Masthead Logo

Nova Southeastern University
NSUWorks

College of Dental Medicine Student Theses, Dissertations and Capstones

College of Dental Medicine

11-10-2015

Color of Porcelain Veneer after Final Cementation in Comparison to Try-in Paste and Permanent Cement: An In Vitro Study

Abdulelah Aldahlawi
Nova Southeastern University

This document is a product of extensive research conducted at the Nova Southeastern University College of Dental Medicine. For more information on research and degree programs at the NSU College of Dental Medicine, please click here.

Follow this and additional works at: https://nsuworks.nova.edu/hpd_cdm_stuetd

Part of the Dentistry Commons

All rights reserved. This publication is intended for use solely by faculty, students, and staff of Nova Southeastern University. No part of this publication may be reproduced, distributed, or transmitted in any form or by any means, now known or later developed, including but not limited to photocopying, recording, or other electronic or mechanical methods, without the prior written permission of the author or the publisher.

NSUWorks Citation

Abdulelah Aldahlawi. 2015. *Color of Porcelain Veneer after Final Cementation in Comparison to Try-in Paste and Permanent Cement: An In Vitro Study.* Master's thesis. Nova Southeastern University. Retrieved from NSUWorks, College of Dental Medicine. (70) https://nsuworks.nova.edu/hpd_cdm_stuetd/70.

This Thesis is brought to you by the College of Dental Medicine at NSUWorks. It has been accepted for inclusion in College of Dental Medicine Student Theses, Dissertations and Capstones by an authorized administrator of NSUWorks. For more information, please contact nsuworks@nova.edu.

المنارة للاستشارات

www.manaraa.com

THE COLOR OF PORCELAIN VENEER AFTER FINAL CEMENTATION IN COMPARISON TO TRY-IN PASTE AND PERMANENT CEMENTS: AN IN VITRO STUDY

A Thesis Presented

By

ABDULELAH HUSSEIN ALDAHLAWI, B.D.S

Submitted to the College of Dental Medicine of Nova Southeastern University in Partial

Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCE

August 2015

المنارة للاستشارات

www.manaraa.com

ProQuest Number: 10118286

All rights reserved

INFORMATION TO ALL USERS
The quality of this reproduction is dependent upon the quality of the copy submitted.

In the unlikely event that the author did not send a complete manuscript
and there are missing pages, these will be noted. Also, if material had to be removed,
a note will indicate the deletion.

ProQuest 10118286

Published by ProQuest LLC (2016). Copyright of the Dissertation is held by the Author.

All rights reserved.
This work is protected against unauthorized copying under Title 17, United States Code
Microform Edition © ProQuest LLC.

ProQuest LLC.
789 East Eisenhower Parkway
P.O. Box 1346
Ann Arbor, MI 48106 - 1346

المنارة للاستشارات

www.manaraa.com

© Copyright by Abdulelah H. Aldahlawi 2015

All Rights Reserved

www.manaraa.com

THE COLOR OF PORCELAIN VENEER AFTER FINAL CEMENTATION IN COMPARISON TO TRY-IN PASTE AND PERMANENT CEMENTS: AN IN VITRO STUDY

By

ABDULELAH HUSSEIN ALDAHLAWI, B.D.S.

A thesis submitted to the College of Dental Medicine of Nova Southeastern University in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Section of Cariology and Restorative Dentistry
College of Dental Medicine
Nova Southeastern University
September 2015

Approved as to style and content by:

APPROVED BY:____
Jeffrey Y. Thompson, B.S, Ph.D. (Committee Chair) Date

APPROVED BY:____
Rafael Castellon, D.D.S, M.S. (Committee member) Date

APPROVED BY:____
Marvin Golberg, D.D.S. (Committee member) Date

APPROVED BY:____
Linda Niessen, D.M.D, M.P.H. (Dean) Date

المنارة للاستشارات
www.manaraa.com

NOVA SOUTHEASTERN UNIVERSITY

Health Professions Division
Department of Cariology and Restorative Dentistry
College of Dental Medicine

STUDENT NAME: Abdulelah Hussein Aldahlawi, B.D.S.

STUDENT E-MAIL ADDRESS: aa1645@nova.edu

STUDENT TELEPHONE NUMBER: (781)-353-4482, (778)-323-9052

COURSE DESCRIPTION: Master of Science in Dentistry with specialization in Postgraduate Operative Dentistry

TITLE OF SUBMISSION: The Color of Porcelain Veneer after Final Cementation in Comparison to Try-in Paste and Permanent Cements: An In Vitro Study

DATE SUBMITED: August, 2015

I certify that I am the sole author of this thesis, and that any assistance I received in its preparation has been fully acknowledged and disclosed in the thesis. I have cited any sources from which I used ideas, data, or words, and labeled as quotations any directly quoted phrases or passages, as well as providing proper documentation and citations. This thesis was prepared by me, specifically for the M.S. degree and for this assignment.

STUDENT SIGNATURE:____
Abdulelah H. Aldahlawi, B.D.S. Date

المنارة للاستشارات
www.manaraa.com

DEDICATION

To my parents, Mr. Hussein Aldahlawi and Mrs. Fawziah Hakeem, to recognize their unconditional love and support throughout my education. All your encouragement and guidance I have been able to accomplish my goals. To my family, my lovely son Ibrahim, and my beloved wife Arwa, without your generous encouragement, helps and support I would not accomplished my study. Thank you for believing in me and being there throughout the entire program. I could not have accomplished this without you.

المنارة للاستشارات
www.manaraa.com

ACKNOWLEDGEMENTS

I would like to acknowledge the following individuals:

Dr. Jeffrey Thompson, for chairing my thesis committee. I am so grateful and honored for all of your support and guidance throughout this process. I have learned a lot from you.

Dr. Rafael Castellon and Dr. Marvin Golberg, for serving on my committee. Thank you for your guidance and assistance during my study.

Dr. Cristina Garcia-Godoy, I greatly appreciate your assistance and support with my study.

Dr. Patrick Hardigan, for the assistance in the statistical analysis.

Mr. James Rothrock, thank you for your great help and all your assistance in the Bioscience Research Center Lab at Nova Southeastern University.

Mrs. Patrice Stack, for all your help with the administrative part of my thesis.

المنارة للاستشارات
www.manaraa.com

ABSTRACT

THE COLOR OF PORCELAIN VENEER AFTER FINAL CEMENTATION IN COMPARISON TO TRY-IN PASTE AND PERMANENT CEMENTS: AN IN VITRO STUDY

DEGREE DATE: SEPTEMBER 2015

ABDULELAH HUSSEIN ALDAHLAWI, B.D.S.
COLLEGE OF DENTAL MEDICINE NOVA SOUTHEASTERN UNIVERSITY

Thesis Directed By:	Jeffrey Y. Thompson, B.S., Ph.D, Committee Chair
	Rafael Castellon, D.D.S, M.S., Committee Member
	Marvin Golberg, D.D.S, Committee Member

Objectives: To evaluate and compare the color of porcelain veneers with try-in paste in relation to porcelain veneers with permanent cement. Also, to evaluate and compare combinations of three different shades and thicknesses of porcelain veneers and three cement shades before and after final cementation. Additionally, to evaluate and compare the color of porcelain veneers with cured permanent cement before and after aging. **Background**: Porcelain veneers and ceramic restorations have become one of the most popular approaches in the anterior area due to their natural appearance and esthetics. However, more conservative approaches have led to thinner restorations

www.manaraa.com

with increased translucency. A potential drawback to these restorations is that any color change in the luting cement can become clinically visible, and possibly affect esthetic appearance. **Methods**: One hundred and eight specimens were cut from feldspathic porcelain blocs (Vitablocs Mark II for CEREC). Three different Vita 3D-Master 1M1, 2M2, and 3M1 shades were assessed. All specimens were 12 x 14 mm, with three different thicknesses of 0.3, 0.5, and 1.0 mm. Light-cured resin cement (Variolink Veneer, Ivoclar Vivadent) with three different shades was used. The specimen color alone, with the try-in paste, and with pre-cured and post-cured resin cement was measured using a spectrophotometer (Color Eye 7000A), which measures CIE-L*a*b* values. Specimens were subjected to 30,000 cycles of accelerated aging (Themo-cycling, Sarbi Dental Enterprises Inc.). Color measurement for all specimens was performed again and ΔE values between groups been calculated. Statistical analysis was performed using one-way and three-way ANOVA, with level of significant set at $\alpha=0.05$, to assess differences between groups. This was followed by post hoc Tukey's tests. **Results**: Statistical analysis showed a significant difference between try-in paste and corresponding cured resin cement. Pre-cured and post-cured resin cement values showed a significant difference between cement shades. Moreover, statistically significant differences were found between post-cured cement and after 30,000 cycles of thermo-cycling. **Conclusions:** The final color of porcelain veneers was highly affected by the different shades of resin cement and by the thicknesses of the porcelain veneer. The use of higher ceramic thickness decreased the ΔE values when compared to thinner veneers. Also, color stability of ceramic veneer restorations luted with resin cement, was significantly influenced by the aging.

المنارة للاستشارات
www.manaraa.com

TABLE OF CONTENTS

Page

المنارة للاستشارات

www.manaraa.com

Chapter 2: Materials and Methods……………………………….…………19

www.manaraa.com

www.manaraa.com

LIST OF TABLES

Page

www.manaraa.com

المنارة للاستشارات

www.manaraa.com

LIST OF FIGURES

Page

www.manaraa.com

www.manaraa.com

LIST OF APPENDICES

Page

www.manaraa.com

Chapter 1

Introduction

1.1 Indirect Tooth Restorations:

1.1.1 Overview and Classification:

It has been established that dental esthetics is one of the most important factors to a patient, and this might have a significant impact in patient psychological parameters and self-esteem.[1] Anterior tooth restorations provide a good esthetic substitute to lost tooth structure. Manufactures have developed several alternatives to gold and alloy restorations for posterior and anterior teeth such as composite and all ceramic restorative choices. For the past few decades, dental ceramic restorations have been widely used because of their excellent esthetics and biocompatibility.[2, 3] Tooth colored restorations can be fabricated either directly, in which they are applied precisely on the tooth; or indirectly, where a chairside or laboratory construction is required and then delivered for cementation to the tooth. Indirect tooth restorations are designed to replace the missing part of tooth structure either fully as with crowns, or partially as with inlay, onlay, or laminated veneers.

1.2 Veneers:

1.2.1 Overview:

A veneer can be defined as "Thin bonded ceramic restoration used to restore the facial surface and part of the proximal surface of a tooth".[4] Porcelain laminated veneers (PLV) and ceramic restorations have become one of the most popular approaches in the anterior area due to their natural appearance and esthetics. Veneers were first introduced by Charles Pincus in 1937. He used them for a temporarily esthetic enhancement of teeth

www.manaraa.com

shapes in movies stars.[5, 6] However, the use of ceramic veneers didn't enter the mainstream of dentistry until the early 1980s, when enamel etching and surface treatments of porcelain become available.[6, 7] Simonsen and Calamia, first described the feldspathic porcelain veneer retained by an acid etch technique as demonstrated by a laboratory published study.[4, 5] Afterward, Horn published the first report of the clinical application of that method. The advancement of composite resin laminated veneers took place in mid 1970s and early 1980s. However, the early use of composite resin veneer presented several problem, such as staining, loss of luster overtime, and a monochromatic appearance.[8]

The success of porcelain veneers has been related to the strong bond between two materials of similar elastic moduli, porcelain and enamel.[9] One review article reported that the survival rate for all ceramic crowns has been greater than 90%, irrespective of observation period and material used. Other studies have reported survival rates of 96% for veneers at 5 years and 91% at 10-13 years.[3, 4, 6, 7, 10, 11]

There is no exact agreement on the optimal veneer design in the literature. However, studies have shown that unprepared enamel is considered to be a poor substrate for bonding because of its complex structure, and this can result in an inferior bond. Also, unmodified tooth surface will result in a bulky gingival contour, which can be difficult to clean, and possibly lead to unhealthy gingiva and eventually gingival recessions.[9] A conservative tooth preparation helps optimize the emergence profile and provides a definite finish line. Many authors agreed that the conventional porcelain veneer thicknesses should range from 0.3 to 1.0 mm.[3, 9] Additionally, the best long-term result in regards to retention will be achieved if 50% of the preparation is kept on enamel and all

www.manaraa.com

the finish lines end on enamel.[3] Accordingly, adequate shear bond strength will be achieved between etched porcelain and tooth surface whenever sufficient enamel is incorporated.[8]

1.2.2 Indications and Advantages:

In the 1980s, veneers provided a conservative treatment for tooth misalignment, unesthetic shape and form, and discoloration.[4] At present, porcelain laminated veneers are used to correct tooth form and position, replace old composite restorations, close diastemas, restore incisal abrasions and tooth erosion, and to mask and reduce tooth discoloration.[3] The material of choice in the esthetic zone should allow the clinician to pursue durable, cost effective, and simple intervention with acceptable survival rates, which meet patient expectations and allow function. Dental ceramic restorations have been widely used in past decades because of their excellent esthetics and biocompatibility, in addition to conservation of tooth structure. Porcelain veneers should be considered as a conservative alternative to cemented crowns. Typically, a facial reduction of 0.5 mm or less is needed, in which local anesthesia is not usually required, as the preparation is limited to the enamel layer of the tooth. Esthetically, veneers should be translucent enough to maximize the light transmission but also opaque enough to mask any discoloration.[7]

1.2.3 Types of Materials:

Since acid-etched ceramics were introduced in the 1970s, porcelain veneers have been widely used in dentistry.[12] For many years, conventional feldspathic porcelains were considered the best material of choice for veneer restorations to provide optimal esthetic results. Feldspathic porcelain is a glass ceramic based on naturally occurring feldspar

المنارة للاستشارات
www.manaraa.com

which is composed of silica and alumina as main elements, with some of potassium oxide and sodium oxide (soda). Feldspathic porcelain veneers help cover enamel precisely, because they require minimal tooth preparation and thickness. However, several studies reported that the most common failures noted with this material were fracture, microleakage, or debonding.[13] This has led to the development of stronger materials, and a better understanding of the tooth-restoration bonding mechanism.

In the 1990s, pressed ceramics such as IPS Empress (Ivoclar Vivadent, Schaan, Liechtenstein), with 40% to 50% increase in leucite volume fraction when compared to feldspathic porcelain and Empress 2 (Ivoclar Vivadent, Schaan, Liechtenstein), based on lithia disilicate glass ceramic chemistry, became available. However, those pressed ceramics required deeper tooth preparations to compensate for their required thickness and marginal mechanical properties. This type of tooth reduction exposes more dentin than the traditional preparations. By the beginning of the 21st century, computer-aided design/computer-aided manufacture (CAD/CAM) technology became available. This technology utilized many materials including Vita Mark porcelain (Vita Zahnfabrik, Bad Sackigen, Germany), Procera alumina (Nobel Biocare, Zurich, Switzerland), reinforced porcelain (Empress, Ivoclar Vivadent, Schaan, Liechtenstein), IPS e.max Press (Ivoclar Vivadent, Schaan, Liechtenstein) and zirconia.[7] The introduction of lithia disilicate glass ceramic (IPS e.max Press, Ivoclar Vivadent, Schaan, Liechtenstein) allowed the fabrication of more durable posterior and anterior crowns, and thin anterior veneers.[12] Although, this material has the same core material as IPS Empress 2 (Ivoclar Vivadent, Schaan, Liechtenstein), it has a higher strength, toughness, and translucency.[14]

One of the most important and required micromechanical properties for porcelain

المنارة للاستشارات
www.manaraa.com

veneers, is the ability to etch the prosthetic surface to facilitate better retention of the restoration. Moreover, it should be strong in tension and compression, and maintain its marginal seal, luster, and shade over time.[7] Alumina and zirconia are difficult to etch, in addition to possessing poor esthetic characteristics, and therefore are not appropriate for veneers. A wide variety of ceramic materials are available in the market (as of 2015), with each having unique properties and clinical indications. (Table 1)

1.3 Principles of Color:

1.3.1 Overview:

The Commission Internationale de l'Eclairage (CIE) or the International Commission on Illumination defines the color as "An attribute of visual perception consisting of any combination of chromatic and achromatic components".[15] Three factors are required for production of color: a light source, an object to be illuminated, and an observer.[16] In 1986, Seghi et al described the color from natural teeth as a result from combination of light reflected from the enamel surface and the light scattered and reflected by the enamel and dentin.[17] Loss of shade match or change in color with the surrounding natural teeth is one of the main reasons for replacement of esthetic restorations.[18] Therefore, color studies in dentistry have increased dramatically over the past several decades.[19] Because of the complex optical characteristics of color on natural dentition, it is challenging to achieve a clinically acceptable shade match between the natural teeth and artificial tooth restorations.[19, 20] Thus, there are some critical factors involved in achieving a successful esthetic dental restoration. These include: the light source used for color evaluation, the individual's perception of color, the surface and

www.manaraa.com

structural characteristics of both the tooth and the restorative materials, and knowledge of some basic principles of color perception.[20]

The human eye is very skillful at detecting small color differences.[21] Therefore, clinicians are required to understand the concept of color, light and the related characteristics of resin and ceramic materials, together with the ability to give clear instructions to technicians when indirect procedures are performed. Color evaluation by human observation involves only the spectrum of visible light entering the eye and stimulating the three types of color receptors on the retina.[22] In addition to that, the light-sensitive mechanism is linked to the existence of light-receptor cells in the retina. Rods and cones, absorb light by means of photosensitive pigments and convert it into a stimulus which the brain recognizes the color.[23] Optical color is independent and varies on multiple elements that involve human perception, material properties, material translucency, illumination conditions, and the texture of the surface to be evaluated. Using ideal devices and techniques, based on optical sensors, permits the impartial evaluation of color and decreases the personal interpretation inherent in visual color judgment.[24]

1.3.2 CIE Standards:

In 1976, the CIE established a color scale system called CIE $L^*a^*b^*$.[15, 25, 26] It provides a reliable standard with a uniform color scale. The CIE $L^*a^*b^*$ scale expresses color by numerical values and calculate the difference between two color coordinates in which: L^* is the degree of lightness of an object, a^* is the degree of redness/greenness, and b^* is the degree of yellowness/blueness.[25, 27] Accordingly, as a^* and b^* values

