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CONCURRENT WHITENING AND ORTHODONTIC TREATMENT

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

by

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## Abstract

### CONCURRENT WHITENING AND ORTHODONTIC TREATMENT

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Thesis Director: Eser Tüfekçi, D.D.S., M.S., Ph.D.  
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The aim was to evaluate whether a whitening system, when used during the final stages of orthodontics, would yield results comparable to whitening alone. Patients were assigned to either the control (n=20) or experimental (n=26) groups. At T<sub>1</sub>, patients were given a ten day supply of Trèwhite™ by Opalescence®, instructions on use, and initial shade determination was made and photographs were taken. At T<sub>2</sub> and T<sub>3</sub>, shade determination was accomplished and updated photographs were taken. Whitening of the teeth occurred in both groups on average, but significantly more whitening was experienced in the experimental group ( $p < 0.004$ ). An average of 87% of teeth whitened during orthodontic treatment compared to 97% of control teeth ( $p < 0.01$ ) were judged to be uniform in appearance. In conclusion, the data do not contraindicate the concurrent accomplishment of teeth whitening during orthodontic treatment.



## CHAPTER 1

### Introduction

Patients play an active role in influencing treatment planning decisions in orthodontics, and esthetic improvement is a primary motivating factor for patients in this process. Increasingly, orthodontic tooth movement is only one part of an interdisciplinary approach to dental care that often includes general dental, prosthodontic, and periodontic contributions. Coordinated care aims to maximize functional and esthetic outcomes for individual patients. Teeth whitening is a popular procedure that can potentially have a significant impact on smile esthetics. If whitening is planned as part of a comprehensive dental esthetic plan, it must be accomplished before shade selection is made for any anterior restorations including cosmetic bonding, veneers, or crowns. Teeth whitening performed concurrently with orthodontic treatment, if effective, would allow patients to transition to a straighter, whiter smile sooner than if the procedures were achieved separately. This could lead to more efficient treatment overall and greater patient satisfaction.

As evidenced by the popularity of teeth whitening products such as Crest White Strips™ (Procter & Gamble, Cincinnati, OH), Simply White™ (Colgate, New York, NY), and many others, as well as the steady number of patients seeking orthodontic treatment, patients are increasingly interested in enhancing the esthetics of their smiles. The most unattractive thing about a smile is having yellow or discolored teeth according to a 2004 American Academy of Cosmetic Dentistry (AACD) scientific poll of the American public.<sup>1</sup> Teeth whitening treatments are the most requested cosmetic dental procedure.<sup>1</sup>

These findings help put into perspective the public's feelings and desires on using teeth whitening to help enhance their smiles. According to the AACD, Americans spent more than \$1.4 billion on over-the-counter whiteners in 2005.<sup>1</sup> The popularity of whitening is also reflected in the large amount of advertising for the products. Recently, this advertising has suggested that whitening can be effectively performed even in the presence of orthodontic appliances.<sup>2</sup>

There are currently numerous different whitening systems available for both in-office bleaching as well as over-the-counter, or take-home bleaching. These products include those with carbamide peroxide and those with hydrogen peroxide as the active ingredient.<sup>3</sup> While the product names and marketing are slightly different, the underlying mechanism of action is essentially the same: the lightening of teeth through the application of a chemical agent that oxidizes the organic pigmentation of teeth.<sup>3</sup> Extensive research on nonvital bleaching, vital bleaching, nightguard bleaching, and dentifrice based whitening have been completed and support the effectiveness and safety of these approaches.<sup>4-13</sup> Based on these studies, it is evident that the whitening effect of teeth whitening systems is time and concentration dependent.<sup>14</sup>

When recommending any dental procedure, especially an elective procedure, it is important to evaluate and explain to the patient any risks before treatment is initiated. As with most dental procedures, the safety of teeth whitening has been evaluated extensively.<sup>8-</sup>

<sup>12</sup> Two common adverse reactions of whitening products, both of the in-office and at-home varieties, are tooth sensitivity and gingival irritation.<sup>4-7, 15-17</sup> Studies have reported that tooth sensitivity occurs in 15-75% of those patients using a whitening regimen.<sup>17-19</sup>

