5-2016

Objective evaluation of clinical shade-matching outcomes.

Erin Ballard

OBJECTIVE EVALUATION OF CLINICAL SHADE-MATCHING OUTCOMES

By

Erin Ballard
B.S. Biology, Eastern Kentucky University, 2014

A Thesis
Submitted to the Faculty of the
School of Dentistry, University of Louisville
in Partial Fulfillment of the Requirements
for the Degree of

Masters of Science in Oral Biology

Department of Oral Biology
University of Louisville
Louisville, Kentucky

May 2016

OBJECTIVE EVALUATION OF CLINICAL SHADE-MATCHING OUTCOMES

By

Erin Ballard
B.S. Biology, Eastern Kentucky University, 2014

A Thesis Approved on

March 4th, 2016

by the following Thesis Committee:

_____

Thesis Co-Mentor, Dr. Wei-Shao Lin

_____

Thesis Co-Mentor, Dr. Michael J. Metz

_____

Third Committee Member, Dr. Jang-Ching Chou

_____

Fourth Committee Member, Dr. Bryan Harris

_____

Fifth Committee Member, Dr. Cynthia J. Metz

DEDICATION

This thesis is dedicated to my parents, Caleb and Beth Ballard. Their constant encouragement and support have allowed me to make it to this point in my education.

I also want to thank my Co-Mentors: Dr. Wei-Shao Lin and Dr. Michael Metz. I appreciate their willingness to foster my curiosity and lead me through the research process.

ACKNOWLEDGEMENTS

Dr. Wei-Shao Lin, Thesis Co-Mentor: For constant support, guidance and willingness to work with me as a Master's student.

Dr. Michael Metz, Thesis Co-Mentor: For constant support, guidance and willingness to work with me as a Master's student.

Dr. Bryan Harris, Thesis Committee Member: For his enthusiasm an contributions to the forward movement of the project.

Dr. Jang-Ching Chou, Thesis Committee Member: For encouragement and support through the research process.

Dr. Cynthia Metz, Thesis Committee Member: For continuing investment and interest in the progression of the project.

ABSTRACT

OBJECTIVE EVALUATION OF CLINICAL SHADE-MATCHING OUTCOMES

Erin Ballard

March 4, 2016

The purpose of this study was to objectively evaluate shade-matching outcomes within an academic institution. Using the Spectrophotometer, ΔE was calculated between the reference shade: restoration shade ($\Delta E_{clinical}$) and restoration shade: prescription shade ($\Delta E_{laboratory}$). The t-test was used to determine if ΔE maintained clinical acceptance at ΔE: 3.7. Satisfaction with shade-match and need for objective measurement were surveyed using a Five Point Likert Scale. Correlational relationships were assessed via Pearson Correlation. Mean ΔE values were above the acceptance value (p<0.05). $\Delta E_{clinical}$ was higher than $\Delta E_{laboratory}$ (p<0.0001). The majority of patients (94.2%), students (82.5%), and faculty (58.3%) were minimally "satisfied" with shade-match outcome. The majority of students (77.7%) and faculty (79.7%) supported objective measurement. $\Delta E_{clinical}$ and faculty satisfaction negatively correlated (r=-0.45; p<0.001); $\Delta E_{clinical}$ and faculty support of objective measurement positively correlated (r =0.35; p<0.001). Within the limitations of this study, student shade-mathcing performance needs improvement; objective measurement could be justified.

TABLE OF CONTENTS

PAGE

ACKNOWLEDGMENTS……..…iv
ABSTRACT……...……..……v
LIST OF TABLES…...……...…...vii
LIST OF
FIGURES……..…… .viii

INTRODUCTION……..……..…1

HYPOTHESES……..17

MATERIALS AND

METHODS……19

RESULTS ……....25

DISCUSSION……..…..35

CONCLUSIONS……..…….48

REFERENCES …….49

APPENDICES…….……..54

CURRICULUM VITA……..56

LIST OF TABLES

TABLE

1. Patient and Provider Statistics ……..…….….. 26

2. Restoration Characteristics …….……...…….….27

3. Shade Differences (ΔE) …….…….…….28

4.

a: Satisfaction with the Shade-Matching Outcome …….……..30

b: Support of Objective Shade Measurement……31

5. Correlations between Shade Differences and Patient, Student, Facutly Data…….. 33

6. Effect of patient, student and faculty characteristics on mean shade difference…..….34

LIST OF FIGURES

FIGURE

1.Difference in Shade (ΔE) Equation …….8

2. Restoration by Material Family and Location ……...……...27

3.. Satisfaction with the Shade-Matching Outcome…….……..……32

4.Support of Objective Shade Measurement…….32

CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

Throughout the years, dental patients have grown to expect more from dental treatment (1); they want functionality, but also a pleasing smile (2). Study of the esthetic concerns has found that patients place the greatest deal of importance on the shade of the teeth, even over orthodontic concerns (3). Therefore, the patient is likely to place a great deal of importance of the shade-match of any restorative work they may receive (3). Shade-matching for such procedures is generally conducted subjectively; dentists must often use their best clinical judgment in the selection of the prescription shade and hope the restoration shade is clinically acceptable (4). This air of subjectivity does not align well with current expectations. As a result, shade-matching continues to be a problem in the dental field.

The Visual Process

The complex nature of observing color does not make solving the problem of shade-matching any easier. A meshing of physiology and physics play a role in our ability to see something (5). When light strikes an object, the object absorbs some of that light and some is reflected back to the viewer (6). The reflected light enters the eye through the pupil and eventually strikes the retina. The photosensitive rods and cones inside detect the light and finally the information is communicated through the nervous

system (5). This synchronized relay between light and the brain is of particular concern when performing a dental restoration. The shade of human teeth can vary from different angles due to the curved and multi-layered nature of tooth structure (7), adding even more variety to an innately complex issue. Secondly, through metamerism, seemingly matching colors can become a mismatch from one light source to the next (6). Adding yet another frustrating layer of variability for the clinician to consider because of course, the patient's smile will be viewed under different lighting throughout the patient's daily life (8).

The Study of Color

The complexity of color has led scientists and artists to attempt to explain it for years (6). Albert Munsell famously studied color in great detail, describing it as a three dimensional concept involving hue, value and chroma (9). Professor Munsell clearly conceptualized this in his comparison of color theory (hue, value, and chroma) to the common concept of volume (height, length and width) (9). Mussel's system is now an international standard utilized in many scientific circles (9), including the dental field (10).

The Three Color Parameters

"Hue" refers to the common name by which people talk about a particular color- the term "red" for example, refers to the object's hue (11). Although the description of hue gives indication of the color family being discussed it stops there, leaving the conversation to wonder about several other visual factors (12); for example, "the red shirt" could be referring to several different types of "red."

The second color parameter "value" describes the lightness or darkness of the hue (12). Robert Sproull (10) clearly described the value parameter by using the example of a black-and-white television. He explains: when watching a black-and-white television only variations of grays are visible, but the differences between objects in the scene are still understandable. Without these distinct variations in value, the image on the television would appear blended and non-discernable (10).

"Chroma" Mussels' third parameter- goes a bit further than hue by describing the potency of the color; as chroma increases the color appears to be deeper (13, 14). As Fondriest (13) described, when increasing amounts of dye are added to a glass of water the hue remains the same; however the chroma increases with each drop because the saturation and intensity of that hue is deepening (13).

The multidimensionality of color gets increasingly complicated as the topic of translucence is introduced. Although translucence is not included in the three-color parameters as described by Munsell, it is a definitive characteristic of human teeth (15) and therefore must be considered when performing restorations. In simple terms, translucence involves the degree at which the light that hit the object was absorbed or transmitted- some mid point along the spectrum of opacity and transparency (8). The color parameters and translucence come together when the restoration is manufactured. Hue and translucence are involved in the creation of both the dentin layer (14, 16) and the enamel layer (14). For reasons such as these, the "stump shade" (also known as the dentin shade) is important information to include when communicating with the laboratory that will be making the all-ceramic restorations (16).

The Visual Shade Guide

The process of taking the prescription shade using the Shade Guide is relatively simple, however some details and recommendations need to be considered. The clinician should view the patient's teeth (reference teeth) from eye level (17). Shade-matching procedures should take place at the beginning of the appointment, keeping in mind that the patient's clothing could influence shade perception (18). Generally, the tabs that comprise the Shade Guide are organized in some fashion according to Mussel's color parameters (13, 19). The best way to match these parameters can be confusing. Some guides suggest assigning hue first; this could hypothetically narrow choices down to tabs in groups A and B, then (looking at only these groups) the clinician would proceed to the other parameters (18). Other sources advise the opposite-match hue last (20). Some sources advise performing a single shade-match with multiple shade guides (17).

No matter the specifics of Shade Guide use, digital cameras can also be involved in the shade-matching process. Jarad et al (21) examined observer ability to shade-match using the popular Vita Lumin shade guide in comparison to digital camera. They found that the color parameter readings of the shade-match outcome when using a digital camera were much more accurate than when only using the shade guide, leading the authors to support the use of the digital photograph in communications between the laboratory and the clinician (21). A review other studies comparing the digital photographs to the Shade Guide have also concluded that the photographs should be used (22). However, special attention needs to be paid to the calibration of the computer monitor being used to convey this information, neglecting this detail can lead to a different appearance in the quality of the image between the clinic and the laboratory (21,

23). In the most basic sense, the digital camera can aid in the communication issues that often occur between the dental office and the dental laboratory, especially in anterior restoration cases (15) as information about translucence, contour and shape of the teeth is easily communicated through these photographs (23).

Sources of Variation

The visual, subjective nature of prescribing shade with the Shade Guide allows for several factors to influence the shade-matching outcome.

Illuminant can cause variation in shade-matching (24). In one study that explored these effects, field accepted standard illuminants for daylight were used to evaluate how changes in lighting affected the shade-match when using a shade guide. Color shift between illuminants outside clinical acceptance thresholds were observed. Specifically, value readings were lower in the incandescent and fluorescent lamp groups in comparison to the daylight groups. Chroma on the other hand, was the opposite; chroma values increased in both lamp simulations (25). Other studies have found that the hue parameter is not excluded from these effects. Lighting that is too dim can compromise assessment because hue cannot be adequately evaluated (26).

