineralization (Guzman-Armstrong, 2010). If no improvement is observed, bleaching can be performed to disguise the appearance of lesions that were not reversed. If no clinical changes are seen, a last resort treatment that can be consulted is micro-abrasion. Hydrochloric acid and pumice are used together to take away micro-layers of the lesion (Greenwall, 2006). Then, resin infiltration is utilized to fill the porosities that result, producing a smooth finish more uniform in hue. Bioactive glass has also been utilized as a form of remineralization therapy to reduce WSLs after orthodontic treatment (Fernando, 2017). In one study, bioactive glass in BiominF toothpaste performed better than CPP-ACP in terms of esthetic results, and showed significantly reduced intensity of fluorescence, implying possible remineralization (Salah, 2022).

Molar-incisor hypomineralization should be diagnosed as early as possible to maximize the ability to treat it and prevent its progression. Dietary evaluation and indicated changes should be implemented. Toothpaste containing a minimum of 1,450 ppm fluoride is recommended. Fluoride varnish should then be applied with the use of CPP-ACP in combination. The ability of CPP-ACP to bond to biofilm present on enamel surfaces allows salivary calcium, phosphate, and fluoride to be maintained as close to the lesion surfaces. This enhances the ability of the body to remineralize the lesions rather than relying on external sources of minerals (Pasini, 2018). Any molars with MIH should receive sealants in the occlusal fissures. Micro-abrasion techniques can be tried once the tooth surface has been remineralized to improve the esthetic appearance. Utilizing bleaching approaches can often result in severe sensitivity because of the porosity of the lesions at the start of treatment. It is best to alternate CPP-ACP and hydrogen peroxide in a 6:1 or 4:3 ratio of days, respectively, to achieve results. If they are insufficient, resin infiltration can be tried, but because the hypomineralized region is closest to the dentin-enamel junction rather than in the superficial enamel, it may need to be performed in a more aggressive manner involving sandblasting (Attal, 2014). Restorations should be considered as a last resort.

## 2.2 Malocclusion

### *2.2.1 Classification*

Malocclusion describes the relationship between a full complement of teeth in both maxillary and mandibular arches as they relate to each other, in a fashion that varies from ideal. Edward H. Angle of the Angle School of Orthodontia first described his now well-known Angle's classification of malocclusion in the 1890s. It is critical because it defined the subtypes of malocclusion, but also provided a definition of ideal occlusion. He proposed that if the mesiobuccal cusps of the maxillary first molars occlude in the buccal grooves of the mandibular first molars, this constitutes normal occlusion, or Class I. Malalignment within an arch exhibiting such a molar relationship is considered Class I malocclusion. The mandibular molars being positioned more distally relative to the maxillary molars is considered Class II malocclusion. The mandibular molars being positioned more mesially relative to the maxillary molars is considered Class III malocclusion. This allows for a total of four categories of occlusion: normal occlusion, and Class I, II, and III malocclusions (Proffit, 2019).

In the mid- and late-1960s into 1970, two national level surveys were conducted on children aged 6-11 and 12-17 years, respectively, with one of its goals being estimation of malocclusions. It is termed the National Health and Nutrition Estimates Survey III (NHANES III). The survey expanded malocclusion to also include the irregularity index of incisor alignment, midline diastemas exceeding 2 mm in width, measures of overbite/open bite and overjet/anterior crossbite, and presence of posterior crossbites. These all pose potential challenges in correcting malocclusions (Proffit, 2019).

### *2.2.2 Within and Between Arches*

The irregularity index used in NHANES III is defined by the sum of the millimetric distances from the contact points on each incisor tooth to the contact point that it *should* touch. For example, mandibular incisors, in their ideal positions, should form a continuous arc where all contact points align in the transverse plane. But crowded mandibular incisors will consist of a series of lines in the anterior-posterior sagittal plane that do not connect. Diastemas, especially those between the central incisors, are another characteristic contributing to intra-arch malocclusion. They describe width of space between two adjacent teeth, and when they exceed 2 mm they are not expected to spontaneously correct with growth (Proffit, 2019).

All other perimeters are only measured based on the relationship between the arches. Overbite describes amount of vertical overlap between the incisors, with an ideal being that of 1-2 millimeters. An open bite would constitute negative overbite, where the incisors exhibit no vertical overlap. An edge-to-edge relationship would constitute 0 mm of overbite. Overjet describes the amount of horizontal distance between the maxillary and mandibular incisors in the sagittal plane, with 1-2 mm being ideal. Reverse overjet, recorded with a negative value, would constitute an anterior crossbite. Posterior crossbites can be unilateral or bilateral, wherein the maxillary premolars and/or molars are inside of those of the mandibular arch in the transverse plane. Buccal crossbites may also exist, where one or more maxillary teeth is completely outside of the mandibular opposing teeth in the transverse plane, such that there is no cusp occlusion. Angle's molar classification can only be measured using both arches in relation to each other (Proffit, 2019).

## 2.3 The Salzmann Index

### *2.3.1 History and Utility*

The American Association of Orthodontists (AAO) first outlined orthodontic treatment that is medically necessary as correction of those malocclusions that compromise physical, emotional, or dental well-being of a patient. This occurred shortly followed the implementing of Medicaid under the Social Security Act in 1965. At this time, the AAO chose the Salzmann Index as its objective method of determining eligibility for orthodontic treatment coverage for handicapping malocclusions under Medicaid insurance (Salzmann, 1967). However, half of funding is allocated by the federal government and the other half by each individual state. In 1985, the AAO decided against utilization of the Salzmann Index, or any index for that matter, in determination of medical necessity of orthodontic treatment (Daniels, 2000). But due to half of the budget coming from the state, many states continue to use the Salzmann Index for submitting for orthodontic coverage, one of those being Pennsylvania (Patel, 2021).