Increasing either the time of application or the concentration of the solution may lead to increased tooth sensitivity.<sup>4-7, 15-17</sup> This sensitivity is most often a short-term side effect shown to either decrease spontaneously or after discontinued use of the whitening product.<sup>4-7, 17-19</sup> Despite precautions such as additive agents including potassium-nitrate, fluoride, or other desensitizing agents, tooth sensitivity associated with teeth whitening is a multifactorial phenomenon which cannot be totally avoided. Sensitivity is not exclusively related to the peroxide whitening material itself, as shown by the occurrence of tooth sensitivity even when whitening trays are worn without whitening gel.<sup>18</sup>

More serious and long-term effects of teeth whitening have also been studied. In a long term retrospective study,<sup>10</sup> patients with previous (9-12 years) whitening participation were examined for potential adverse effects by evaluating tooth vitality, gingival index, and the presence of external cervical resorption. The results showed minimal side effects at approximately 10 years post whitening. Based on the results of several studies,<sup>8-12</sup> the use of whitening products containing either hydrogen peroxide or carbamide peroxide also does not appear to pose an increased risk of oral cancer.

Few studies have examined the relationship between teeth whitening and orthodontic procedures. Miles et al in 1994, measured the effect of whitening with a carbamide peroxide agent on the bond strength of orthodontic brackets.<sup>20</sup> This *in vitro* study using extracted premolar teeth showed significantly decreased bond strengths in teeth that were treated with the carbamide peroxide whitening agent before orthodontic appliances were placed. As a result of the findings, the authors recommended at least a 1

week waiting period between when patients finish tooth whitening and when they present for the bonding of orthodontic attachments.

Comparing the enamel color changes of teeth which had been previously bonded with orthodontic appliances versus those teeth which had never experienced such bonding and debonding, Hintz et al.<sup>21</sup> found that both groups responded positively to the whitening treatment with no significant differences between them. However, the authors noted the previously bonded group took longer to show any initial lightening differences in color from the whitening procedure. It was postulated that the differences were attributable to any of several factors including the saturation of enamel by resin tags and residual adhesive that may have been left after debonding, the debonding procedure itself, as well as the ability of the enamel to show color differences as some amount of enamel may have been lost during the debonding and adhesive removal procedures.<sup>21</sup>

The outcomes of several studies suggest that tooth whitening can occur effectively even when there is not direct and uniform contact between the whitening agent and the enamel surface. In a study conducted by Oliver and Haywood<sup>22</sup> in 1999, bleaching trays were deliberately under-trimmed and ill fitting. The purpose was to determine if effective bleaching extended beyond the borders of a shortened tray or if a demarcation line would be found. The results of the study showed that successful bleaching occurred uniformly, indicating that the clinician does not necessarily need to remake the tray if it does not cover all portions of the teeth.

Studies support the idea that teeth are able to be whitened despite restorations covering the facial surfaces of the teeth.<sup>23-24</sup> In these cases, the restorations do not whiten,

but the presence of the restorations does not prevent the rest of the tooth from whitening. Several studies substantiate the penetration of whitening agents into the pulp chamber and support the theory that whitening agents can traverse directly through the entire mass of a tooth.<sup>15,16, 25-27</sup> These studies, along with those which demonstrate the ability to successfully lighten teeth with porcelain veneers using an at-home carbamide peroxide whitening system show an ability for whitening solutions to pass through all surfaces and layers of a tooth providing uniform whitening along the way.<sup>15, 16, 23-27</sup>

The evidence suggests that effective and uniform teeth whitening could occur beneath bonded orthodontic appliances if patients use whitening agents during orthodontic treatment. The purpose of this study was to determine whether teeth whitening during orthodontic treatment was effective and provided a uniformly shaded surface despite the presence of fixed orthodontic appliances.

