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EFFECT OF POLISHING TECHNIQUES AND THE RESISTANCE TO STAIN OF UNIVERSAL DENTAL COMPOSITES

by

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A thesis submitted to the Faculty of the
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To all of my mentors who got me through this journey. From the beginning stages of small ideas, to making those ideas an actual hypothesis that could be further investigated. Thank you for always having an open door and open ears to let me come bounce ideas or just listen to me vent throughout this residency. I strive to become like all of you: great officers, great mentors, and great leaders. May the Navy continue to bring great people onto my path as I continue this amazing adventure.

DEDICATION

To Mariah and Scarlett and my Husband

DISCLAIMER

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ABSTRACT

Effect of Polishing Techniques and the Resistance to Stain of Universal Dental Composites

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Introduction: Composite resins are dental restorative materials that have superior esthetic properties, with "Universal" composites claiming one-type-suits-all shade matching ability to most tooth shades. Although esthetically desirable, composites are susceptible to staining by external factors (e.g.: coffee, tea, red wine, smoking, etc.). Excessive staining may generate patient dissatisfaction and the desire to replace the restoration, regardless of disease status, resulting in unnecessary dental restorative procedures. Objective: (1) To compare the staining of two universal and one shade-based (control) composites using spectrophotometry and visual shade matching after 1 year of simulated exposure to coffee, and (2) To evaluate the effect of finishing and polishing protocols on stain prevention. Methods: Thirty composite disc samples (3mm x 10mm) were made for each composite: Ten were cured with clear Mylar matrix strip, ten finished and polished with Sof-Lex Discs and ten finished and polished with Enhance/PoGo System. The samples were incubated in deionized water at 37º for 24hrs to maximize polymerization. Initial shades were measured with a spectrophotometer and confirmed by VITA Classical Shade Guide tabs. All samples were submersed in coffee solution for 15 days, simulating one year of coffee staining, and final shades were measured. Results: There was no significant difference in shade value, post exposure to coffee, amongst the three unpolished composites. However, Control and Universal Type I samples finished to semi-gloss status using the Sof-Lex system were less likely to stain (comparing values D4 vs. C4) compared to matte-finished Universal Type II samples utilizing Sof-Lex or PoGo systems ($p<0.05$). Conclusions: Universal composites claim to have several advantages over shade-based composites. Without finishing/polishing, universal composites perform similar to shade-based composites in stain resistance. A certain combination of universal composite and finishing/polishing procedures can maximize shade stability and esthetics.

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LIST OF ABBREVIATONS

Bis-GMA	2,2-bis[4(2-hydroxy-3-mehtacyloxy-propyloxy)-phenyl] propane
°C	Degrees Celsius
LED	Light Emitting Diode
mm	Millimeter
MPTS	3- methacryloxypropyltrimethoxysilane
nm	Nanometer
ORMOCER	Organically Modified Ceramic
SiO_2-ZrO_2	Silicone Dioxide-Zirconium Dioxide
UDMA	Urethane Dimethacrylate
US	United States
vol	Volume
wt	Weight

CHAPTER 1: Introduction

The Evolution of Composites

Composite resin has become the predominant material when placing direct restorations in modern dentistry. Dental offices have moved away from restoring with amalgam, partly due to the environmental factors required for its disposal and storage. In 2017, the US Environmental Protection Agency required dental offices to use amalgam separators, in order to reduce the discharge of mercury by 5.1 tons annually.[1] Composite does not require filtration equipment or specialized waste handling, and most patients prefer it's matching ability to natural tooth color. New composite materials have emerged on the market, claiming to "chameleonize" with any tooth shade. Does the final finishing and polishing steps of these materials matter? Is there an effect on how quickly the restorative material is susceptible to staining?