A Salzmann Index cannot be completed if a patient presents in mixed dentition. If a patient exhibits permanent dentition with no primary teeth present, the index can be obtained. The Salzmann Index is divided into Intra-Arch and Inter-Arch Deviation subsections. Each one receives its own score, and the sum of those scores is the total Salzmann score. The Intra-Arch deviation section classifies the maxillary and mandibular arches separately, based on missing, crowded, or rotated teeth in the anterior and posterior segments, and presence of open or closed spacing. Open spacing it true space between two adjacent teeth, whereas closed spacing is space that exists due to an impacted or partially

erupted tooth, that when it is fully erupted, would take up more space when the widest mesio-distal portion is exposed. Anterior maxillary classifications hold two times the overall point value in this section than the others. The maximum score that could be allotted here is 20 (Appendix 1).

The Inter-Arch deviation section contains two subsections, one assessing the relationship between the arches in the anterior segment, and the other in the posterior segments. The anterior segment is scored based on overjet, overbite, crossbite, or openbite. The number of teeth involved in any of these characteristics is tallied and multiplied by two. The posterior segment is classified based on the sagittal position of the mandibular teeth to the maxillary teeth on both the right and left segments, as well as the presence of posterior crossbites or lateral open bites. The canines, first and second premolars, and molars are all scored if they exhibit a distal or mesial relationship from ideal. Each tooth that is in crossbite or open bite is tallied. The sum of these produces the total posterior segment score. Adding the anterior and posterior segment scores gives the total Inter-Arch deviation score (Appendix 1).

### *2.3.2 Medicaid Approval*

The Salzmann Index evaluation form reports that a score of 25 points or greater must be achieved in order to render a patient eligible for comprehensive orthodontic treatment under the Affordable Care Act Essential Health Benefits. However, additional comments can be added in cases where the score is less than 25, but the patient has additional complicating factors that the clinician believes warrant treatment coverage (Appendix 1).

# CHAPTER 3

## AIMS OF THE INVESTIGATION

Specific Aims: The aim of this study is to investigate whether a higher Salzmann index score is correlated with an increased white spot lesion incidence among patients treated with traditional braces, with consideration of treatment duration, pre-treatment white spot lesions, and oral hygiene.

# CHAPTER 4

# MATERIALS AND METHODS

## 4.1 Participants and Inclusion Criteria

Two-hundred subjects with ages ranging from 10-18 years that have completed comprehensive orthodontic treatment (≥12 months duration) with fixed metal braces were recruited from Temple University Kornberg School of Dentistry Department of Orthodontics for involvement in a retrospective chart review study. Research protocols were approved by the IRB and validated by the dean of clinics. The study design was retrospective and did not require patient consent due to protection of patient health information and absence of patient identification. A request was made of the informatics department to perform a search of Axium software for patients from 2018-present that had completed either adolescent comprehensive orthodontic treatment or Medicaid approved adolescent comprehensive orthodontic treatment, with a filter applied to ensure the age range between 10-18 years. This generated a list of patients that have undergone comprehensive orthodontic treatment with traditional metal braces. The resulting list of chart numbers was searched via Axium software and the attachments section was viewed for each to determine presence of a Salzmann Index. All patients without Salzmann Index scores were deleted and the remainder were assigned unique study identifiers corresponding to all data to be collected. Patients were viewed within Dolphin Imaging software. Treatment duration in months was calculated from time of fixed appliance placement to removal as notated within appointment tabs.

## 1.2 Exclusion Criteria

Patients that have undergone phase 1 interceptive treatment, surgical treatment, limited treatment (<12 months duration) or treatment with ceramic braces, lingual braces, or clear aligners were not included. Data collection was conducted via accessing clinical intra-oral photos of maxillary and mandibular incisor and canine teeth within Dolphin imaging. Any subjects exhibiting pre-treatment WSLs not caused by caused by caries, extensive facial restorations, missing teeth, missing pre- or post- treatment intra-oral photographs, unerupted teeth, partially erupted teeth with a majority of the crown surface covered by gingival tissue, deep bites covering one or more lower incisors, and anterior crossbites with lower incisors covering one or more upper incisors were excluded. Confounding WSLs included fluorosis, traumatic hypomineralization, and molar-incisor hypomineralization. Teeth presenting with generalized WSLs in either a symmetric linear or a “snowflaking” pattern, and ranging from mild to severe, where severe forms present with mottling of enamel, were considered fluorosis (Figure 1). WSLs displaying on only one tooth, appearing within the incisal third of the crown with a well-defined, opaque, and uniform presentation were considered traumatic hypomineralziation. First molars, with or without involvement of the incisors, presenting with a yellow, mottled appearance were considered molar-incisor hypomineralizaiton. Cases including any of these conditions were excluded from the study.

a b

**Figure 1 (a and b):** Examples of moderate pre-treatment fluorosis with linear WSLs.

### 1.3 Oral Hygiene Data Collection

Oral hygiene was recorded pre-, mid-, and post-orthodontic treatment. Pre-treatment OH data was collected via clinical exam form, whereas mid- and post-treatment OH was determined via clinical intra-oral photographs. Clinical exam forms obtained for every subject were accessed via the attachments section of Axium. Pre-treatment OH was recorded as good, fair, or poor as indicated by the line checked on the clinical exam form taken at each patient's initial records appointment by the resident clinician. Clinical intra-oral photographs of patient dentition and gingival tissues taken from facial, right, and left buccal views were accessed within Dolphin Imaging. Chart numbers were used to locate subjects. Mid- and post-treatment OH were also graded as good, fair, or poor but were determined by viewing at least one set of mid-treatment intra-oral images, determined chronologically as the midpoint between start and finish. Each patient's mid- and post-treatment OH was operationally defined based on the following criteria, adapted from Buschang, et al. (Table 1).