## CHAPTER 2

### Material and Methods

This prospective clinical study included 46 patients recruited at Virginia Commonwealth University, School of Dentistry, Department of Orthodontics. Approval from the Institutional Review Board at Virginia Commonwealth University was obtained to conduct the study. Subjects chosen were in good health and without a medical or dental history that would otherwise affect the outcome. Excluded were those patients who had used tooth whitening products (not including whitening dentifrices) within the past two years, patients with restorations present on their maxillary anterior teeth, or a documented history of poor oral hygiene or cooperation. Participants for the experimental group (n = 26) were chosen as the first active orthodontic patients who were within two visits of appliance removal and also met the inclusion criteria. Participants for the control group (n = 20) were recruited from the pool of patients without orthodontic appliances in place who returned for retention checks, as well as School of Dentistry employees who were interested in tooth whitening. Randomization was not possible due to the selection criteria. After patients were selected to be in the study, three appointments were scheduled for each participant.

The VITA Easy shade<sup>®</sup> digital shade detection system (Vident<sup>™</sup>, Brea, CA) was used to evaluate changes in tooth shades as a result of whitening. Prior to the start of the study, it was calibrated using the included calibration block. After calibrating the digital

shade guide, shade A2 of the Vita Classic shade guide was selected for measurement to test for accuracy and reliability. The measurement was repeated 20 times, with digital calibration between each measurement. Ten of the measurements were taken at the center of the shade tab, while the other ten were taken by placing the tip of the digital shade detector on the incisal one third of the shade tab. This was done to check for differences between measurements taken at the center of the tooth versus the incisal one-third. It was necessary to take measurements at the incisal one-third during the study because teeth in the experimental group had orthodontic appliances bonded in the center of the tooth. All shades taken throughout the study in both the experimental and control groups were at the incisal one-third to ensure uniformity in measurement protocol.

The Opalescence Trèwhite™ 10% hydrogen peroxide whitening system (Ultradent Products Inc., South Jordan, UT) was used as the whitening agent throughout the study. The Trèwhite™ whitening system kit included manufacturer's directions on use and 20 trays (10 maxillary and 10 mandibular). The contents were packaged as 10 individual foil top containers each with a maxillary and mandibular tray. The trays were pre-filled, adaptable and disposable. Each tray consisted of a semi-rigid outer tray and a thin inner membrane pre-loaded with two distinct gels, an activating gel and a barrier gel. The activator gel contained 10% hydrogen peroxide. The barrier gel was along the gingival margin of the inner membrane and acted as protection for the tissues while the tray was in use. The gels were mint flavored.

At the first participant appointment ( $T_1$ ), terms of the study were explained and consent was obtained. The participants were informed that they would be given \$25 upon

completion of the study to offset any costs (travel, parking, etc.) incurred for their cooperation in the study. Initial records included an intra-oral digital photograph of the anterior dentition in occlusion and initial tooth shade determination using the VITA Easy shade<sup>®</sup> digital shade detection system. All patient photographs were taken with the same Canon EOS Rebel XT digital camera (Cannon U.S.A., Inc., Lake Success, NY) with ring-flash using the same flash and camera settings. The maxillary right central incisor was chosen as the tooth to be used throughout the study for shade determination and analysis. The subjects were instructed to thoroughly brush their teeth using a soft bristled toothbrush with a standard non-whitening dentifrice. After brushing, they were shown the correct way to insert and wear the whitening trays as indicated by the manufacturer's instructions. This included centering the tray on the arch, light pressure to secure the tray into place, removal of the outer tray, and finally lightly adapting the inner tray to the teeth. The subjects were instructed to wear each tray for 60 minutes per day for ten days as indicated by the manufacturers' directions included in the whitening kits. For participants in the experimental group, T<sub>1</sub> was scheduled for ten days prior to the removal of the patients' orthodontic appliances. For participants in the control group, T<sub>1</sub> was scheduled at the convenience of the participant. The subjects were then given the whitening kits for home use and dismissed.

The second appointment (T<sub>2</sub>) was scheduled for ten days after the delivery of the whitening system (T<sub>1</sub>), marking the completion of the whitening phase of the study. Participants in the experimental group had braces debonded, residual cement removed, and teeth pumiced before T<sub>2</sub> measurements were taken. Immediate post whitening shades as



well as immediate post treatment photographs were taken for both groups. Impressions for retainers were also taken for the experimental group during this visit.

Final records were taken at T<sub>3</sub>, one week after T<sub>2</sub>. The week between T<sub>2</sub> and T<sub>3</sub> allowed time to compensate for and identify any dehydration effects that may have been present during T<sub>2</sub>. Final shade determination was made and intra-oral photographs were taken. Participants were also given the \$25 for their participation as promised. Retainers were delivered to patients in the experimental group.