Even everyday issues such as oral dehydration that naturally occurs during the office visit have been shown to influence the shade characteristics of the teeth. A randomized controlled trial observed the effects of tooth dehydration at time intervals of 10, 30 and 60 minutes. Changes in all of the color parameters occurred after only ten minutes. At the sixty-minute mark, all the parameters were notably different, with the exception of value (27). After allowing rehydration to occur for thirty minutes, the

lightness characteristics were still not restored. These results were similar across all anatomical areas of the tooth (cervical, middle and incisal) and were both visually apparent and quantifiable (27).

Simply the process of manufacturing the restoration can cause variation in shade-match. The differences between the metal-ceramic restoration material group and the all-ceramic restoration material group are of particular concern for various clinical and esthetic reasons. Review of the literature indicates that restorations created using metal yielded darker restorations; on the other hand restorations involving gold backed samples yielded lighter, more yellow looking restorations (28). The subcategories within the all-ceramic group have different properties that can affect the final shade-match as well. While high strength ceramics may be attractive in one restorative case, higher translucence may be desired for other cases. These choices can skew the results of the shade-match because higher strength materials are often more opaque (29). All ceramic systems such as the lithium discilicate and zirconium oxide have been shown to be subject to changes in the value parameter as the number of firings is increased during manufacturing (30).

Human Error as a Source of Variation

The subjectivity of the Shade Guide allows for human error to compromise the prescription process, complicating the issues mentioned above even further. Unfortunately, many of these issues stem from natural, unavoidable clinician characteristics. The natural process of aging can influence how well the clinician can discern yellows and browns (8). Clinicians are not immune to color blindness (31). This

deficit is due to problems in the cones of the eye that allow the clinician to properly see color, causing limitations in the assessment of hue and chroma. Value will be somewhat influenced, but not as strongly because the cone structures modulate the other two parameters more than value (8). Larger issues such as gender (32, 33), eye color and use of contacts or glasses (32) have been excluded as potential sources of discrepancy.

Visual Shade Guide Options

As with any dental material, there are several options when choosing a shade guide. According to a 2009 study, the most commonly used guides are the Vita 3D Master and the Vita Classical (34). The original (Vita Classical) was introduced in the mid 1950's and has since been the accepted as a universal standard for the visual Shade Guide (8); this is the guide used by the student clinics at the University of Louisville School of Dentistry. These guides have been shown to retain their popularity outside academia along with the Chromoscope (26). Problems arise from the variability of these brands. The three color parameters are not always arranged in standard, logical intervals on each type of shade guide (19): for example the arrangement of value and hue in the Chormoscope and the Vita Lumin have been shown to be non-uniform (24). Variation occurs within a single brand as well. Simply the layering process of manufacturing prevents any shade guide form being identical to the next (35). Commercially available shade guides may not be made of the same materials as dental ceramics, therefore the light reflective properties of the restoration material and the guide may be different in the first place (35). The necessity of routine sterilization can cause changes in the shade of the tabs that compose the Shade Guide (36-38). The Vita Classic in particular showed

statistically significant changes, becoming more red with increasing autoclave cycles (36).

With all these issues in mind, it may be difficult to understand why the Shade Guide is still so commonly used when other digital methods are available. Restorative materials may be keyed to popular shade guides (8). Simpler reasons such as cost and time economy are also keeping the visual method of shade match as the "go to" among clinicians (2).

The Objective Approach

Considering the complexities discussed, a standard was needed to communicate the intricacies of color measurement. The International Commission on Illumination (CIE) set fourth in the 1930's to standardize these communications, therefore lessening the potential for subjectivity when judging the color difference between two objects (6). As an objective, quantitative measurement of color difference, ΔE is calculated according the CIELAB Equation below (31). The equation incorporates the color parameters described by Munsell; "L" refers to the lightness (or value) (39) of the object, "C" refers to the chroma, and "H" refers to the hue (40).

Figure 1:

$$\Delta E *_{ab} = [(\Delta L *)^2 (\Delta C * ab)^2 (\Delta H * ab)^2]½$$

Where $\Delta H *_{ab} = 2(C *_{ab,1} C *_{ab,2})^{\frac{1}{2}} \sin ((h_{ab,2} - h_{ab,1}))^{1/2}$

Note: Subscripts 1 and 2 correspond to the reflectance from the white standard and the object in question respectively

There have been efforts to improve the qualitative, subjective nature of Shade Guide as newer tools have been introduced into the market (7) . Examples of these devices include: the colorimeter, the spectroradiometer and the spectrophotometer (31).

Specifically, the Spectrophotometer is a multi-component machine capable of using the light signal that reflects from the tooth structure (7). The capabilities of the Spectrophotometer are also used in other fields such as advertising to insure accurate and precise recreations of the color associated with the brand logo (6). The Spectrophotometer is able to perform the measurements required for this by comparing the reflectance from "pure white" on the color spectrum at various angles to the reflectance of light from the surface of the object (31).

As ΔE increases the shade difference becomes more visible (41). The "perceptibility threshold" (PT) refers to the difference in shade-match that is detectable by the human eye (41) . The "acceptability threshold" (AT) refers to the ΔE value of a "successful" restoration in dentistry (41). These two values tend to differ. For example the perceptibility threshold of metal-ceramic crowns have been shown to be lower than the acceptability threshold, largely due to the influence of chroma (42). Although a steadfast threshold value may be difficult to find, a review of the literature concluded that the commonly accepted PT to be ΔE =1 and the field accepted AT to be ΔE= 3.7 (41). Scrutiny toward shade difference seems to be a learned skill; dental professionals are able to detect differences better than patients (43). In regards to esthetics, the patient's perception is the principle concern, therefore patient opinion needs to considered in addition to the values.

Objective Outcomes

Due to the objective measurements involved, the Spectrophotometer has multiple benefits over the subjective Shade Guide. As the literature suggests, many in the field have studied the spectrophotometer's capabilities in regards to shade-matching accuracy.

The Standardized Environment

Kim-Pusateri et al (44) designed a study to test the reliability and accuracy of instrumental shade-matching tools in standardized, non-clinical conditions. Several brands were tested against many different types of shade guide, in simulated conditions, multiple times. Reliability results were similar, all the tested instruments scored in the 90% range. Accuracy however, showed statistically significant differences ranging from 60%-90%. Only the Vita Easy Shade (Vita-Zahnfabrik, Germany) scored within the 90% range for both accuracy and reliability (44). Being that these results were found under standard conditions that do not reflect the variability of the human mouth, it is possible that the absence of such factors as curvature, layering of dentin etc.… in human teeth influenced these accuracy readings (44) .

The Non Standardized Clinical Environment

Another group went a step further (45) , investigating both the standardized and clinical environments. The in vitro portion of the study used fabricated teeth, shade-matched by two observers using multiple instrumental shade measuring devices. The in vivo portion used the same instrumental shade measuring devices to shade-match real human teeth that had been evaluated for anomalies before hand. Analysis of the standardized, in vitro portion showed no significant differences in accuracy or reliability.

In contrast, the in vivo, clinical based portion of the study found accuracy and precision both varied- likely due to the non standard environment of the oral cavity. In collective analysis, the authors concluded that the spectrophotometer was once again the most accurate and the most precise, outranking the digital camera and the colorimeter (46).

Differences in Experience

Shade-matching success has been shown to vary with dental training (32, 45, 47). When groups of non-dental observers, dental students and clinically experienced dentists where asked to shade-match, accuracy verification showed that the dentists most often chose the best match, even when provided with two different shade guides under two different illuminants (48). Comparison between students and faculty shade-matching ability indicated once again the importance of experience. After each group selected their prescription shade, the spectrophotometer was used to calculate ΔE between each measurement and a standard shade guide. According to the data, both groups were somewhat inaccurate in their shade prescription. However, it is worth noting that the clinician group's results for ΔE were within the previously mentioned perceptibility threshold of 1.0, meaning these errors were not detectable by the human eye. The self-group was above the perceptibility threshold; those errors were visually detectable (49). Another study found similar results: increasing experience with restorative procedures (general dentist in comparison to a prosthodontist) seemingly correlated with a better ability to shade-match (32).

The previously mentioned study conducted by Capa et al (32) concluded that factors such as eye color, sex and use of eyeglasses had no significant effect on shade-matching ability. However, variations in experience did play a role. Specialties such as

oral surgery and periodontics did not shade-match as well as other dental professionals such as the dental technicians or prosthodontics (32). It is not enough to have dental experience in general, experience in restorative procedures seems to be much more important as far as shade-matching is concerned.

Comparing Expertise to Machine

The accuracy of the Spectrophotometer in comparison to the abilities of the experienced clinician was more directly tested in another study. Clinicians pre-screened for experience qualifications were asked to shade-match the body portion of several teeth using the Shade Guide on three separate occasions at monthly intervals. The same teeth were shade matched using the Spectrophotometer. The Spectrophotometer once again provided a closer, more persistent match than the clinicians using the Shade Guide. Analysis of CIE LAB data points showed that the clinicians performed well in the lightness (L) (also known as value) component of shade-matching. Perhaps errors in other portions of shade-matching such as hue contributed to the overall error in the clinician group (50). A slightly more complicated, but related study compared crown acceptance between two groups: the first, crowns produced based on shade prescription with one of three different shade guides; the second, crowns produced based on a spectrophotometer prescribed shade. After several trials the shade guide based crowns were found to have acceptance ratings of 22%, in contrast to the spectrophotometer crowns acceptance rate of 77.8%. The higher percentage rate was linked to lower ΔE recordings among the spectrophotometer assessment group (51).

A review of the literature showed similar results as seen in the fore mentioned studies above. Out of all the studies screened for review, twenty-six studied the precision

and accuracy of shade-matching methods. Again, the Spectrophotometer was found to be more accurate and more precise than the Shade Guide (22).

Restoration Procedures and Dental Education

The state of dental education is of particular importance when thinking about the trajectory of the field. A few studies have examined these concepts in reference to esthetics and shade-matching.

