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Prevalence of White Spot Lesions during Orthodontic Treatment

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This is to certify that the thesis prepared by Julian Spencer Dixon IV, D.M.D., entitled Prevalence of White Spot Lesions during Orthodontic Treatment with Fixed Appliances has been approved by his committee as satisfactory completion of the thesis requirement for the degree of Master of Science in Dentistry.

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Prevalence of White Spot Lesions during Orthodontic Treatment with Fixed Appliances

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Dentistry at Virginia Commonwealth University.

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Table of Contents

List of Tables

List of Figures

Abstract

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By Julian Spencer Dixon IV, DMD

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Dentistry at Virginia Commonwealth University.

Virginia Commonwealth University, 2009

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The reported prevalence of decalcification in orthodontic patients varies from 2 to 96% mainly due to the lack of a standard examination technique. The aims of this study were: 1) to determine the prevalence of white spot lesions around brackets using visual examination and the DIAGNOdent; 2) to determine which teeth were the most susceptible to decalcification; and 3) to test the accuracy of the DIAGNOdent by comparing to the visual examination.

The presence of white spot lesions was determined in two groups of patients who were 6 and 12 months into orthodontic treatment, respectively. The control group consisted of patients who were examined for white spot lesions immediately after having their braces placed on their teeth. The prevalence of white spot lesions was 38%, 46%, and 11% for the 6-month, 12-month, and control groups, respectively. There was a statistically significant correlation ($r = 0.71$) between the DIAGNOdent measurements and the visual examination.

Introduction

Enamel decalcification is a significant risk associated with orthodontic treatment when oral hygiene is poor. The prevention of demineralization during orthodontic treatment is one of the greatest challenges faced by clinicians despite the modern advances in caries prevention. The development of white spot lesions (WSL) is attributed to the prolonged plaque accumulation around the brackets.[1-5] Not only do fixed orthodontic appliances make conventional oral hygiene procedures more difficult, but they also increase the amount of plaque retention sites on surfaces of the teeth that are normally less susceptible to caries development.[6]

After the introduction of orthodontic fixed appliances into the oral cavity, there is a rapid shift in the bacterial flora of plaque. Higher levels of acidogenic bacteria are present in the plaque, most notably *S. mutans* and *Lactobacilli*.[7] These high levels of bacteria are capable of decreasing the pH of plaque in orthodontic patients more than that of non-orthodontic patients.[8]

The progression of caries is faster in patients with full orthodontic appliances. White spot lesions can become noticeable around the brackets within 1 month of the bracket placement although the formation of regular caries takes usually at least 6 months.[9] These lesions are commonly seen on the buccal surfaces of teeth around the brackets, especially in the gingival region. [1,6,10]

A plaque layer on the enamel surface provides a source of acid production and acts as a physical barrier by limiting the diffusion of acid away from the tooth surface. Therefore, the potential for remineralization from the available exogenous calcium and phosphate ions in the saliva is greatly reduced in the presence of plaque.[10]

The reported prevalence of white spot lesions among orthodontically treated patients varies widely from 2 to 96%.[10] This large range is thought to be mainly due to

the difficulty in standardizing clinical examinations.[11] Gorelick et al.[1] investigated the prevalence of carious white spots in gingival areas immediately after removal of bonded appliances and reported that about 50% of the patients had a white spot lesion on at least one tooth. In the same study, the segment with the highest percentage of incidence was found to be the maxillary anterior segment (15.3%), and the single tooth with the highest percentage of incidence was the maxillary lateral incisor (23%).

Although many methods have been developed over the years for the prevention of enamel decalcification, the best approach is the implementation of good oral hygiene measures. Extensive oral hygiene instruction and supervision, mechanical removal of plaque with a fluoridated dentifrice, and daily fluoridated mouthrinses are the most important mechanisms of defense against white spot lesions. Consistent use of a mouthrinse containing 0.05% sodium fluoride during orthodontic treatment has been shown to significantly reduce the amount of decalcification on the buccal surfaces of the teeth.[4] However, this protocol depends on patient compliance, and Geiger reported that less than 15% of orthodontic patients rinse daily as instructed.[4]

Less compliant patients may often need supplemental fluoride applications in the form of a varnish or fluoride releasing bonding materials to combat the development of enamel decalcification. Fluoride releasing composite resins and glass ionomer cements have been reported to prevent enamel decalcification, but the bond strength of these materials was shown to be lower than conventional orthodontic resins.[12-16] Therefore, resin-modified glass ionomer cements have been developed which exhibit both fluoride releasing capabilities and clinically acceptable bond strengths.[17-21] Patients can also receive an in-office application of a high concentration of fluoride in the form of a varnish. In a study by Stecksen-Blicks,[22] the incidence of white spot lesions during treatment was 7.4% in a group of patients receiving topical fluoride varnish applications

every 6 weeks compared to a 25.3% incidence of white spot lesions in a placebo group. Another study reported a 44.3% reduction in enamel demineralization in orthodontic patients who had regular applications of a fluoride varnish.[23] Despite the advantages of topical fluoride varnish application, some clinicians do not find its use feasible because of a need for multiple applications, increased chair time and cost, and temporary discoloration of the teeth and gingiva.