The initial shade taken at T<sub>1</sub> was compared to the shades taken at both T<sub>2</sub> and T<sub>3</sub> to determine the degree of whitening that had occurred. The 3D - Master<sup>®</sup> shade guide was used to quantify the numerical difference in value between the shades taken at each time-point (T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub>). The difference was the number of shades each tooth whitened during the study. Changes in hue and chroma were not evaluated. The Wilcoxon signed-rank statistical analysis was used to test for differences in shade within groups as well as between groups.

Final photographs were stored in a Microsoft Office Power Point 2003<sup>®</sup> (Microsoft Corporation, Redmond, WA) file. Images were cropped to show only the maxillary right central incisor. The compilation of images in a random order was shown to three evaluators individually who were asked to answer the question “Does the tooth appear uniform in color?” for each tooth. Inter-evaluator agreement was assessed and the uniformity between the control and experimental teeth was compared using a repeated-measures logistic regression using SAS software (SAS Inc., Cary, NC).

## CHAPTER 3

### Results

Accuracy and reliability of shade determination was assessed by evaluating the shade measured at the center and incisal one-third of the A2 sample of the VITA Easy shade<sup>®</sup> guide. The data in Table I show 90% accuracy and reliability for shades taken at the center of the tooth and the incisal one-third. This shows the ability of the VITA Easy shade<sup>®</sup> digital shade detection system to be accurate when taking measurements either from the center or incisal one-third of the tooth. Measurements were taken at the incisal one-third for both the control and experimental groups.