When Paravina et al (34) surveyed dental education faculty, they found that color is being taught at both the pre-doctoral and post-doctoral level at levels of 80% and higher. Both groups were instructed on appropriate shade-matching conditions in terms of lighting and color; both groups also received instruction on the concepts of the color dimensions and color vision. Differences in pre-doctoral and post-doctoral education became apparent when the survey questions began to delve deeper. More hourly instruction time was dedicated to color and shade-matching at the postdoctoral level than the pre-doctoral level in key areas like color notation and color communication. Because many restorative procedures are performed in the pre-doctoral clinic, discrepancies such as these could be problematic (34). The majority of respondents for this web-based survey were dental schools in the US, indicating these results can be applied to other academic institutions.

A study that focused on the shade-matching ability of dental students at the first, second, third and fourth year found that clinical shade-matching ability increased with education level even as the complexity of the case increased from bench top assignments

to clinical based assignments with natural teeth. The authors proposed that this might be because students depended mainly on natural matching ability for simple cases, and then tapped into their newly acquired knowledge for the complex cases (52).

Although the student dental clinic provides is a unique learning environment, patient satisfaction needs to be maintained as it is in the private clinic. A particular study that evaluated this concept found, perhaps unsurprisingly, patients reported being more satisfied with the results of their restoration to a statistically significant degree when the restoration was placed or overseen by a prosthodontist, even when the prosthodontists was not as satisfied with the restoration (53). A third finding from this study sheds light on another interesting phenomenon in the student dental clinic: the worth of student-based work. Patients in this study stated higher satisfaction with restorations received from an academic institution as opposed to restorations received from the private practice setting. The authors speculated that this favored opinion toward academic based work may be due to the institutions reputation or perhaps more practical reasons such as having a more controlled environment or a closely connected laboratory. The authors also acknowledge that the patients surveyed may have been hedging for the students for fear of what their opinions might mean for the student's grade (53).

Statistical Considerations and Background

When studying issues concerning quality control such as shade-matching surveying can be a useful tool. When surveying the sample size is of key importance; it is critical that the smaller set of data (the sample) reflects what is actually going on in the bigger picture (the population). Convenience sampling is easy to implement (54) and it

has multiple characteristics that benefit the busy environment of the dental school clinic. Other statistical parameters such as the type of questions to be asked are of chief concern as well. For example, nominal data that has no order or preference in its meaning (gender for example) (55) will need to be included in the questionnaire. In addition, ordinal data that orders the answers could also be used (55), such as rating of patient satisfaction with treatment. Closed-ended questions could also warrant the use of the Likert Scale, which measures a person's attitudes or opinions toward something (such as quality, or satisfaction) generally on a scale of one to five (54).

The presence or absence of an interviewer in survey situations must be considered as well (56). When the presence of the interviewer is required, it is pertinent that the questions are asked in the same order and in the same manner ever time. Failing to adhere to these details would compromise the standardization of the survey, and therefore compromise the results (57). Even the aural or visual delivery of the questions can influence how the subjects of the study respond (56). Situations of interviewer influence such as these can introduce bias and therefore must be monitored (56). Designing effective surveys can be difficult, due to the multiple factors; issues such as true mode effects can arise (56). Statistical concerns such as this must be considered when investigating such problems as shade-matching in restorative dentistry.

Summary

Shade-matching is clearly a continuing problem in the dental field. The state of dental education concerning this matter is of critical importance in expanding the knowledge of field and potentially leading to a solution to the problem. The purpose of

this study is to evaluate these shade-matching procedures within an academic institution to determine if an accurate restoration shade is consistently delivered under the current subjective shade-matching protocols. To decipher potential differences between the restoration the student orders and the restoration the laboratory creates, two different ΔE data points will be collected. First, the ΔE between the reference shade (the shade of the patient's natural teeth) and the prescription shade (as assessed by the student using the shade guide) $\Delta E_{clinical}$; second, the ΔE between the prescription shade and the restoration shade (the shade of the luted crown) $\Delta E_{laboratory}$. These ΔE data points will be collected using the Vita Easyshade spectrophotometer. In effort to capture the student and faculty perception of the shade-matching quality, both nominal and ordinal survey questions and the Likert Scale will be implemented. Students and faculty were also asked for open ended responses to highlight their view points and suggestions for what it takes to shade-match adequately.

CHAPTER II

HYPOTHESES

Research Hypotheses

It is hypothesized that:

1. ΔE between both groups ($\Delta E_{clinical}$, $\Delta E_{laboratory}$) will be below the literature supported clinical acceptance value of 3.7.
2. Patients, students and faculty will be satisfied with the shade-match of the delivered restoration in comparison with the natural teeth.
3. Students and faculty will support the need for an objective shade-measuring tool in the future.
4. Lower ΔE will correlate with higher patient, student and faculty satisfaction with shade-match; lower ΔE will also correlate with lower student and faculty support of the need for an objective shade-matching tool.

Objectives

The Specific Aims of this research are:

1. Calculate ΔE between the reference shade-prescription shade ($\Delta E_{clinical}$) as well as the ΔE between the prescription shade-restoration shade ($\Delta E_{laboratory}$)

using the Spectrophotometer for eligible crown placements within the Student Dental Clinic.

2. Evaluate patient, student and faculty satisfaction with the shade-match using a Five Point Likert Scale questionnaire.
3. Evaluate student and faculty support of objective shade measurement via the Spectrophotometer as a way to improve shade-match in restorative procedures within the Student Dental Clinic
4. Evaluate potential correlational relationships using the Pearson Correlation Test. .

CHAPTER III

MATERIALS AND METHODS

Research Design

In accordance with IRB Approval (14.1182) this observational study recruited 103 study participants as suggested by preliminary power analysis through convenience sampling within the University of Louisville School of Dentistry Student Clinic. Eligible patients were identified using the following IRB Approved inclusion and exclusion criteria below:

1. Inclusion Criteria
    a. Must be a patient of record in the University of Louisville Dental Clinic.
    b. Patient must have received treatment in the form of full coverage, indirect, tooth-colored restorations.
    c. Must have the use of the Vita Classic Shade Guide noted in the Laboratory Authorization.
    d. Must be able to understand and be willing to sign to consent form.
    e. The esthetic outcome has been confirmed by both clinician and patient as clinically acceptable and luted on the abutment teeth or dental implants.
2. Exclusion Criteria
    a. Person is not listed as a patient of record in the University of Louisville Dental Clinic.

b. Patient did not receive restorative work in the form of full coverage, indirect, tooth-colored restorations.
c. The Vita Classic Shade Guide was not used and/or included in the Laboratory Authorization.
d. Inability to understand and sign the consent form.
e. The esthetic outcome has not been confirmed by both the clinician and the patient as clinically acceptable.

After the patient was identified as an eligible candidate for the study, the research team explained the purpose, methods, participation requirements, benefits and potential risks in both verbal and written form as mandated by IRB Approval (14.1182). The patient was also informed that their participation or decline to do so did not affect the student's grade in anyway. If the patient agreed to participate, the IRB Approved Consent Form was signed by both the research team and the patient, then filed with other research materials in a locked office only accessible by the principle investigator (Dr. Wei-Shao Lin). Students were also briefed in the same manner about purpose, methods, participation requirements, benefits and risk. Preliminary consent paperwork was given to the student for their records; signature was not required for student consent.

After consent was gathered, the Laboratory Authorization Form was obtained from the patient's file, copied and added to the other research materials to be locked away for safekeeping. The Laboratory Authorization is the communication modality between the clinician(s) working on the restoration and the dental technician(s) that will be creating the restoration in the laboratory. Information form this form was added to the

Data Collection Sheet (See Appendix); these details included: restoration location (anterior or posterior), underlying abutment structure (implant or natural dentition), and material used to manufacture the restoration. The prescription shade –as assessed by the student using the visual Shade Guide- is also written on this form. The prescription shade is a letter number code that the laboratory technician will use to recreate the desired shade-match in the restoration shade. The inclusion or exclusion of clinical digital photographs was also noted from the Laboratory Authorization.

After the student had luted the restoration, the research team began the two-fold process of taking the Spectrophotometric measurements. The student was asked which of the patient's natural teeth was used as the reference when the prescription shade was assessed and recorded on the Laboratory Authorization Form. This tooth-"reference tooth"-was measured with the Spectrophotometer at the incisal, body and cervical portions; this gave three separate letter number shade codes (according to the Vita Classical shade system) that were written into the Data Collection Sheet, one for each anatomical portion of the tooth. For example, the readings on the reference tooth were shown as A1, A2 or A3 at the incisal, body and cervical portions respectively. The luted crown created by the laboratory (known as the restoration shade), according to the selected shade (prescription shade) from the Laboratory Authorization Form, was also measured with the Spectrophotometer in the same manner detailed above, the number letter shade codes for the incisal, cervical and body portions of the tooth were noted in the Data Collection Sheet.

Finally, the Spectrophotometer was used to measure two individual ΔE values ($\Delta E_{clinical}$, $\Delta E_{laboratory}$). The ΔE data point is a two digit number indicating how close

the shade of the laboratory created restoration was to the actual shade of the patient's natural tooth, the smaller the number, the closer the match. The first the ΔE (difference in shade) between the restoration shade and the reference shade was measured in all three anatomical portions of the tooth. Henceforth, this ΔE (the difference between the restoration and reference shades) will be referred to as $\Delta E_{clinical}$. The second ΔE indicates the difference between the prescription shade (determined in the clinic) and the restoration shade (determined in the laboratory). This ΔE will be referred to as $\Delta E_{laboratory}$. $\Delta E_{clinical}$ reflects the student's ability to appropriately prescribe shade; $\Delta E_{laboratory}$ reflects the laboratory's ability to properly recreate that shade into the restoration.

After completion of the Spectrophotometric measurements, two survey questions were asked. The first survey question concerned student, patient and faculty satisfaction with the shade-matching outcome of the restoration procedure (see Appendix.) Student, faculty and staff were briefed on the Likert Rating Scale before answering. For example, answering "1" indicated "extremely dissatisfied" with the shade-match; answering "5" indicated being "extremely satisfied" with the shade-match. The second survey question was concerned with student and faculty support of the need for an objective shade-measuring tool as a way of improving cosmetic outcome; in other words, would having an objective tool such as the Spectrophotometer potentially improve the esthetics of the shade-match (see Appendix.) Once again the student and faculty were briefed on the Likert Scale answering system: answering "1" indicated "strongly disagree," whereas answering "5" indicated being "strongly agree." Patients, students and faculty were

asked all these questions in private to prevent bias. Patients were given a hand held mirror so that they could properly view the teeth.