Previous studies have shown that white spots developed during orthodontic treatment are surface lesions (superficial) rather than sub-surface (deep) decalcification.[9] Surface lesions are found to remineralize much faster than the sub-surface ones.[24,25] Willmot[26] reported that there was a significant decrease in the size of enamel surface lesions following orthodontic treatment. High concentrations of fluoride, however, are contraindicated following debanding as this will cause the remineralization of the outer enamel surface that can slow or prevent complete remineralization by restricting mineral ion diffusion into deeper regions of the lesion.[9,25] Therefore, the recommended treatment is to allow the patient's own saliva to naturally remineralize the lesion over time, resulting in a greater repair with a less visible and more esthetically pleasing appearance.[9]

If this strategy still does not eliminate the white spots because of the severity of the lesions, other approaches have been advocated such as tooth whitening and microabrasion. Microabrasion is typically carried out by polishing the patient's teeth with a mixture of hydrochloric acid and pumice. This process removes small amounts of surface enamel leaving a highly polished enamel surface with calcium phosphate packed into the interprismatic enamel surface space.[27] In one study, the mean reduction in lesion size after microabrasion was reported to be 83%.[28] Tooth whitening can also be performed to camouflage mild white spot lesions.[27] By whitening the entire buccal surfaces of the teeth, the white spot lesions are less noticeable. If all of these techniques

are used, and the patient is still unhappy with the appearance of their teeth, then irreversible restorative procedures such as veneers can be further done to improve the esthetics.

Clinically, early carious lesions are in the form of a white opaque spot that is softer than the surrounding enamel. The white appearance is created by an optical phenomenon and increases in whiteness as dried with air.[9] Various methods have been used to test and visualize white spot lesion development. The standard technique to determine the presence of the buccal surface lesions is done by visual inspection and tactile sensation with an explorer. Due to the large degree of subjectivity with visual inspection, other methods have been tested such as photographic examination, fluorescent dye uptake, ultraviolet light, lasers, and quantitative light-induced fluorescence.[29]

Fluorescence is a phenomenon by which light at one wavelength is absorbed into a substance and emitted as a different wavelength. Even though not fully understood, dental hard tissues exhibit fluorescence characteristics. When excited by light in the ultraviolet and short-wave visible range, the luminescence is different between intact and carious tooth structure.[30] Because of this difference, two methods of assessing demineralization using laser fluorescence have been developed: quantitative laser fluorescence (QLF) and the DIAGNOdent (KaVo America, Lake Zurich, Ill.).

In QLF, a light source produces light in the blue-green range of the electromagnetic spectrum (440-570 nm). When the light illuminates the tooth surface, a digital fluorescent image is captured by a camera, transferred to a computer, and displayed on a monitor. In order to prevent the detection apparatus from measuring scattered wavelengths from the original blue-green spectrum, it has a filter that only allows light in the yellow region (565-560 nm) to pass. The amount of yellow light emitted, therefore, is the amount of fluorescence. Custom made software stores and

analyzes the images. In the captured images, carious lesions appear dark compared to sound enamel, and the mineral loss from caries is detected and measured as a decrease in fluorescence.

In the early 1980's, investigators began to use QLF as a more objective way to detect and monitor caries *in vivo*. Al-Khateeb et al.[31] was among the first to longitudinally study the natural behavior of white spot lesions from orthodontic treatment with fixed appliances using QLF. Seven patients with active carious lesions were monitored on the day of bracket removal and once a month thereafter for a year. During the one year follow-up period, the areas of the lesion decreased, and the enamel fluorescence lost was partly regained indicating that a remineralization process had occurred. It was also concluded that QLF was a suitable method for *in vivo* monitoring of demineralization. Another study[11] used QLF to examine the prevalence and severity of white spot lesions in orthodontic patients after treatment with fixed appliances. All of the buccal surfaces from first molar to first molar were scanned using QLF immediately following the debonding appointment. Almost all of the 62 participants (97%) had one or more decalcifications, and 30% of the teeth had decalcifications at the debonding appointment. Van der Veen et al.[32] also used QLF to study the prevalence of white spot lesions after debonding. QLF measurements were taken the day of debonding, 6 weeks after debonding, and 6 months after debonding. Immediately following the debonding appointment, 94.8% of the subjects had at least one area of decalcification. The study also reported a significant lesion regression during the first 6 weeks, and a further significant but smaller lesion regression after 6 months. Furthermore, the severity of the lesion did not hamper its ability to remineralize, and significant regression was seen even in well advanced lesions. However, nearly 10% of the lesions followed longitudinally showed significant progression and worsened over time. Clearly, QLF has proven to be a

valuable tool in the detection and observation of white spot lesions. However, the equipment needed for such an analysis is extensive and expensive. Therefore, for the practicing orthodontist, QLF may not be a practical way to monitor white spot lesions.

The DIAGNOdent pen is a portable, user friendly device that works in a similar manner. It consists of a light source that emits light in the red wavelength and a detector. At this range, there is a large difference in fluorescence between the carious and sound dental hard tissues. The filter, as in QLF, absorbs the scattered short wavelength light and transmits the longer wavelength fluorescence. Instead of producing an image on a computer screen as in QLF, the DIAGNOdent gives a digital reading between 0 and 99, with 0 being minimum fluorescence and 99 being maximum fluorescence. Carious tooth structure fluoresces much more strongly than sound tooth structure.[33]

The use of QLF and DIAGNOdent for the detection of caries was investigated in two *in vitro* studies where the measurements obtained by these two instruments were correlated to the lesion depth and the mineral loss determined by the histopathology and transverse microradiography techniques. In a study by Aljehani,[34] the correlation analysis showed the associations between the two fluorescence methods to be comparable and accurate when the lesion depth was measured. The same conclusion was found in a previous study by Shi et al.[35] However, in the assessment of mineral loss, there were differences in the correlation of QLF and DIAGNOdent measurements. While both of the fluorescence techniques were shown to correlate well with the lesion depth, only QLF was also able to depict the amount of mineral loss as opposed to the DIAGNOdent.