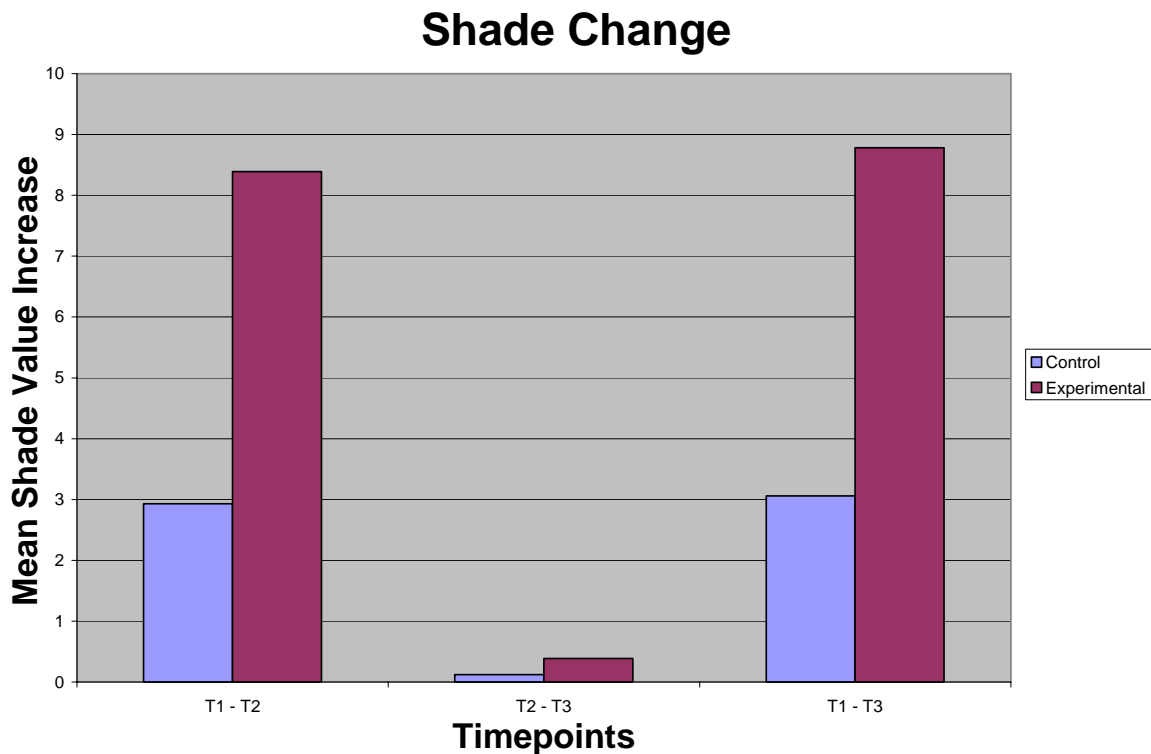
**Table I**

**Measurements of Vita Classic shade guide A2 with the VITA Easy shade<sup>®</sup> digital shade detection system**

Measurement	Shade	
	Center	Incisal Edge
1	A2	A2
2	A2	A2
3	A2	A2
4	A2	A2
5	A2	A2
6	A2	B1
7	A2	A2
8	B1	A2
9	A2	A2
10	A2	A2

Of the 46 study participants, all but 6 participants were able to complete the ten day whitening regimen. Of the six participants who withdrew from the study, five were from the control group and one from the experimental group. The five control group participants who withdrew from the study cited “severe gingival discomfort” related to the tray borders extending onto the gingival tissues causing irritation and ulceration as their reason for withdrawing. The participant from the experimental group who did not complete the study did not return for final measurements within the specified time period. Eight of the 40 remaining participants who did complete the study were unable to wear the trays for the entire 60 minutes per day as instructed. These participants, all from the control group, were able to wear the tray for at least thirty minutes per day for ten days. These eight participants were still included in all of the study results and were considered to have successfully completed the study. The results were not evaluated for any demographic descriptors such as age, gender, or ethnicity.

Shade measurements at T<sub>1</sub>, T<sub>2</sub>, and T<sub>3</sub> within the control and experimental groups were compared to evaluate if the whitening regimen had any tooth whitening effects. Significant whitening was found for both the control ( $p < 0.001$ ) and experimental ( $p < 0.001$ ) groups when comparing shades at T<sub>1</sub> to both T<sub>2</sub> and T<sub>3</sub>. No significant differences ( $p = 0.5$ ) were found in either group comparing shades taken at T<sub>2</sub> with those taken at T<sub>3</sub>.