Statistical Analysis

Several levels of statistical analysis were performed, as detailed in the following paragraphs.

Descriptive Statistical Analysis

Descriptive sample information such as student and patient age and gender, crown material choice, crown location (anterior or posterior) etc… were collected throughout the study. Because these are nominal data points, median and interquartile range were used in analysis.

Inferential Statistical Analysis

Null Hypotheses:

1. There is no difference between ΔE in both data sets ($\Delta E_{clinical}$ and $\Delta E_{laboratory}$) and the clinical acceptance value 3.7.
2. There is no correlation between patient, student, and faculty satisfaction and the demonstrated support for the need of an objective shade-matching tool in the Student Dental Clinic.

Mean and standard deviation was calculated for both $\Delta E_{clinical}, \Delta E_{laboratory}$. The t-test was used to determine if the average $\Delta E_{clinical}$ and $\Delta E_{laboratory}$ fell within the literature stated clinical acceptance value of 3.7 (41). The linear model was used to

assess any potential differences in $\Delta E_{clinical}$ and $\Delta E_{laboratory}$ by restoration location (anterior verses posterior); these ΔE values were also subjected to the t-test to examine success of shade-match by restoration location.

Pearson Correlation Test was used to assess the relationships between student and faculty descriptor (age, gender, specialty) and ΔE data; relationships between Likert Scale responses and the ΔE data were also analyzed with the Pearson Correlation Test.

p-values are reported from t-tests where appropriate. All analyses were conducted in SAS version 9.4 (SAS Institute, Cary, NC) using a statistical significance of $p \leq .05$.

CHAPTER IV

RESULTS

The results of this study are found below, organized in sections and accompanied by the corresponding data set. Statistical analysis was conducted by Ms. Christina Pinkston, University of Louisville, Department of Bioinformatics and Biostatistics.

Participant and Provider Characteristics

Of the 103 restorations completed, the majority 71 (69%) were performed on posterior teeth. The median age of the patients was 59 years (IQR: 16 years); however, the median age of anterior restoration patients was 5 years younger than those receiving a posterior restoration (56 years vs. 61 years). More patients were male (56%) than female (44%). Student providers had a median age of 28 years (IQR: 4), were split nearly identically by gender (47% vs. 53% for males and females, respectively), and were mostly fourth year (senior) students (99%). The majority of student providers did not have previous experience in the dental field (73%). Overseeing faculty members were mostly likely to be a prosthodontist (78%). See Table 1).

Table 1: Participant and Provider Characteristics	**Median (IQR or %)**		**Crown Positions**			
			Anterior		**Posterior**	
Patient Characteristics						
N	103		32	(31.1)	71	(68.9)
Age, years	59	IQR	56	(24)	61	(12)
Gender						
Male	58	56.3	19	(59.4)	39	(54.9)
Female	45	43.7	13	(40.6)	32	(45.1)
Provider Characteristics						
Age, years	28	(4)	28	(5)	27	(4)
Gender						
Male	48	(46.6)	13	(40.6)	35	(49.3)
Female	55	(53.4)	19	(59.4)	36	(50.7)
Dental Background						
No Prior Experience	75	(72.8)	18	(56.3)	57	(80.3)
Prior Experience	28	(27.2)	14	(43.8)	14	(19.7)
Year in Dental School						
Junior/D3	4	(3.9)	3	(9.4)	1	(1.4)
Senior/D4	99	(99.0)	29	(90.6)	70	(98.6)
Overseeing Faculty Credentials						
General Dentist, Other	23	(22.3)	5	(15.6)	18	(25.4)
Prosthodontist	80	(77.7)	27	(84.4)	53	(74.6)

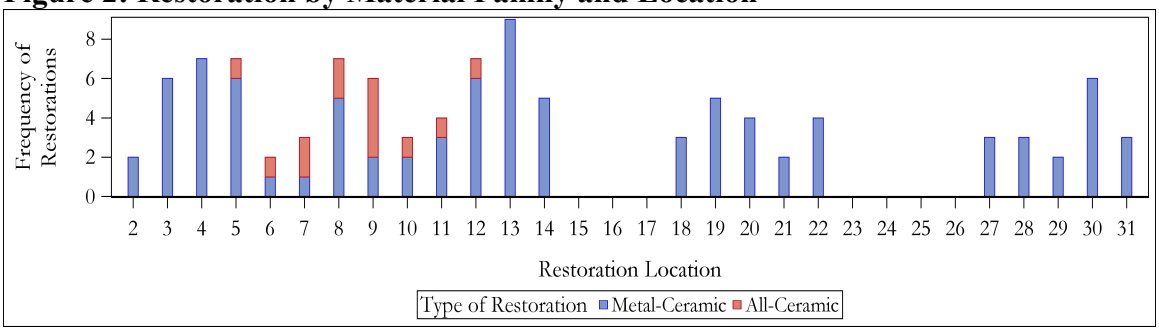
p-values are an indication of a difference in the distribution of the restoration characteristics by restoration location.
* indicates statistical significance of $p \leq 0.05$

The surface of the restoration was split 52% vs. 48% for natural dentition vs. implant, respectively. Forty-seven percent of the posterior restorations were on a natural dentition abutment, compared to 66% of the anterior restorations. While metal-ceramic

was used for the majority of the restorations (87%), those with posterior restorations were significantly more likely to have this material compared to anterior restorations (97% vs. 66%, respectively). Table 2 summarizes the restoration characteristics overall and stratified by restoration location. Figure 2 represents the distribution of the restoration by tooth location and type of restoration material (metal-ceramic vs. all-ceramic)

Table 2: Restoration Characteristics						
Restoration Characteristics	**N**	**(%)**	Anterior		Posterior	
Surface						
Implant	49	(47.6)	11	(34.4)	38	(53.5)
Natural Dentition	54	(52.4)	21	(65.6)	33	(46.5)
Material						
Metal-Ceramic	90	(87.4)	23	(71.9)	69	(97.2)
All-Ceramic	13	(12.6)	9	(28.1)	2	(2.8)
Exact Material						
Base-Metal Alloy	8	(7.8)	2	(6.3)	6	(8.5)
Noble Metal Alloy	83	(80.6)	21	(65.6)	62	(8.5)
High Noble Metal Alloy	1	(1.0)	0	(0.0)	1	(1.4)
Emax	9	(8.7)	8	(25.0)	1	(1.4)
Zirconia	2	(1.9)	1	(3.1)	1	(1.4)

Figure 2: Restoration by Material Family and Location



Shade-Match Differences (ΔE)

The primary goal of this study was to assess the difference in shade (ΔE) at two stages in the restoration process. The first: reference shade and the prescriptions shade ($\Delta E_{clinical}$); second: between the prescription shade and the restoration shade ($\Delta E_{laboratory}$) using the Spectrophotometer. Previous research has set the acceptable difference at 3.7(41), for this reason this value was used as a benchmark to determine if shade measurements were statistically within an acceptable range.

As summarized in Table 3, t-test showed shade differences were significantly higher than 3.7 for all study participants ($\Delta E_{laboratory}$ and $\Delta E_{clinical}$) (p<.05 for all of group a). Mean $\Delta E_{clinical}$ was greater than mean $\Delta E_{laboratory}$ (6.5, 4.3 respectively).

Table 3: Shade Differences (ΔE)										
				Crown Position						
	***Mean* (*SD*)^c**		***p* − *Vlaue* ^{a}**	***Anterior***		***p* − *Vlaue* ^{a}**	***Posterior* ^{c}**		***p* − *Vlaue* ^{a}**	***p* − *Value*^{b}**
$\Delta E_{clincial}$										
Average	6.5	2.4	<.001*	5.6	2.5	<.001*	6.9	2.3	<.001*	.13
$\Delta E_{laboratory}$										
Average	4.3	2.0	.002*	4.6	2.0	.01*	4.2	1.9	.04*	>.99
*indicates statistical significance of $p \leq .05$ *a: Difference of median value from 3.7*										
b: Statistical differences between shade measurements, based on crown position p value adjusted										
c: Note: ΔE is significantly higher in $\Delta E_{clinical}$ compared to the $\Delta E_{laboratory}$ p<.001										
Tukey adjusted pair-wise comparison preformed for both $\Delta E_{clincial}$ and $\Delta E_{laboratory}$										

Satisfaction and Support of Objective Shade Measurement

A five-point Likert-Scale survey was provided to patients, student providers, and faculty at the end of the study to assess their satisfaction to the shade-matching outcome and their agreement with the use of objective shade-matching equipment to improve cosmetic outcome (providers only).

Table 4a and Figure 3 summarize satisfaction survey results. In general, the majority of the survey respondents expressed satisfied to extremely satisfied responses to the questions toward shade-matching outcomes (patients 94.2%, students 82.5%, faculty 58.3%). Regardless of the group surveyed, there were no differences in the level of satisfaction based on the location of the restoration, although faculty tended to have a more neutral satisfaction to the posterior restorations (39.3%) compared to the anterior restorations (18.8%).

Table 4b and Figure 4 summarize survey results corresponding to the support of an objective tool. Generally, both student (77.7%) and faculty (79.7%) providers agreed or strongly agreed with the use of a digital shade-matching tool to improve cosmetic outcome. However, student providers tended to agree with this statement more than the faculty providers.