The early detection of white spots lesions during orthodontic treatment is of paramount importance as it would allow clinicians to implement preventive measures to control the demineralization process before the lesion progresses. Compared to visual inspection, the use of DIAGNOdent may provide a more objective and reproducible

method to assess the presence of white spot lesions. If the DIAGNOdent is sensitive enough to detect initial carious lesions in smooth enamel surfaces *in vitro*, then it could be a valuable tool to longitudinally monitor the progression of enamel decalcifications during fixed orthodontic treatment because of its ease of use in a clinical setting.

The purpose of this study was three-fold: 1) to determine the prevalence of white spot lesions in patients with fixed orthodontic appliances using visual examination and the DIAGNOdent; 2) to determine which teeth were the most susceptible to white spot lesions; and 3) to test the accuracy of the DIAGNOdent by investigating the correlation between the visual examination and the DIAGNOdent measurements.

Materials and Methods

Before the start of the clinical study, approval was obtained from the Institutional Review Board of the Virginia Commonwealth University, Office of Research. Subjects who agreed to participate in the study were recruited among patients who were being treated with fixed orthodontic appliances at the VCU orthodontic clinic. The participants and their legal guardians were informed about the purpose of the study, and informed consent was obtained. All examinations and measurements were performed by the same clinician who was also professionally trained by KaVo on the use of the DIAGNOdent pen. Prior to the study, five patients were examined with the DIAGNOdent to evaluate the reliability of the measurements and to determine the feasibility of the experiment.

Patients 12 years and older with complete initial records and maxillary fixed appliances from canine to canine were included in the study. Subjects on a daily supplemental fluoride regimen were excluded. The initial records of the patients were evaluated for the presence of white spot lesions. Patients who have already had white spot lesions, hypoplastic, or fluorotic enamel in their original photo taken before the start of the orthodontic treatment were excluded from the study.

The study consisted of three groups of patients who were examined for the presence of enamel decalcification. Group 1 comprised 37 subjects (16 females, 21 males) with a mean age of 17.38 ± 1.34, who were 6 months (± 3 weeks) into orthodontic treatment. Group 2 comprised 35 patients (18 females, 17 males) with a mean age of 17.51 ± 1.38, who were 12 months (± 4 weeks) into orthodontic treatment. Group 3 (control) consisted of 28 patients (13 females, 15 males) with a mean age of 15.07 ± 1.54, who were examined for white spot lesions immediately after having their braces placed on their teeth. The original goal was for each group to consist of 50 subjects (a total of 150) by the end of the study, but it was only possible to recruit a total of 100 subjects.

The demographics for the subjects are presented in Table 1. The groups were not significantly different by age, gender, or race.

Table 1. Demographic variables of the three groups

	6-month (n=37)	12-month (n=35)	Control (n=28)
Mean age ± S.D.	17.38 ± 1.34	17.51± 1.38	15.07 ± 1.54
Gender			
Female	16 (43%)	18 (51%)	13 (46%)
Male	21 (57%)	17(49%)	15 (54%)
Race			
Caucasian	15 (41%)	18 (51%)	16 (57%)
African American	17 (46%)	16 (46%)	7 (25%)
Other	5 (13%)	1 (3%)	5 (18%)

On a regular basis a research assistant searched the schedule at the VCU Department of Orthodontics for patients that fell into those time points (day of bonding, 6 months, or 12 months). The previously identified subjects were asked if they would participate in the study and informed consent was obtained prior to the measurements by the principal investigator who was blind as to the patient's time frame of orthodontic therapy.

Initially, the buccal surfaces of the patient's maxillary anterior teeth were thoroughly cleaned with a toothbrush and water to remove any plaque or debris that may affect the DIAGNOdent measurements. The original study design included measurements from

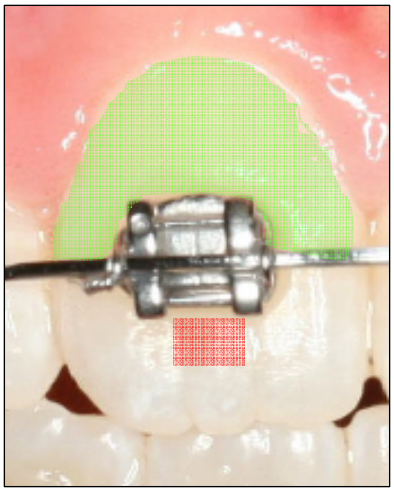


Figure 1. Areas of DIAGNOdent Measurement. The tooth structure gingival to the archwire (shaded green) was examined for white spot lesions. An area of sound enamel near the incisal edge was also measured (shaded red).

second premolar to second premolar in the maxilla, but in the preliminary study, very few measurements were possible gingival to the bracket on the maxillary premolars due to gingival hyperplasia and inflammation.