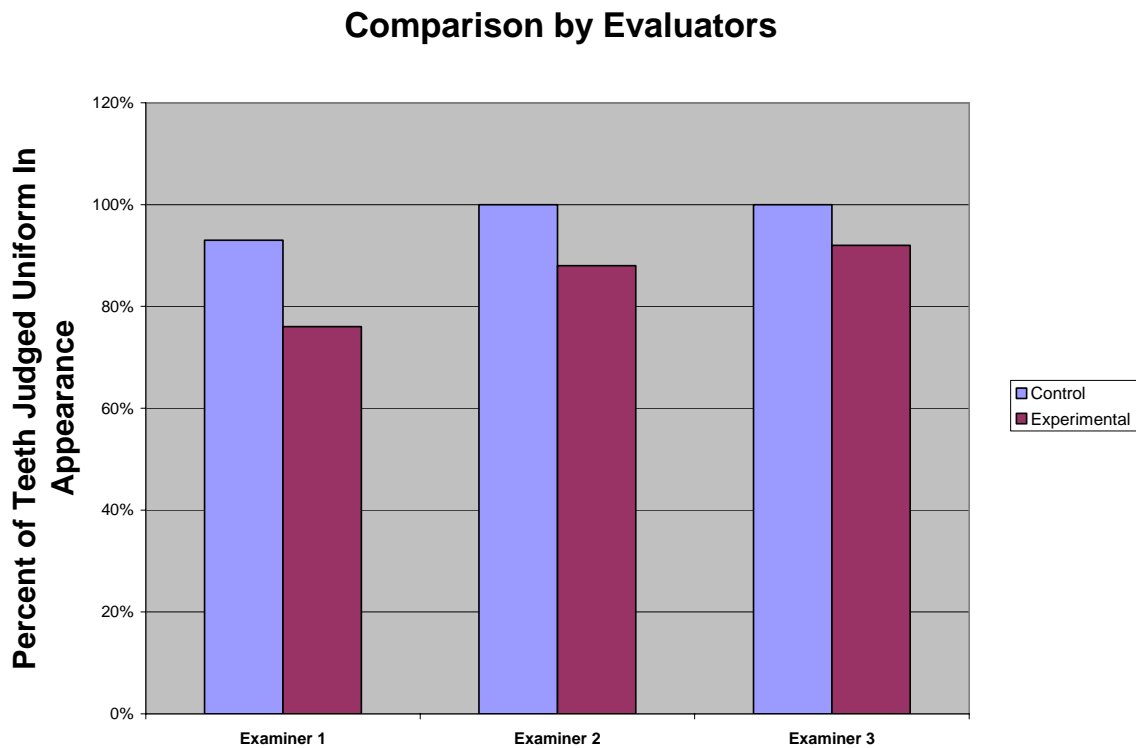


**Fig 1.** Chart showing comparison of the mean amount of shade value increase for the control and experimental groups between time points.

Comparing the shade change from  $T_1$  to  $T_3$  between the groups, there was a statistically significant difference with the experimental group showing more whitening effect than the control group (Fig. 1;  $p < 0.004$ ). The control group whitened an average of  $3.0 \pm 2.5$  shades while the experimental group whitened an average of  $8.4 \pm 4.6$  shades.

All teeth ( $N=40$ ) were rated for uniformity of appearance (Uniform or Not) by three examiners at  $T_3$ . The uniformity of control teeth ( $n = 15$ ) and experimental teeth ( $n = 25$ ) was compared to determine whether there were differences in their appearance attributable to having fixed orthodontic appliances in place during the whitening procedure.

Agreement among the three examiners ranged from 78% to 88%. Most of the teeth in both groups were rated as uniform in appearance by all three examiners. While two of the examiners only rated 3 or fewer of the 40 teeth as non-uniform, the other examiner rated 7 teeth as non-uniform (Fig 2). However, there were no significant differences among examiners ( $p = 0.24$ ). Using the data from all three examiners, 98% of the ratings of control teeth were uniform and 87% of the ratings of experimental teeth were uniform. This difference was statistically significant ( $p = 0.01$ ) with the experimental teeth more likely than the control teeth to be rated as non-uniform in appearance after whitening.



**Fig 2.** Chart depicting the examiner differences in judging uniformity in tooth appearance.

## CHAPTER 4

### Discussion

This study compared the results of whitening teeth with bonded orthodontic appliances in place to whitening teeth without orthodontic appliances. The purpose was to evaluate whether or not whitening teeth with orthodontic appliances in place resulted in an area of discoloration from unequal whitening beneath the orthodontic bracket when the appliances were removed. The study found both the control ( $p > 0.005$ ) and experimental ( $p > 0.005$ ) groups experienced significant whitening. The results showed statistically significant differences in shade measurement from  $T_1$  to  $T_2$  and  $T_3$ , confirming that tooth whitening occurred in both groups. Also, the experimental group experienced significantly more whitening than the controls when the groups were compared. At the conclusion of the study, photographs evaluated by three dental professionals were rated as being uniform in appearance in 87% of the experimental and 97% of the control teeth. The findings confirming statistically significant whitening during the study are consistent with previous studies evaluating the efficacy of similar whitening systems.

The control group displayed significantly less whitening than the experimental group, on average. This is likely due to a number of control group participants (8 of 15) who were unable to wear the whitening trays for the full 60 minutes per day due to gingival irritation. Although these 8 participants were considered as successfully completing the study, it is probable that the full whitening effect was not achieved due to

the decreased time of tray wear. Several previous studies have shown a time dependence of teeth whitening, where a positive correlation exists between the amount of whitening achieved and the wear time of the whitening trays.<sup>4-14</sup>

In an attempt to increase the number of control participants who could wear the whitening tray for a full 60 minutes, future studies might use a customized nightguard bleaching tray instead of the Trèwhite™ whitening system. A possible tray design for orthodontic patients could include the modification of a traditional nightguard bleaching tray by removing the facial aspect of the tray material apical to the incisal edge of the bonded orthodontic appliances. The idea behind this design would be to deliver a whitening solution from the lingual aspect of the tray and allow the tooth whitening solution to diffuse through the tooth from the lingual to the buccal. In this study, the Trèwhite™ whitening system was chosen because it simplified and standardized delivery of the whitening solution among all subjects. Each tray contained a standardized dose of whitening gel. Despite the benefit of reproducibility and standardization, using the commercially available Trèwhite™ delivery system did pose some problems for 28% (13/46) of the study participants. Interestingly, the 13 patients who had problems during the study were all from the control group and the problems were all concerned with gingival irritation thought to be caused by the extension of the borders of the trays. Five of these participants found the experience to be uncomfortable enough to make them withdraw from the study. One possible explanation for all of the participants with gingival sensitivity falling in the control group could be that the presence of the orthodontic appliances in the experimental group helped to keep the borders of the tray from contacting