*Table 1: Oral Hygiene Evaluation Criteria*

| Oral Hygiene | Mid-Treatment | Post-Treatment |
|---|---|---|
| Good | No visible plaque, no gingivitis | No visible plaque, no hypertrophy, gingival bleeding only due to composite removal |
| Fair | Some visible plaque, isolated areas of gingivitis | Some visible plaque, isolated gingivitis or hypertrophy, gingival bleeding only due to composite removal |
| Poor | Thick and/or generalized plaque, with gingivitis | Multiple areas of visible plaque and/or generalized hypertrophy, gingivitis and gingival bleeding |

No visible plaque and no signs of gingivitis constituted good OH, some visible plaque and localized sites of gingivitis constituted fair OH, and thick or generalized plaque with generalized gingivitis constituted poor OH mid-treatment (Julien, 2013)(Bushang, 2019). Gingival hypertrophy and bleeding were evaluated in addition to plaque presence for the post-treatment photos taken immediately after braces were removed, where no hypertrophy or bleeding, localized, and generalized constituted good, fair and poor, respectively (Figures 2, 3 and 4).

a b c

**Figure 2:** Examples of pre-, mid-, and post- treatment good OH. Note localized site of bleeding only related to composite removal on the lower right canine and lower left lateral incisor (Fig. 1c)

a b c

**Figure 3:** Examples of pre-, mid-, and post- treatment fair OH

a b c

**Figure 4:** Examples of pre-, mid- and post- treatment poor OH

A score of 1, 2 or 3 were recorded for each subject for pre-, mid-, and post-treatment OH, to indicate good, fair, and poor, respectively. All study variable data was entered into a study spreadsheet (Appendix 2).

### 1.4 White Spot Lesion Data Collection

Pre- and post-treatment intra-oral photographs taken from frontal, right buccal and left buccal views were viewed on a computer screen and examined for the presence of white chalky areas of decalcification. Pre-treatment presence of confounding WSLs was determined based on the study's diagnostic criteria described previously. Pre- and post-treatment WSLs were recorded for each tooth in the anterior maxillary and mandibular segments for each subject. This included the central and lateral incisors and canines in both arches. A score of 0 or 1, indicating no WSL or the presence of a WSL, respectively, was assigned for each tooth, pre- and post- treatment. If a WSL was noted in pre-treatment photos and was unchanged in post-treatment photos, it was not counted. If it displayed worsening and/or increase in size in post-treatment photos, it was counted. New WSLs that formed following treatment were counted.

A separate set of data was collected to stage the severity of each WSL as mild, moderate, or severe based on the extent of facial tooth surface occupied by the lesion as well as signs of progression to cavitation (Gorelick, 1982). Lesions occupying less than one third of the facial tooth surface were considered mild. Those occupying more than one third of the facial surface were considered moderate. Those with nearly all exposed enamel surfaces on the facial aspect, i.e. everywhere the bracket is not, or with visible cavitations, were considered severe (Sampson, 2020) (Figures 5 and 6). Teeth with no lesions received a score of zero. Mild, moderate, and severe lesions received a score of 1, 2, or 3, respectively (Table 2). All pre- and post-treatment WSL severity data was entered into designated study spreadsheets (Appendices 3 and 4).

**Figure 5:** Examples of classic post-treatment orthodontic WSLs in two patients at braces removal

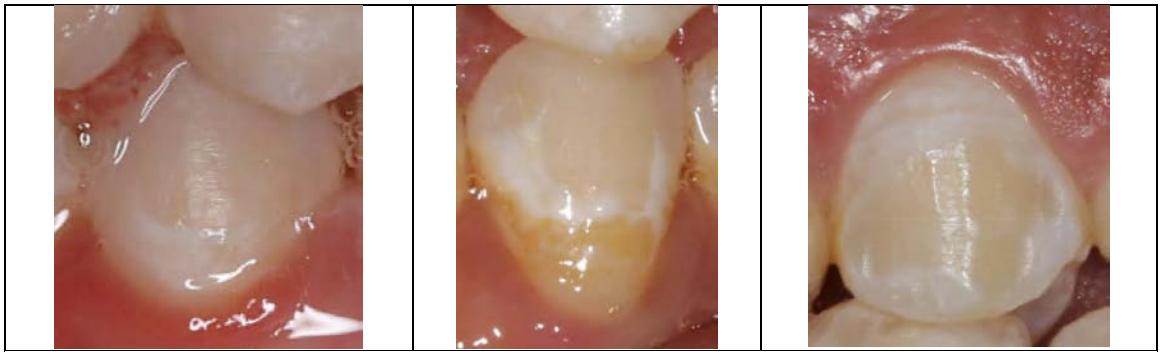

**Figure 6:** Examples of post-treatment mild, moderate, and severe orthodontic WSLs, respectively, on individual teeth at braces removal

*Table 2: White Spot Lesion Evaluation Criteria*

| WSL severity | Score | Clinical presentation |
|---|---|---|
| None | 0 | No lesions present |
| Mild | 1 | The lesion occupies less than one third of the facial tooth surface |
| Moderate | 2 | The lesion occupies more than one third of the facial tooth surface |
| Severe | 3 | The lesion occupies nearly all exposed enamel surfaces on the facial aspect where the bracket is not, or the lesion exhibits one or more sites of visible cavitation |

## 4.5 Evaluator Calibration

Two investigators separately viewed and scored twenty randomly selected subjects for pre- and post-treatment WSL presence or absence and level of severity at the beginning of the study to verify inter-rater reliability. Upper and lower incisors and canines were evaluated and scored independently and if assessments differed, the teeth were viewed jointly and re-assessed. Adjustments were made to disagreeing values and an average Pearson's Correlation Coefficient value of 0.77 was calculated. This process was also performed for mid-treatment OH and post-treatment OH. Each investigator also individually repeated this process at two time points one week apart to verify intra-rater reliability.

## 4.6 Statistical Analysis

A paired student's t-test was performed for the repeated measurements taken for the two dependent samples of the study, being the subjects before treatment and the same subjects after treatment. Logistical regression analyses were performed for each variable in the study, including pre-treatment WSLs, pre-treatment OH, mid-treatment OH, duration of treatment, and Salzmann Indices. Chi square tests were performed to determine statistically significant relationships between all variables.

A regression was designed to evaluate how well one could predict a composite score of WSLs for a patient using the following variables: average OH over the course of treatment, by taking the mean of the pre-, mid- and post-treatment measures, pre-treatment composite WSLs, SI score, and treatment duration. Regression models were also designed

to predict WSLs present before treatment using Pre-Treatment OH and SI score, and to predict the increase in WSLs during treatment using treatment duration, SI score, composite WSLs, and average OH.