Prior to the measurements, the teeth to be examined were isolated with cotton rolls and air dried for 5 seconds. Each tooth surface was examined visually for enamel decalcification gingival to the archwire using the following scale (Figure 1):

Score 0 = No visible white spots or surface disruption (no decalcification)

Score 1 = Visible white spot without surface disruption (mild decalcification)

Score 2 = Visible white spot lesion having a roughened surface but not requiring a restoration (moderate decalcification)

Score 3 = Visible white spot lesion requiring restoration (severe decalcification).

In addition, a surface was considered as having a lesion when it had a white spot, a brown discolored lesion, or was cavitated. Hypoplastic or fluorotic enamel was not scored as caries.

Figure 2. DIAGNOdent Calibration..

After visual inspection, each tooth was also examined using the DIAGNOdent. As recommended by the manufacturer, before every measurement session, the instrument was calibrated against the ceramic standard to ensure an accurate reading (Figure 2). In addition, on each subject, a site of sound enamel on the labial surface of an upper central incisor near the incisal edge was measured to obtain baseline measurement. The instrument was then zeroed so that all measurements from that point on were in comparison to the sound enamel in the incisal portion of the central incisor (Figure 1). Only the tooth surfaces gingival to the archwire were scanned and measured with the DIAGNOdent because this is the area most prone to develop enamel decalcification

during orthodontic treatment when oral hygiene is poor.[36] The areas were carefully scanned with the probe by holding the tip in contact with the tooth surface and tilting the tip around the measuring site in order to collect the fluorescence from all directions. The DIAGNOdent measurements provided the actual reading of the spot that was currently being measured (moment) as well as a peak reading over the selected area (Figure 3). A peak measurement for each tooth gingival to the archwire was recorded as well as a measurement of an area of sound enamel near the incisal edge (incisal score) which was used to compare each tooth's baseline measurements (Figure 4). By doing the measurements in this way, each tooth had a measurement of sound enamel and a measurement of the most decalcified enamel (if present).

Figure 3. **DIAGNOdent pen with the display panel showing the peak and the actual moment measurement**

The patient's date of birth, race, and gender were recorded. After the measurements were taken, each patient, in the presence of their legal guardian, was given oral hygiene instructions based on the findings and the general condition of their teeth and gums.

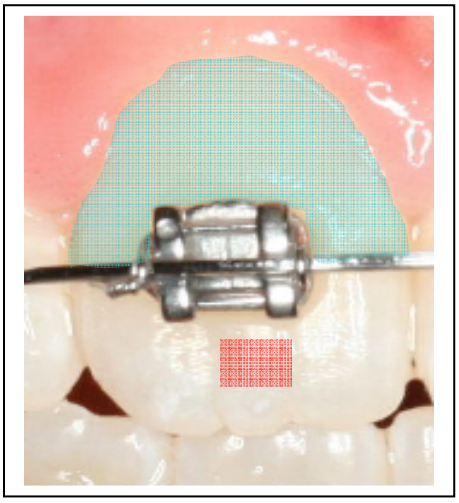
White Spot Lesion / DIAGNOdent Study

Date: _____

Patient # : _____

Patient Initials: _____

Group: **Control** **6-month (+/- 3 weeks)** **12-month (+/- 4 weeks)**



Maxillary Arch

	3	2	1	1	2	3
Visible White Spot Lesion						
Visual Score						
DIAGNOdent Measurement (Incisal)*						
DIAGNOdent Measurement (Gingival) **						

*** Measurement in sound enamel near the incisal edge of each tooth.**
**** Peak value gingival to the bracket.**

Visual Scores

Score 0 = **No visible white spots or surface disruption (no decalcification)**
Score 1 = **Visible white spot without surface disruption (mild decalcification)**
Score 2 = **Visible white spot lesion having a roughened surface but not requiring a restoration (moderate decalcification)**
Score 3 = **Visible white spot lesion requiring restoration (severe decalcification)**

Additional Notes:

_____
_____
_____
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_____
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_____
_____

Figure 4. Data recording sheet.

Statistical Analysis

The three groups were evaluated for differences in the prevalence of having at least one white spot by logistic regression. Time, gender, and race were modeled as covariates, and interactions between group and gender and race and gender were included in the model. Analysis of variance was used with similar models to evaluate the mean number of white spots per subject and the mean DIAGNOdent readings per subject.

Secondary analyses were conducted to evaluate the effect of tooth type and the relationship between the occurrence of white spots and the DIAGNOdent readings. The prevalence of white spots by tooth type was evaluated with logistic regression. Spearman correlation was used to evaluate the relationship between the DIAGNOdent readings and the severity of the white spot lesions. The significance level was set at $P < 0.05$.

Results

Visual Examination

The frequency of individuals having a white spot lesion upon visual examination is presented in Table 2. In the control group, only 10.71 % of the sample had at least one visible white spot lesion. In the 6- and 12-month groups, however, the percentages increased to 38% and 46%, respectively. Both the 6-month ($p = 0.021$) and the 12-month groups ($p = 0.005$) were significantly different from the control group but not significantly different from each other ($p = 0.5$). The mean number of white spot lesions per group is shown in Table 3. The 6- and 12-month groups showed significantly higher mean numbers of white spot lesions per individual (1.03 and 1.11, respectively) than the control group (0.14) ($p = 0.005$).