المنارة للاستشارات
www.manaraa.com

increase, the chroma of color increases. Both industry and dentistry depend now on color difference measurements, and it has become essential in color science studies. However, the appearance of an object does not only relay on the attributes of the CIE *L*a*b**, but is also influenced by the features of appearance such as opacity/transparency, gloss, translucency, and some optical phenomena like metamerism, fluorescence and opalescence. Indeed, these aspects have an influence on the optical characteristics of a tooth. It can be difficult to obtain a proper esthetic result, and there is not a truly standardized and predictable procedure when considering the full range of available materials and variables. Undoubtedly, one single value is not adequate for color matching. Therefore, differentiation between perceptibility (the difference that can be recognized by the human eye) and acceptability (the difference that is considered tolerable) were proposed.[24] Dental color matching was further developed to minimize the errors in visual color selection. In 1983, Clarke and colleagues,[25] proposed the total difference in color between two items, and derived the concept of ΔE, which can be calculated by applying the formula:

$$\Delta E^* = [(L_1^* - L_2^*)^2 + (a_1^* - a_2^*)^2 + (b_1^* - b_2^*)^2]^{1/2}$$

In the *L*a*b** color space, ΔE indicates the degree of color difference but not the direction of the color difference. Color discrimination, which is characterized by the human observer, is determined by the illuminant and the relative positions of the illuminant, the object, and the observer; previous eye exposure; and color perception differences among individuals. Despite the fact that there is much variability between humans for color matching, it is beneficial to identify the acceptable range of color

المنارة للاستشارات
www.manaraa.com

differences between shades of esthetic dental restorative materials and the teeth that need to be restored. Sim and colleagues, determined that color perception varies between different groups of dental personnel, and established the individuality of color perception.[28] Spectrophotometers have the ability to detect small differences in color at a level that is not visible by the human eye. Studies suggest that detection of a color difference depends on a combination of eye characteristics and skill of the operator. According to their findings, ΔE values of less than 1 were found to be not discernable by the human eye. ΔE values greater than 1 but less than 3.3 were considered to be appreciable by some skilled operators, but were deemed clinically acceptable. ΔE values greater than 3.3 were considered to noticeable by untrained operators and observers, and considered to be clinically not acceptable.[29-31]

1.3.3 Instrumental Color Measurements:

The first shade tab introduced to the dental field in 1950. Sproull, in the early 1970s, published a series of classic articles aiming to explain the complex relationship between the three dimensional nature of the color and shade matching. As a result, a series of theoretical and practical indications were proposed in order to improve color matching in dentistry.[32] The traditional clinical procedure of visually matching shade tabs with teeth might be negatively influenced by several factors including, variations in the type and quality of light, differences in gender, the presence of color blindness and/or color perception defects, and variations in experience of the evaluators.[20] A variety of technologies of shade matching have been developed in an effort to increase the success of shade matching, communication, verification, and reproduction of esthetics in dentistry. Moreover, the development of a variety of shade matching instruments has

المنارة للاستشارات

www.manaraa.com

helped overcome traditional shade matching errors.[19] The determination of tooth shade can be enhanced by the use of particular devices such as colorimeters or spectrophotometers, which have been developed to precisely measure color and color difference. Nevertheless, the repeatability and the inter-device arrangement of these devices have not been deeply studied. The optical determination of tooth color with traditional shade guides is a subjective technique of color communication, conditional on variables such as the light source, the operator, and the tooth.[33] Also, there is an important connection of human perception of shade variation with the evaluation of the polished porcelain, color analysis, surface texture, and also the effect of glaze on porcelain.[34]

1.3.3.1 Colorimeters:

The colorimeter is generally a quite simple and low-cost instrument that is designed to measure color on the basis of three axes or stimuli by using a filter that simulates the human eye. In the 1970s, colorimeters were used for quality control of manufactured materials to detect color difference rather than measuring the exact color.[16] There are essential two types of colorimeters devices. One measures the source and the other measures materials. The instrument has a detector system that contains a colored glass filter and a photodetector. Colorimeters measure tristimulus values and filter light in red, green and blue areas of the visible spectrum. Colorimeters do not register spectral reflectance, and can be less accurate than spectrophotometers.[20]

1.3.3.2 Spectrophotometer:

The spectrophotometer is more sophisticated instrument than a colorimeter. They

المنارة للاستشارات
www.manaraa.com

have been built to reflectance from or transmittance through a material as a function of wavelength, giving the entire spectral curve. However, this approach is limited to the visible frequency range (usually 350–800 nm) in assessing color.[16, 20] Spectrophotometers measure the amount of light energy reflected from an object at 1–25 nm intervals along the visible spectrum.[19] A spectrophotometer measures the color based on the CIE *L*a*b** color space system, which allows measurement of color in three-dimensional space.[16]

Main components for color measurement include: source of optical radiation, an optical system for defining the geometric conditions of measurement, means of dispersing light, and a detector and signal processing system that converts light into signals suitable for analysis.[16, 19] Any light source with sufficient power over the visible spectrum can be used for spectrophotometry. The light source in a spectrophotometer should ideally be identical to the light of the viewing environment. Most instruments use light sources that attempt to match the spectral characteristic of D65 between 300 and 780 nm. Even other light sources, i.e. incandescent, use glass filters to adjust their spectral properties to simulate those of D65.[16]

Spectrophotometers are one of the most accurate, useful and flexible instruments for overall color matching in dentistry.[19] Another significant advantage is the ability to analyze the principal components of a series of spectra, even from a secondary source, and the ability to convert this data to various color measuring systems. These devices possess software that can be used in conjunction with images taken with a digital camera. The images can be sent to a spectrophotometer, which in some cases is combined with an imaging system. This can be particularly useful in clinical dentistry.

المنارة للاستشارات
www.manaraa.com

With advancements in electronics more sophisticated CCDs for digital imaging and better fiber optic technology have resulted in the development of clinical dental shade taking devices. One of most common devices available for clinical color measuring is the SpectroShade Micro (MHT, Niederhasli, Switzerland) which combines digital color imaging with a spectrophotometer and is one of the most representative of available instruments (Circa 2015). This device obtains images with a 45/45° geometry in conjunction with the use of a polarized filter to avoid specular reflection from the tooth surface, which may have an impact on color evaluation. The polarized images are then used for color analysis, and for comparison with a data set of several shade guides stored in the instrument. The adjunct software can perform several functions, including both coarse and fine color shade mapping. It can overlay the clinical image with the images taken by the porcelain manufacturer to perform a virtual try-in, and it can send data via e-mail to the laboratory. Another instrument available commercially is the Easyshade Compact (Vita Zahnfabrik, Bad Sackingen, Germany). It became available in 2009 as an improvement of the former Easyshade.[20] Nevertheless, digital cameras represent the most basic approach to electronic shade taking, still requiring a certain degree of subjective shade selection with the human eye.[19]

Several studies have evaluated the shade match performance between visual assessment and the electronic instrument measurement, mainly from a validity and repeatability viewpoint. Tung et al. concluded that clinicians agreed with each other with 73% of the color selections, while the colorimeter agreed with itself 82% of the time.[35] Paul et al. found that visual shade selections matched 26.6% of the time, while spectrophotometric shade selection matched 83.3% of the time.[36] Clinical studies

www.manaraa.com

concluded that procedures fabricated using a spectrophotometer had more reproducible, a significantly better color match and a lower rate of rejection due to shade mismatch compared to procedures fabricated with a conventional shade-matching method.[37, 38] Spectrophotometry is also useful for evaluating the effectiveness of tooth bleaching. This may be helpful for evaluating the effect of bleaching as well as to assess when the bleached tooth color has become stable.[39] Clinical spectrophotometers look promising for assisting clinicians with shade selection. Yet, spectrophotometry is still considered being an adjunct to and not a replacement of visual assessment clinically.

1.4 Cements:

1.4.1 Overview:

Luting agents or restoration cements are primarily used to fill the void space between a tooth preparation and the indirect dental restorations. The cement prevents any dislodgment and helps in retaining the restorations to the tooth during function.[40] Literature reports three types of retention mechanisms for restorations retained by dental cements. These are chemical, mechanical (friction), or micromechanical (hybridized tissue). Usually, the restoration is retained by a combination of two or three mechanisms depending on the substrate and the nature of the cement.[41] There are various types of cements with specific characteristics that suit different clinical situations. With the expanding variety of available dental materials, a board range of indirect restoration options is possible. Because of this, cements have been developed to address strength, solubility, and esthetics concerns. Many types of dental cement are available, such as zinc phosphate, zinc oxide eugenol, zinc oxide non-eugenol, resin, glass-ionomer, resin-

المنارة للاستشارات
www.manaraa.com

modified glass-ionomer, and polycarboxylate.[40] Improper selection and manipulations of specific cements can have a significant impact on a restoration’s longevity. Unfortunately, the rapid development of cement products and the claim for multipurpose use by manufactures can be confusing and overwhelming. Cements are used in specific clinical procedures, such as cementation of posts, veneers, ceramic restorations, indirect composite restorations, and metal/metal-ceramic restorations. The most commonly used cements for esthetic dental procedures are resin based or glass ionomer cements.[40, 42]

1.4.1 Advantages and Disadvantages:

In the early 1950s, methyl metharylate-based resin cements were introduced with superior physical characteristics like low solubility, but also with significant short-coming like high coefficient of thermal expansion, extensive polymerization shrinkage, and water absorption. These negative characteristics can lead to microleakage at the tooth-resin interface, and difficulty of excess material removal. Modern resin cements have a significant influence on today’s dental practice, mainly because of their versatility, low solubility, high compressive and tensile strengths, and their favorable esthetic characteristics. Other advantages includes absorption of interfacial stresses and subsequent elimination of microcrack propagation on the internal surfaces of porcelain restorations, prevention of microleakage, and enhancement of marginal adaptation.[43] These cements are however very technique sensitive, and performance can vary from clinician to clinician.

Glass ionomer cement was first formulated by Wilson and Kent in 1969, and by the late 1990s it became widely used as a luting cement. The main disadvantages with

المنارة للاستشارات
www.manaraa.com

glass ionomer cement include low early strength and high solubility. In the 1980s, resin modified glass ionomer (RMGI) cement was introduced to overcome those problems. Both cements show good physical properties including: ease of mixing, good flow properties, cariostatic potential due to fluoride release, adequate strength, adhesion to tooth structure and base metal, good translucency, and relatively low cost per unit. However, resin cements are the material of choice under dental veneer restorations, because of their color match and stability.[40]

1.4.2 Classification:

Luting cement materials are commonly categorized by their mechanism of matrix formation or setting reaction of polymerization. They can be self- or auto-polymerized, light activated/cured, or dual-activated.[43] Chemically activated or self-cured material is initiated by mixing two pastes. The main disadvantages of those materials are trapping of air (oxygen) during mixing and short working time after mixing. Polymerization of light activated materials is initiated by blue light at a peak wavelength of 470 nm, which is absorbed by a photo-activator, such as comphorquinone.[44] Those materials offer extended working time, setting on demands, and improved color stability. However, they are limited to shallow cementations like veneers, inlays, and restorations with minimal thickness and lighter colors, which do not affect the capability of the curing light to polymerize the cement through the restoration.[41] Dual-cured resins were introduced to combine the favorable properties of both self- and light-cured resin. The main advantages of these materials are extended working time and the ability to reach a high degree of conversion and polymerization either with or without the presence of light.[45]

www.manaraa.com

Dental restoration cements can also be divided and classified based on bonding procedure as: total etch, bond resin; one-step etch, bond resin; self-adhesive resin; and dual-affinity adhesive resin. Self-adhesive resins are composed of phosphoric and/or carboxylic acid methacrylate monomers that bond chemically to tooth apatite and to the superficial oxide of the restoration.[46] Most of these bonding systems are technique sensitive, and following the manufacturer instructions step by step is the best way to achieve accurate bonding. Accordingly, it is been proven that total etch adhesive systems are more complicated and technique sensitive compared to self-etch systems. Studies have reported that self-adhesive resins achieve lower flexural and compressive strengths in comparison to conventional resin cements. However, both resin cements showed a superior statistical result when compared to other types of cements (i.e. resin modified glass ionomer, glass ionomer, or zinc phosphate cements). One study suggested that the only materials that self-adhere to the tooth structure are glass ionomers.[47] The glass-ionomer components diffuse and establish a micro-mechanical bond with the tooth after the removal of the smear layer from tooth structure by the use of polyalkenoic acid. Additionally, the material chemically bonds to the tooth by the ionic interaction of carboxyl groups to the collagen fibrils in dentin, and that helps to resist hydrolytic degradation.

1.5 Accelerated Aging Systems:

1.5.1 Overview:

Accelerated aging processes stimulate the effects of long-term exposure to environment conditions similar to the oral environment or condition. These laboratory

المنارة للاستشارات
www.manaraa.com

stimuli are performed because clinical trials for the same studies are often costly or time consuming, and can be difficult to manage.[48] Since 1978, accelerated aging has been adopted to test the color stability of dental materials.[18] The accelerated weathering process may involve: ultraviolet light exposure, temperature cycling, and humidity changes. Aging processes attempt to replicate the hydrolytic degradation in the material which might occur in the oral environments.[49]

1.5.2 Xeno-test:

One approach that has been used in laboratory studies is wreathing of specimens using xenon and UV light as an aging instrument. One of the common devices for this type of aging process is the Xenon weather-Ometer (Atlas Electronic Devices, Chicago, IL, USA) (Figure 1), where the specimens are subjected to both visible light (xenon lamp with a filter) and UV light. The testing cycle consist of 40 minutes of light only, followed by 20 minutes of light and front water spray, then 60 minutes of light, and finally 60 minutes of dark with back water spray. The specimens are exposed to 150 kJ/m^2 of total energy.[2, 50] According to the weathering instrument manufacturer, 300 hours of aging is estimated to be equivalent to one year of clinical service. Literature suggests that the greatest amount of color change occurs in the first 100 hours of accelerated aging.[18]

1.5.3 Thermo-cycling Test:

Thermo-cycling aging instruments represent a widely used laboratory aging method to simulate the thermal changes of a material in the oral cavity. The instrument subjects the specimens to hot and cold baths for specific periods of time in cyclic fashion, until the required number of test cycles is achieved.[51] Gale et al, suggested that 10,000

www.manaraa.com

cycles of thermo-cycling corresponds to one clinical service year.[48] One study concluded that thermo-cycling results in faster chemical degradation, contraction and expansion stresses of the specimens. Also, other studies suggest that the hot water may accelerate the hydrolysis of adhesive layer.[46, 52]

1.6 Purpose of the Study:

The purpose of the present study was to compare the color of porcelain veneers with try-in paste and with permanent cement before and after the final cured cementation. Also, the effect of porcelain shade, restoration thickness, and simulated aging was assessed in this study.

1.7 Specific Aims and Hypotheses:

1.7.1 Specific Aims:

- To evaluate and compare the color of porcelain veneers with try-in paste in relation to porcelain veneers with permanent cement.
- To evaluate and compare combinations of three different shades and thicknesses of porcelain veneers and three different cement shades before and after final cementation.
- To evaluate and compare the color of porcelain veneers with cured permanent cement before and after aging.

1.7.2 Null Hypotheses:

- There are no differences between the colors of porcelain veneers with try-in paste in comparison to porcelain veneers with permanent cement.

www.manaraa.com

- There is no difference in the final color of porcelain veneer between the different shades and thickness of porcelain veneers before and after final cementation.
- The aging process does not facilitate any significant change in color of porcelain veneers backed with a layer of cured permanent cement.

1.8 Location of the Study:

The design, preparation and data collection of the study took place at:

Bioscience Research Center, Room 7356
Nova Southeastern University
Health Professions Division
College of Dental Medicine
3200 South University Drive
Fort Lauderdale, Florida 33328-2018

المنارة للاستشارات
www.manaraa.com

Chapter 2

Materials and Methods

2.1Experimental Design:

2.1.1 Pilot Study:

A pilot study was conducted using three samples of each thickness (from each study group). All techniques and equipment were adjusted and reviewed. The operator was calibrated to be familiar with the system.

2.1.2 Sample Size Calculation:

A power analysis was conducted using the pilot data, and following the protocol from *N. AlGhazali et al*.[1] The G power Statistics software was used to calculate the sample size for this study. Based on that sample size calculation, it was determined that the size of each study group would be 12 specimens.

2.1.3 Specimen Preparation:

Feldspathic porcelain blocs (Vitablocs Mark II for CEREC, Vita Zahnfabrik, Bad Sackigen, Germany) (Figure 2) were cut into plate-shaped specimens using a diamond impregnated saw blade mounted on a low speed machine (IsoMet® 1000, Buehler ITW, Lake Bluff, IL, USA) (Figure 3). Three different shades of porcelain were assessed Vita 3D-Master 1M1, 2M2, 3M1 (corresponded to Vita shade guide B1, A2, C1 respectively). All specimens were 12 X 14 mm, with three different thickness of 0.3, 0.5, 1.0 mm ± 0.05 (Figure 4-6). The thickness of each specimen was standardized, and an electronic digital caliper was used to measure specimen thickness. Specimens with any irregularities were eliminated.

2.2 Experimental Groups:

المنارة للاستشارات

www.manaraa.com

A total of 108 specimens were cut, cleaned with water and dried, then divided into three groups according to porcelain shade. Each group consisted of 36 specimens which were subdivided into 3 subgroups with 12 specimens each according to specimen thickness. (Figure 7)

Group 1: Porcelain shade 1M1/B1 with 0.3 mm thickness

Group 2: Porcelain shade 1M1/B1 with 0.5 mm thickness

Group 3: Porcelain shade 1M1/B1 with 1.0 mm thickness

Group 4: Porcelain shade 2M2/A2 with 0.3 mm thickness

Group 5: Porcelain shade 2M2/A2 with 0.5 mm thickness

Group 6: Porcelain shade 2M2/A2 with 1.0 mm thickness

Group 7: Porcelain shade 3M1/C1 with 0.3 mm thickness

Group 8: Porcelain shade 3M1/C1 with 0.5 mm thickness

Group 9: Porcelain shade 3M1/C1 with 1.0 mm thickness

2.3 Resin Cement:

A commercially-available light-cured veneer resin cement (Variolink Veneer, Ivoclar Vivadent, Schaan, Liechtenstein) (Figure 8) was used according to the manufacturer instructions. Three different shades were used, which represented the broadest color variation available within the cement shades (LV -3, MV 0, and HV +3) (Figure 9). The corresponding try-in pastes of each shade (Figure 10) were used to evaluate differences in appearance (color) between try-in paste and the actual cement.