Dental composites were originally developed in the 1950s. Polymethyl methacrylate was introduced but this was just the beginning of modern-day dental resin composites. Composites are chemically composed of a resin matrix, filler particles, a coupling agent, and a photo initiator. The two most common composite resins used today are 2,2-bis[4(2-hydroxy-3-mehtacyloxy-propyloxy)-phenyl] propane (Bis-GMA) and urethane dimethacrylate (UDMA).[2, 3] Fillers serve as the structural foundation of dental composites making up 30% to 70% by volume or 50% to 85% by weight. They are chemically made up of a combination of borosilicate, fused quartz, aluminum silicate, lithium aluminum silicate, ytterbium fluoride, and barium, strontium, zirconium and zinc glasses. The coupling agent combines the reinforcing phase and matrix phase and the most commonly used agent is 3- methacryloxypropyltrimethoxysilane (MPTS).[4] The most commonly used photo initiator in dental composites is camphorquinone, a yellow-colored activator with light absorption in the range of 425-495nm. This activator serves to release free radicals from the methacrylate monomer as heat to chemically activate and polymerize the dental composite.[5]

As composites have evolved, their properties have also changed to include different sizes of filler particles. The size of the silicate particles vary from macrofiller (10-100 microns), midifiller (1-10 microns), minifiller (0.1-1 micron), microfiller (0.01-0.1microns) or nanofiller (0.001-0.01 microns).[6] Studies have concluded that filler particle size and shape impact the wear resistance of the composite material itself.[7] Smaller fillers have a higher wear resistance, thus providing a longer lasting restoration, especially in occlusal posterior teeth that are susceptible to frequent occlusal forces. Studies also show that filler size and shape influence polymerization shrinkage-strain, and that this strain is lower for spherical filler composites over irregular filler composites.[8] Therefore, spherical composites suffer less from microleakage and are longer lasting due to less secondary caries due to microleakage.

The structural properties of composites are critical for providing a long-lasting dental restoration with minimal wear and polymerization shrinkage. The final finish and polishability of composites are other important characteristics of dental composites. A smooth restorative surface reduces plaque retention, reducing the risk of developing secondary caries and periodontal inflammation.[9] Not only should the surface be smooth, it should also be polished, as this helps achieve a stain-resistant surface that is more esthetically stable.[10]

Finishing and Polishing of Composites

Many different finishing and polishing systems exist for composites, but they are not all equal. Aluminum oxide-coated abrasives, silicone disks, tungsten carbide finishing burs, abrasive impregnated rubber cups, abrasive strips, diamond rotary instruments and polishing pastes are the most common items used in polishing resin composites.[3] A bench top study by St. Pierre, et al., examined four different composite resins polished with 12 different polishing systems and found statistically significant differences in composite surface roughness among the different polishing systems.[11] The study concluded that a multi-step polishing system was better than a single step system, and that diamond-impregnated polishers yielded smoother final composites.[11]

Composite Color Matching

As composites have evolved to withstand staining and resist wear, they have also evolved in color matching. Earlier generation dental composite systems were manufactured in various shades to match the VITA Classical Shade Guide (A1, A2, A3, etc.) and then emerged a wider selection of colors to match dentin and enamel shades based on translucency. FilTek Supreme Plus Universal Restorative by 3M market their product on the "Shade Selector Wheel" which provides a recipe for a single shade, two-shade or multi-shade restoration selection after a single shade is selected based on the VITA Classical Shade Guide to account for color and opacity.[2] Tooth color is affected by numerous different factors to include intrinsic and extrinsic stains. Tooth color is influenced by lighting, translucency, opacity, light scattering, gloss and the human eye and brain.[12] By taking all of these things into account, color matching to a tooth with a direct restorative composite poses its challenges. Picking the correct color shade in a dental office under fluorescent lighting can yield a mismatch to the natural tooth shade. If the restoration is not polished to a smooth enough surface, there is a risk of stain and plaque retention.

More recent developments in shade matching technology have produced composites that go one step further and claim to be "universal." These universal shade matching composites can potentially eliminate the guessing game of the dental provider and appease the hard to please, esthetically driven patient. By eliminating the need to layer different composites to obtain a "perfect match," chair time can be reduced, production optimizes, and patient satisfaction increased.