Table 2. Frequency of individuals with white spot lesions (visual examination).

Group	No WSL	WSL Present
6-month	23	14* (38%)
12-month	19	16* (46%)
Control	25	3 (11%)

* $p < 0.05$

Table 3. The mean number of white spot lesions per individual.

Group	N	Mean ± S.D.
6-month	37	1.03 ± 0.24*
12-month	35	1.11 ± 0.24*
Control	28	0.14 ± 0.27

* $p < 0.05$

Table 4 presents the distribution of the white spots in greater detail. Almost 90% of the control group did not present with any white spot lesions on the day of their bonding, and all of the remaining 10% had between 1 and 3 white spot lesions per patient. The 6-month group, however, was different. Of the total 37 patients, 62% presented with no detectable white spot lesions, 22% had between 1 and 3 white spot lesions, and 16% had greater than or equal to 4. In some cases, all six of the maxillary anterior teeth presented with white spot lesions. The 12-month group was similar with 54% unaffected, 34% with 1 to 3 white spot lesions, and 12% with greater than or equal to 4 lesions per individual.

Table 4. Distribution of white spot lesions per individual.

	6-month	12-month	Control
No WSL	23 (62%)	19 (54%)	25 (90%)
1-3 WSL	8 (22%)	12 (34%)	3 (10%)
≥ 4 WSL	6 (16 %)	4 (12%)	0 (0%)

In this study, there was a statistically significant difference ($p = 0.0015$) in the prevalence of white spot lesions between males and females. In fact, 76% of the subjects in the study that had at least one visible white spot were males compared to 24% females (Table 5).

Table 5. Gender effect on white spot lesion formation.

Group	Number of males with WSL	Number of females with WSL
6-month	11	3
12-month	12	4
Control	2	1
Total	25 (76%)	8 (24%)

DIAGNOdent measurements

The Spearman correlation coefficient between the DIAGNOdent gingival readings and the visual score showed a statistically significant relationship between the two measurements ($r = 0.71$). There was not a strong correlation between the DIAGNOdent incisal readings and the visual score ($r = 0.11$, $p = 0.28$).

To determine if any one tooth had significantly more white spot lesions than the other teeth, the mean DIAGNOdent incisal and gingival measurements and the mean visual score were also analyzed. There were no significant differences by tooth type for any measure at any time (see Appendix).

Discussion

The results of the present study indicate that white spot lesions remain a considerable problem during orthodontic treatment with full fixed appliances when oral hygiene is poor. The fixed appliances serve as plaque retention sites, and in the absence of good oral hygiene, the plaque accumulates, and the acidogenic bacteria cause marked decalcification. In this study, 38% of the subjects had a visual white spot lesion 6 months into treatment, and this number increased to 46% for the 12-month group. Only 11% of the control group presented with at least one white spot lesion. Gorelick et al.[1] reported a prevalence of about 50% in their study. A higher prevalence may be contributed to the inclusion of both the maxillary and mandibular teeth and to the length of the orthodontic treatment. In this study, only the maxillary anterior teeth were examined for the presence of white spot lesions and measurements took place at 6 and 12 months rather than after debonding.

In this study, it was only possible to examine the maxillary anterior teeth because the tooth surface gingival to the archwire was covered by the inflamed gingiva in the premolar region. This was probably due to a more gingival bracket placement on the premolars as well as gingival hyperplasia and inflammation as a result of poor oral hygiene. In the presence of poor oral hygiene, the gingival tissues can trap plaque, and white spot lesions can develop underneath the inflamed, hyperplastic gingiva complicating white spot lesion detection for the clinician. Therefore, white spot lesions become almost impossible to detect unless gingival surgery is performed for the removal of excess gingiva. This problem is not always isolated to the premolars as it can easily happen on any tooth where the bracket placement is close to the gingival margin or any time when oral hygiene is inadequate.

It is perhaps more devastating for the patient if the lesions develop in the esthetic zone of the maxillary anterior segment. Because of this concern, it has been recommended to perform laser gingivectomy on teeth where there is inadequate space between the gingiva and the bracket.[37] This procedure creates a cleansable and accessible tooth surface that is less prone to inflammation and decalcification as long as oral hygiene is adequate.

In the literature, there has been conflicting reports on the distribution of these lesions. Gorelick et al.[1] reported that the most common tooth affected was the maxillary lateral incisor. On the other hand, Mizrahi[36] concluded the maxillary and mandibular first molars to be the most common tooth affected. In a later study, Øgaard was in agreement with Mizrahi's conclusions.[5] In contrast, Geiger et al.[4] reported that lesions occurred most frequently on maxillary lateral incisors and canines. The present study, however, found no significant differences between the distribution of white spot lesions at 6 months, 12 months, or the day of bonding (control).

The high prevalence of white spot lesions at only 6 months into active orthodontic treatment suggests that decalcification is an important concern in the presence of fixed appliances when oral hygiene is poor. According to Øgaard et al.,[9] these lesions can become noticeable around the brackets within 1 month of bonding. Therefore, it is of utmost importance for the clinician to recognize inadequate oral hygiene and implement extra measures to prevent decalcification from occurring.