2.4 Specimen Background:

Clear glass microscope slides (thickness of 0.96 to 1.06 mm) were used as a background for the specimens with two cover slips fixed on the slide, with a space in

المنارة للاستشارات
www.manaraa.com

between to standardize the thickness of the cement (the thickness of the each cover slip is 0.1 mm or 100 μm) (Figure 11).

2.5 Spectrophotometer Measurement:

Color evaluation was performed using a color spectrophotometer (Color Eye 7000A, GretagMacbeth LLC, New Windsor, NY, USA) (Figure 12). The specimens were characterized according to the color scale relative to the standard illuminant D65, with the specular component setting included (SCI). The spectrophotometer has an aperture size of 3mm x 8mm. The spectrophotometer measures CIE *L*a*b** values, which give a numerical representation of a 3-dimentional (3D) measure of color. Before the experimental measurements, the spectrophotometer was calibrated according to the manufacture by using a black light trap then white background, supplied by the manufacturer. Calibration was performed before each study group was analyzed, and whenever recalibrating was required by the assistive computer software. The CIE *L*a*b** color system was used to measure the mean of *L**, *a** and *b** values in Color iQC professional software (Quality Control software, Version 7.5.10) (Figure13).

The color measurements of the specimen alone were performed to establish a baseline value. The reading of the *L**, *a**, *b** values were performed two times; the average of the two readings was calculated by the computer software to give the initial color of the specimen. Afterward, the try-in paste was placed on the microscopic clear slide between the two cover slips (Figure 14), and the veneer placed and pressed on top to give a uniform thickness (Figure 15). All paste excesses were removed using a microbrush (Figure 16), and then the specimen color was measured again from the ceramic surface. After that, the specimen was gently lifted and all the paste washed off

www.manaraa.com

with running water. Then the slide and the specimen were dried using paper tissue. The corresponding permanent resin cement shade was then placed between the cover slips (Figure 17), and again the specimen placed on top and pressed to standardize the thickness of the cement (Figure 18). All cement excesses were removed using a microbrush. The color of the specimen with the un-cured cement then measured. Next, the cement was cured for 30 seconds using a halogen light curing unit (Optilux 501, Kerr, Orange, CA, USA) (Figure 19) with a 90 degree angulation on top of the ceramic surface (Figure 20). The color of the specimen was measured again. All the pervious steps were performed for each specimen. The mean and standard deviation values were then calculated for each group.

2.6 Calculation of the Color Difference:

The L^*, a^*, b^* values were used in the ΔE formula: $\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$ to calculate the difference in color between groups, where ΔL^*, Δa^*, Δb^* represent the difference between L^*, a^*, b^* values of two groups.

In order to determine the effect of try-in pastes and permanent resin cements, a ΔE of 3.3 was considered as the perceptibility threshold in this study.

2.7 Thermo-cycling Test:

A thermo-cycling (Sabri Dental Enterprises Inc.; Downers Grove, IL, USA) (Figure 21) aging device was used to subject the specimen in a cyclic fashion to hot (55ºC) and cold (15ºC) baths of deionized water, with 30 second dwell time for 30,000 cycles. These conditions should be a simulation equivalent of 3 years of clinical service.[48] After the thermo-cycling test, the specimens were dried gently, and the color

المنارة للاستشارات
www.manaraa.com

measurements of each specimen performed again using the spectrophotometer. One specimen (specimen 7, veneer shade 3M1 0.5 mm) has been missing after thermo-cycling.

2.8 Data and Statistical Analysis:

Descriptive analysis means and standard deviations were calculated for ΔE of try-in past verses post-cured cement (Figure 22), pre-cured cement verses post-cured cement (Figure 23), and post-cured cements verses after 30,000 cycles of thermo-cycling (Figure 24). To look for the difference within the three groups, a one-way analysis of variance (ANOVA) at $\alpha = 0.05$ was created. Tukey's post-hoc test was used to find means that are significantly different from each other. A multi-factor of variance three-way ANOVA test was conducted to evaluate the final color between groups when controlling the veneer thickness, veneer shade, and cement shade. Additionally, proportional statistical analysis been performed to look for the differences in color between all groups and the average threshold for acceptability in which ΔE=3.3. The independent variables were the thickness of the porcelain (0.3 mm, 0.5 mm, and 1.0 mm), the shade of the cements (LV -3, MV 0, and HV +3), the shade of the porcelain (1M1, 2M2, and 3M1) and the time of the color measurement (baseline, with try-in paste, pre-cured cement, and with post-cured cement). The dependent variable was the ΔE value.

المنارة للاستشارات
www.manaraa.com

Chapter 3

Results

3.1 ΔE Try-in Paste Verses Post-cured Cement:

Descriptive statistical analysis means and standard deviations of ΔE values for each subgroup are given in tables according to veneer thickness, veneer shade and shade of cement (Table 2, 3, 4).

The mean ΔE value for 0.3, 0.5, and 1.0 mm veneer thicknesses were 4.11, 3.74, and 2.71 respectively. The comparison between ΔE means for different thicknesses showed a significant difference with p=0.008. A post hoc Tukey's test showed that ΔE means differ significantly between group 1.0 mm and 0.3 mm (p=0.008, Table 5).

The veneer shades 1M1, 2M2, and 3M1 showed ΔE mean values of 2.95, 4.25, and 3.35 correspondingly. Again, the comparison between ΔE means for different veneer shades showed a significant difference with p=0.017. However, the Tukey's test showed the significant difference of ΔE means only between group 1M1 and 2M2 (p=0.015, Table 6).

For the third subgroup, cement shades, the ΔE mean values were 2.60 for cement shade LV -3, 3.08 for MV 0, and 4.87 for HV +3 with a significant difference at p=0.000 when comparing the ΔE means for the three shades. The post hoc Tukey's test showed significant different between LV -3 and HV +3 group at p=0.000 and MV 0 and HV +3 at p=0.000 but was not significantly different for MV 0 and LV -3 (p=0.484, Table 7).

A multi-factor of variance three-way ANOVA test was conducted to evaluate the final color of the PLV with the try-in paste verses the post-cured cement when controlling the veneer thickness, veneer shade, and cement shade [F(26,81)=3.78, P=000]. All those

المنارة للاستشارات
www.manaraa.com

factors were still significant in relation to the ΔE of post-cured cement, even after adjusting each other, and within the possible interaction (p-values <0.005). Interactions of veneer thickness, veneer shade, and cement shade were not significantly associated with the final color of PLV at the post-cured cement stage [F(8,81)=0.81, p=0.587] (Table 8).

3.2 ΔE Pre-cured Cement Verses Post-cured Cement:

Descriptive statistical analysis means and standard deviations of ΔE values for each subgroup are given in tables according to veneer thickness, veneer shade and cement shade (Table 9, 10, 11).

The mean ΔE values for 0.3, 0.5, and 1.0 mm veneer thickness were 2.85, 3.18, and 2.35 respectively. The comparison between ΔE means for different thicknesses did not show significant difference (p=0.129).

The veneer shades 1M1, 2M2, and 3M1 had ΔE mean values of 2.959, 3.22, and 2.57 respectively. However, the comparison between ΔE means for different veneer shades did not show any significant difference (p=0.201).

The ΔE mean values for cement shades were 2.52 for cement shade LV -3, 4.16 for MV 0, and 1.70 for HV +3. The comparison between ΔE means for different cement shades showed a significant difference at p=0.000. The post hoc Tukey's test showed significant different between LV -3 and HV +3 group at p=0.045, MV 0 and HV +3 group at p=0.000, and between MV 0 and LV -3 group (p=0.000, Table 12).

A three-way ANOVA test was conducted to evaluate the final color of the PLV with pre-cured cement verses post-cured cement when controlling the veneer thickness, veneer shade, and cement shade [F(26,81)=03.46, p= 0.000]. Both veneer thickness and cement shade factors were significant in the relationship with ΔE post-cured, even after

المنارة للاستشارات
www.manaraa.com

adjusting each other and possible interaction (p-values <0.05). These were not significant for veneer shade factor, while interactions veneer thickness, veneer shade, and cement shade were not significantly associated with the final color of PLV with post-cured cement [F(8,81)=0.58, p = 0.794] (Table 13).

3.3 Δ*E* Post-cured Cement Verses after 30,000 cycles of Thermo-cycling:

Descriptive statistical analysis means and standard deviations of Δ*E* values for each subgroup are given in tables according to the veneer thickness, shade of the veneer and cement shade (Table 14, 15, 16).

The mean Δ*E* values for veneer thicknesses were 13.37 for 0.3 mm, 12.25 for 0.5 mm, and 7.82 for 1.0 mm. The comparison between Δ*E* means for different thicknesses showed a significant difference at p=0.000. The post hoc Tukey's test showed that Δ*E* means differ significantly between the two groups of 1.0 mm and 0.3 mm at p=0.000, and 1.0 and 0.5 mm at p=0.002 but not for 0.5 and 0.3 group (p=0.641, Table 17).

The veneer shades 1M1, 2M2, and 3M1 had Δ*E* mean values of 10.80, 11.27, and 11.34 respectively. The comparison between Δ*E* means for different veneer shades did not show any significant difference (p=0.912).

The cement shades LV -3, MV 0, and HV +3 had Δ*E* mean values of 11.95, 16.37, and 5.22 respectively. The comparison between Δ*E* means for different cement shades showed a significant difference at p=0.000. The post hoc Tukey's test showed significant differences between LV -3 and HV +3 group at p=0.000, MV 0 and HV +3 group at p=0.000, and between MV 0 and LV -3 group (p=0.000, Table 18).

A three-way ANOVA was conducted to evaluate the effect of aging (thermo-cycling) on the final color of PLVs when controlling veneer thickness, veneer shade,

المنارة للاستشارات

www.manaraa.com

cement shade and interaction of all those factors [F(26,80)=31.29, p = 0.000]. Moreover, all three factors were still significant in relation to Δ*E* after thermo-cycling even after modifying each other and within possible interaction (p-values <0.005) The interactions of veneer thickness, veneer shade, and cement shade were not significantly different after thermo-cycling and not associated with the final color of PLV [F(8,80)= 0.99, p = 0.447] (Table 19).

Proportional statistical analysis of each Δ*E* value in each of the three previous groups and the set level of Δ*E* threshold (Δ*E*=3.3*)* were performed and summarized in Table 20. The highest differences in proportion were found between the post cured and after 30,000 cycle of thermo-cycling with a proportion of 100%. This indicates that most of the samples show a significant visible color difference greater than the average threshold. Mild to moderate significant difference with a 8-42 proportional percent were found between try-in paste verses post-cured cements, and pre-cured cement verses post-cured cement stages in most samples especially for veneer shade 1M1 and veneer thickness of 1.0 mm, 1M1 with a 0.3 mm thickness, and 2M2 with a thickness of 1.0 mm.

المنارة للاستشارات

www.manaraa.com

Chapter 4

Discussion

The purpose of this *in vitro* study was to compare the color of porcelain veneers with try-in paste, permanent cement before and after the final cured cementation, and to evaluate the effect of simulated aging on the color of cemented veneers. In the present study, the final color of porcelain veneers was affected by many factors including the thickness of the veneer, the veneer shade, and the cement shade. Cement shade showed the highest significant difference ($p<0.001$) among all factors in all groups followed by veneer thickness then lastly veneer shade.

As has been described, the color difference (ΔE) of two objects can be calculated quantitatively by comparing the difference between respective coordinate ($L^*a^*b^*$) values of each object.[25] In contrast, qualitative visual assessments represent either a detectable color difference (perceptibility) or an unacceptable color difference (acceptability).[53] The scientific literature provides a wide range of different values of color change for the acceptable and perceptible thresholds for in vivo and in vitro conditions. In the present study, we use a ΔE of 3.3 as the perceptible ΔE threshold, and any values above that were considered clinically unacceptable. That value was consistence with that found in previous studies.[29-31]

One important factor to consider for achieving accurate shade match is the thickness of substrate material, in this study a porcelain veneer.[54] However, the thickness of veneer restorations is controlled by the amount of tooth preparation/reduction. Many authors suggest keeping the preparation for a veneer on the enamel as much as possible to have a durable bond.[3, 8] Based on anatomical studies, the thickness of enamel of

www.manaraa.com

maxillary anterior teeth ranges between 0.4-1.3 mm depending on the area of the tooth structure, and the enamel becomes thinner from the incisal third to the gingival third.[55] In addition, as the ceramic thickness decreases, the translucency of the ceramic increases.[56] Thus, the color of the ceramic, porcelain in this case, will be affected as the light is transmitted through the restoration to the surface of the cement, and the shade of the cement will be reflected back. In this study, we prepared our porcelain specimens to uniform thicknesses of 0.3, 0.5 and 1.0 mm. The ΔE values measured in this study displayed an inverse relationship with ceramic thickness. This study confirmed that ΔE values increase as veneer thickness decrease, and that thickness has a significant effect on the overall color of a veneer restoration. A previous study concluded that when veneer thickness increased to 1.5 mm, substrate color differences can be detected only with color measuring devices, whereas when ceramic thickness is less than 1.0 mm, the color differences are readily detectable by the human eye.[56] Moreover, Dozic et al. reported that 2 mm thick ceramic crowns were not affected by substrate color, but when ceramic thickness was 1.0 to 1.5 mm, visible, noticeable differences in color were observed.[57]

In the present study, we controlled the cement thickness at 0.1 mm increments, because different thicknesses of cement might have an influence on the final color of the veneer restoration. In a clinical situation, the cement thickness underneath a veneer is determined by the internal fit of the veneer. Magne et al. concluded that approximately 0.1 mm is a suitable thickness for the internal fit of a veneer restoration, and helps in creating a thin, conformal interface for distribution of stress between the resin cement and the ceramic restoration.[58] Another published study suggests that a 0.1 mm cement thickness can be used to evaluate the optical properties of composite luting cements.[59]

www.manaraa.com

In the current study, we found a significant difference affecting the final color of the veneer restorations when the shade of resin cement is altered, which is consistent with the findings of a recent study by Chen et al.[31] The differences in color between different resin cement shades might be related to the different amounts of opacity of the ingredients within the cement.[2] Moreover, the inorganic filler within the cement represents a phase of different refractive index from the bulk of the material, with a consequent scattering of light and different degrees of translucency.[18]

In this study, the ΔE values between the try-in paste and the permanent cement showed a significant difference in color between veneer thicknesses 1.0 mm and 0.3 mm, veneer shades 1M1 and 2M2, and between the cement shades HV +3 and both MV 0 and LV -3 ($p < 0.05$). Therefore, the first null hypothesis that there is no difference between the colors of porcelain veneers with try-in paste in comparisons to porcelain veneers with permanent cement was rejected. ΔE values of permanent cements and try-in pastes in the present study ranged from 0.32 to 11.49, which have a greater range than the result found by Xing et al.[60] and by Bladeramose et al.[61] However, the latter study implies that there is a significant difference in color between resin cement and the corresponding try-in paste, which is an agreement with our study. Another study concluded that there is a significant difference between the color of try-in paste and the same shade of cured resin cement.[1] These investigators found that the ΔE values between try-in paste and corresponding shades of resin cements were perceptible with a range from 1.05 to 3.34. However, all were below their clinical acceptable threshold which was 5.5. The try-in paste should provide a visual indication of how the final color of the restoration will be before final boding. However, it has been suggested that the guidance of the try-in paste is limited

المنارة للاستشارات
www.manaraa.com

and the uncured resin cement should be used to guide the final restoration for more accurate match.[1]

The null hypothesis that there is no difference in the final color of porcelain veneer between the different shades and thickness of porcelain, before and after final cementation or curing, was rejected. The ΔE values calculated between pre-cured and post-cured resin cements ranged from 0.59 to 12.01, with a statistically significant difference for veneer thickness, and between all groups of cement shades. Previous studies that evaluated the color differences between veneers and resin cements did not give attention to the difference between cured and uncured resin cement. However, Alghazali et al.[1] reported a small color differences (ΔE 0.78-1.41) for this type of comparison, and attribute it to polymerization of resin cement and a reduction in absorption of blue light by photo initiators after light curing. Moreover, they concluded that the final color of the veneer restoration was influenced by resin cement, as it became darker after light polymerization beneath the 1 and 2 mm thick porcelain veneers.

To determine color differences/changes of materials over time, and to simulate clinical conditions, artificial accelerated aging methods can be used. Discoloration of a material, such as a resin cement, may occur due to extrinsic factors such as heat, water, food colorants, exposure to environmental factors, ambient and ultraviolet (UV) irradiation, or due to intrinsic factors including the loading and particle size distribution in the material, the composition of the resin matrix and filler, type of photoinitiator, and the percentage of remaining carbon-carbon double bonds after curing. In addition, the intensity and duration of polymerization can lead to discoloration.[62] UV irradiation produces a color changes in restorative materials by means of chemical alterations to the

المنارة للاستشارات
www.manaraa.com

initiator, activator, and the resin itself. Degradation of residual amines, and oxidation of residual unreacted carbon-carbon double bonds, initiates the formation of yellow compounds.[63, 64] The results of this study imply a significant difference before and after the aging process, and therefore significant changes to the final color of veneers restorations. Thus, the third hypothesis that the aging process does not facilitate any significant change in color of porcelain veneers backed with a layer of cured permanent cement is rejected. The ΔE values for these comparisons within this study were higher than the clinical acceptable threshold. The high ΔE values can be related to the direct exposure of resin cement to the ageing process, as it was not supported or sealed completely with a tooth or a substrate underneath. These results are consistent with other published studies.[50, 65] However, other studies have concluded that there are color changes after aging, but that those changes were within an acceptable range of ΔE.[2, 18, 29, 66-68]

Many authors have discussed the influence of core foundations underneath restorations to the final color of restored teeth. It is well know that dentin can be considered the primary source of color in teeth, and depending on the thickness and translucency of the overlying enamel the color can be modified. Heffernan et al.[69] stated that the core material contributes to the overall color and translucency of a restoration. Crispin et al.[70] determined that core translucency was one of the primary factors in controlling esthetics and color. Furthermore, Azer et al.[71] concluded that the shade of the underlying core foundation or substrate has a significant influence on the final shade of 0.5 mm thick ceramic restorations, regardless to the ceramic shade. However, in this study, specimens were not backed with any core material, and it was anticipated that any

المنارة للاستشارات

www.manaraa.com

effects on the color of veneer restorations and resin cements alone would be observable and valid.