Table 4a: Satisfaction with the Shade-Matching Outcome

		Crown Position	
	Overall N(%)	**Anterior**	**Posterior**
Survey	**N(%)**	**N(%)**	**N(%)**
Satisfaction with the shade-matching outcome:			
Patient			
Extremely Dissatisfied	1 (1.0)	0 (0.0)	1 (1.4)
Somewhat Dissatisfied	0 (0.0)	0 (0.0)	0 (0.0)
Neutral	5 (4.9)	1(3.1)	4 (5.6)
Satisfied	21 (20.4)	7 (21.9)	14 (19.8)
Extremely Satisfied	76 (73.8)	24 (75.0)	52 (73.2)
Medium (IQR)	5 (1.0)	5 (0.5)	5 (1.0)
Mean (SD)	4.7 (0.7)	4.7 (0.5)	4.6 (0.7)
Student Providers			
Extremely Dissatisfied	1 (1.0)	1 (3.1)	1(0.0)
Somewhat Dissatisfied	0 (0.0)	0 (0.0)	0 (0.0)
Neutral	17 (16.5)	5 (15.6)	12 (16.9)
Satisfied	59 (57.3)	18 (56.3)	41 (57.8)
Extremely Satisfied	26 (25.2)	8 (25.0)	18 (25.4)
Medium (IQR)	4 (1.0)	4 (0.5)	4 (1.0)
Mean (SD)	4 (0.7)	4 (0.8)	4.1 (0.6)
Faculty			
Extremely Dissatisfied	0 (0.0)	0 (0.0)	0 (0.0)
Somewhat Dissatisfied	9 (8.7)	3 (9.4)	6 (8.5)
Neutral	34.0 (33.0)	6 (18.8)	28 (39.4)
Satisfied	45 (43.7)	17 (53.1)	28 (39.4)
Extremely Satisfied	15 (14.6)	6 (18.8)	9 (12.7)
Median (IQR)	4 (1.0)	4 (1.0)	4 (1.0)
Mean (SD)	3.6 (0.8)	3.8 (0.9)	3.6 (0.8)

Table 4b: Support of Objective Shade Measurement

		Crown Position	
	Overall N(%)	**Anterior**	**Posterior**
Survey	**N(%)**	**N(%)**	**N(%)**
"Use of an objective shade-matching device would improve cosmetic outcome"			
Student Providers			
Strongly Disagree	3 (2.9)	0 (0.0)	3 (4.2)
Disagree	5 (4.9)	0 (0.0)	5 (7.0)
Neutral	15 (14.6)	6 (18.8)	9 (12.7)
Agree	32 (31.1)	13 (40.6)	19 (26.8)
Strongly Agree	48 (46.6)	13 (40.6)	35 (49.3)
Medium (IQR)	4 (1.0)	4 (1.0)	4 (1.0)
Mean (SD)	4.1 (1.0)	4.2 (0.8)	4.1 (1.1)
Faculty			
Strongly Disagree			
Disagree	0 (0.0)	0 (0.0)	0 (0.0)
Neutral	12 (11.7)	4 (12.5)	8 (11.3)
Agree	29 (28.2)	11 (34.4)	18 (25.4)
Strongly Agree	53 (51.5)	14 (43.8)	39 (54.9)
Medium (IQR)	4 (1.0)	4 (1.0)	4 (1.0)
Mean (SD)	3.6 (0.8)	3.5 (0.8)	3.6 (0.8)

Figure 3: Satisfaction with the Shade-Matching Outcome

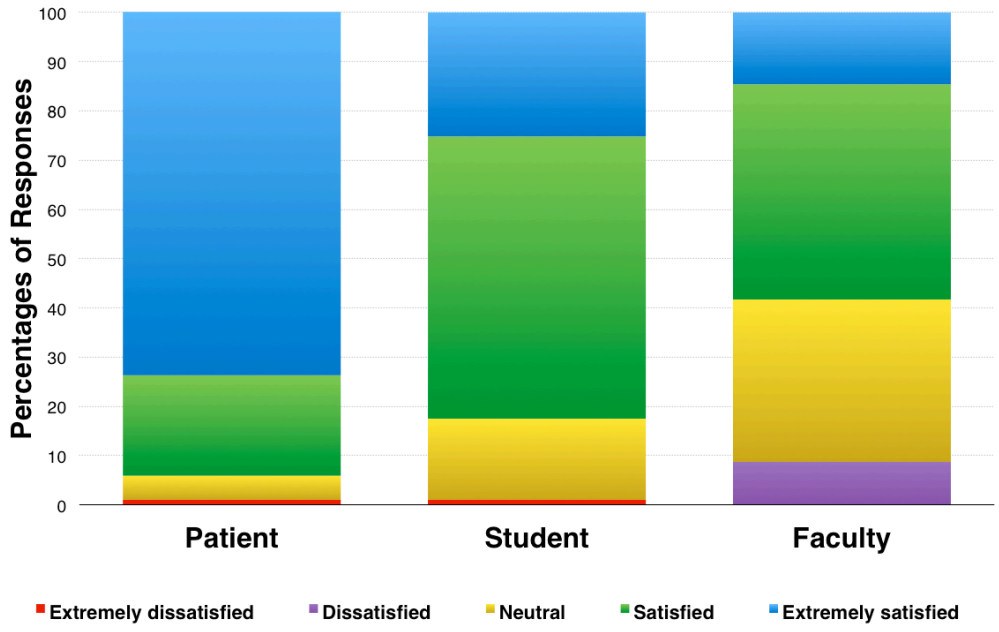
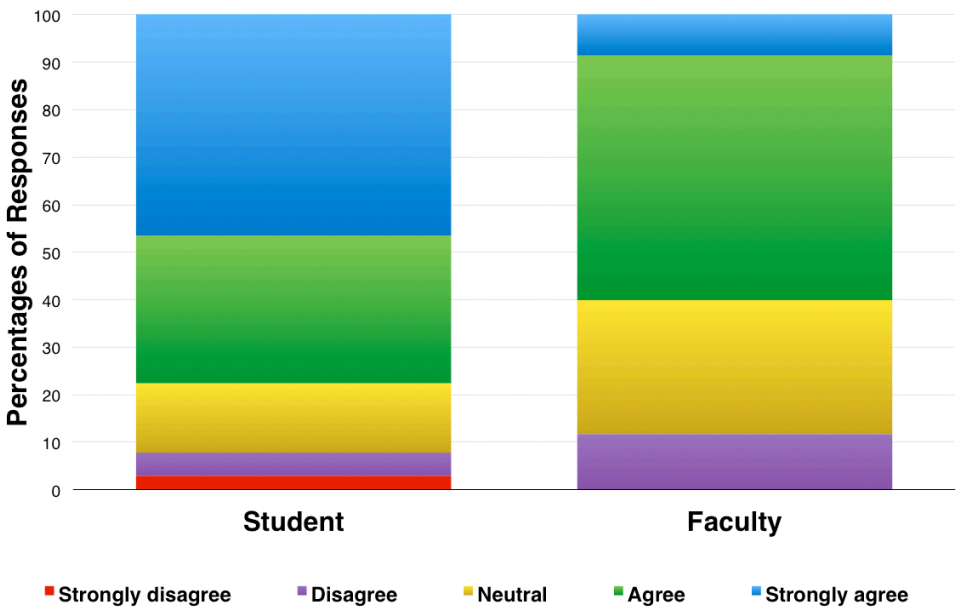


Figure 4: Support of Objective Shade Measurement



Correlations between ΔE and Patient, Student, and Faculty Data

In general, there were no correlations between the shade difference measurements and patient characteristics, student provider characteristics, or faculty background.

Faculty's satisfaction with the shade-matching was very dependent on the ($\Delta E_{clinical}$). The higher the shade difference, the less likely the faculty member was to be satisfied with the matching (r= -0.45, p<.001).. Additionally, faculty was most likely to agree with objective shade-matching equipment use if $\Delta E_{clinical}$ was high (r= .35, p<.001). See Table 5.

Table 5: Correlations between shade differences and patient, student, and faculty data

	$\Delta E_{clincial}$		$\Delta E_{laboratory}$	
	Correlation Coefficient	***p*-value**	**Correlation Coefficient**	***p*-value**
Patient Characteristics				
Age	.17	.09	-0.03	.76
Student Provider Characteristics				
Age	-0.15	.12	-0.04	.69
Survey Responses				
Satisfaction to the shade-matching outcome				
Patient	-0.06	.55	.05	.63
Student provider	-0.06	.57	.07	.47
Faculty	-0.45*	<0.001*	-0.13	.21
Use of objective shade-matching equipment to improve cosmetic outcome				
Student Providers	.11	.27	-0.09	.36
Faculty	.35*	<.001*	.10	.33

*indicates statistical significance of $p \leq 0.05$

According to t-test with adjustment for multiple comparison, of other characteristic such as gender, specialty, and several restoration characteristics did not show significant

correlational relationships to either $\Delta E_{clinical}$ or $\Delta E_{laboratory}$. See Table 6: Effect of patient, student and faculty characteristics on mean shade difference.

Table 6: Effect of patient, student and faculty characteristics on mean shade difference

	$\Delta E_{clincial}$			$\Delta E_{laboratory}$		
	Estimate	**StdErr**	***Adjusted p*-value***	**Estimate**	**StdErr**	***Adjusted p*-value***
Patient Characteristics						
Gender (Male vs. Female)	0.07	0.48	>0.99	0.33	0.39	>0.99
Student Provider Characteristics						
Gender (Male vs. Female)	-0.32	0.47	>0.99	-0.65	0.39	0.94
Educational Background (None vs. Some)	0.68	0.53	>0.99	0.13	0.44	>0.99
Dental Year (D3 vs. D4)	-2.20	1.20	0.69	-0.44	1.01	>0.99
Overseeing Faculty Background						
(General Dentist vs. Specialist)	1.03	0.31	>0.99	0.83	0.51	>0.99
Restoration Characteristics						
Abutment Surface	0.92	0.46	0.5	0.32	0.39	>0.99
Metal vs. Ceramic	-0.16	0.71	>0.99	-1.22	0.58	0.36
Exact Material Used[b]			>0.99			0.52
Anterior vs. Posterior	-1.25	0.49	0.13	0.44	0.42	>0.99

Uses t-test to determine differences by group. b: One Way ANOVA
significance (p<0.05) not observed
p values adjusted with multiple comparison to compensate Family-Wise Error Rate

CHAPTER V

DISCUSSION

Visual shade-matching procedures have been shown to be highly subjective, potentially leading to discrepancies in the shade-match of the luted restoration. This study set out to evaluate the quality outcomes of these shade-matching procedures at an academic institution.

Study Overview

Dental students performed shade-matching procedures for patients receiving full coverage restorations using the visual Shade Guide. $\Delta E_{clinical}, \Delta E_{laboratory}$ were measured using the objective Spectrophotometer to assess quality of shade-match based on the literature stated clinical acceptance value of $\Delta E = 3.7$ (41) .

Patient, student and faculty satisfaction with the quality of the shade-match were assessed with a Five Point Likert Scale. Patient satisfaction represents the true metric of quality in esthetic procedures such as shade-matching outcome. Student and faculty satisfaction ratings evaluate the competency attitudes towards these procedures within the academic institution.