# CHAPTER 5

# RESULTS

## 5.1 Results Overview

Two-hundred subjects with ages ranging from 10-18 years that completed comprehensive orthodontic treatment ($\geq$12 months duration) with fixed metal braces were recruited. Of the subjects included, average treatment duration was 24.5 $\pm$ 7.0 months. Average total Salzmann Index score was 27.3 $\pm$ 6.8. A significant overall increase in WSL severity between pre- and post-treatment was observed ($p<.001$), with average composite WSL severity per patient increasing by 3.6 times from pre- to post-treatment. Higher SI score and average overall OH showed a moderate level correlation to WSL increase, with Determination Coefficient (R2) values of 0.22 and 0.22, respectively. Duration of treatment and presence of pre-treatment WSLs showed low level correlation to WSLs, with R2 values of 0.07 and 0.07, respectively. Pre-treatment OH showed moderate level correlation to pre- and post-treatment WSLs with R2 values of 0.31 and 0.27, respectively.

## 5.2 Predicting Post-Treatment WSLs

The results of the regression designed to evaluate WSL prediction from average OH over the course of treatment, pre-treatment composite WSLs, SI score, and treatment duration, showed that the model was significant ($p<.001$) and explained approximately 34% of WSL severity post-treatment. Salzman Score ($p=.007$), Composite WSL Score

(pre-treatment) (p<.001), and average OH (p=.014) were all significant predictors. Treatment duration was not a significant predictor (p=.654) (Table 3)(Figures 7 and 8).

*Table 3: Regression to Predict Post-Treatment White Spot Lesions*

| | Unstandardized Coefficients | | Standardized Coefficients | | |
|---|---|---|---|---|---|
| | B | Std. Error | Beta | t | Sig. |
| (Constant) | -1.970 | 2.548 | | -.773 | .440 |
| Treatment Duration | .028 | .062 | .026 | .448 | .654 |
| Salzmann Index Score | .176 | .064 | .161 | 2.748 | .007 |
| Composite Pre-treatment WSLs | .994 | .125 | .488 | 7.940 | .000 |
| Average OH | 1.998 | .808 | .155 | 2.471 | .014 |

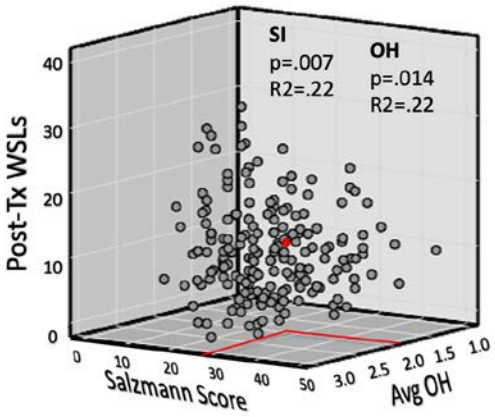


**Figure 7:** Three-dimensional graphical representation of SI score and average overall OH as predictors of post-treatment WSLs, where red lines represent averages for independent variables (SI, average overall OH), and the red dot represents average intersection of independent variables with the dependent variable (Post-Tx WSLs).

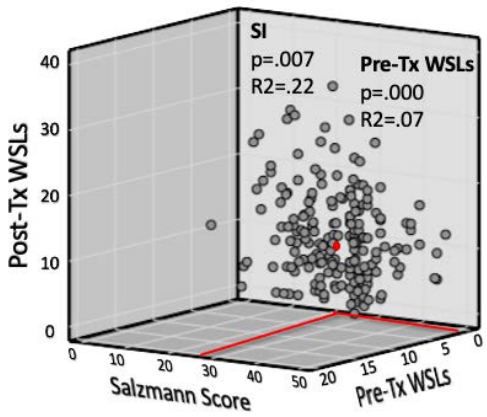


**Figure 8:** Three-dimensional graphical representation of SI score and composite pre-treatment WSLs as predictors of post-treatments WSLs, where red lines represent averages for independent variables (SI, Pre-Tx WSLs), and the red dot represents average intersection of independent variables with the dependent variable (Post-Tx WSLs).

### 5.3 Oral Health Correlations

There were positive correlations among the three measures of OH. Weak correlations were observed between pre-treatment OH and mid-treatment OH, and pre-treatment OH and post-treatment OH, with Pearson Correlation Coefficients of .388 and .283, respectively. The correlation was strongest between mid- and post-treatment OH assessments, with a Pearson Correlation Coefficient of .785 (Table 4). A positive linear relationship can be seen (Figure 9).

*Table 4: Oral Hygiene Correlations*

| | Pre-OH | Mid-OH | Post-OH |
|---|---|---|---|
| **Pre-OH** | **1** | | |
| **Mid-OH** | **.388**** | **1** | |
| **Post OH** | **.283**** | **.785**** | |

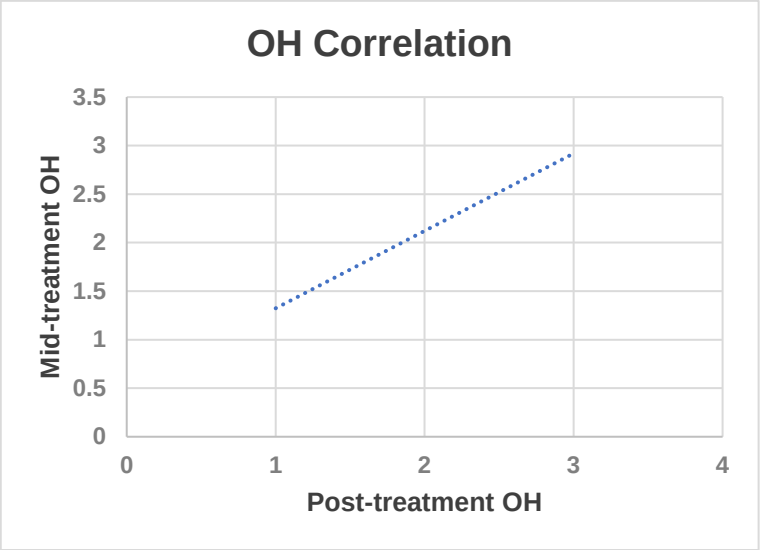


**Figure 9:** A strong positive linear correlation relationship was observed between mid- and post-treatment OH values (Pearson Correlation Coefficient of .785).