The limitations of this study include the fact that this is an *in vitro* study that will not replicate *in vivo* conditions, or replace well-designed clinical studies. In addition, a core material should be fabricated in future studies to better resemble a tooth like substrate, as in a clinical setting. Moreover, the color differences of only one type of resin composite cement (Variolink Veneer, Ivoclar Vivadent, Schaan, Liechtenstein), as well as one ceramic material (Vitablocs Mark II for CEREC, Vita Zahnfabrik, Bad Sackigen, Germany), were evaluated. Also, we used only one shade range from each shade category (1M1, 2M2, 3M1). Another limitation on the study, was the fabrication of disk shaped specimens rather than veneer shaped restorations.

Further studies are necessary to investigate the effect of a wider range of cement shades, ceramic types, and core materials with different veneer thicknesses and shades on the final color outcome.

المنارة للاستشارات
www.manaraa.com

Chapter 5

Conclusion

Within the limitations of this in vitro study, the following conclusions were drawn:

- The final color of PLV is highly affected by the different shades of resin cement and thickness of the porcelain veneer.
- The use of higher ceramic thicknesses (1.0 mm) decreased the ΔE values when compared to thinner veneers.
- Significant differences were found between the try-in pastes and the corresponding cured resin cements.
- Significant differences were also found between pre-cured and post-cured cements.
- The aging process significantly influenced color stability of ceramic veneer restorations luted with resin cement.

All of these conclusions have clinical relevance, as the esthetic appearance of ceramic veneers in vivo is perhaps the greatest measure of efficacy.

المنارة للاستشارات
www.manaraa.com

Table 1. Types of Dental Ceramic Materials

Core Material	System	Classification	Manufacturer
Glass Ceramic			
Feldspathic	VITAVM9	Conventional feldspathic	Vita Zahnfabrik
	VITA PM9	Pressable feldspathic	Vita Zahnfabrik
	VITABLOCS Mark II	Milled feldspathic	Vita Zahnfabrik
	VITABLOCS Esthetic line	Milled feldspathic	Vita Zahnfabrik
	IPS Empress Esthetic	Pressable feldspathic	Ivovlar Vivadent
	IPS Empress CAD	Milled feldspathic	Ivovlar Vivadent
	Kavo Everest	Milled feldspathic	Kavo Dental
Leucite	IPS Empress	Heat pressed	Ivovlar Vivadent
Lithia disilicate	IPS Empress 2	Heat pressed	Ivovlar Vivadent
	IPS e.max Press	Pressable lithia disilicate	Ivovlar Vivadent
	IPS e.max CAD	Milled lithia disilicate	Ivovlar Vivadent
Alumina			
Aluminum-oxide	In-Ceram Alumina	Slip-cast, Milled	Vita Zahnfabrik
	In-Ceram Spinell	Milled	Vita Zahnfabrik
	Procera	Densely sintered	Nobel Biocare
Zirconia			
Yttrium tetragonal zirconia polycrystals	Lava Zirconia	Green milled, sintered	3M ESPE
	Procera	Densely sintered, milled	Nobel Biocare

www.manaraa.com

Table 2. ΔE Try-in Paste vs. Post-cured Cement for Veneer Thickness

Thickness	n	Mean	SD	Min	Max
0.3 mm	36	4.11	2.27	1.65	11.49
0.5 mm	36	3.74	1.99	0.48	8.82
1.0 mm	36	2.71	1.47	0.32	6.61
Total	108				

[F(2,105)=5.04, p = 0.008]

Table 3. ΔE Try-in Paste vs. Post-cured Cement for Veneer Shade

Veneer Shade	n	Mean	SD	Min	Max
1M1/B1	36	2.95	1.30	0.48	6.15
2M2/A2	36	4.25	2.46	0.32	11.49
3M1/C1	36	3.35	1.92	1.44	8.75
Total	108				

[F(2,105)=4.22, p = 0.017]

Table 4. ΔE Try-in Paste vs. Post-cured Cement for Cement Shade

Cement Shade	n	Mean	SD	Min	Max
LV -3	36	2.60	1.10	0.48	5.85
MV 0	36	3.08	1.69	0.77	8.82
HV +3	36	4.87	2.30	0.32	11.49
Total	108				

[F(2,105)=16.43, p = 0.000]

المنارة للاستشارات

www.manaraa.com

Table 5. Post Hoc Tukey's Test for Δ*E* Try-in Paste vs. Post-cured Cement and Veneer Thickness

Groups	Difference	Lower 95% CI	Upper 95% CI	P-value
0.5 vs 0.3 mm	-0.370	-1.455	0.714	0.696
1.0 vs 0.3 mm	-0.138	-2.482	-0.313	0.008
1.0 vs 0.5 mm	-1.027	-2.112	0.057	0.067

Table 6. Post Hoc Tukey's Test for Δ*E* Try-in Paste vs. Post-cured Cement and Veneer Shade

Groups	Difference	Lower 95% CI	Upper 95% CI	P-value
1M1/B1 vs 2M2/A2	-1.302	-2.394	-0.209	0.015
3M1/C1 vs 2M2/A2	-0.905	-1.997	0.187	0.125
3M1/C1 vs 1M1B1	0.397	-0.696	1.489	0.665

Table 7. Post Hoc Tukey's Test for Δ*E* Try-in Paste vs. Post-cured Cement and Cement Shade

Groups	Difference	Lower 95% CI	Upper 95% CI	P-value
LV-3 vs HV+3	-2.267	-3.258	-1.276	0.000
MV0 vs HV+3	-1.784	-2.777	-0796	0.000
MV0 vs LV-3	0.480	-0.511	1.471	0.484

www.manaraa.com

Table 8. Factorial Analysis (Three-way ANOVA) for Δ*E* Try-in Paste vs. Post-cured Cement

Source	SS	df	F	P-Value
Veneer Thickness	37.75	2	7.85	0.001
Veneer Shade	32.06	2	6.67	0.002
Cement Shade	102.73	2	21.36	0.000
V-Thickness # V-Shade	9.54	4	0.99	0.417
V-Thickness # C-Shade	28.34	4	2.95	0.025
V-Shade # C-Shade	9.98	4	1.04	0.393
V-Shade # C-Shade # V-Thickness	15.77	8	0.82	0.587
Model	236.17	26	3.78	0.000

المنارة للاستشارات
www.manaraa.com

Table 9. ΔE Pre-cured Cement vs. Post-cured Cement for Veneer Thickness

Thickness	n	Mean	SD	Min	Max
0.3 mm	36	2.85	1.08	1.42	5.54
0.5 mm	36	3.18	2.35	1.36	12.01
1.0 mm	36	2.35	1.51	0.59	8.18
Total	108				

[F(2,105)=2.09, p = 0.129]

Table 10. ΔE Pre-cured Cement vs. Post-cured Cement for Veneer Shade

Veneer Shade	n	Mean	SD	Min	Max
1M1/B1	36	2.59	1.19	0.78	0.54
2M2/A2	36	3.22	2.08	0.59	12.01
3M1/C1	36	2.57	1.82	0.82	11.31
Total	108				

[F(2,105)=1.63, p = 0.201]

Table 11. ΔE Pre-cured Cement vs. Post-cured Cement for Cement Shade

Cement Shade	n	Mean	SD	Min	Max
LV -3	36	2.52	0.93	1.28	5.24
MV 0	36	4.16	2.19	1.71	12.01
HV +3	36	1.70	0.65	0.59	3.78
Total	108				

[F(2,105)=27.79, p = 0.000]

المنارة للاستشارات
www.manaraa.com

Table 12. Post Hoc Tukey's Test for ΔE Pre-cured Cement vs. Post-cured Cement and Cement Shade

Groups	Difference	Lower 95% CI	Upper 95% CI	P-value
LV-3 vs HV+3	0.813	0.015	1.612	0.045
MV0 vs HV+3	2.458	1.659	3.257	0.000
MV0 vs LV-3	1.645	0.846	2.443	0.000

Table 13. Factorial Analysis (Three-way ANOVA) for ΔE Pre-cured Cement vs. Post-cured Cement

Source	**SS**	**Df**	**F**	**P-Value**
Veneer Thickness	12.48	2	3.27	0.043
Veneer Shade	9.83	2	2.57	0.082
Cement Shade	112.90	2	29.58	0.000
V-Thickness # V-Shade	8.63	4	1.13	0.348
V-Thickness # C-Shade	15.61	4	2.04	0.096
V-Shade # C-Shade	3.35	4	0.44	0.780
V-Shade # C-Shade # V-Thickness	8.81	8	0.58	0.794
Model	171.61	26	3.46	0.000

www.manaraa.com

Table 14. ΔE Post-cured Cement vs. After 30,000 Cycles of Thermo-cycling for Veneer Thickness

Thickness	n	Mean	SD	Min	Max
0.3 mm	36	12.95	5.82	3.78	21.65
0.5 mm	35	10.69	3.95	2.97	17.71
1.0 mm	36	7.08	3.06	1.64	11.92
Total	107				

[F(2,104)=16.04, p = 0.000]

Table 15. ΔE Post-cured Cement vs. After 30,000 Cycles of Thermo-cycling for Veneer Shade

Veneer Shade	n	Mean	SD	Min	Max
1M1/B1	36	10.28	5.02	2.97	20.01
2M2/A2	36	10.08	5.14	1.77	21.36
3M1/C1	35	10.35	5.07	1.64	21.65
Total	107				

[F(2,104)=0.03, p = 0.974]

Table 16. ΔE Post-cured Cement vs. After 30,000 Cycles of Thermo-cycling for Cement Shade

Cement Shade	n	Mean	SD	Min	Max
LV -3	36	12.06	3.88	4.07	17.85
MV 0	35	13.24	4.75	4.93	21.65
HV +3	36	5.49	2.01	1.64	9.76
Total	107				

[F(2,104)=45.17, p = 0.000]

المنارة للاستشارات
www.manaraa.com

Table 17. Post Hoc Tukey's Test for Δ*E* Post-cured Cement vs. After 30,000 Cycles of Thermo-cycling and Veneer Thickness

Groups	Difference	Lower 95% CI	Upper 95% CI	P-value
0.5 vs 0.3 mm	-2.259	-4.764	0.245	0.086
1.0 vs 0.3 mm	-5.873	-8.360	-3.386	0.000
1.0 vs 0.5 mm	-3.614	-6.119	-1.109	0.002

Table 18. Post Hoc Tukey's Test for Δ*E* Post-cured Cement vs. After 30,000 Cycles of Thermo-cycling and Cement Shade

Groups	Difference	Lower 95% CI	Upper 95% CI	P-value
LV-3 vs HV+3	6.567	4.486	8.648	0.000
MV0 vs HV+3	7.748	5.652	9.884	0.000
MV0 vs LV-3	1.181	-0.915	3.277	0.376

المنارة للاستشارات
www.manaraa.com

Table 19. Factorial Analysis (Three-way ANOVA) for Δ*E* Post-cured Cement vs. After 30,000 Cycles of Thermo-cycling

Source	SS	df	F	P-Value
Veneer Thickness	632.64	2	45.81	0.000
Veneer Shade	1.72	2	0.12	0.088
Cement Shade	1234.66	2	89.40	0.000
V-Thickness # V-Shade	50.27	4	1.82	0.133
V-Thickness # C-Shade	146.03	4	5.29	0.001
V-Shade # C-Shade	5.03	4	0.18	0.947
V-Shade # C-Shade # V-Thickness	44.96	8	0.81	0.592
Model	2127.09	26	11.85	0.000

www.manaraa.com

Table 20. Proportional Percentage of the Three Groups of Δ*E*

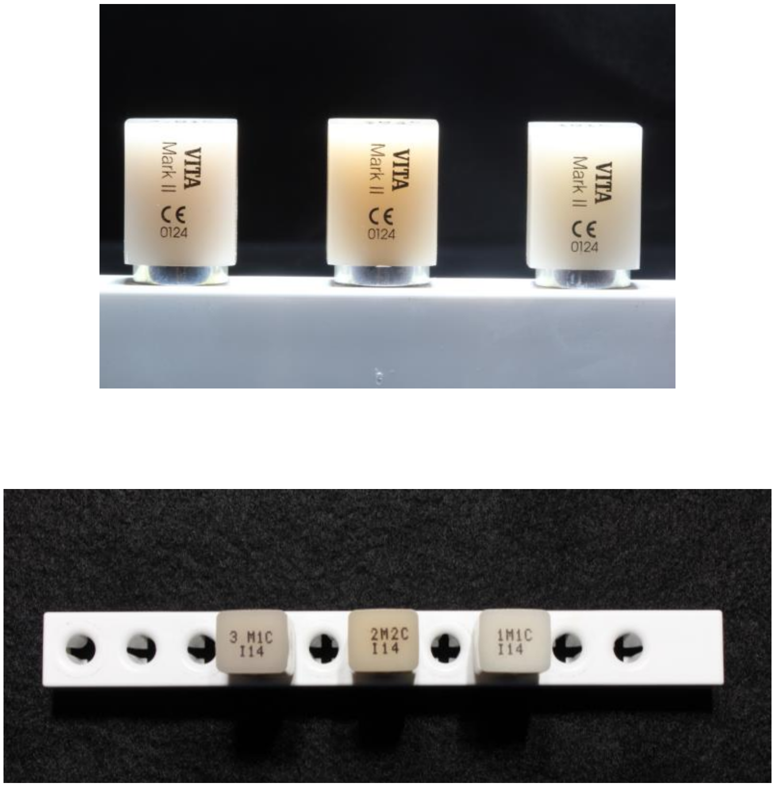
Veneer Shade and Thickness		ΔE Try in paste vs. Pre cured cement	ΔE Pre cured cement vs. Post cured cement	ΔE Post cured cement vs. After 30,000 cycle of TC
1M1 1.0 mm	Percent	8%	25%	100%
	Lower 95% CI	0%	1%	100%
	Upper 95% CI	24%	50%	100%
1M1 0.5 mm	Percent	33%	33%	92%
	Lower 95% CI	7%	7%	76.0%
	Upper 95% CI	60%	60%	100%
1M1 0.3 mm	Percent	33%	17%	100%
	Lower 95% CI	7%	0%	100%
	Upper 95% CI	60%	38%	100%
2M2 1.0 mm	Percent	17%	42%	83%
	Lower 95% CI	0%	14%	62%
	Upper 95% CI	38%	70%	100%
2M2 0.5 mm	Percent	33%	33%	92%
	Lower 95% CI	7%	7%	76%
	Upper 95% CI	60%	60%	100%
2M2 0.3 mm	Percent	33%	33%	92%
	Lower 95% CI	7%	7%	76%
	Upper 95% CI	60%	60%	100%
3M1 1.0 mm	Percent	33%	33%	92%
	Lower 95% CI	7%	7%	76%
	Upper 95% CI	60%	60%	100%
3M1 0.5 mm	Percent	33%	33%	92%
	Lower 95% CI	7%	7%	76%
	Upper 95% CI	60%	60%	100%
3M1 0.3 mm	Percent	33%	33%	92%
	Lower 95% CI	7%	7%	76%
	Upper 95% CI	60%	60%	100%

المنارة للاستشارات
www.manaraa.com

Figure 1. Xenon weather-Ometer (Atlas Electronic Devices, Chicago, IL, USA)

www.manaraa.com

Figure 2. Feldspathic porcelain blocs (Vitablocs Mark II for CEREC, Vita Zahnfabrik, Bad Sackigen, Germany)

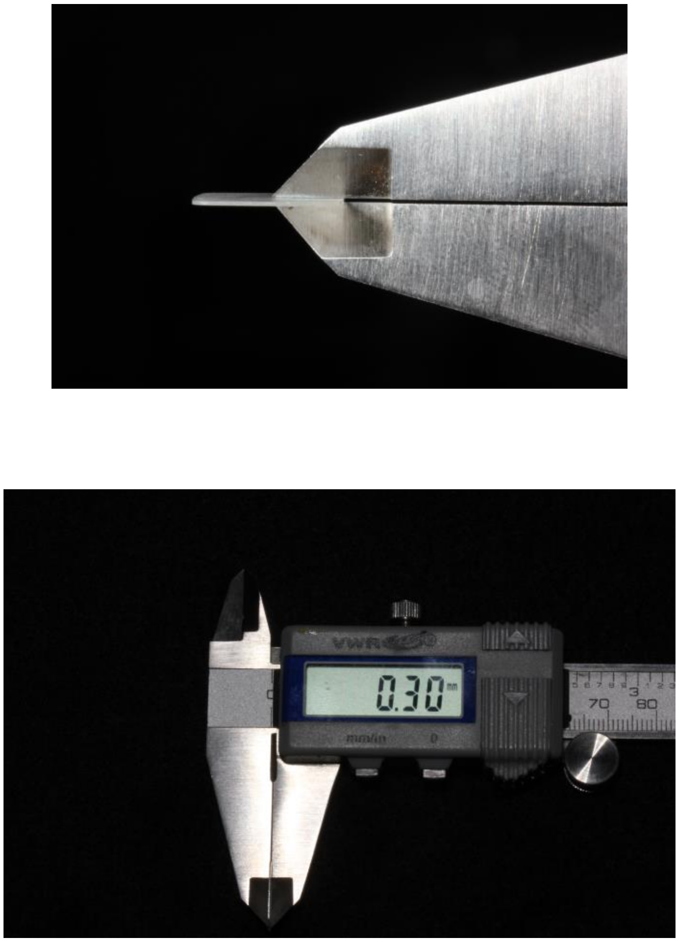


www.manaraa.com

Figure 3. IsoMet® 1000 (Buehler ITW, Lake Bluff, IL, USA)