The Likert Scale was also used to evaluate student and faculty support of adopting objective measurement within the school as a way to improve cosmetic outcome. The purpose of this assessment was to evaluate interest and need in this technology that academic institutions may want to explore.

Finally, correlational relationships between ΔE data points ($\Delta E_{clinical}, \Delta E_{laboratory}$), Likert Scale satisfaction ratings, and Likert Scale support of the use of an objective tool within the institution, and other descriptive data were investigated through Pearson Correlation. Discussion of these findings to follow.

Descriptive Data Outcomes

The sample for this research was obtained through convenience sampling within the dental school. Descriptive data for this patient population, the students and faculty involved as well as several restoration factors such as restoration surface, material choice and location (anterior or posterior) were included in data collection. A couple significant trends between these descriptors and restoration location were noted.

Analysis shows that younger patients were more likely to receive anterior restorations than posterior restorations ($p = .03$). The small subset of students with previous dental experience were assigned the majority of these anterior cases, leaving the posterior cases for the majority of students (99%) who lacked previous dental experience ($p = .02$), indicating that the dental administration attempts to tailor to individual patient need.

Analysis of restoration material choice shows that descriptive factors significantly differed by restoration location (p: 0.01) and by material family (p:.0496). Indicating that students are potentially including location as a factor in their restoration material choice. Different materials will have different shade properties (28, 29), making material choice of an important factor in the shade-matching process.

Shade-Match Discrepancies

In accordance with IRB Approved Inclusion/Exclusion Criteria (14.1182), all patient, students and faculty approved the restoration shade for luting before the start of data collection, thus indicating that all the restorations can be considered successful. Despite this success, $\Delta E_{clinical}$ values were outside the literature supported clinical acceptance value of 3.7 (41) in general sense and by location detail. The overall, average $\Delta E_{clinical}$ was statistically different (larger) than this 3.7 cut off (p<.001). These differences held true on a more specific sense as both anterior and posterior $\Delta E_{clinical}$ were above the literature cut off (anterior p <.001; posterior p <.001). As $\Delta E_{clinical}$ shows, the accuracy of the student based shade-match depended on the location (anterior or posterior) of the restoration (p= .01). $\Delta E_{clinical}$ was also determined to be significantly higher than $\Delta E_{laboratory}$ as noted by mean and standard deviation for both data sets ($\Delta E_{clinical}$ 6.5, 2.4) ($\Delta E_{laboratory}$ 4.3, 2.0).

$\Delta E_{laboratory}$ values were also above literature stated clinical acceptance values in general (p=.002) and by location (p=.01 anterior, p=.04 posterior). As mentioned, these values were slightly closer to the literature stated values than the $\Delta E_{clinical}$ group,

indicating that the laboratory was able to obtain a shade-match closer to the goal than the students were.

It is likely that this difference in experience contributed to the closer proximity of the $\Delta E_{laboratory}$ values to the clinical acceptance values in comparison the $\Delta E_{clinical}$. The laboratory technicians making the restoration shade are generally more experienced in shade-matching than the students that issue the initial prescription shade. This experience has been shown to influence quality of the shade-match, more so than any other observer quality (32). Experienced clinicians have been shown to produce shade-match results better than students, yielding lower ΔE and therefore a closer match (49). Specialists that perform a lot of restorative work such as laboratory technicians and prosthodontists routinely perform better in shade-matching procedures than other dental professionals (32).

The majority of students failed to include a digital photograph with the prescription shade on the Laboratory Authorization Form. Study of the digital camera through CIE data points has shown correlations that indicate the integrity of digital photographs (21). This means that digital photographs systems have the potential to "fill in the gaps" with CIELAB data, which as previously mentioned, directly relate to ΔE through the Munsell equation (23, 40). Aside from the mathematical argument, literature review also supports the use of digital photographs (15). Often times (as in the present study) the laboratory technician never sees the patient; they only see the letter number code as written in the prescription shade. Additional information is helpful in when communicating between two separate entities such as the clinic and the laboratory. Information such as contour and translucence cannot be easily communicated (16, 21)

which is of particular importance in the anterior region (12). Although these details are not directly incorporated into ΔE, they can further enhance the quality of the restoration.

The data also showed that the majority of students did not include the dentin shade (stump shade) for the all-ceramic restorations in the Laboratory Authorization Form. Without this information, the laboratory may not be able to adequately incorporate the hue of the underlying tooth structure to create an accurate shade-match (14). The stump shade can aid the lab in incorporating the hue and translucence qualities needed for a natural looking restoration (15, 17)

Satisfaction Outcomes

Despite the discrepancies in both $\Delta E_{clinical}$ and $\Delta E_{laboratory}$ data sets, Likert Scale survey responses indicated that the majority of patients (94.2%), students (82.5%) and faculty (58.3%) were "satisfied" to "extremely satisfied" with the restoration shade. No study participant was shown the ΔE reading from the Spectrophotometer; the answers to these questions were based completely on visual assessment. Both $\Delta E_{clinical}$ and $\Delta E_{laboratory}$ were consistently and significantly above previously mentioned literature stated perceptibility values (41). However, patients, students and faculty gave high satisfaction ratings, indicating that they did not detect discrepancies in both ($\Delta E_{clinical}$ and $\Delta E_{laboratory}$) that theoretically should have been visually apparent.

These results indicate that perhaps these thresholds may need to be re-evaluated for added flexibility, especially in academic institutions where it is likely that experience levels are lower.

Support Outcomes

Due to these positive satisfaction ratings, it is natural to assume that the faculty and students would disagree with the second Likert Scale survey statement: The use of an objective shade-matching devise may improve cosmetic outcome. Based on the ratings of their performance, perhaps they think visual shade-matching is sufficient. However, both students and faculty were strongly supportive of the use of an objective shade-matching tool. Students and faculty may not feel confident in the accuracy of a shade-match performed with a shade guide. It is general knowledge among the dental community that visual shade-matching is subject to many variation inducing factors (7, 17-19, 24); it is also well known that other digital measurement tools provide more accurate measurement (15, 32, 41)- giving clinicians and students multiple reasons to second guess themselves.

Correlational Considerations

Knowledge of potential relationships between these findings (ΔE, satisfaction ratings and support of an objective tool) could be useful to the progression of the field. Pearson Correlational analysis showed several interesting trends, which are discussed below.

Correlation with Restoration Characteristics

A few restoration characteristics showed correlations that are believed to have influenced $\Delta E_{clinical}$ and $\Delta E_{laboratory}$ outcomes.

$\Delta E_{clinical}$ and Restoration Location

The $\Delta E_{clinical}$ data shows that the posteriorly located restorations did not match the surrounding natural reference shade as well as anteriorly located restorations, to a statistically significant degree (p = .0496). The posterior teeth are more difficult to see during the prescription process; and of course, not as easily viewed in the patient's everyday life. It is very likely that the student and patient were not as concerned with getting the shade of the posterior teeth as close to the reference teeth as possible, causing the $\Delta E_{clinical}$ to be higher than expected.

$\Delta E_{laboratory}$ and Material Choice

Material choice (metal or ceramic) significantly correlated with $\Delta E_{laboratory}$ (p= .04) indicating that the all-ceramic material was harder for the laboratory to shade-match than metal-ceramic materials. Shade-matching outcome can be difficult to predict with ceramics, depending largely on technique (29). Significant changes can occur as firing level and dentin ceramic thickness are manipulated (30). Other studies have found that the ceramic materials do not always match the shade guides, indicating that material compounds may be an important factor contributing to shade discrepancies (35).

Correlation with Survey Responses

ΔE and Satisfaction Survey Responses

Although $\Delta E_{clinical}$ and $\Delta E_{laboratory}$ were higher than expected and therefore outside of clinical acceptance norms, all parties involved were "satisfied" to "extremely

satisfied" with the restoration shade. There could be several reasons behind these surprising results.

As Al-Wahadni et al found (53), patients tend to rate restorations more favorably when the restoration is received in an academic institution (53). The authors concluded that allegiance and pride toward the school or even the attitude that academic clinicians are involved in the work improved the patient's opinion of the care received (53) - these conclusions could certainly be applicable here. It is also plausible that this patient population is slightly different in their expectation than a private practice patient pool would be. Dental school patients receive restorations at a discounted rate and they are aware that dental students will be performing the restoration. This could slightly lower their expectation for the restoration shade in comparison to an analogous private practice patient. While the research team was careful to ask survey questions in private, it is still possible that the patient slightly adjusted their answers for concern of impacting the student's grade. Simple, personal choice could have also influenced these results. Often times, as revealed in the open ended question asked of the students and faculty, the patient requested that the restoration shade be slightly lighter than the surrounding reference shaded teeth. It is possible that the patient stated being "satisfied" with restoration shade simply because they liked the whiter shade.

Students rated their work very well, despite $\Delta E_{clinical}$ discrepancies. As mentioned, patients frequently asked for lighter shades, usually with the intention to lighten their teeth after finishing the restoration appointment. If the restoration shade seemingly matched the (lighter) prescription shade the student may feel inclined to state

that they were "satisfied" with the restoration shade, because that was indeed what they ordered from the Laboratory.

The effects of experience cannot be ruled out as a potential influence in these correlations, accuracy in shade-match has been directly linked to experience. Clinicians who spend a lot of time working on restorative procedures, such as prosthodontists and dental laboratory technicians, have proven to be more successful at shade-matching (32). The students included in this study are still working toward the General Dentistry (DMD) degree, they have yet to reach the restorative expertise of such specialists. However, because the patient population accepted the restoration for luting, and was satisfied with the outcome of the shade-match, these procedures can still be rated as a "success." According to review (41) the majority of studies that contribute to current knowledge of acceptability/perceptibility thresholds are in vitro based, potentially excluding the clinical environment (41). For reasons such as these, in conjunction with the high patient satisfaction ratings, it may be useful to re-evaluate the stringent ΔE thresholds.

$\Delta E_{clinical}$ and faculty satisfaction were significantly negatively correlated (r= -0.45; p <.001). This tendency towards higher levels of scrutiny could again relate to a higher level of experience. Of all the factors that may influence the ability to shade-match (ie gender, age(32), lighting (48) experience is the most influential (32). The vast majority of faculty members included in this study were prosthodontists, it is likely that this specialty allowed the faculty assess shade-match with greater accuracy than other members of the research team (32), especially inexperienced dental students. While expertise allows experienced dentists to discern these differences (32, 53), the

spectrophotometer still needs to be considered. In multiple studies, even experienced clinicians were not able to perform better than this objective tool (35, 50).