### 5.4 Predicting Pre-Treatment WSLs

The results of the regression designed to predict pre-treatment WSLs using pre-treatment OH and SI showed that the model was significant overall ($p<.001$) and predicted approximately 10% of WSL composite severity. Only pre-treatment OH was a significant predictor ($p<.001$), indicating that case complexity is unrelated to WSL development prior to orthodontic treatment ($p=.686$) (Table 5).

*Table 5: Regression to Predict Pre-Treatment White Spot Lesions*

| | Unstandardized Coefficients | | Standardized Coefficients | | |
|---|---|---|---|---|---|
| | B | Std. Error | Beta | t | Sig. |
| (Constant) | -.511 | 1.214 | | -.421 | .674 |
| Salzmann Index Score | .015 | .036 | .027 | .405 | .686 |
| Pre-treatment OH | 1.653 | .358 | .313 | 4.617 | .000 |

## 5.5 Predicting Increase in WSLs

The results of the regression designed to predict the increase in WSLs during the course of treatment was significant overall (p=.002), with SI score and average OH being statistically significant predictors (p=.007 and p=.014, respectively). Treatment duration and Composite pre-treatment WSLs were not significant predictors (p=.654 and p=.963, respectively) (Table 6).

*Table 6: Regression to Predict Increase in White Spot Lesions*

| | Unstandardized Coefficients | | Standardized Coefficients | | |
|---|---|---|---|---|---|
| | B | Std. Error | Beta | t | Sig. |
| (Constant) | -1.970 | 2.548 | | -.773 | .440 |
| Treatment Duration | .028 | .062 | .031 | .448 | .654 |
| Salzmann Index score | .176 | .064 | .191 | 2.748 | .007 |
| Composite Pre-treatment WSLs | -.006 | .125 | -.003 | -.046 | .963 |
| Average OH | 1.998 | .808 | .185 | 2.471 | .014 |

### 5.6 Differences in WSL Severity Pre- and Post-Treatment

In all sites in the mouth, the average WSL severity per tooth increased between pre- and post-treatment time points (Tables 7 and 8) (Figure 10). This increase in WSL severity was statistically significant for all teeth ($p<.000$) (Table 8). The most drastic increase in WSL severity was observed in the upper anterior, with the upper centrals showing the greatest increase on average, followed by the upper laterals, and then upper canines. In the lower arch, the observation was inverse, with the greatest WSL increase being observed in the lower canines, followed by the lower laterals, and then the lower centrals (Figure 10).

*Table 7: Paired Samples of White Spot Lesion Severity Differences*

**Paired Samples Statistics**

| | | Mean | N | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|
| Pair 1 | UR3PR | .28 | 199 | .559 | .040 |
| | UR3PO | 1.07 | 199 | .877 | .062 |
| Pair 2 | UR2PR | .37 | 199 | .588 | .042 |
| | UR2PO | 1.34 | 199 | .950 | .067 |
| Pair 3 | UR1PR | .40 | 199 | .602 | .043 |
| | UR1PO | 1.35 | 199 | .952 | .067 |
| Pair 4 | UL1PR | .38 | 199 | .599 | .042 |
| | UL1PO | 1.29 | 199 | .923 | .065 |
| Pair 5 | UL2PR | .35 | 199 | .527 | .037 |
| | UL2PO | 1.25 | 199 | .966 | .069 |
| Pair 6 | UL3PR | .31 | 199 | .533 | .038 |
| | UL3PO | 1.09 | 199 | .936 | .066 |
| Pair 7 | LR3PR | .17 | 199 | .390 | .028 |
| | LR3PO | .76 | 199 | .830 | .059 |
| Pair 8 | LR2PR | .16 | 199 | .382 | .027 |
| | LR2PO | .63 | 199 | .719 | .051 |
| Pair 9 | LR1PR | .15 | 199 | .354 | .025 |
| | LR1PO | .46 | 199 | .609 | .043 |
| Pair 10 | LL1PR | .14 | 199 | .349 | .025 |
| | LL1PO | .51 | 199 | .635 | .045 |
| Pair 11 | LL2PR | .18 | 199 | .395 | .028 |
| | LL2PO | .57 | 199 | .677 | .048 |
| Pair 12 | LL3PR | .16 | 199 | .368 | .026 |
| | LL3PO | .64 | 199 | .759 | .054 |

*Table 8: Paired Samples of Average White Spot Lesion Severity Changes*

**Paired Samples Test**

| | | Paired Differences | | | | | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference Lower | Upper | | | |
| Pair 1 | UR3PR - UR3PO | -.789 | .826 | .059 | -.904 | -.673 | -13.472 | 198 | .000 |
| Pair 2 | UR2PR - UR2PO | -.970 | .887 | .063 | -1.094 | -.846 | -15.422 | 198 | .000 |
| Pair 3 | UR1PR - UR1PO | -.950 | .880 | .062 | -1.073 | -.827 | -15.217 | 198 | .000 |
| Pair 4 | UL1PR - UL1PO | -.905 | .874 | .062 | -1.027 | -.782 | -14.602 | 198 | .000 |
| Pair 5 | UL2PR - UL2PO | -.899 | .964 | .068 | -1.034 | -.765 | -13.163 | 198 | .000 |
| Pair 6 | UL3PR - UL3PO | -.779 | .888 | .063 | -.903 | -.655 | -12.368 | 198 | .000 |
| Pair 7 | LR3PR - LR3PO | -.588 | .766 | .054 | -.695 | -.481 | -10.826 | 198 | .000 |
| Pair 8 | LR2PR - LR2PO | -.472 | .680 | .048 | -.567 | -.377 | -9.797 | 198 | .000 |
| Pair 9 | LR1PR - LR1PO | -.312 | .606 | .043 | -.396 | -.227 | -7.254 | 198 | .000 |
| Pair 10 | LL1PR - LL1PO | -.367 | .652 | .046 | -.458 | -.276 | -7.934 | 198 | .000 |
| Pair 11 | LL2PR - LL2PO | -.397 | .680 | .048 | -.492 | -.302 | -8.232 | 198 | .000 |
| Pair 12 | LL3PR - LL3PO | -.477 | .717 | .051 | -.578 | -.377 | -9.399 | 198 | .000 |