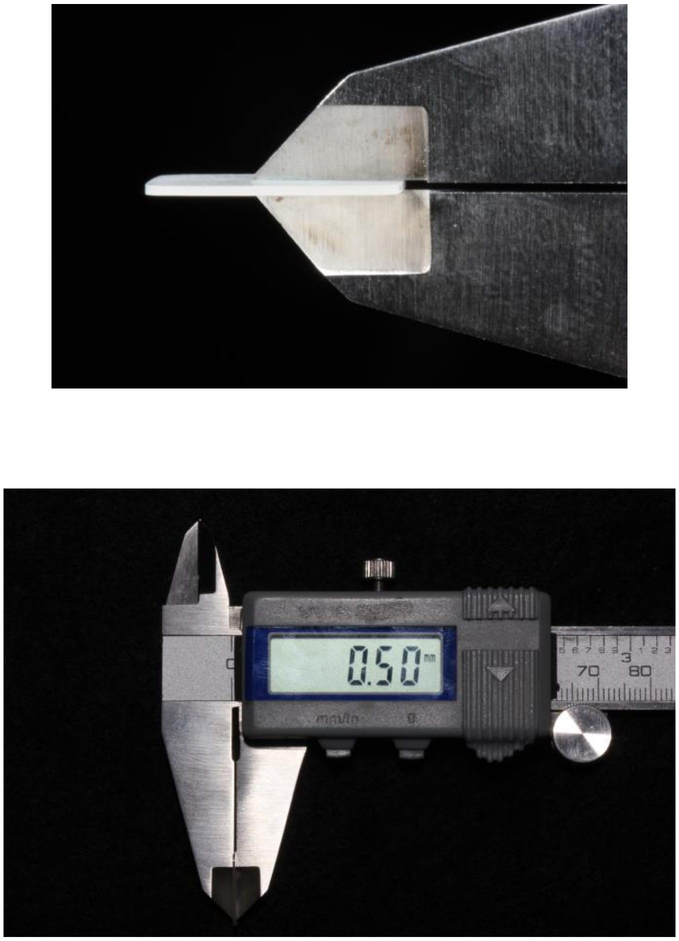
www.manaraa.com

Figure 4. 0.3 mm Specimen



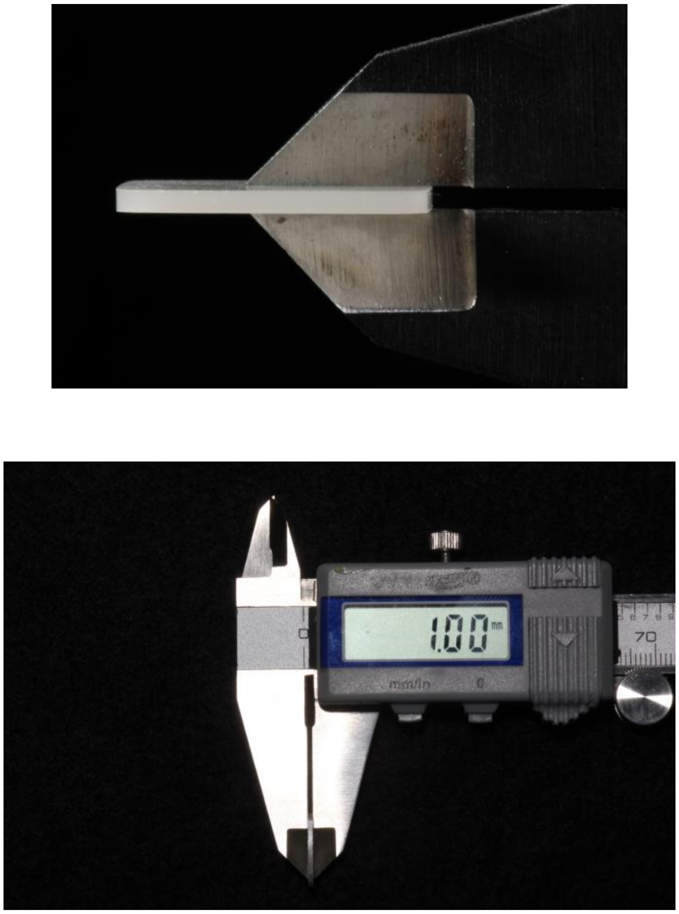
www.manaraa.com

Figure 5. 0.5 mm Specimen



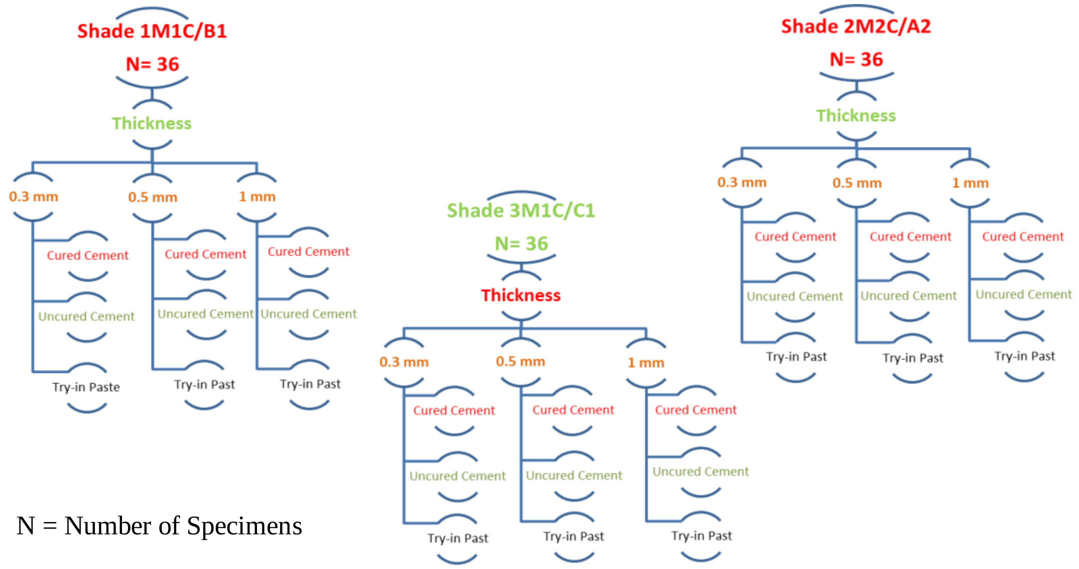
المنارة للاستشارات
www.manaraa.com

Figure 6. 1.0 mm Specimen



www.manaraa.com

Figure 7. Specimen Groups



N = Number of Specimens

www.manaraa.com

Figure 8. Variolink Veneer (Ivoclar Vivadent, Schaan, Liechtenstein)

www.manaraa.com

Figure 9. Variolink Veneer resin cement (Ivoclar Vivadent, Schaan, Liechtenstein)

Figure 10. Variolink Veneer try-in paste (Ivoclar Vivadent, Schaan, Liechtenstein)

المنارة للاستشارات
www.manaraa.com

Figure 11. Clear microscopic glass slide with two cover slips

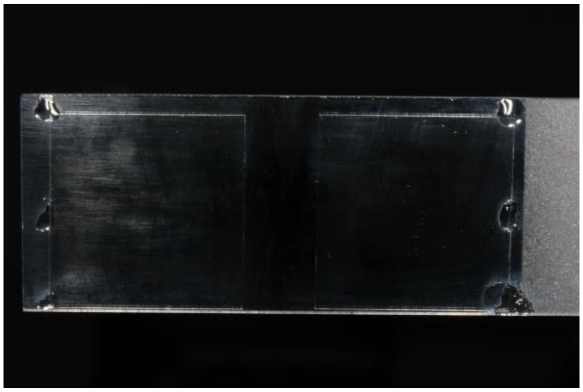
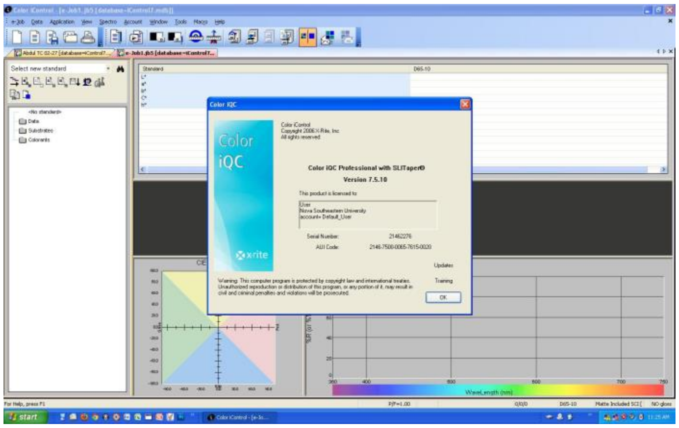


Figure 12. Spectrophotometer (Color Eye 7000A, GretagMacbeth LLC, New Windsor, NY, USA)

المنارة للاستشارات
www.manaraa.com

Figure 13. Color iQC professional software (Quality Control software, Version 7.5.10)



Color iControl
Copyright 2006 X-Rite, Inc
All rights reserved

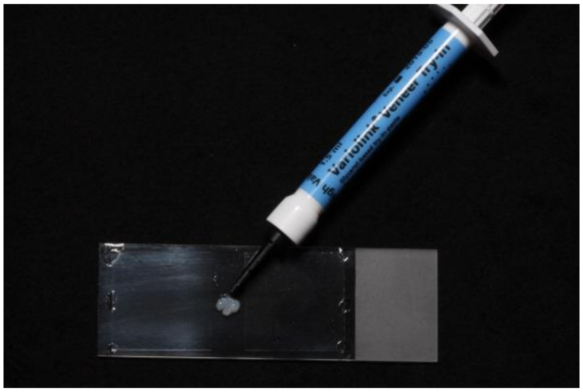
Color iQC Professional with SLITaper®
Version 7.5.10

This product is licensed to:
User
Nova Southeastern University
account= Default_User

Serial Number: 21462276
AUI Code: 2146-7500-0065-7615-0020

Warning: This computer program is protected by copyright law and international treaties. Unauthorized reproduction or distribution of this program, or any portion of it, may result in civil and criminal penalties and violations will be prosecuted.

Figure 14. Application of try-in paste to microscope slide



www.manaraa.com

Figure 15. Specimen with try-in paste

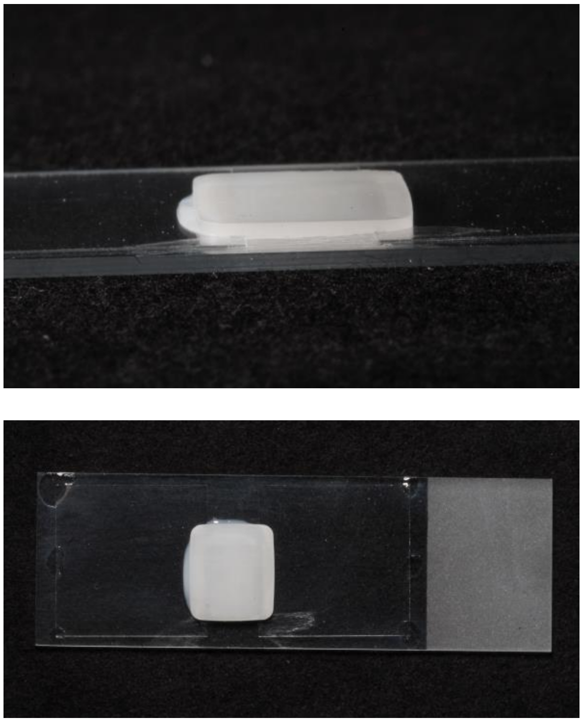
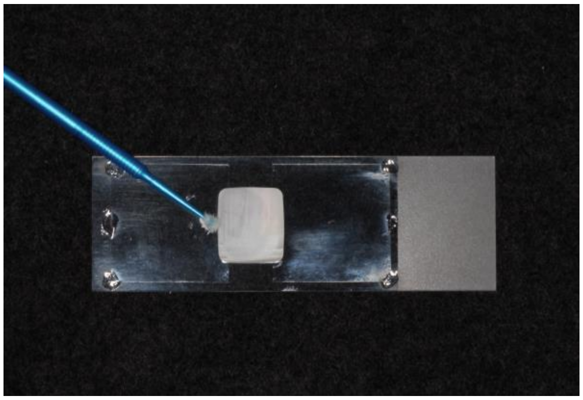


Figure 16. Removal of excesses with microbrush



www.manaraa.com

Figure 17. Application of resin cement to microscope slide

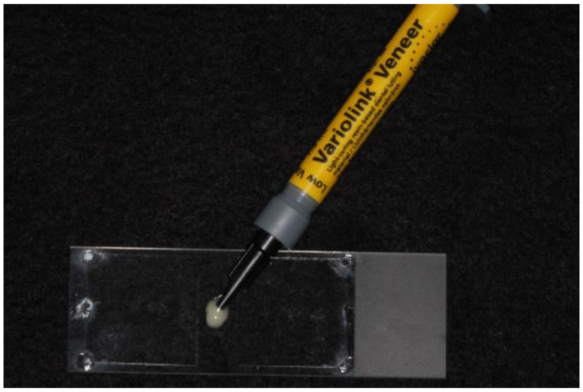
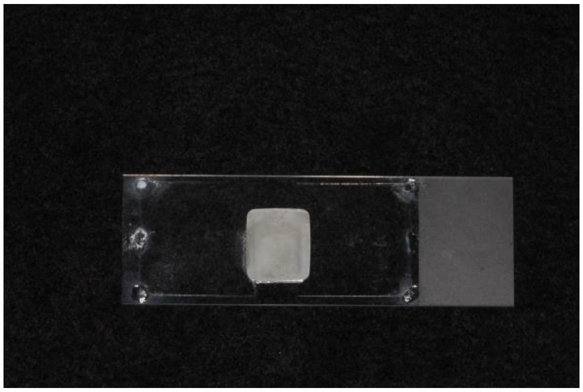


Figure 18. Specimen with resin cement



www.manaraa.com

Figure 19. Halogen light curing unit (Optilux 501, Kerr, Orange, CA, USA)

Figure 20. Specimen with resin cement post-cured

المنارة للاستشارات
www.manaraa.com

Figure 21. Thermo-cycling (Sabri Dental Enterprises Inc., Downers Grove, IL, USA)

www.manaraa.com

Figure 22. Boxplot for descriptive analysis of *ΔE* try-in paste vs. post-cured cement

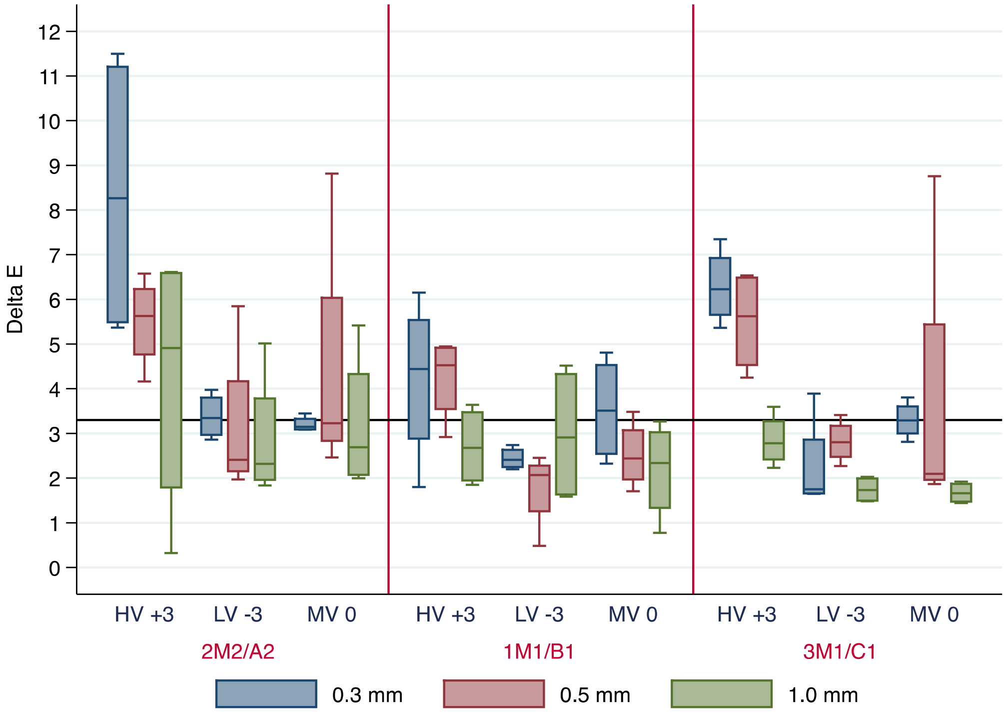
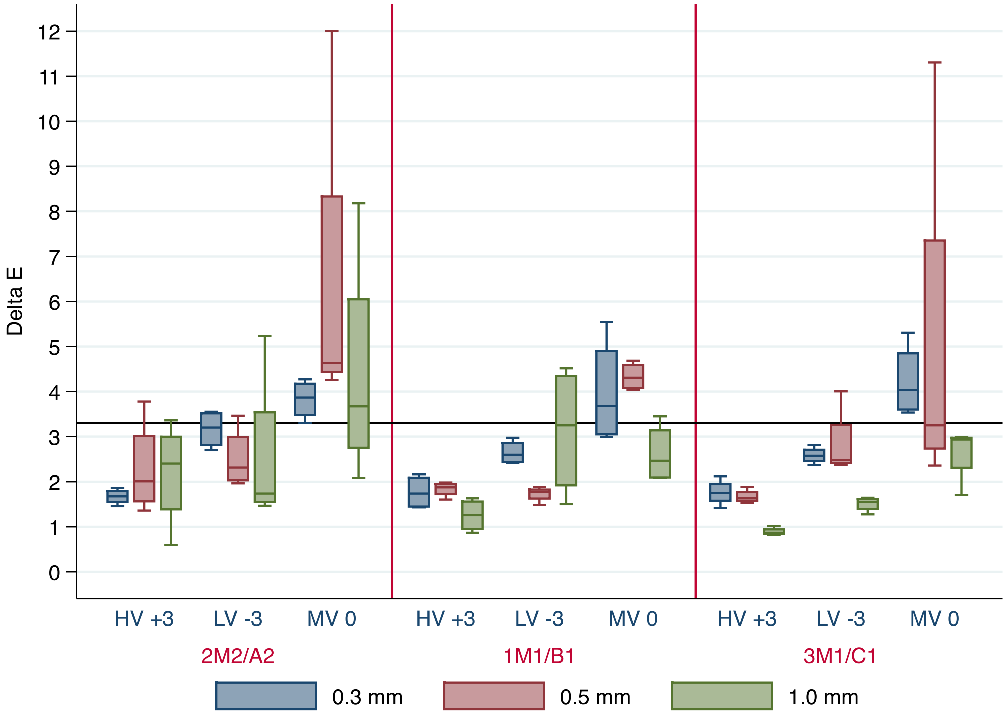
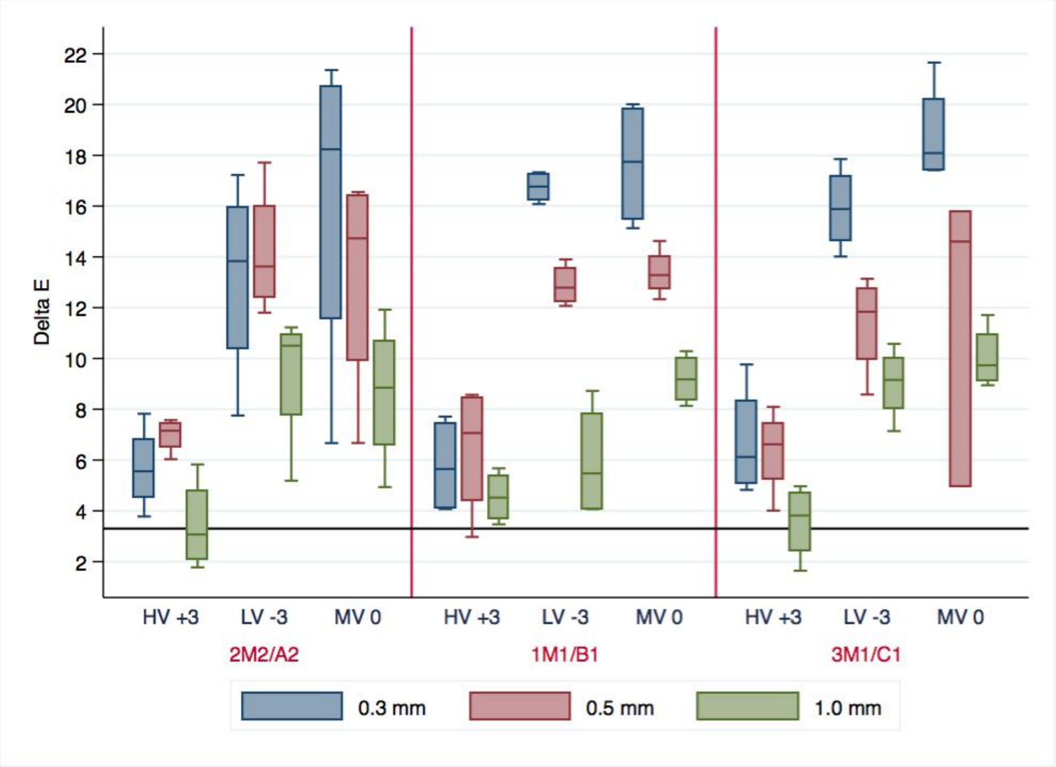