ΔE and Support Ratings:

Overall, students were generally supportive of the need for an objective shade-matching tool. Students know they are inexperienced. They may not be confident in their ability to consistently shade-match each individual case for each individual patient, every single time. With this in mind, the idea of using a purely objective, digital device would certainly be well received.

Faculty support of an objective tool was significantly positively correlated with $\Delta E_{clinical}$ (r= .35; p<0.001). The faculty never saw the actual $\Delta E_{clinical}$ value; this correlation comes from strictly visual assessment. This ability to discern visual inaccuracies in shade without knowledge of any quantitative markers has been seen in other studies. For example, Da Silva et al (51) created two sets of crowns, evaluated the accuracy of these crowns and then had experienced faculty choose the most accurate shade-match, again, through visual means only. The experienced clinicians consistently chose the group with the lower ΔE. It is worth noting for the purpose of the current research that this selected group of crowns were created using a Spectrophotometer and the rejected group was created using a Shade Guide (51).

While it is well documented that experience plays a role in shade-matching accuracy, even seasoned clinicians are not always able to shade-match with in ΔE thresholds themselves. AlSaleh et al (49) found that while clinicians shade-matched

more accurately than their student counterparts, the crowns created based on their shade guide created prescriptions were slightly above perceptibility thresholds (49) and therefore in theory visually detectable. These findings in conjunction with the satisfaction ratings discussed above provide evidence that perhaps the current ΔE requirements need to be revaluated.

Comparing the Digital Photograph to the Spectrophotometer

Student uncertainty and faculty scrutiny may be eased through objective measurement via the Spectrophotometer. The Spectrophotometer does well in non-clinical, controlled environments (44) and also in the variable clinical environment (46). It could be used to lessen the effects of experience (51, 53)-performing better in shade measurement than experienced faculty using a shade guide (50). Crowns created with the Spectrophotometer have lower rejections rates (51) meaning that valuable clinic time and resources could be saved. Literature review concludes that the Spectrophotometer can be used as a reliable shade-measuring device (22).

As discussed earlier, digital photographs have been proven to improve visual shade-matching outcomes (16, 22, 23). While the literature supports the integrity of digital photographs and CIE data for these photographs show correlations in the color parameters (21), the Spectrophotometer maintains favor. Study of multiple shade-matching devices ranging from the Spectrophotometer to the Digital Camera to others like the Calorimeter have shown that the Spectrophotometer is the most reliable among

the options for instrumental measurement (46). Review of shade-matching instruments concluded that while digital tools like the Spectrophotometer have strong positive results in shade-matching; their cost sometimes limits the use of them (7). In times like this, the digital photograph should be used to supplement the subjective shade guide to improve the communication with the laboratory (7). Thus, digital photographs are an essential addition to visual shade guide prescription, but not a replacement for the Spectrophotometer.

If the shade guide is kept in use for reasons such as price, convenience or familiarly, it may be advisable to periodically test the guide to insure that the shade tabs are stable and have not changed due to routine autoclaving (36). The Spectrophotometer used in this study has a feature that allows for such quality control measurements. For example, the Spectrophotometer can be used to make sure that the A1 tab is truly still A1 in shade. If widespread use of the Spectrophotometer is out of the question for budgeting reasons, perhaps a more conservative approach would be to use the Spectrophotometer in a quality control sense.

Strengths and Limitations

Several studies have tested the accuracy of the spectrophotometer (22, 46, 51) the subjectivity of the shade guide (17-19) and even the ability of students to self shade-match (49). The current study is unique in that no study of its kind has been completed within an educational institution. These findings could potentially lead to improvements in shade-matching curriculum throughout dental education. In a more immediate sense, patients within this sample were pleased with the quality of care they received at this

particular institution, indicating that esthetic education in this area is on track within this particular school. Interest in objective measurement indicates that future dentists are open to new technologies that may potentially improve patient care.

Further study of this topic would need to include the CIE coordinates involved in the ΔE. The data shows that both $\Delta E_{clinical}$ and $\Delta E_{laboratory}$ were well outside clinical acceptance values, but it is unclear which component of the multifaceted ΔE equation contributed to these outcomes. The research team did not include vision screenings in the study participation criteria; this would be advisable in the future to decrease the influence of variables such as the inability to adequately discern value differences (8). Future studies would also need to include the relative amount of time the patient was in the dental chair before the prescription shade was assessed. The shade of the teeth is highly sensitive to dehydration that frequently occurs while sitting in the dental chair with the mouth open (27). Without this information, the investigators cannot rule out oral dehydration as a factor in $\Delta E_{clinical}$ discrepancies. While only one laboratory was used in the creation of the restoration shade, the laboratory technician's name was not included to prevent having too many variables in the statistical analysis.

CHAPTER VI

CONCLUSION

Within the limitations of this study, the following can be concluded:

- $\Delta E_{clinical}$ and $\Delta E_{laboratory}$ were both outside literature stated clinical acceptance values.
- Patients, students and faculty were satisfied with the outcome of the shade-match.
- Both students and faculty support the use of an objective tool to improve cosmetic shade-matching outcome.
- Faculty support of an objective tool was based on $\Delta E_{clinical}$. The higher the difference in shade, the more likely the faculty supported the use of an objective tool in future shade-measurement.

Student shade-matching accuracy may need improvement. Therefore, an objective tool may beneficial. At the very least digital photographs should be included with the prescription shade. Considering the statistically significant ΔE discrepancies, high satisfaction ratings, and the lack of in vivo established thresholds, future study would need to further explore the potential that current ΔE minimums may need to be relaxed.

REFERENCES

1. Sim CP, Yap AU, Teo J. Color perception among different dental personnel. Operative dentistry. 2001;26(5):435-9.

2. Joiner A. Tooth colour: a review of the literature. Journal of dentistry. 2004;32 Suppl 1:3-12.

3. Samorodnitzky-Naveh GR, Geiger SB, Levin L. Patients' satisfaction with dental esthetics. Journal of the American Dental Association (1939). 2007;138(6):805-8.

4. Kelly JR, Nishimura I, Campbell SD. Ceramics in dentistry: Historical roots and current perspectives. The Journal of prosthetic dentistry. 1996;75(1):18-32.

5. Judd DB WG. Color in Business, Science and Industry. Third ed: John Wiley & Sons, Inc. ; 1975.

6. Feisner EA RR. Color Studies 3ed: Bloomsbury Publishing Inc 2014.

7. Chu SJ, Trushkowsky RD, Paravina RD. Dental color matching instruments and systems. Review of clinical and research aspects. Journal of dentistry. 2010;38 Suppl 2:e2-16.

8. Chu SJ, Devigus A, Paravina RD, Mieleszko A. Fundamentals of Color: Shade Matching and Communication in Esthetic Dentistry. Second Edition. . In: Read M, editor. 2 ed. Hanover Park, IL 60133: Quintessence Publishing Co, Inc 2010. p. 16-34.

9. Cochrane S. The Munsell Color System: a scientific compromise from the world of art. Studies in history and philosophy of science. 2014;47:26-41.

10. Sproull RC. Color matching in dentistry. Part I. The three-dimensional nature of color. 1973. The Journal of prosthetic dentistry. 2001;86(5):453-7.

11. Munsell Book of Color Defining, Explaining and Illustrating the Fundamental Characteristics of Color. A Revision and Extension of "The Atlas of the Munsell Color System" by A.H. Munsell Standard Edition ed. Baltimore, Maryland The Hoffman Brothers Co. ; 1929.

12. F B. A Basic Treatise on the Color System of Albert H. Munsell NY, New York Van Nostrand Reinhold Company 1969.

13. Fondriest J. Shade matching in restorative dentistry: the science and strategies. The International journal of periodontics & restorative dentistry. 2003;23(5):467-79.
14. Chiche GJ PA. Esthetics of Anterior Fixed Prosthodontics Toppan Printing, Co., (H.K.) Ltd., China Quintessence Publishing Co, Inc. ; 1994.

15. Derbabian K, Marzola R, Donovan TE, Arcidiacono A. The science of communicating the art of esthetic dentistry. Part III: precise shade communication. Journal of esthetic and restorative dentistry : official publication of the American Academy of Esthetic Dentistry [et al]. 2001;13(3):154-62.

16. M G. Esthetic Dentistry in Clinical Practice Wiley-Blackwell 2010.

17. Paravina R, Stanković D, Aleksov L, Mladenović D, Ristić K. Problems in standard shade matching and reproduction procedure in dentistry: a review of the state of the art1997.

18. Bartlett DW FN. Clinical Problem Solving in Prosthodontics Churchill Livingstone, Elsevier Science Limited 2004.

19. Ahn JS, Lee YK. Color distribution of a shade guide in the value, chroma, and hue scale. The Journal of prosthetic dentistry. 2008;100(1):18-28.

20. Sikri VK. Color: Implications in dentistry. Journal of conservative dentistry: JCD. 2010;13(4):249.

21. Jarad F, Russell M, Moss B. The use of digital imaging for colour matching and communication in restorative dentistry. British dental journal. 2005;199(1):43-9.

22. Chen H, Huang J, Dong X, Qian J, He J, Qu X, et al. A systematic review of visual and instrumental measurements for tooth shade matching. Quintessence international (Berlin, Germany : 1985). 2012;43(8):649-59.

23. Schropp L. Shade matching assisted by digital photography and computer software. Journal of prosthodontics : official journal of the American College of Prosthodontists. 2009;18(3):235-41.

24. Park JH, Lee YK, Lim BS. Influence of illuminants on the color distribution of shade guides. The Journal of prosthetic dentistry. 2006;96(6):402-11.

25. Lee YK, Yu B, Lim JI, Lim HN. Perceived color shift of a shade guide according to the change of illuminant. The Journal of prosthetic dentistry. 2011;105(2):91-9.

26. Bhat V, Prasad DK, Sood S, Bhat A. Role of colors in prosthodontics: application of color science in restorative dentistry. Indian journal of dental research : official publication of Indian Society for Dental Research. 2011;22(6):804-9.
27. Burki Z, Watkins S, Wilson R, Fenlon M. A randomised controlled trial to investigate the effects of dehydration on tooth colour. Journal of dentistry. 2013;41(3):250-7.