and irritating the gingival mucosa during the treatment duration. This problem may be avoided in future studies by using either custom fabricated nightguard bleaching trays or a commercially available tray designed to adapt more closely to the teeth and not extend so far over the gingival tissues.

The study found no difference between the examiners when judging uniformity of tooth appearance. However, a difference in uniformity was found between the groups. This difference in the uniformity of appearance between groups could have been either a real difference or the result of more teeth in the experimental group displaying common white-spot lesions, thereby appearing non-uniform in appearance. Future studies incorporating a control group with orthodontic appliances but without whitening could help to clarify the effect of white spot lesions on the appearance of shade uniformity. The study limitations pertaining to the subjectivity of examiner opinion regarding uniformity of color could possibly have been minimized if more stringent and defined criteria were given to the evaluators before judging the uniformity of the teeth. The subjectivity of examiner opinion could possibly be avoided altogether in future studies if there was a protocol for measurement of tooth color uniformity that did not involve the subjective opinions of examiners. Methods to remove the subjectivity of outside examiners could include the use of a digital colorimeter to record the exact color of the tooth in different locations such as mesial, distal, incisal, gingival, as well as the area of previous orthodontic appliance attachment.

In an attempt to remove as many examiner biases as possible, the VITA Easy shade<sup>®</sup> digital shade detection system was used in this study. The VITA Easy shade<sup>®</sup>



system incorporates multiple color spectrophotometers at varying angles for accurate shade measurement. In a number of previous whitening studies, matching of tooth color appearance with a standard shade guide was used to evaluate pre and post treatment shades.<sup>3-7, 11-13, 21-24, 27-36</sup> The subjective nature of this shade determination protocol is accepted and attempts are made to minimize outside influences on the process.

Metamerism, intra-examiner and inter-examiner differences, examiner experience, age, fatigue of the human eye, room color and decoration all are important factors that should be considered and best efforts made to avoid their influence in shade determination process.<sup>3,4-6</sup> In this study, the same operator was used for each participant, lighting effects were controlled, and patient position was reproducible. The VITA Easy shade<sup>®</sup> digital shade detection system provided an objective, reliable and reproducible method for shade determination. Future studies should attempt to control and define methodology to minimize variability due to subjectivity and environmental factors.

## CHAPTER 5

### Conclusions

The purpose of this study was to determine whether teeth with bonded orthodontic appliances could be whitened successfully and uniformly. Both patients with and without bonded appliances in place experienced significant whitening as a result of 10 days of the whitening protocol. Patients with orthodontic appliances tolerated the stock whitening trays better and experienced significantly more whitening on average. Though the majority of teeth in both groups were evaluated as having a uniform appearance following whitening, uniformity was judged to be more common in control teeth (98%) than those with bonded appliances (87%). These results suggest that whitening can be achieved successfully in orthodontic patients prior to the completion of treatment, thereby enhancing the final esthetic result. However, more research is needed to confirm the ability to whiten teeth with bonded orthodontic appliances without any adverse effects of incomplete or non-uniform whitening under the appliances.

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APPENDIX AVITA

Dr. Jason Gladwell was born in Omaha, Nebraska on October 14<sup>th</sup>, 1979 and is an American citizen. He attended North Carolina State University in Raleigh, NC where he earned a Bachelor of Science degree of Biological Business Management in 2001. He then attended the University of North Carolina at Chapel Hill School of Dentistry where he was awarded his Doctor of Dental Surgery degree in 2005. The following year he entered the Virginia Commonwealth University graduate orthodontics program and is anticipating receiving a Master of Science in Dentistry degree and a Certificate in Orthodontics in 2007. He plans to enter private practice as an orthodontist in North Carolina upon graduation.