Figure 23. Boxplot for descriptive analysis of *ΔE* pre-cured cement vs. post-cured cement



المنارة للاستشارات
www.manaraa.com

Figure 24. Boxplot for descriptive analysis of *ΔE* post-cured cements vs. after 30,000 cycles of thermo-cycling



www.manaraa.com

Appendix A: Raw Data for Group 1

Specimen #	Veneer Shade	Veneer Thickness	Cement Shade	Reading	Baseline	Try-in Paste	Pre-cured Cement	Post-cured Cement	After 30,000 Cycles of Thermo-cycling
1	1M1/B1	0.3 mm	LV -3	L*	59.39	53.09	51.91	51.20	67.12
				a*	-0.83	-1.02	-1.10	-1.03	-0.79
				b*	-1.39	-1.68	-1.31	-3.66	0.15
2	1M1/B1	0.3 mm	LV -3	L*	55.70	48.65	48.97	48.24	65.40
				a*	-0.70	-0.90	-1.03	-0.93	-0.92
				b*	-0.90	-0.93	-0.45	-3.09	-0.70
3	1M1/B1	0.3 mm	LV -3	L*	57.05	48.58	48.92	48.27	65.17
				a*	-0.72	-0.90	-1.11	-1.03	-0.87
				b*	-0.95	-0.95	-0.55	-3.45	-0.41
4	1M1/B1	0.3 mm	LV -3	L*	54.43	49.30	48.69	48.52	64.41
				a*	-0.65	-0.90	-1.03	-0.90	-0.86
				b*	-1.06	-0.86	-0.62	-3.02	-0.57
5	1M1/B1	0.3 mm	MV 0	L*	56.63	44.57	42.13	43.50	63.00
				a*	-0.72	-0.84	-0.64	-0.63	-1.11
				b*	-0.88	-2.58	-2.46	-5.12	-2.93
6	1M1/B1	0.3 mm	MV 0	L*	55.52	44.39	42.95	47.96	62.96
				a*	-0.67	-0.82	-0.63	-0.84	-1.03
				b*	-0.94	-2.65	-2.60	-4.96	-2.97
7	1M1/B1	0.3 mm	MV 0	L*	59.40	46.78	44.19	47.62	63.17
				a*	-0.93	-1.06	-0.79	-0.92	-1.05
				b*	-1.97	-3.89	-3.54	-6.05	-2.91
8	1M1/B1	0.3 mm	MV 0	L*	59.55	47.31	41.40	42.82	62.73
				a*	-0.95	-0.95	-0.55	-0.51	-1.09
				b*	-2.14	-3.46	-2.36	-5.12	-3.18
9	1M1/B1	0.3 mm	HV +3	L*	57.62	63.41	65.97	65.20	62.82
				a*	-0.79	-1.88	-2.38	-1.93	-1.29
				b*	-1.69	-3.54	-1.76	-3.73	-0.41
10	1M1/B1	0.3 mm	HV +3	L*	60.18	61.67	66.19	65.63	67.66
				a*	-0.82	-1.74	-2.29	-1.92	-1.36
				b*	-1.64	-3.57	-1.70	-3.59	-0.11
11	1M1/B1	0.3 mm	HV +3	L*	58.43	60.98	65.11	65.89	73.06
				a*	-0.81	-1.74	-2.27	-1.84	-1.38
				b*	-1.29	-3.21	-1.78	-2.90	-0.10
12	1M1/B1	0.3 mm	HV +3	L*	56.90	58.62	64.29	64.76	71.39
				a*	-0.70	-1.70	-2.15	-1.82	-1.34
				b*	-0.95	-3.29	-1.59	-2.94	-0.28

المنارة للاستشارات

www.manaraa.com

Appendix B: Raw Data for Group 2

Specimen #	Veneer Shade	Veneer Thickness	Cement Shade	Reading	Baseline	Try-in Paste	Pre-cured Cement	Post-cured Cement	After 30,000 Cycles of Thermo-cycling
1	1M1/B1	0.5 mm	LV -3	L*	60.81	53.51	51.74	53.45	65.83
				a*	-0.65	-0.88	-0.98	-0.75	-0.77
				b*	0.11	-0.28	-0.33	-0.74	0.29
2	1M1/B1	0.5 mm	LV -3	L*	59.33	52.37	50.81	50.95	62.85
				a*	-0.70	-0.91	-1.00	-0.93	-0.83
				b*	-0.39	-0.29	-0.42	-2.29	-0.27
3	1M1/B1	0.5 mm	LV -3	L*	60.44	53.95	51.19	52.24	65.21
				a*	-0.72	-0.91	-1.02	-0.91	-0.62
				b*	-0.22	-0.40	-0.58	-1.62	0.53
4	1M1/B1	0.5 mm	LV -3	L*	60.38	52.39	51.99	51.64	65.29
				a*	-0.67	-0.93	-1.04	-0.97	-0.76
				b*	-0.18	-0.43	-0.59	-2.32	0.30
5	1M1/B1	0.5 mm	MV 0	L*	59.85	48.64	47.51	51.75	63.79
				a*	-0.72	-1.05	-0.88	-1.07	-0.96
				b*	-0.06	-2.41	-2.50	-3.98	-1.31
6	1M1/B1	0.5 mm	MV 0	L*	60.92	49.89	47.69	51.50	64.24
				a*	-0.71	-1.03	-0.87	-1.09	-0.91
				b*	-0.02	-2.46	-2.46	-4.00	-0.79
7	1M1/B1	0.5 mm	MV 0	L*	60.65	49.34	46.62	50.30	64.59
				a*	-0.71	-1.10	-0.85	-1.04	-0.92
				b*	0.03	-2.59	-2.34	-4.00	-0.89
8	1M1/B1	0.5 mm	MV 0	L*	60.45	49.05	46.62	50.95	64.07
				a*	-0.77	-0.97	-0.81	-1.03	-0.96
				b*	-0.56	-2.62	-2.70	-4.47	-1.61
9	1M1/B1	0.5 mm	HV +3	L*	58.44	58.83	64.30	63.71	71.44
				a*	-0.64	-1.58	-2.07	-1.73	-1.19
				b*	-0.13	-2.40	-0.87	-2.32	0.63
10	1M1/B1	0.5 mm	HV +3	L*	59.58	60.56	64.29	63.46	71.32
				a*	-0.68	-1.62	-2.06	-1.73	-1.27
				b*	0.02	-1.93	-0.65	-2.26	1.12
11	1M1/B1	0.5 mm	HV +3	L*	60.34	60.02	65.85	64.96	70.01
				a*	-0.73	-1.58	-2.11	-1.78	-1.25
				b*	-0.61	-2.53	-0.68	-2.42	0.45
12	1M1/B1	0.5 mm	HV +3	L*	59.12	60.06	65.16	64.22	62.85
				a*	-0.61	-1.54	-2.04	-1.72	-1.13
				b*	0.20	-1.80	-0.05	-1.68	0.89

www.manaraa.com

Appendix C: Raw Data for Group 3

Specimen #	Veneer Shade	Veneer Thickness	Cement Shade	Reading	Baseline	Try-in Paste	Pre-cured Cement	Post-cured Cement	After 30,000 Cycles of Thermo-cycling
1	1M1/B1	1.0 mm	LV -3	L*	59.82	55.10	54.65	53.92	62.44
				a*	-0.71	-0.84	-0.95	-0.95	-0.71
				b*	1.38	0.70	0.82	-0.49	1.37
2	1M1/B1	1.0 mm	LV -3	L*	60.80	56.54	56.29	60.30	64.29
				a*	-0.68	-0.83	-0.93	-0.37	-0.65
				b*	1.20	0.58	0.26	2.26	1.43
3	1M1/B1	1.0 mm	LV -3	L*	59.83	54.71	55.15	59.02	63.08
				a*	-0.67	-0.86	-0.92	-0.43	-0.62
				b*	1.31	0.63	0.45	1.91	2.07
4	1M1/B1	1.0 mm	LV -3	L*	59.62	55.59	54.34	55.99	62.65
				a*	-0.64	-0.81	-0.93	0.71	-0.69
				b*	1.39	0.97	0.59	0.76	1.65
5	1M1/B1	1.0 mm	MV 0	L*	60.21	53.20	53.64	55.67	63.19
				a*	-0.72	-1.04	-1.02	-1.16	-0.86
				b*	1.21	-0.79	-1.55	-2.06	1.03
6	1M1/B1	1.0 mm	MV 0	L*	60.07	53.26	51.64	55.07	63.40
				a*	-0.66	-1.09	-0.96	-1.08	-0.91
				b*	1.44	-0.73	-0.95	-1.29	0.95
7	1M1/B1	1.0 mm	MV 0	L*	61.43	53.13	51.62	53.64	63.64
				a*	-0.77	-1.06	-0.93	-1.05	-0.90
				b*	0.59	-0.88	-0.95	-1.46	0.95
8	1M1/B1	1.0 mm	MV 0	L*	59.02	50.84	51.19	53.95	63.33
				a*	-0.72	-1.02	-0.97	-1.15	-0.94
				b*	1.43	-0.71	-1.10	-1.70	0.86
9	1M1/B1	1.0 mm	HV +3	L*	60.74	59.53	63.23	63.16	66.65
				a*	-0.74	-1.29	-1.61	-1.45	-1.06
				b*	0.87	0.16	1.35	0.33	2.13
10	1M1/B1	1.0 mm	HV +3	L*	60.15	60.30	62.86	62.33	67.51
				a*	-0.71	-1.34	-0.62	-1.46	-1.00
				b*	1.37	0.03	0.93	-0.17	2.10
11	1M1/B1	1.0 mm	HV +3	L*	59.95	59.35	61.90	62.59	65.77
				a*	-0.73	-1.36	-1.64	-1.35	-1.01
				b*	1.26	0.08	1.21	0.77	2.11
12	1M1/B1	1.0 mm	HV +3	L*	60.42	59.64	60.15	61.44	65.92
				a*	-0.78	-1.39	-1.59	-1.46	-1.04
				b*	1.00	-0.42	0.99	0.00	2.39

المنارة للاستشارات

www.manaraa.com

Appendix D: Raw Data for Group 4

Specimen #	Veneer Shade	Veneer Thickness	Cement Shade	Reading	Baseline	Try-in Paste	Pre-cured Cement	Post-cured Cement	After 30,000 Cycles of Thermo-cycling
1	2M2/A2	0.3 mm	LV -3	L*	53.83	49.24	47.07	46.26	58.89
				a*	-0.50	-0.83	-0.97	-0.92	-0.70
				b*	0.62	0.73	1.56	-1.90	1.14
2	2M2/A2	0.3 mm	LV -3	L*	54.87	47.68	45.74	45.76	53.41
				a*	-0.78	-0.82	-0.84	-0.80	-0.79
				b*	0.18	0.36	0.94	-1.76	-0.49
3	2M2/A2	0.3 mm	LV -3	L*	55.89	48.10	46.23	45.97	60.28
				a*	-0.73	-0.83	-0.85	-0.81	-0.57
				b*	0.75	0.46	1.16	-1.75	1.48
4	2M2/A2	0.3 mm	LV -3	L*	51.05	48.38	46.50	45.77	62.72
				a*	-0.69	-0.84	-0.84	-0.80	-0.61
				b*	0.23	0.50	1.39	-2.01	1.05
5	2M2/A2	0.3 mm	MV 0	L*	53.22	43.21	40.10	42.72	49.26
				a*	-0.60	-0.78	-0.46	-0.61	-1.40
				b*	0.76	-1.43	-1.10	-4.47	-3.44
6	2M2/A2	0.3 mm	MV 0	L*	53.43	43.62	40.73	43.25	59.43
				a*	-0.63	-0.77	-0.54	-0.71	-0.94
				b*	0.86	-1.24	-1.22	-4.42	-1.49
7	2M2/A2	0.3 mm	MV 0	L*	52.25	42.36	40.99	42.41	62.26
				a*	-0.66	-0.71	-0.58	-0.55	-1.03
				b*	0.33	-1.51	-1.62	-4.60	-1.96
8	2M2/A2	0.3 mm	MV 0	L*	55.01	45.22	41.21	43.06	64.07
				a*	-0.72	-0.96	-0.60	-0.69	-1.02
				b*	0.74	-1.80	-1.32	-4.47	-0.65
9	2M2/A2	0.3 mm	HV +3	L*	55.94	58.39	63.83	63.75	70.74
				a*	-0.69	-1.62	-2.12	-1.84	-1.38
				b*	0.72	-1.57	0.33	-1.36	2.12
10	2M2/A2	0.3 mm	HV +3	L*	54.81	57.43	62.19	63.03	62.26
				a*	-0.70	-1.69	-2.19	-1.94	-1.18
				b*	0.29	-1.73	-0.21	-1.85	1.77
11	2M2/A2	0.3 mm	HV +3	L*	55.42	57.13	66.33	67.96	63.75
				a*	-0.63	-1.63	-2.13	-2.00	-1.27
				b*	0.93	-1.52	-0.25	-0.18	2.94
12	2M2/A2	0.3 mm	HV +3	L*	55.14	57.46	67.45	68.82	73.76
				a*	-0.59	-1.63	-1.98	-1.98	-1.25
				b*	1.04	-1.40	-0.18	0.32	3.32