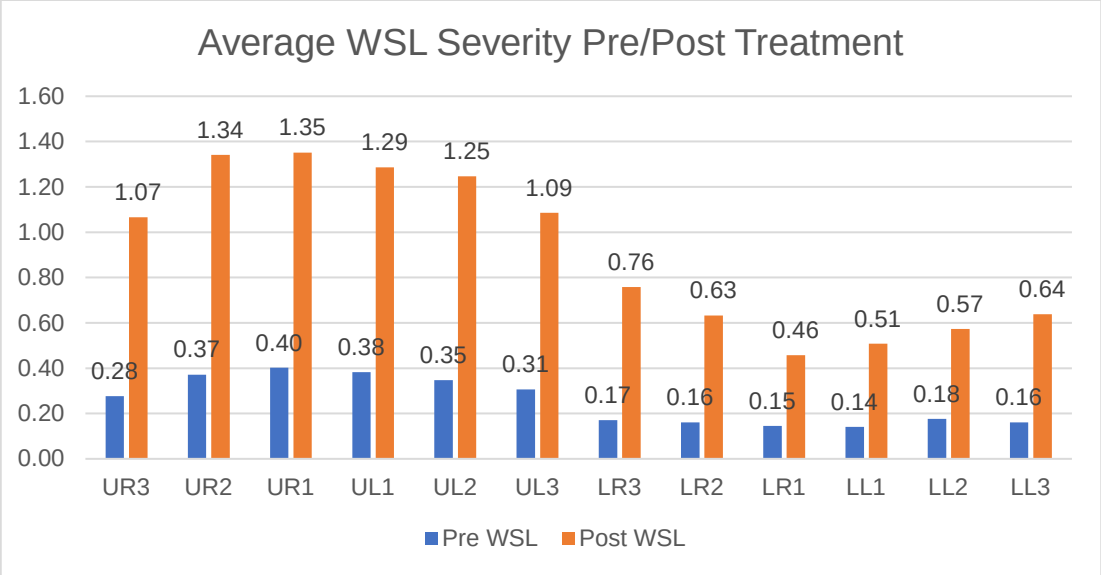


**Figure 10:** Average WSL severity per tooth pre- and post-treatment.

Lower canines showed the greatest percent increase in average WSL severity between pre- and post-treatment time points (~325%), followed by upper canines (266%), upper lateral incisors (~260%), lower lateral incisors (~253%), and upper and lower central incisors displaying the smallest overall percent increase (238% and 234%, respectively) (Figure 11). However, upper centrals, laterals, and canines, respectively, exhibited the highest average overall WSL severity post-treatment when compared to all pairs of teeth in the study. The lower centrals, laterals, and canines, respectively, showed the least (Figure 12).