In an *in vivo* study by O'Reilly and Featherstone,[3] enamel decalcification that developed after one month around fixed appliances was measured by microhardness tests. The results revealed a 15% mineral loss, both occlusal and cervical to orthodontic brackets on premolars, in patients who only brushed daily with a sodium fluoride (1,100 ppm fluoride) dentifrice. Demineralization, however, could not be observed clinically by

visual examination. In the same study, patients who brushed daily with the same fluoride dentifrice but also rinsed with a 0.05% sodium fluoride mouthrinse showed complete reversal of the lesions. The demineralization process happens gradually, and in incipient lesions, only the surface enamel is softened, which can lead to further destruction and subsurface lesions. Furthermore, lesions of softened outer enamel have potential to remineralize faster and more completely than subsurface lesions.[9] Therefore, the use of topical fluoride in patients with poor oral hygiene is highly effective in preventing decalcification as shown in O'Reilly and Featherstone's study.[3]

Detecting white spot lesions during active treatment can be challenging for the clinician. The clinical crown must be free from plaque and debris, and the presence of excess gingival tissues can make visualization of the white spot lesions difficult. Furthermore, in order to detect incipient white spot lesions, the tooth must be air dried. If these steps are not followed, a white spot lesion could easily be overlooked. Therefore, a thorough examination of each patient should be done at each appointment, and each patient should receive a customized oral hygiene treatment regimen to halt the progression of any decalcification.

In this study, the 6- and 12-month groups had an average of 1.03 and 1.11 white spots per individual, respectively, but these averages may be deceiving as many patients had a much larger problem with decalcification. For instance, of the subjects in the 6-month group with white spot lesions, 43% of them had four or more lesions in the maxillary anterior segment. However, not all of the subjects had such a severe problem, and the individual results reflected a great amount of individual variability indicating that in the presence of poor oral hygiene several teeth may be affected.

Another interesting finding of the study was the overwhelming difference between the prevalence of white spot lesions for males and females. Of the subjects

found to have at least one white spot lesion, 76% of them were male. These findings differ from Gorelick's findings.[1] In that study, the incidence was 44% for boys and 54% for girls. However, a more recent study by Boersma[11] found that 40% of the buccal surfaces in males had decalcification compared to 22% in females. Similarly, van der Veen et al.[32] found a statistically significant difference between number of lesions in male and female subjects. Of the 417 white spot lesions found, 62% of them were from the male subjects and 38% of from the female subjects. One possible explanation for these results is that females are generally more compliant orthodontic patients. Some studies reported that girls were more adherent to orthodontic instructions than boys,[38-40] whereas others found no association between sex and compliance.[41]

One of the main purposes of this study was to examine if there was a correlation between the visual scores for white spots and the measurements from the DIAGNOdent. The results showed a statistically significant correlation between the visual score and the gingival measurements from the DIAGNOdent. As expected, there was not a strong correlation between the visual score and the incisal measurements from the DIAGNOdent because the incisal measurements were made in sound enamel in order to obtain a baseline reading of tooth enamel. The correlation between the DIAGNOdent measurements and the visual score represents the possibility of the DIAGNOdent being a useful tool to follow the progression of white spots longitudinally throughout orthodontic treatment. From the results of this study, it is still unclear whether or not the DIAGNOdent can identify lesions before they are visually detectable. If there was a visually detectable white spot lesion, the DIAGNOdent was able to detect it as well. In a clinical setting, an orthodontist could have an assistant scan each patient's teeth with the DIAGNOdent for white spot lesions at the beginning of each appointment. If any lesions are found, the orthodontist can confirm and examine the lesion and recommend certain

strategies to combat the progression of the lesion. Therefore, the device could serve as a tool for an orthodontist to know when to recommend a more intense oral hygiene regimen for patients who are more susceptible to the development of white spot lesions. Early detection of white spot lesion development is of ultimate importance, and visual inspection alone may be inadequate to monitor lesions over time.

Conclusions

This study was conducted to establish an accurate evaluation of the prevalence of white spot lesions during fixed orthodontic treatment at the 6 month, 12 month, and day of bonding time points. A statistically significant increase in the amount of white spot lesions was found in both the 6- and 12-month group when compared to the control group. There was a great amount of individual variability among the patients with some displaying no evidence of decalcification and others having decalcification almost on each tooth. In this study, there was a statistically significant difference in the prevalence of white spot lesions between male and female subjects with the female subjects having significantly fewer white spot lesions present. No one tooth was found to have a higher prevalence of white spot lesions than the others. Also, the results showed a significant correlation between the visual examination and the DIAGNOdent measurements, indicating that the DIAGNOdent is capable of identifying white spot lesions. However, further studies are needed to determine whether the DIAGNOdent is capable of detecting a white spot lesion before it becomes clinically visible.

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Appendix

12 month group: Differences between individual teeth.

Tooth #	Number in group	Mean Visual Score	Mean Incisal DIAGNOdent Measurement	Mean Gingival DIAGNOdent Measurement
UL1	35	0.228571	0.057143	2.91429
UL2	35	0.285714	0.028571	3.20000
UL3	35	0.257143	0.171429	3.82857
UR1	35	0.228571	0.000000	3.74286
UR2	35	0.314286	0.028571	3.62857
UR3	35	0.200000	0.085714	3.62857

6 month group: Differences between individual teeth.