المنارة للاستشارات
www.manaraa.com

Appendix E: Raw Data for Group 5

Specimen #	Veneer Shade	Veneer Thickness	Cement Shade	Reading	Baseline	Try-in Paste	Pre-cured Cement	Post-cured Cement	After 30,000 Cycles of Thermo-cycling
1	2M2/A2	0.5 mm	LV -3	L*	56.38	50.48	49.58	49.51	63.40
				a*	-0.45	-0.72	-0.85	-0.85	-0.49
				b*	2.39	1.85	1.69	-0.27	2.82
2	2M2/A2	0.5 mm	LV -3	L*	57.38	52.36	51.92	51.32	64.12
				a*	-0.44	-0.62	-0.75	-0.78	-0.43
				b*	2.50	2.78	2.98	0.53	2.83
3	2M2/A2	0.5 mm	LV -3	L*	58.92	51.33	49.32	49.73	61.09
				a*	-0.51	-0.81	-0.90	-0.88	-0.51
				b*	2.33	1.00	1.91	-0.15	3.03
4	2M2/A2	0.5 mm	LV -3	L*	57.10	51.94	48.18	46.33	63.68
				a*	-0.57	-0.79	-0.85	-0.84	-0.47
				b*	2.06	1.11	2.39	-0.54	3.01
5	2M2/A2	0.5 mm	MV 0	L*	56.83	45.01	42.79	46.65	62.37
				a*	-0.52	-0.78	-0.63	-0.94	-0.85
				b*	2.27	-0.29	-0.57	-3.09	1.21
6	2M2/A2	0.5 mm	MV 0	L*	54.17	46.80	44.11	48.40	61.56
				a*	-0.44	-0.95	-0.67	-0.84	-0.78
				b*	2.35	-0.60	-0.52	1.27	1.21
7	2M2/A2	0.5 mm	MV 0	L*	57.03	45.53	44.34	46.70	63.13
				a*	-0.47	-0.77	-0.63	-0.88	-0.78
				b*	2.41	0.11	-0.44	3.09	1.07
8	2M2/A2	0.5 mm	MV 0	L*	54.75	48.27	44.93	56.91	63.29
				a*	-0.41	0.80	-0.69	-0.95	-0.74
				b*	2.49	0.26	-0.58	0.16	2.10
9	2M2/A2	0.5 mm	HV +3	L*	54.94	58.07	62.80	63.07	69.70
				a*	-0.43	-1.44	-1.89	1.62	-0.91
				b*	2.28	0.29	2.19	0.82	3.46
10	2M2/A2	0.5 mm	HV +3	L*	56.50	58.29	64.61	63.63	70.15
				a*	-0.45	-1.49	-1.98	-1.60	-0.92
				b*	2.55	0.50	3.01	1.03	4.30
11	2M2/A2	0.5 mm	HV +3	L*	54.49	56.47	61.31	62.95	68.36
				a*	-0.44	-1.44	-1.89	-1.48	-0.90
				b*	2.49	0.24	1.88	1.36	3.97
12	2M2/A2	0.5 mm	HV +3	L*	56.54	59.98	63.39	64.09	70.43
				a*	-0.45	-1.55	-1.98	-1.55	-0.91
				b*	2.35	0.43	2.18	1.10	3.96

www.manaraa.com

Appendix F: Raw Data for Group 6

Specimen #	Veneer Shade	Veneer Thickness	Cement Shade	Reading	Baseline	Try-in Paste	Pre-cured Cement	Post-cured Cement	After 30,000 Cycles of Thermo-cycling
1	2M2/A2	1.0 mm	LV -3	L*	56.44	52.38	51.84	56.46	61.55
				a*	-0.29	-0.54	-0.53	0.19	-0.15
				b*	4.71	3.43	3.89	6.25	5.32
2	2M2/A2	1.0 mm	LV -3	L*	56.29	52.09	51.57	50.72	60.84
				a*	-0.27	-0.52	-0.56	-0.66	-0.11
				b*	4.97	3.81	3.99	2.60	5.79
3	2M2/A2	1.0 mm	LV -3	L*	56.10	52.01	51.13	50.26	61.15
				a*	-0.26	-0.49	-0.58	-0.60	-0.18
				b*	4.76	3.74	3.79	2.61	5.29
4	2M2/A2	1.0 mm	LV -3	L*	56.19	52.71	51.67	50.47	60.36
				a*	-0.26	-0.52	-0.55	-0.61	-0.21
				b*	4.66	3.62	3.79	2.40	5.52
5	2M2/A2	1.0 mm	MV 0	L*	56.64	50.61	47.91	55.69	60.52
				a*	-0.33	-0.65	-0.68	-0.29	-0.61
				b*	4.29	2.56	1.90	4.40	3.44
6	2M2/A2	1.0 mm	MV 0	L*	56.91	50.36	49.70	53.60	61.79
				a*	-0.26	-0.69	-0.68	-0.64	-0.55
				b*	4.81	2.25	1.94	2.28	3.46
7	2M2/A2	1.0 mm	MV 0	L*	56.75	49.67	48.32	49.71	61.28
				a*	-0.26	-0.69	-0.71	-0.95	-0.62
				b*	4.74	2.03	1.58	0.05	2.90
8	2M2/A2	1.0 mm	MV 0	L*	56.39	49.98	48.56	51.94	61.02
				a*	-0.27	-0.70	-0.65	-0.88	-0.53
				b*	4.67	2.28	1.94	1.43	3.93
9	2M2/A2	1.0 mm	HV +3	L*	56.11	57.79	59.92	58.05	63.70
				a*	-0.29	-1.05	-1.22	-1.06	-0.45
				b*	4.70	3.77	4.68	3.58	4.86
10	2M2/A2	1.0 mm	HV +3	L*	56.52	57.02	59.61	60.07	63.28
				a*	-0.24	-0.98	-1.14	-0.90	-0.35
				b*	4.80	3.61	5.03	4.74	6.50
11	2M2/A2	1.0 mm	HV +3	L*	56.55	57.09	59.96	63.13	64.90
				a*	-0.29	-0.98	-1.12	-0.52	-0.41
				b*	4.52	3.53	5.23	6.18	6.19
12	2M2/A2	1.0 mm	HV +3	L*	56.67	56.85	60.45	62.91	65.00
				a*	-0.26	-1.03	-1.24	-0.65	-0.39
				b*	4.75	3.21	5.00	5.71	6.93

www.manaraa.com

Appendix G: Raw Data for Group 7

Specimen #	Veneer Shade	Veneer Thickness	Cement Shade	Reading	Baseline	Try-in Paste	Pre-cured Cement	Post-cured Cement	After 30,000 Cycles of Thermo-cycling
1	3M1/C1	0.3 mm	LV -3	L*	55.29	46.02	46.78	45.82	59.67
				a*	-0.55	-0.71	-0.60	-0.43	-0.42
				b*	-1.40	-0.71	0.13	-2.51	-0.37
2	3M1/C1	0.3 mm	LV -3	L*	56.42	49.72	47.86	46.28	62.59
				a*	-0.65	-0.80	-0.66	-0.44	-0.44
				b*	-1.54	-0.89	-0.61	-2.67	-0.20
3	3M1/C1	0.3 mm	LV -3	L*	54.34	47.10	47.71	46.90	64.62
				a*	-0.52	-0.77	-0.68	-0.50	-0.39
				b*	-1.39	-1.13	-0.35	-2.76	-0.61
4	3M1/C1	0.3 mm	LV -3	L*	53.46	46.24	46.09	47.78	63.00
				a*	-0.41	-0.74	-0.59	-0.31	-0.31
				b*	-0.81	-0.89	0.35	-1.29	-0.02
5	3M1/C1	0.3 mm	MV 0	L*	53.83	41.75	39.49	44.05	61.29
				a*	-0.43	-0.59	-0.36	-0.52	-0.75
				b*	-0.79	-2.25	-2.04	-4.75	-2.19
6	3M1/C1	0.3 mm	MV 0	L*	51.43	41.00	38.63	40.29	61.81
				a*	-0.40	-0.45	-0.23	-0.20	-0.81
				b*	-1.03	-2.03	-1.62	-4.74	-2.44
7	3M1/C1	0.3 mm	MV 0	L*	53.00	41.57	39.00	41.83	60.36
				a*	-0.40	-0.53	-0.34	-0.42	-0.77
				b*	-0.74	-2.18	-1.99	-5.35	-2.55
8	3M1/C1	0.3 mm	MV 0	L*	54.69	41.79	40.92	43.24	60.40
				a*	-0.52	-0.53	-0.49	-0.56	-0.72
				b*	-1.10	-1.87	-2.55	-5.39	-2.43
9	3M1/C1	0.3 mm	HV +3	L*	54.30	56.90	63.70	63.40	59.95
				a*	-0.41	-1.50	-2.04	-1.72	-0.82
				b*	-0.75	-3.27	-1.44	-3.15	0.10
10	3M1/C1	0.3 mm	HV +3	L*	53.18	56.11	62.64	62.03	71.00
				a*	-0.41	-1.47	-1.99	-1.70	-1.00
				b*	-0.75	-3.20	-1.71	-3.72	0.07
11	3M1/C1	0.3 mm	HV +3	L*	57.21	57.21	64.41	64.55	70.68
				a*	-0.61	-1.45	-1.99	-1.70	-1.01
				b*	-1.33	-3.26	-1.89	-3.27	-0.22
12	3M1/C1	0.3 mm	HV +3	L*	53.01	56.78	61.88	62.13	66.72
				a*	-0.41	-1.50	-2.27	-1.80	-1.26
				b*	-0.96	-3.36	-1.94	-3.59	-0.88

المنارة للاستشارات

www.manaraa.com

Appendix H: Raw Data for Group 8

Specimen #	Veneer Shade	Veneer Thickness	Cement Shade	Reading	Baseline	Try-in Paste	Pre-cured Cement	Post-cured Cement	After 30,000 Cycles of Thermo-cycling
1	3M1/C1	0.5 mm	LV -3	L*	54.44	47.94	46.31	46.09	60.52
				a*	-0.32	-0.65	-0.73	-0.67	-0.36
				b*	0.20	0.06	0.57	-1.88	0.75
2	3M1/C1	0.5 mm	LV -3	L*	55.52	48.99	46.77	46.30	58.38
				a*	-0.36	-0.68	-0.74	-0.68	-0.36
				b*	0.17	0.10	0.46	-2.00	0.50
3	3M1/C1	0.5 mm	LV -3	L*	55.15	48.11	47.03	51.01	62.31
				a*	-0.32	-0.67	-0.71	-0.40	-0.31
				b*	0.28	-0.02	0.55	0.25	1.14
4	3M1/C1	0.5 mm	LV -3	L*	56.14	49.23	48.55	47.92	60.76
				a*	-0.31	-0.65	-0.75	-0.73	-0.37
				b*	0.34	-0.12	0.31	-1.97	0.78
5	3M1/C1	0.5 mm	MV 0	L*	55.86	45.25	42.70	53.99	62.50
				a*	-0.37	-0.69	-0.49	-0.65	-0.62
				b*	0.10	-1.93	-1.82	-2.43	-1.33
6	3M1/C1	0.5 mm	MV 0	L*	56.99	45.55	43.65	46.60	62.13
				a*	-0.29	-0.66	-0.51	-0.61	-0.59
				b*	0.40	-1.71	-1.80	-3.48	-0.62
7	3M1/C1	0.5 mm	MV 0	L*	57.50	46.54	43.28	45.55	MISSING
				a*	-0.29	-0.73	-0.48	-0.61	MISSING
				b*	0.45	-1.98	-1.74	-3.86	MISSING
8	3M1/C1	0.5 mm	MV 0	L*	58.29	47.69	45.40	47.14	61.14
				a*	-0.30	-0.77	-0.66	-0.67	-0.43
				b*	0.52	-2.32	-2.51	-4.10	0.05
9	3M1/C1	0.5 mm	HV +3	L*	57.40	57.91	62.54	62.15	66.18
				a*	-0.23	-1.25	-1.63	-1.33	-0.57
				b*	0.48	-1.60	0.07	-1.38	1.41
10	3M1/C1	0.5 mm	HV +3	L*	54.27	56.91	61.83	63.25	66.60
				a*	-0.28	-1.30	-1.70	-1.24	-0.57
				b*	0.18	-1.98	-0.19	-0.90	1.20
11	3M1/C1	0.5 mm	HV +3	L*	54.43	56.78	61.96	61.58	67.51
				a*	-0.31	-1.30	-1.71	-1.43	-0.76
				b*	0.24	-1.85	-0.05	-1.59	0.89
12	3M1/C1	0.5 mm	HV +3	L*	55.36	56.07	62.40	61.45	68.98
				a*	-0.31	-1.25	-1.71	-1.42	-0.73
				b*	0.21	2.01	-0.10	-1.70	1.19

www.manaraa.com

Appendix I: Raw Data for Group 9

Specimen #	Veneer Shade	Veneer Thickness	Cement Shade	Reading	Baseline	Try-in Paste	Pre-cured Cement	Post-cured Cement	After 30,000 Cycles of Thermo-cycling
1	3M1/C1	1.0 mm	LV -3	L*	55.39	49.65	48.76	48.20	56.77
				a*	-0.10	-0.38	-0.42	-0.51	0.04
				b*	1.56	1.14	1.37	-0.17	2.14
2	3M1/C1	1.0 mm	LV -3	L*	55.11	50.21	49.46	48.91	57.97
				a*	-0.04	-0.33	-0.43	-0.45	0.07
				b*	1.82	1.31	1.17	-0.24	2.27
3	3M1/C1	1.0 mm	LV -3	L*	55.60	50.13	49.27	49.07	59.35
				a*	0.02	-0.37	-0.41	-0.44	0.08
				b*	1.97	0.95	1.18	-0.08	2.35
4	3M1/C1	1.0 mm	LV -3	L*	54.83	49.60	49.57	48.76	55.45
				a*	-0.01	-0.36	-0.36	-0.36	0.16
				b*	1.89	1.06	1.17	-0.19	2.25
5	3M1/C1	1.0 mm	MV 0	L*	54.82	47.21	46.01	48.80	57.67
				a*	-0.04	-0.55	-0.47	-0.58	-0.21
				b*	1.89	-0.43	-0.69	-1.51	1.37
6	3M1/C1	1.0 mm	MV 0	L*	55.39	47.12	45.87	47.18	58.53
				a*	-0.12	-0.59	-0.48	-0.57	-0.29
				b*	1.20	-0.60	-0.95	-2.04	0.82
7	3M1/C1	1.0 mm	MV 0	L*	55.24	48.41	46.65	49.55	59.48
				a*	-0.02	-0.54	-0.46	-0.59	0.27
				b*	1.92	-0.37	-0.65	-1.35	0.44
8	3M1/C1	1.0 mm	MV 0	L*	54.81	46.60	45.21	48.01	56.55
				a*	-0.09	-0.55	-0.46	-0.60	-0.26
				b*	1.66	-0.47	-0.66	-1.62	1.02
9	3M1/C1	1.0 mm	HV +3	L*	54.76	55.23	57.85	57.82	62.17
				a*	-0.01	-0.74	-0.90	-0.76	-0.13
				b*	1.93	0.56	1.68	0.87	3.18
10	3M1/C1	1.0 mm	HV +3	L*	55.24	55.38	58.22	58.32	60.93
				a*	-0.01	-0.74	-0.93	-0.76	-0.17
				b*	1.96	0.51	1.62	0.78	2.47
11	3M1/C1	1.0 mm	HV +3	L*	54.53	55.16	57.58	57.38	61.26
				a*	-0.08	-0.82	-0.99	-0.87	-0.22
				b*	1.88	0.48	1.49	0.65	2.76
12	3M1/C1	1.0 mm	HV +3	L*	54.92	55.11	57.63	58.59	59.96
				a*	-0.01	-0.73	-0.89	-0.63	-0.17
				b*	1.87	0.45	1.54	1.34	2.12

www.manaraa.com

Appendix J: Raw Data of *ΔE* Values for Group 1

Specimen #	Veneer Shade	Veneer Thickness	ΔE Try-in Paste vs. Post-cured Cement	ΔE Pre-cured Cement vs. Post-cured Cement	ΔE Post-cured Cement vs. After 30,000 Cycles of Thermos-cycling
1	1M1/B1	0.3 mm	2.74	2.46	16.37
2	1M1/B1	0.3 mm	2.20	2.74	17.33
3	1M1/B1	0.3 mm	2.52	2.97	17.17
4	1M1/B1	0.3 mm	2.30	2.41	16.08
5	1M1/B1	0.3 mm	2.76	2.99	19.63
6	1M1/B1	0.3 mm	4.25	5.54	15.13
7	1M1/B1	0.3 mm	2.32	4.25	15.86
8	1M1/B1	0.3 mm	4.81	3.10	20.01
9	1M1/B1	0.3 mm	1.80	2.16	4.13
10	1M1/B1	0.3 mm	3.96	2.01	4.07
11	1M1/B1	0.3 mm	4.92	1.43	7.71
12	1M1/B1	0.3 mm	6.15	1.47	7.16

Appendix K: Raw Data of *ΔE* Values for Group 2

Specimen #	Veneer Shade	Veneer Thickness	ΔE Try-in Paste vs. Post-cured Cement	ΔE Pre-cured Cement vs. Post-cured Cement	ΔE Post-cured Cement vs. After 30,000 Cycles of Thermos-cycling
1	1M1/B1	0.5 mm	0.48	1.77	12.42
2	1M1/B1	0.5 mm	2.45	1.88	12.07
3	1M1/B1	0.5 mm	2.10	1.48	13.15
4	1M1/B1	0.5 mm	2.03	1.77	13.90
5	1M1/B1	0.5 mm	3.48	4.49	12.33
6	1M1/B1	0.5 mm	2.23	4.12	13.14
7	1M1/B1	0.5 mm	1.71	4.04	14.62
8	1M1/B1	0.5 mm	2.65	4.68	13.43
9	1M1/B1	0.5 mm	4.88	1.60	8.29
10	1M1/B1	0.5 mm	2.92	1.84	8.57
11	1M1/B1	0.5 mm	4.95	1.98	5.83
12	1M1/B1	0.5 mm	4.17	1.91	2.97

Appendix L: Raw Data of *ΔE* Values for Group 3

Specimen #	Veneer Shade	Veneer Thickness	ΔE Try-in Paste vs. Post-cured Cement	ΔE Pre-cured Cement vs. Post-cured Cement	ΔE Post-cured Cement vs. After 30,000 Cycles of Thermos-cycling
1	1M1/B1	1.0 mm	1.68	1.50	8.72
2	1M1/B1	1.0 mm	4.14	4.52	4.09
3	1M1/B1	1.0 mm	4.52	4.17	4.07
4	1M1/B1	1.0 mm	1.59	2.33	6.86
5	1M1/B1	1.0 mm	2.78	2.10	8.14
6	1M1/B1	1.0 mm	1.89	3.45	8.63
7	1M1/B1	1.0 mm	0.77	2.09	10.29
8	1M1/B1	1.0 mm	3.27	2.83	9.73
9	1M1/B1	1.0 mm	3.64	1.03	3.95
10	1M1/B1	1.0 mm	2.04	1.48	5.67
11	1M1/B1	1.0 mm	3.31	0.87	3.47
12	1M1/B1	1.0 mm	1.85	1.63	5.09

المنارة للاستشارات
www.manaraa.com

Appendix M: Raw Data of *ΔE* Values for Group 4

Specimen #	Veneer Shade	Veneer Thickness	ΔE Try-in Paste vs. Post-cured Cement	ΔE Pre-cured Cement vs. Post-cured Cement	ΔE Post-cured Cement vs. After 30,000 Cycles of Thermos-cycling
1	2M2/A2	0.3 mm	3.98	3.55	12.99
2	2M2/A2	0.3 mm	2.86	2.70	7.75
3	2M2/A2	0.3 mm	3.07	2.92	14.67
4	2M2/A2	0.3 mm	3.62	3.48	17.23
5	2M2/A2	0.3 mm	3.08	4.27	6.67
6	2M2/A2	0.3 mm	3.20	4.08	16.44
7	2M2/A2	0.3 mm	3.09	3.30	20.03
8	2M2/A2	0.3 mm	3.44	3.65	21.36
9	2M2/A2	0.3 mm	5.37	1.71	7.82
10	2M2/A2	0.3 mm	5.61	1.86	3.78
11	2M2/A2	0.3 mm	10.92	1.64	5.29
12	2M2/A2	0.3 mm	11.49	1.46	5.83