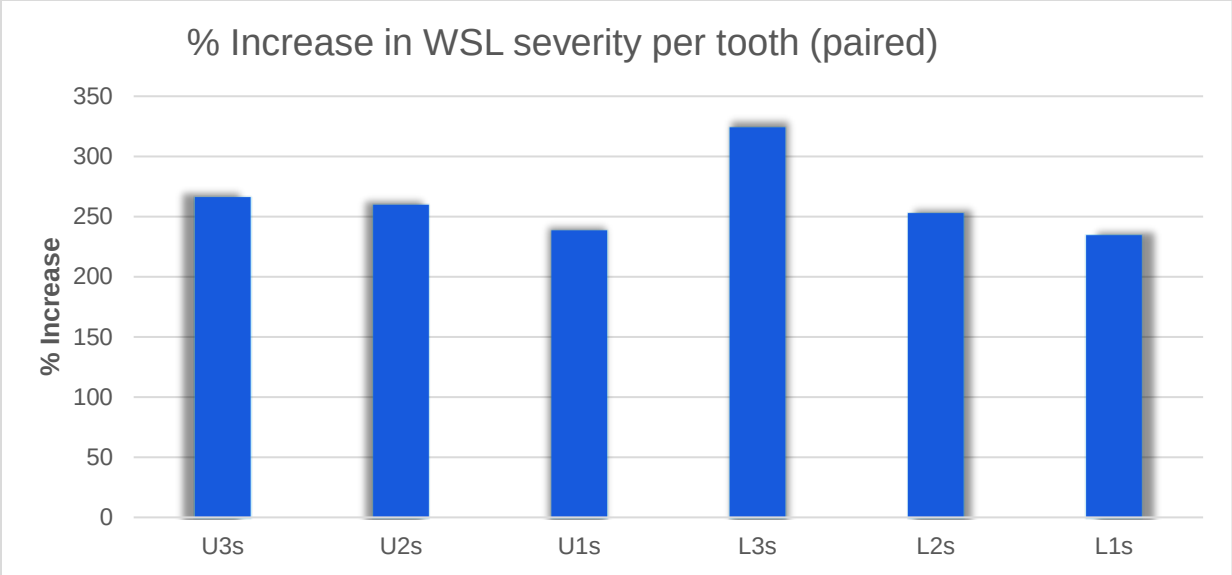


**Figure 11:** Percent increase in average WSL severity for pairs of teeth pre- and post-treatment.

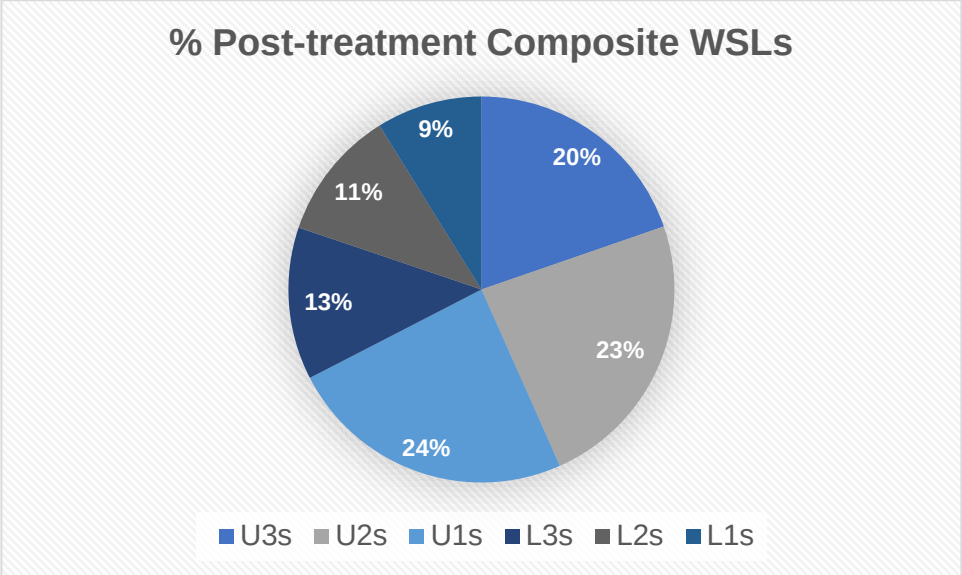


**Figure 12:** Percent breakdown of average WSL severity per tooth (paired) post-treatment.

# CHAPTER 6

# DISCUSSION

## 6.1 Discussion Overview

The sample size utilized in the study was sufficient, which was evidenced by the statistical significance of the resulting data. The average treatment duration of 24.5 months was expected, being that the average non-extraction orthodontic case is estimated to take between 18-24 months, but in the Temple Orthodontic Clinic setting can be extended due to factors such as higher rates of missed appointments among the Medicaid population (Zadmehr, 2022). Average Salzmann Index score was expected, due to tendency for Medicaid patients that score below 25 to get denied and not pursue treatment due to lack of financial coverage.

Significant overall increase in WSLs between pre- and post-treatment time points was expected, due to the established known increased risk for WSL development with orthodontic treatment with fixed metal braces (Buschang, 2019). Average OH being a significant predictor of and exhibiting moderate level correlation to WSL increase demonstrates the known relationship between plaque accumulation around brackets and subsequent development of WSLs (Cochrane, 2010). Similarly, Pre-treatment OH showing moderate level correlation to pre- and post-treatment WSLs was expected, due to this same known relationship between plaque presence and lesion development.

High SI score being a significant predictor of and exhibiting moderate level correlation to WSL increase demonstrates that patients with higher Salzmann Indices may be advised on a greater predilection to WSL formation, and in some cases may be due to

increased difficulty with plaque removal when more crowding and/or rotations are present. This is because the inter-bracket distance decreases with greater amount of inward rotation present between two adjacent teeth. If two adjacent teeth are rotated towards each other, this scenario is amplified. If one or more teeth is crowded out of the arch, this may prevent ideal bonding of certain teeth and complicate access to all surface for proper hygiene.

The impact of other determining criteria of overall SI score on complications with WSL formation in the anterior region is less easily rationalized. Deep bites can be associated with higher rates of incisal wear of mandibular incisors with grinding against the cingulae of maxillary incisors, leading to smaller clinical crowns, and less surface area for bracket placement. This would allow less overall surface area to need to develop WSLs that fit into the severe category. However, this is a more likely phenomenon in older patients, due to decreased rates of incisal wear with age, and would be less likely viewed among subjects aged 10-18 years in this study. Additionally, this cannot be deduced from the results of this study, as deep bite cases were not utilized due to inability to visualize lower teeth on digital images in such cases.

Duration of treatment showing only low-level correlation to WSL formation and being insignificant as a predictor of WSL increase was unexpected, as one would presume that the longer braces are placed, the longer their risk for WSLs is elevated and would seem more likely. This also contradicts the findings of previous studies (Brown, 2016). Nonetheless, it may be the case that this relationship may become more significant after a certain treatment duration beyond those exhibited in the subjects of this study.

Pre-treatment WSL's, which also showed only low-level correlation to WSL increase, may not have displayed as strong of a relationship due to possible difficulty in

diagnosing increased severity, especially on teeth with less overall surface area, making it harder to distinguish increases. Additionally, for cases that began with severe WSLs, this would make it impossible to note an increase due to lack of higher classification on the severity scale. This would explain pre-treatment WSLs being insignificant as predictors of WSL increase in general. However, they were still statistically significant as predictors of post-treatment WSLs, which supports previous findings in similar studies (Julien, 2013). This also supports the concept that pre-existing WSLs do not resolve or decrease in their severity during treatment.

Pre- and post-treatment OH were only moderately correlated, suggesting that OH was not very consistent over the course of treatment. The strongest OH correlations were between mid- and post-treatment assessments, meaning that perhaps this is an intervention point at which behaviors developed during the treatment period that were likely to persist past the end of treatment. This may serve to further motivate clinicians to enhance reinforcement of OH improvement among their patient population, which can involve positive reinforcement and proper patient/guardian education.

Pre-treatment OH predicting 10% of pre-treatment WSL composite severity suggests that genetic factors may play a larger role in WSL formation absent of plaque accumulation. Salzmann Index score not being a significant predictor indicates that case complexity is unrelated to WSL development prior to orthodontic treatment, which supports previous studies demonstrating that evidence suggests only a small association between malocclusions and caries rate among adolescent patients (Brignardello-Petersen, 2018). From this one may incur that malocclusion severity does not preclude patients from performing proper oral hygiene to prevent decalcifications.

## 6.2 Study Limitations

Maxillary teeth may have shown an overall greater percent increase in WSL severity due to greater visibility of tooth surfaces in digital photos when compared to mandibular teeth, making it easier to diagnose lesions both pre- and post-treatment. Even a half millimeter of overlap of upper teeth over lower teeth impacts the ability to accurately assess the entire dimension of facial tooth surface of lower incisors and canines. However, the smaller overall facial surface area of lower versus upper teeth also presents potential to score a lower tooth more severely simply due to less surface area needed to classify a severe lesion. For example, the same amount of surface area on a maxillary tooth may correspond to a smaller severity score due to ratio of tooth surface absent of decalcification when compared to a mandibular tooth.

The ability to perform this study and extend it to include posterior teeth and stratify data by quadrant was also not possible due to the retrospective study design which was limited to intraoral digital photography that does not consistently capture entire buccal surfaces of first molars, depending on the tonicity of peri-oral musculature of subjects. Nonetheless, inclusion of the premolars would be feasible. Similarly, deep bite cases could not be utilized due to lack of ability to visualize mandibular teeth. Cases involving anterior crossbites with severe overlap of the maxillary teeth by the mandibular teeth would also apply.