Tooth #	Number in group	Mean Visual Score	Mean Incisal DIAGNOdent Measurement	Mean Gingival DIAGNOdent Measurement
UL1	37	0.216216	0.162162	3.16216
UL2	37	0.270270	0.324324	2.75676
UL3	37	0.243243	0.243243	4.16216
UR1	37	0.189189	0.054054	2.00000
UR2	37	0.189189	0.216216	2.18919
UR3	37	0.189189	0.378378	3.21622

Control group: Differences between individual teeth.

Tooth #	Number	Mean Visual Score	Mean Incisal DIAGNOdent Measurement	Mean Gingival DIAGNOdent Measurement
UL1	28	0.071429	0.071429	0.71429
UL2	28	0.035714	0.142857	1.17857
UL3	28	0.000000	0.178571	1.14286
UR1	28	0.000000	0.035714	0.75000
UR2	28	0.035714	0.107143	0.96429
UR3	28	0.000000	0.250000	1.07143

Raw Data

Date_exam	Pt_ID	Pt	Group	R3VS	R2VS	R1VS	L1VS	L2VS	L3VS	R3DI	R2DI	R1DI	L1DI	L2DI	L3DI	R3GI	R2GI	R1GI	L1GI	L2GI	L3GI
4/15/2008	1	ms	6m	0	0	0	0	1	0	0	0	0	0	0	0	2	2	0	0	1	4
4/15/2008	2	cr	6m	0	0	0	0	0	0	2	0	0	0	2	0	4	0	1	1	3	0
8/7/2008	3	ml	c	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
8/6/2008	4	as	c	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
7/30/2008	5	br	6m	0	0	0	0	0	0	2	1	2	0	0	2	5	5	4	4	5	5
7/30/2008	6	ah	12m	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	1	2	0
7/10/2008	7	ap	6m	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	0	1	2
6/19/2008	8	cc	12m	1	0	0	0	0	1	0	0	0	0	0	0	7	1	0	1	0	14
6/18/2008	9	aj	c	0	0	0	0	0	0	1	0	0	0	0	1	5	1	0	0	1	1
6/18/2008	10	db	12m	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
6/18/2008	11	tb	12m	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
6/18/2008	12	kc	6m	0	0	0	0	0	0	0	1	0	1	2	0	2	1	0	0	4	3
6/12/2008	13	nm	6m	2	2	0	2	2	0	0	0	0	0	0	0	17	11	4	7	13	31
6/11/2008	14	ta	12m	1	1	0	2	0	1	0	0	0	0	0	1	5	5	0	14	2	12
6/11/2008	15	sc	6m	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	1
6/11/2008	16	ct	6m	0	0	0	0	0	0	1	0	0	0	1	1	1	1	8	4	3	2
6/10/2008	17	mc	6m	1	0	1	1	0	1	0	0	0	0	0	0	14	0	11	16	0	10
6/9/2008	18	bk	6m	0	0	0	0	0	0	1	0	0	0	0	1	5	1	1	1	1	4
6/6/2008	19	ad	6m	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1	1	1	5
6/6/2008	20	ep	6m	1	1	2	2	0	1	0	0	0	0	0	0	12	11	9	26	0	10
6/4/2008	21	af	12m	3	2	3	2	2	2	0	0	0	0	0	2	45	43	65	27	20	21
6/4/2008	22	dj	12m	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
5/29/2008	23	bc	12m	0	1	1	0	1	0	1	1	0	1	1	1	3	7	7	3	5	3
5/28/2008	24	lb	6m	0	0	0	0	0	1	1	0	0	0	0	2	1	0	2	2	0	10
5/28/2008	25	cn	6m	1	0	1	0	1	1	1	0	0	0	0	0	5	0	1	0	2	3
9/8/2008	26	jv	6m	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	2	0	1
9/8/2008	27	bl	12m	0	0	0	0	0	0	0	0	0	0	0	0	7	4	3	3	3	7
9/5/2008	28	km	12m	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0	4	4
9/5/2008	29	nt	6m	0	0	0	0	0	0	0	0	0	0	0	0	4	0	1	0	1	1
9/5/2008	30	sn	12m	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
9/3/2008	31	ng	12m	0	0	0	0	0	0	0	0	0	0	0	0	2	4	1	0	5	0
9/3/2008	32	rk	12m	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
9/3/2008	33	ck	12m	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	3	4
8/28/2008	34	sd	c	0	0	0	0	0	0	2	0	0	0	0	1	1	1	1	0	1	1
8/28/2008	35	kj	12m	0	1	0	0	0	0	0	0	0	0	0	0	1	6	0	2	1	0
8/28/2008	36	cp	6m	2	2	1	1	2	2	0	0	0	0	2	2	13	9	6	13	11	15
8/27/2008	37	cr	6m	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	1	3	1
8/27/2008	38	mk	12m	0	1	0	0	0	0	0	0	0	0	0	0	2	5	1	1	3	1
8/27/2008	39	dh	c	0	0	0	1	0	0	0	0	0	0	1	0	1	2	2	11	5	2
8/27/2008	40	np	c	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
8/27/2008	41	mm	12m	0	1	0	0	0	0	0	0	0	0	0	0	1	7	0	0	1	1
8/25/2008	42	cp	12m	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	2	0
8/25/2008	43	ts	c	0	0	0	1	1	0	0	0	0	0	0	0	1	1	0	1	5	1
8/25/2008	44	ls	6m	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
8/25/2008	45	mv	6m	0	0	0	0	0	1	2	1	0	0	0	0	5	1	0	1	2	9
8/21/2008	46	ys	c	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	1	1