Appendix N: Raw Data of *ΔE* Values for Group 5

Specimen #	Veneer Shade	Veneer Thickness	ΔE Try-in Paste vs. Post-cured Cement	ΔE Pre-cured Cement vs. Post-cured Cement	ΔE Post-cured Cement vs. After 30,000 Cycles of Thermos-cycling
1	2M2/A2	0.5 mm	2.33	1.96	14.23
2	2M2/A2	0.5 mm	2.48	2.52	13.01
3	2M2/A2	0.5 mm	1.97	2.10	11.80
4	2M2/A2	0.5 mm	5.85	3.47	17.71
5	2M2/A2	0.5 mm	3.25	4.62	16.30
6	2M2/A2	0.5 mm	2.46	4.65	13.16
7	2M2/A2	0.5 mm	3.20	4.25	16.55
8	2M2/A2	0.5 mm	8.82	12.01	6.67
9	2M2/A2	0.5 mm	5.89	3.78	7.57
10	2M2/A2	0.5 mm	5.37	2.24	7.33
11	2M2/A2	0.5 mm	6.58	1.77	6.03
12	2M2/A2	0.5 mm	4.16	1.36	6.98

Appendix O: Raw Data of *ΔE* Values for Group 6

Specimen #	Veneer Shade	Veneer Thickness	ΔE Try-in Paste vs. Post-cured Cement	ΔE Pre-cured Cement vs. Post-cured Cement	ΔE Post-cured Cement vs. After 30,000 Cycles of Thermos-cycling
1	2M2/A2	1.0 mm	5.01	5.24	5.19
2	2M2/A2	1.0 mm	1.83	1.63	10.63
3	2M2/A2	1.0 mm	2.09	1.47	11.22
4	2M2/A2	1.0 mm	2.55	1.84	10.38
5	2M2/A2	1.0 mm	5.41	8.18	4.93
6	2M2/A2	1.0 mm	3.24	3.91	8.28
7	2M2/A2	1.0 mm	2.00	2.08	11.92
8	2M2/A2	1.0 mm	2.14	3.43	9.42
9	2M2/A2	1.0 mm	0.32	2.18	5.83
10	2M2/A2	1.0 mm	3.25	0.59	3.70
11	2M2/A2	1.0 mm	6.61	3.36	1.77
12	2M2/A2	1.0 mm	6.57	2.63	2.43

المنارة للاستشارات
www.manaraa.com

Appendix P: Raw Data of *ΔE* Values for Group 7

Specimen #	Veneer Shade	Veneer Thickness	ΔE Try-in Paste vs. Post-cured Cement	ΔE Pre-cured Cement vs. Post-cured Cement	ΔE Post-cured Cement vs. After 30,000 Cycles of Thermos-cycling
1	3M1/C1	0.3 mm	1.83	2.81	14.01
2	3M1/C1	0.3 mm	3.89	2.61	16.50
3	3M1/C1	0.3 mm	1.66	2.55	17.85
4	3M1/C1	0.3 mm	1.65	2.37	15.27
5	3M1/C1	0.3 mm	3.40	5.31	17.43
6	3M1/C1	0.3 mm	2.81	3.53	21.65
7	3M1/C1	0.3 mm	3.18	4.39	18.74
8	3M1/C1	0.3 mm	3.81	3.67	17.41
9	3M1/C1	0.3 mm	6.50	1.77	4.82
10	3M1/C1	0.3 mm	5.95	2.12	9.76
11	3M1/C1	0.3 mm	7.34	1.42	6.88
12	3M1/C1	0.3 mm	5.36	1.73	5.36

Appendix Q: Raw Data of *ΔE* Values for Group 8

Specimen #	Veneer Shade	Veneer Thickness	ΔE Try-in Paste vs. Post-cured Cement	ΔE Pre-cured Cement vs. Post-cured Cement	ΔE Post-cured Cement vs. After 30,000 Cycles of Thermos-cycling
1	3M1/C1	0.5 mm	2.68	2.46	14.67
2	3M1/C1	0.5 mm	3.41	2.51	12.34
3	3M1/C1	0.5 mm	2.93	4.00	11.34
4	3M1/C1	0.5 mm	2.27	2.37	13.14
5	3M1/C1	0.5 mm	8.75	11.31	8.58
6	3M1/C1	0.5 mm	2.06	3.40	15.79
7	3M1/C1	0.5 mm	2.13	3.11	MISSING
8	3M1/C1	0.5 mm	1.87	2.36	14.60
9	3M1/C1	0.5 mm	4.25	1.53	4.96
10	3M1/C1	0.5 mm	6.43	1.65	4.01
11	3M1/C1	0.5 mm	4.81	1.61	6.46
12	3M1/C1	0.5 mm	6.54	1.88	8.10

Appendix R: Raw Data of *ΔE* Values for Group 9

Specimen #	Veneer Shade	Veneer Thickness	ΔE Try-in Paste vs. Post-cured Cement	ΔE Pre-cured Cement vs. Post-cured Cement	ΔE Post-cured Cement vs. After 30,000 Cycles of Thermos-cycling
1	3M1/C1	1.0 mm	1.96	1.64	8.89
2	3M1/C1	1.0 mm	2.03	1.51	9.42
3	3M1/C1	1.0 mm	1.48	1.28	10.58
4	3M1/C1	1.0 mm	1.51	1.58	7.14
5	3M1/C1	1.0 mm	1.92	2.91	9.33
6	3M1/C1	1.0 mm	1.44	1.71	11.71
7	3M1/C1	1.0 mm	1.50	2.99	10.13
8	3M1/C1	1.0 mm	1.82	2.96	8.95
9	3M1/C1	1.0 mm	2.61	0.82	4.97
10	3M1/C1	1.0 mm	2.95	0.86	3.16
11	3M1/C1	1.0 mm	2.23	0.87	4.46
12	3M1/C1	1.0 mm	3.59	1.01	1.64

المنارة للاستشارات
www.manaraa.com

BIBLIOGRAPHY

1. Alghazali N, Laukner J, Burnside G, et al. An investigation into the effect of try-in pastes, uncured and cured resin cements on the overall color of ceramic veneer restorations: An in vitro study. Journal of Dentistry 2010;38:e78-e86.
2. Kilinc E, Antonson SA, Hardigan PC, Kesercioglu A. Resin cement color stability and its influence on the final shade of all-ceramics. Journal of Dentistry 2011;39:e30-e36.
3. Fradeani M, Redemagni M, Corrado M. Porcelain laminate veneers: 6- to 12-year clinical evaluation--a retrospective study. Int J Periodontics Restorative Dent 2005;25(1):9-17.
4. Layton DM, Walton TR. The up to 21-year clinical outcome and survival of feldspathic porcelain veneers: accounting for clustering. Int J Prosthodont 2012;25(6):604-12.
5. Peumans M, Van Meerbeek B, Lambrechts P, Vanherle G. Porcelain veneers: a review of the literature. J Dent 2000;28(3):163-77.
6. Layton D, Walton T. An up to 16-year prospective study of 304 porcelain veneers. Int J Prosthodont 2007;20(4):389-96.
7. Layton DM, Clarke M. A systematic review and meta-analysis of the survival of non-feldspathic porcelain veneers over 5 and 10 years. Int J Prosthodont 2013;26(2):111-24.
8. Shillingburg HT, Hobo S, Whitsett LD, Jacobi R, Brackett SE, editors. Fundamentals of Fixed Prosthodontics. 3rd ed. Coral Stream, IL: Quintessence; 1997.
9. Ge C, Green CC, Sederstrom D, McLaren EA, White SN. Effect of porcelain and enamel thickness on porcelain veneer failure loads in vitro. J Prosthet Dent 2014;111(5):380-7.
10. Shetty A, Kaiwar A, Shubhashini N, et al. Survival rates of porcelain laminate restoration based on different incisal preparation designs: An analysis. J Conserv Dent 2011;14(1):10-5.
11. Della Bona A, Kelly JR. The clinical success of all-ceramic restorations. J Am Dent Assoc 2008;139 Suppl:8s-13s.
12. Barizon KT, Bergeron C, Vargas MA, et al. Ceramic materials for porcelain veneers: part II. Effect of material, shade, and thickness on translucency. J Prosthet Dent 2014;112(4):864-70.
13. Sadowsky SJ. An overview of treatment considerations for esthetic restorations: a review of the literature. J Prosthet Dent 2006;96(6):433-42.
14. Esquivel-Upshaw JF, Young H, Jones J, Yang M, Anusavice KJ. In vivo wear of enamel by a lithia disilicate-based core ceramic used for posterior fixed partial dentures: first-year results. Int J Prosthodont 2006;19(4):391-6.
15. Illumination CICo. Colometry-technical report. Vienna, Austria: Illumination ICo.; 1986;15.
16. Berns RS. Principles of Color Technology. 3rd ed. Canada: John Wiley & Sons, Inc; 2000.
17. Seghi RR, Johnston WM, O'Brien WJ. Spectrophotometric analysis of color differences between porcelain systems. J Prosthet Dent 1986;56(1):35-40.

المنارة للاستشارات
www.manaraa.com

18. Ghavam M, Amani-Tehran M, Saffarpour M. Effect of accelerated aging on the color and opacity of resin cements. Oper Dent 2010;35(6):605-9.
19. Chu SJ, Trushkowsky RD, Paravina RD. Dental color matching instruments and systems. Review of clinical and research aspects. J Dent 2010;38 Suppl 2:e2-16.
20. Vichi A, Louca C, Corciolani G, Ferrari M. Color related to ceramic and zirconia restorations: a review. Dent Mater 2011;27(1):97-108.
21. Lindsey DT, Wee AG. Perceptibility and acceptability of CIELAB color differences in computer-simulated teeth. J Dent 2007;35(7):593-9.
22. Johnston WM. Color measurement in dentistry. J Dent 2009;37 Suppl 1:e2-6.
23. Nathans J, Piantanida TP, Eddy RL, Shows TB, Hogness DS. Molecular genetics of inherited variation in human color vision. Science 1986;232(4747):203-10.
24. Lehmann KM, Igiel C, Schmidtmann I, Scheller H. Four color-measuring devices compared with a spectrophotometric reference system. J Dent 2010;38 Suppl 2:e65-70.
25. Mohan M, Shey Z, Vaidyanathan J, et al. Color changes of restorative materials exposed in vitro to cola beverage. Pediatr Dent 2008;30(4):309-16.
26. Illimination CCo. Light as a True Visual Quantity: Principle of Meaurement. Vienna, Austria: Illimumination ICo.; 1978;41.
27. Paravina RD, Majkic G, Imai FH, Powers JM. Optimization of tooth color and shade guide design. J Prosthodont 2007;16(4):269-76.
28. Sim CP, Yap AU, Teo J. Color perception among different dental personnel. Oper Dent 2001;26(5):435-9.
29. Archegas LR, Freire A, Vieira S, Caldas DB, Souza EM. Colour stability and opacity of resin cements and flowable composites for ceramic veneer luting after accelerated ageing. J Dent 2011;39(11):804-10.
30. Dozic A, Tsagkari M, Khashayar G, Aboushelib M. Color management of porcelain veneers: Influence of dentin and resin cement colors. Quintessence International 2010;41(7):567-73.
31. Chen XD, Hong G, Xing WZ, Wang YN. The influence of resin cements on the final color of ceramic veneers. J Prosthodont Res 2015.
32. Sproull RC. Color matching in dentistry. I. The three-dimensional nature of color. J Prosthet Dent 1973;29(4):416-24.
33. Sarafianou A, Kamposiora P, Papavasiliou G, Goula H. Matching repeatability and interdevice agreement of 2 intraoral spectrophotometers. J Prosthet Dent 2012;107(3):178-85.
34. Lappin JS, Norman JF, Phillips F. Fechner, information, and shape perception. Atten Percept Psychophys 2011;73(8):2353-78.
35. Tung FF, Goldstein GR, Jang S, Hittelman E. The repeatability of an intraoral dental colorimeter. J Prosthet Dent 2002;88(6):585-90.
36. Paul S, Peter A, Pietrobon N, Hammerle CH. Visual and spectrophotometric shade analysis of human teeth. J Dent Res 2002;81(8):578-82.
37. Derdilopoulou FV, Zantner C, Neumann K, Kielbassa AM. Evaluation of visual and spectrophotometric shade analyses: a clinical comparison of 3758 teeth. Int J Prosthodont 2007;20(4):414-6.

www.manaraa.com

38. Da Silva JD, Park SE, Weber HP, Ishikawa-Nagai S. Clinical performance of a newly developed spectrophotometric system on tooth color reproduction. J Prosthet Dent 2008;99(5):361-8.
39. Ishikawa-Nagai S, Yoshida A, Da Silva JD, Miller L. Spectrophotometric analysis of tooth color reproduction on anterior all-ceramic crowns: Part 1: analysis and interpretation of tooth color. J Esthet Restor Dent 2010;22(1):42-52.
40. Hill EE, Lott J. A clinically focused discussion of luting materials. Aust Dent J 2011;56 Suppl 1:67-76.
41. Pegoraro TA, da Silva NR, Carvalho RM. Cements for use in esthetic dentistry. Dent Clin North Am 2007;51(2):453-71, x.
42. Hill EE. Dental cements for definitive luting: a review and practical clinical considerations. Dent Clin North Am 2007;51(3):643-58, vi.
43. Spitznagel FA, Horvath SD, Guess PC, Blatz MB. Resin bond to indirect composite and new ceramic/polymer materials: a review of the literature. J Esthet Restor Dent 2014;26(6):382-93.
44. Anusavise KJ. Phillips' Science of Dental Materials. 11th ed. St. Louis, Missouri: Elsevier Science; 2003.
45. Faria-e-Silva AL, Piva E, Lima GS, et al. Effect of immediate and delayed light activation on the mechanical properties and degree of conversion in dual-cured resin cements. J Oral Sci 2012;54(3):261-6.
46. De Munck J, Van Landuyt K, Peumans M, et al. A critical review of the durability of adhesion to tooth tissue: methods and results. J Dent Res 2005;84(2):118-32.
47. Yoshida Y, Nagakane K, Fukuda R, et al. Comparative study on adhesive performance of functional monomers. J Dent Res 2004;83(6):454-8.
48. Gale MS, Darvell BW. Thermal cycling procedures for laboratory testing of dental restorations. J Dent 1999;27(2):89-99.
49. Cotes C, Cardoso M, de Melo RM, Valandro LF, Bottino MA. Effect of composite surface treatment and aging on the bond strength between a core build-up composite and a luting agent. J Appl Oral Sci 2015;23(1):71-8.
50. Turgut S, Bagis B, Turkaslan SS, Bagis YH. Effect of ultraviolet aging on translucency of resin-cemented ceramic veneers: an in vitro study. J Prosthodont 2014;23(1):39-44.
51. http://www.sabridentalenterprises.com/search/label/Thermo-Cycling%20Testing%20Instrument.
52. Baracco B, Fuentes MV, Garrido MA, Gonzalez-Lopez S, Ceballos L. Effect of thermal aging on the tensile bond strength at reduced areas of seven current adhesives. Odontology 2013;101(2):177-85.
53. Douglas RD, Steinhauer TJ, Wee AG. Intraoral determination of the tolerance of dentists for perceptibility and acceptability of shade mismatch. J Prosthet Dent 2007;97(4):200-8.
54. Chu FC, Chow TW, Chai J. Contrast ratios and masking ability of three types of ceramic veneers. J Prosthet Dent 2007;98(5):359-64.
55. Ferrari M, Patroni S, Balleri P. Measurement of enamel thickness in relation to reduction for etched laminate veneers. Int J Periodontics Restorative Dent 1992;12(5):407-13.

المنارة للاستشارات
www.manaraa.com

56. Vichi A, Ferrari M, Davidson CL. Influence of ceramic and cement thickness on the masking of various types of opaque posts. J Prosthet Dent 2000;83(4):412-7.
57. Dozic A, Kleverlaan CJ, Meegdes M, van der Zel J, Feilzer AJ. The influence of porcelain layer thickness on the final shade of ceramic restorations. J Prosthet Dent 2003;90(6):563-70.
58. Magne P, Versluis A, Douglas WH. Effect of luting composite shrinkage and thermal loads on the stress distribution in porcelain laminate veneers. J Prosthet Dent 1999;81(3):335-44.
59. Chang J, Da Silva JD, Sakai M, Kristiansen J, Ishikawa-Nagai S. The optical effect of composite luting cement on all ceramic crowns. J Dent 2009;37(12):937-43.
60. Xing W, Jiang T, Ma X, et al. Evaluation of the esthetic effect of resin cements and try-in pastes on ceromer veneers. J Dent 2010;38 Suppl 2:e87-94.
61. Balderamos LP, O'Keefe KL, Powers JM. Color accuracy of resin cements and try-in pastes. Int J Prosthodont 1997;10(2):111-5.
62. Sarafianou A, Iosifidou S, Papadopoulos T, Eliades G. Color stability and degree of cure of direct composite restoratives after accelerated aging. Oper Dent 2007;32(4):406-11.
63. Janda R, Roulet JF, Latta M, Steffin G, Ruttermann S. Color stability of resin-based filling materials after aging when cured with plasma or halogen light. Eur J Oral Sci 2005;113(3):251-7.
64. Lu H, Powers JM. Color stability of resin cements after accelerated aging. Am J Dent 2004;17(5):354-8.
65. Turgut S, Bagis B. Colour stability of laminate veneers: an in vitro study. J Dent 2011;39 Suppl 3:e57-64.
66. Kilinc E, Antonson SA, Hardigan PC, Kesercioglu A. Resin cement color stability and its influence on the final shade of all-ceramics. J Dent 2011;39 Suppl 1:e30-6.
67. Turgut S, Bagis B. Effect of resin cement and ceramic thickness on final color of laminate veneers: an in vitro study. J Prosthet Dent 2013;109(3):179-86.
68. Hekimoglu C, Anil N, Etikan I. Effect of accelerated aging on the color stability of cemented laminate veneers. Int J Prosthodont 2000;13(1):29-33.
69. Heffernan MJ, Aquilino SA, Diaz-Arnold AM, et al. Relative translucency of six all-ceramic systems. Part I: core materials. J Prosthet Dent 2002;88(1):4-9.
70. Crispin BJ, Okamoto SK, Globe H. Effect of porcelain crown substructures on visually perceivable value. J Prosthet Dent 1991;66(2):209-12.
71. Azer SS, Rosenstiel SF, Seghi RR, Johnston WM. Effect of substrate shades on the color of ceramic laminate veneers. J Prosthet Dent 2011;106(3):179-83.

المنارة للاستشارات
www.manaraa.com