Other challenges that came with utilization of digital intraoral photography include factors such as level of flash reflection depending on amount of saliva, changes in flash reflection with varying photo angulation, and inability to accurately assess tooth surface

ratio due to angulation of teeth. For instance, proclined teeth viewed facially are skewed to appear inciso-gingivally shorter. This may impact the investigator's determination of assigning a severity score of 1 versus 2 or 2 versus 3 for a lesion.

In terms of Salzmann Indices, it was less common to find patients with low Salzmann scores that completed comprehensive treatment, because many patients that get denied coverage do not pursue treatment due to the financial expense. This may have skewed the SI score results by increasing the overall mean score and narrowing the range.

### 6.3 Future Considerations

A future aim of a study with the same design could be to determine whether the intra-arch deviation score of the Salzmann Index alone influences an increase in WSL development. Additionally, further studies may evaluate potential significant relationships between inter- and intra-arch SI score with each variable, including OH, treatment duration, and pre-treatment WSLs.

To include more teeth in future studies and stratify data by quadrant, one could introduce the practice of taking open-mouth intra-oral photos to guarantee visualization of both maxillary and mandibular anterior teeth with zero overlap. One could also include lack of ability to visualize entire buccal tooth surfaces of first molars as part of exclusion criteria to allow inclusion of all dentition from first molar to first molar. From this, WSL incidence and severity between anterior and posterior segments could be investigated.

In the Temple Orthodontic Clinic setting, one could repeat the protocol with a larger sample size or add to the current sample population to increase the amount of lower SI's included.

This would potentially allow for adjustment of data skewed towards higher SI scores, allowing for the possibility of further conclusions to be drawn regarding the relationship between SI score and post-treatment WSL incidence and severity.

# CHAPTER 7

# CONCLUSION

Findings suggest that patients with higher SI scores may be advised on greater predilection to WSL development regardless of treatment duration. Those with poor pre-treatment OH may benefit from greater reinforcement and monitoring of OH. Placement of orthodontic sealants on facial tooth surfaces prior to bonding fixed appliances should be considered to increase prevention of WSLs.

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# APPENDIX A
# THE SALZMANN INDEX EVALUATION FORM

**ORTHODONTIC SERVICE**
**SALZMAN EVALUATION INDEX**

| PATIENT'S NAME – LAST, FIRST, MIDDLE INITIAL | MEMBER # | DATE OF BIRTH |
|---|---|---|
| REFERRING DENTIST | | |
| ORTHODONTIST'S NAME | TAX ID | DATE OF ASSESSMENT |

**HANDICAPPING MALOCCLUSION ASSESSMENT RECORD**

A. Intra - Arch Deviation

| SCORE TEETH AFFECTED ONLY | | MISSING | CROWDED | ROTATED | SPACING | | NO. | POINT VALUE | SCORE |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | OPEN | CLOSED | | | |
| MAXILLA | ANT | | | | | | | X2 | |
| | POST | | | | | | | X1 | |
| MANDIBLE | ANT | | | | | | | X1 | |
| | POST | | | | | | | X1 | |
| | | | | | | | | TOTAL SCORE | |

ANT = Anterior Teeth (4 incisors)
POST = Posterior Teeth (include canine, premolars and first molars)
NO. = Number of teeth affected

B. Inter - Arch Deviation

1. Anterior Segment

| SCORE MAXILLARY TEETH AFFECTED ONLY EXCEPT OVERBITE* | OVERJET | OVERBITE | CROSSBITE | OPENBITE | NO. | POINT VALUE | SCORE |
|---|---|---|---|---|---|---|---|
| | | | | | | X2 | |
| | | | | | | TOTAL SCORE | |

*Score Maxillary or Mandibular Incisors
No. = Number of teeth affected

2. Posterior Segment

| SCORE AFFECTED TEETH ONLY | RELATE MANDIBULAR TO MAXILLARY TEETH | | | | SCORE AFFECTED MAXILLARY TEETH ONLY | | | | NO. | POINT VALUE | SCORE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | DISTAL | | MESIAL | | CROSSBITE | | OPENBITE | | | | |
| | Right | Left | Right | Left | Right | Left | Right | Left | | | |
| CANINE | | | | | | | | | | X1 | |
| 1ST PREMOLAR | | | | | | | | | | X1 | |
| 2ND PREMOLAR | | | | | | | | | | X1 | |
| 1ST MOLAR | | | | | | | | | | X1 | |
| | | | | | | | | | | TOTAL SCORE | |

GRAND TOTAL

No primary teeth may exist and a Salzmann Evaluation Index score of 25 points or more must be achieved to be eligible for comprehensive orthodontic treatment under the ACA Essential Health Benefits.

## APPENDIX B
## PRE-, MID-, AN POST-TREATMENT VARIABLES

| Study ID | Pre-tx OH | Mid-tx OH | Post-tx OH | Pre-tx WSLs | Tx duration in months |
|---|---|---|---|---|---|
| | | | | | |

| OH | WSLs |
|---|---|
| 1 = good | 0 = absent |
| 2 = fair | 1 = present |
| 3 = poor | |

## APPENDIX C
## PRE-TREATMENT WSL SEVERITY PER TOOTH

| Study ID | UR3 | UR2 | UR1 | UL1 | UL2 | UL3 |
|---|---|---|---|---|---|---|
| | | | | | | |

| Study ID | LR3 | LR2 | LR1 | LL1 | LL2 | LL3 |
|---|---|---|---|---|---|---|
| | | | | | | |

| WSL severity |
|---|
| 0 = absent |
| 1 = mild |
| 2 = moderate |
| 3 = severe |

## APPENDIX D
## POST-TREATMENT WSL SEVERITY PER TOOTH

| Study ID | UR3 | UR2 | UR1 | UL1 | UL2 | UL3 |
|---|---|---|---|---|---|---|
| | | | | | | |

| Study ID | LR3 | LR2 | LR1 | LL1 | LL2 | LL3 |
|---|---|---|---|---|---|---|
| | | | | | | |

| WSL severity |
|---|
| 0 = absent |
| 1 = mild |
| 2 = moderate |
| 3 = severe |