28. Stevenson B, Ibbetson R. The effect of the substructure on the colour of samples/restorations veneered with ceramic: a literature review. Journal of dentistry. 2010;38(5):361-8.

29. Spear F, Holloway J. Which all-ceramic system is optimal for anterior esthetics? Journal of the American Dental Association (1939). 2008;139 Suppl:19s-24s.

30. Ozturk O, Uludag B, Usumez A, Sahin V, Celik G. The effect of ceramic thickness and number of firings on the color of two all-ceramic systems. The Journal of prosthetic dentistry. 2008;100(2):99-106.

31. Powers JM, Paravina RD. Esthetic color training in dentistry: Elsevier Mosby; 2004.

32. Capa N, Malkondu O, Kazazoglu E, Calikkocaoglu S. Evaluating factors that affect the shade-matching ability of dentists, dental staff members and laypeople. Journal of the American Dental Association (1939). 2010;141(1):71-6.

33. Poljak-Guberina R, Celebic A, Powers JM, Paravina RD. Colour discrimination of dental professionals and colour deficient laypersons. Journal of dentistry. 2011;39, Supplement 3:e17-e22.

34. Paravina RD, O'Neill PN, Swift EJ, Jr., Nathanson D, Goodacre CJ. Teaching of color in predoctoral and postdoctoral dental education in 2009. Journal of dentistry. 2010;38 Suppl 2:e34-40.

35. Paul S, Peter A, Pietrobon N, Hammerle CH. Visual and spectrophotometric shade analysis of human teeth. Journal of dental research. 2002;81(8):578-82.

36. Schmeling M, Sartori N, Monteiro S, Baratieri L. Color stability of shade guides after autoclave sterilization. The International journal of periodontics & restorative dentistry. 2014;34(5):689-93.

37. ArRejaie Aws SA. The effect of chemical disinfectants on the color of a porcelain shade guide. International journal of health sciences.8(3):299-304.

38. Huang Peterson YP. The effect of various disinfectants on dental shade guides. Journal of Prosthetic Dentistry.112(3):613-7.

39. Vichi A, Louca C, Corciolani G, Ferrari M. Color related to ceramic and zirconia restorations: a review. Dental materials : official publication of the Academy of Dental Materials. 2011;27(1):97-108.

40. Wyszecki G SW. Color Science: Concepts and Methods, Quantitative Data and Formulae. Two ed: John Wiley & Sons 1982.

41. Khashayar G, Bain PA, Salari S, Dozic A, Kleverlaan CJ, Feilzer AJ. Perceptibility and acceptability thresholds for colour differences in dentistry. Journal of dentistry. 2014;42(6):637-44.

42. Douglas RD, Brewer JD. Acceptability of shade differences in metal ceramic crowns. The Journal of prosthetic dentistry. 1998;79(3):254-60.

43. Ramesh AS, Sharma A, Rijesh K, Prakash R, Devi L, Raja E. Assessment of perceptibility and acceptability of color variations between matched teeth among trainee dentist and lay person. Journal of pharmacy & bioallied sciences. 2015;7(Suppl 2):S632-5.

44. Kim-Pusateri S, Brewer JD, Davis EL, Wee AG. Reliability and accuracy of four dental shade-matching devices. The Journal of prosthetic dentistry. 2009;101(3):193-9.

45. Al-Dosari AAF. Reliablity of Tooth Shade Perception by Dental Professionals Pakistan Oral and Dental Journal 2010;30(1):244-9.

46. Dozic A, Kleverlaan CJ, El-Zohairy A, Feilzer AJ, Khashayar G. Performance of five commercially available tooth color-measuring devices. Journal of prosthodontics : official journal of the American College of Prosthodontists. 2007;16(2):93-100.

47. Li Q, Yu H, Wang YN. In vivo spectroradiometric evaluation of colour matching errors among five shade guides. Journal of oral rehabilitation. 2009;36(1):65-70.

48. Della Bona A, Barrett AA, Rosa V, Pinzetta C. Visual and instrumental agreement in dental shade selection: three distinct observer populations and shade matching protocols. Dental materials : official publication of the Academy of Dental Materials. 2009;25(2):276-81.

49. Alsaleh S, Labban M, AlHariri M, Tashkandi E. Evaluation of self shade matching ability of dental students using visual and instrumental means. Journal of dentistry. 2012;40 Suppl 1:e82-7.

50. Browning WD, Chan DC, Blalock JS, Brackett MG. A comparison of human raters and an intra-oral spectrophotometer. Operative dentistry. 2009;34(3):337-43.

51. Da Silva JD, Park SE, Weber HP, Ishikawa-Nagai S. Clinical performance of a newly developed spectrophotometric system on tooth color reproduction. The Journal of prosthetic dentistry. 2008;99(5):361-8.

52. Jaju RA, Nagai S, Karimbux N, Da Silva JD. Evaluating tooth color matching ability of dental students. Journal of dental education. 2010;74(9):1002-10.

53. Al-Wahadni A, Ajlouni R, Al-Omari Q, Cobb D, Dawson D. Shade-match perception of porcelain-fused-to-metal restorations: a comparison between dentist and patient. Journal of the American Dental Association (1939). 2002;133(9):1220-5; quiz 60-1.

54. PM N. Dong Survey Research: A Guide to Quantitative Methods J L, editor: Pearson Education, Inc 2003. 66-107 p.

55. Fowler FJ. Survey Research Methods Second. ed. Brickman L RD, editor: Sage Publications 1993.

56. Dillman DA, Smyth JD, Christian LM. Internet, phone, mail, and mixed-mode surveys: the tailored design method: John Wiley & Sons; 2014.

57. Weisberg HF BB. An Introduction to Survey Research and Data Analysis. San Francisco: W.H. Freeman and Company; 1977.

APPENDICES

1. Enrollment Sequence			
2. Treatment and Data Collection Date			
3. Gender of Patient: 0=Male, 1=Female			
4. Age of Patient			
5. Gender of Student Provider: 0=Male, 1=Female			
6. Age of Student Provider			
7. Student Provider Previous Dental Field Background: 0=No Dental Background , 1= Dental Related Lab Tech, Hygenist, etc..			
8. Year in Dental School: 0=Junior/D3 year, 1=Senior/D4 year, 2=Others			
9. Overseeing Faculty Educational Background: 0=General Dentist, 1=Restorative/Operative Specialist, 2=Prosthodontist, 3=Others			
10. Restoration on Natural Dentition vs Implant: 0=Dental Implant, 1=Natural Dentition			
11. Type of Restoration: 0=Partial Coverage, 1=Full coverage			
12. Type of Restoration, Metal vs. Ceramic: 0= Metal-Ceramic, 1= All-Ceramic , 2=Others			
13. Type of Restoration, Exact Material Used: 0=Base-Metal Alloy, 1=Noble Metal alloy, 2=High Noble alloy, 3=Emax, 4= Empress, 5= Zirconia, 6=Feldspathic, 7=Others			
14. Tooth Number for Reference			
15. Tooth Number for Restoration			
16. Vita Shade Measurement of Reference Tooth, and or the Intended Shade as the information specified on the Laboratory Authorization. (Recorded by the visual assessment via shade guide) Cervical Third, Body, Incisal Third	Cervical Third	Body	Incisal Third
17. Quality Assessment of Written Laboratory Authorization. Any noted missing information. (Examples, Dentin Shade for All-ceramic restorations, Missing information on the specification of restorative materials …)			
18. Clinical Photos provided to the laboratory			

19. Vita Shade Measurement of Reference Tooth (Measurement by the Spectrophotometer) Cervical Third, Body, Incisal Third	Cervical Third	Body	Incisal Third
20. Vita Shade Measurement of Luted Restoration (Measurement by the Spectrophotometer) Cervical Third, Body, Incisal Third	Cervical Third	Body	Incisal Third
21. Shade difference (ΔE) Between Shade Measurement of Luted Restoration and the Reference Teeth, (Measurement by the Spectrophotometer) Cervical Third, Body, Incisal Third	Cervical Third	Body	Incisal Third
22. Shade difference (ΔE) Between Shade Measurement of Luted Restoration and the prescribed Shade as specified in Lab Authorization. Cervical Third, Body, Incisal Third	Cervical Third	Body	Incisal Third
23. How satisfied is the patient toward the shade-matching outcome? 1=Extremely Dissatisfied; 2=Somewhat Dissatisfied; 3=Neutral; 4=Satisfied; 5=Extremely Satisfied.			
24. How satisfied is the Student Provider toward the shade-matching outcome? 1=Extremely Dissatisfied; 2=Somewhat Dissatisfied; 3=Neutral; 4=Satisfied; 5=Extremely Satisfied.			
25. How satisfied is the Faculty toward the shade-matching outcome? 1=Extremely Dissatisfied; 2=Somewhat Dissatisfied; 3=Neutral; 4=Satisfied; 5=Extremely Satisfied.			
26. Question for Student: The use of an objective shade matching equipment may improve the cosmetic outcome in this treatment provided to the patient. 1=Strongly Disagree; 2=Disagree; 3=Neutral; 4=Agree; 5=Strongly Agree.			
27. Question for Faculty: The use of an objective shade matching equipment may improve the cosmetic outcome in this treatment provided to the patient. 1=Strongly Disagree; 2=Disagree; 3=Neutral; 4=Agree; 5=Strongly Agree.			
28. Open Ended Question for Faculty and Students: What are your recommendations for making accurate shade selections?			

CURRICULUM VITA

NAME: Erin Ballard

ADDRESS: 2400 Mellwood Avenue Apt 1320
Louisville, Kentucky 40206

DOB: July 9, 1991

EDUCATION
& TRAINING: B.S., Biology
Eastern Kentucky University
2011-2014

University of Kentucky
2009-2011

AWARDS: Summer Research Program, University of Louisville
2015

MSOB Tuition Scholarship
Fall 2015- Spring 2016

Academic Dean's List
Spring 2012

President's Award
Fall 2011

University of Kentucky Professional Education Program I-II
Summer 2009, Summer 2011

PROFESSIONAL SOCIETIES:
Student Research Group, Secretary
Spring 2016-Spring 2017

Student Research Group, Member
Fall 2014-Spring 2016