8/20/2008	47	ts	12m	0	0	0	1	1	0	1	0	0	0	0	0	2	3	0	7	8	2
8/20/2008	48	ks	6m	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
8/14/2008	49	dh	c	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
8/13/2008	50	ap	6m	0	0	1	1	1	1	1	1	0	1	1	1	1	3	6	10	6	11
11/12/2008	51	tm	12m	0	1	0	0	1	1	1	0	0	0	0	0	1	0	0	1	5	5
11/12/2008	52	ts	6m	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	3	0
11/12/2008	53	dm	c	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	1	2	2
11/12/2008	54	mh	6m	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1
11/12/2008	55	lh	6m	0	0	0	0	0	0	1	0	0	0	1	0	0	1	2	1	1	0
11/12/2008	56	tg	6m	0	0	0	0	0	0	0	1	0	1	1	0	2	3	2	4	2	0
11/12/2008	57	fg	6m	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
11/10/2008	58	ih	6m	0	0	0	0	1	0	0	0	0	0	0	0	2	2	3	1	6	1
10/23/2008	59	aw	12m	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3	2	2	2
10/22/2008	60	km	12m	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1	1
10/22/2008	61	jd	c	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	1	1
10/16/2008	62	bm	12m	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2	0
10/13/2008	63	df	12m	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	3	5	1
10/13/2008	64	ef	6m	0	1	0	0	1	1	0	0	0	0	0	0	2	9	1	3	10	9
10/13/2008	65	jr	6m	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
10/13/2008	66	rj	12m	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	1	1	2
11/10/2008	67	dg	c	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
11/10/2008	68	df	12m	1	1	0	0	1	1	0	0	0	0	0	0	6	5	2	3	8	10
11/3/2008	69	cr	12m	0	0	0	0	0	0	0	0	0	0	0	0	3	1	1	1	0	1
11/3/2008	70	es	6m	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	1	2	2
12/5/2008	71	ep	12m	1	1	3	3	0	2	0	0	0	0	0	0	13	11	33	23	0	15
12/4/2008	72	sm	12m	0	0	0	0	1	0	0	0	0	0	0	1	2	2	0	1	7	2
12/4/2008	73	ca	6m	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0
12/3/2008	74	es	c	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	1
12/3/2008	75	kh	c	0	0	0	0	0	0	0	0	0	1	0	0	1	2	0	0	1	1
12/3/2008	76	np	c	0	0	0	0	0	0	1	1	0	0	1	0	3	1	1	0	1	2
12/2/2008	77	tc	c	0	0	0	0	0	0	0	0	0	1	0	1	3	3	0	0	1	5
12/1/2008	78	mj	6m	0	0	0	0	0	0	1	1	0	1	1	0	3	3	0	4	1	0
12/1/2008	79	nv	6m	0	0	1	0	1	0	0	0	0	0	0	0	5	3	4	2	8	6
12/1/2008	80	af	c	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1
11/19/2008	81	mm	c	0	0	0	0	0	0	1	1	0	0	0	1	1	2	0	0	0	1
11/19/2008	82	th	c	0	0	0	0	0	0	1	0	0	0	1	1	1	0	2	2	1	1
12/19/2008	83	sw	c	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
12/19/2008	84	jb	c	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	1	1	0
12/18/2008	85	hg	c	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1
12/15/2008	86	er	12m	0	0	1	0	0	0	0	0	0	0	0	0	0	2	6	1	2	3
12/15/2008	87	jc	c	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	0	2	1
12/12/2008	88	rm	12m	0	0	0	0	1	1	0	0	0	1	0	0	0	0	1	3	11	9
12/11/2008	89	wc	c	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	2
12/11/2008	90	jb	6m	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	2
11/12/2008	91	jp	6m	0	0	0	1	0	0	0	1	0	0	0	0	2	1	0	4	1	1
12/10/2008	92	bk	12m	0	1	0	0	1	0	0	0	0	0	0	0	0	6	1	2	5	0
12/10/2008	93	ba	12m	0	0	0	0	0	0	0	0	0	0	0	0	5	2	2	1	1	5
12/10/2008	94	re	12m	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	1	1
12/11/2008	95	bc	c	0	0	0	0	0	0	0	0	0	0	0	0	2	2	1	1	2	2
12/11/2008	96	bb	c	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	1	2	2
12/8/2008	97	gg	6m	0	1	0	0	0	0	0	0	0	1	0	0	3	7	2	4	4	3
12/8/2008	98	ja	12m	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	1	1	4

1/12/2009	99	lc	c	0	0	0	0	0	0	0	0	1	0	0	0	1	1	2	0	1	0
1/12/2009	100	ee	c	0	1	0	0	0	0	0	0	0	0	0	0	0	4	1	0	0	0

Vita

J. Spencer Dixon IV was born in Orangeburg, South Carolina on June 2, 1980. He attended Orangeburg Preparatory School until 1998. He proceeded to Wofford College in Spartanburg, South Carolina and graduated with a Bachelor of Science degree in Biology. In May of 2007, he graduated from the College of Dental Medicine at the Medical University of South Carolina as valedictorian of his class. He is currently a postgraduate resident in the Orthodontic program at Virginia Commonwealth University and will receive a certificate in Orthodontics along with a Master of Science degree in Dentistry.