UNIVERSAL COMPOSITES

Omnichroma is a one-shaded resin-based composite manufactured by Tokuyama Dental. This composite does not contain any color pigments and claims "smart chromatic technology" through its uniform 260nm spherical fillers of SiO_2-ZrO_2 accounting for 79 wt% (68 vol%).[13] This material differs from traditional composite materials in that it does not rely on red and yellow dyes and pigments to mimic natural tooth shade. Omnichroma's fillers are small enough that they allow ambient light to pass through it, optically matching the surrounding tooth structure, and allowing a single composite to be used for a direct restoration.

Admira Fusion x-tra is a single shade omni-chromatic nano-ORMOCER restorative material manufactured by VOCO that claims it not only covers a classic shade range, but is also a bulk fill material allowing up to 4mm depth of cure. Its properties differ from Omnichroma in that it is a ceramic-based restorative material containing "ORganically MOdified CERamic" with silicone oxide as its base filler and matrix. This

ORMOCER matrix contains 60% nano-particulate and 40% micro and macro particulate.[14] It claims that the size and shape of its particles allow it to not diffract or refract light and therefore the light can pass through the material and what color is seen, is influenced by the surrounding tooth structure.

STUDY OBJECTIVES

Although these restorative materials claim to be the one material that can match all esthetic shade matching demands, it has not been fully investigated how color-stable they are in an oral environment. The primary objective of this study was to determine the degree of staining universal composites would undergo in a simulated oral environment over a specific period of time compared to their shade-based counterparts. The secondary objective of this study was to evaluate the effect of finishing and polishing systems on the degree of staining.

CHAPTER 2: Materials and methods

Study Design

This study evaluated three different composite materials: Filtek Supreme Ultra Universal Restorative (3M, St. Paul, MN; "Control"), Omnichroma (Tokuyama Dental America, Encinitas, CA; "Universal 1"), and Admira Fusion x-tra (VOCO GmBH, Cuxhaven, Germany; "Universal 2"). Each material was finished and polished with either Sof-Lex discs (3M) or Enhance Finishing Points/PoGo Polishing Points (Denstply Sirona – Ultimate Dental, Cordova, TN), commonly used systems for finishing and polishing restorations, as well as without any polish following curing through a clear Mylar matrix strip (Henry Schein, Melville, NY). Each composite disc shade was recorded with a VITA Classical Shade Guide and using a spectrophotometer (Vita Easy Shade V; VITA North America, Yorba Linda, CA) to verify shade. The discs were placed into a staining solution of coffee and the color change was recorded. It was then determined how much composites stained and what polishing system best resisted stain. From these data, it was determined if these new composites were able to maintain their optical properties to really be the chameleon restorative product they claimed to be.

Preparation of Samples

Thirty disc-shaped specimens of each composite were produced from a 3D printed silicone mold (12mm in diameter × 3mm in height). The control composite (Filtek Supreme Ultra Universal Restorative) was used in shade A2. Composite was extruded from a composite gun into the mold and a handheld instrument was used to evenly pack the composite in two layers, curing each layer separately. A clear Mylar matrix strip was placed on top of the final layer of composite and mold to attain uniform discs with a flat surface and was light cured again for 20 seconds at a distance of 0mm with a LED Curing Device (VALO Grand cordless, Ultradent, South Jordan, UT) used in "standard mode" emitting multiwavelength LED at 395-480nm.

The specimens were split into three different groups for finishing and polishing (n=10/group). Ten samples of each composite were not finished and polished after light curing though the clear matrix. Ten samples of each composite were finished and polished with four sequential grit Sof-Lex discs (500-, 1200-, 2400- and 4000- grit) under wet conditions and 10 samples of each composite were finished with Enhance Points under wet conditions and polished with PoGo Polishing Points. All the finishing and polishing procedures were performed by a single, calibrated, and experienced operator using an electric motor handpiece.

After polishing, the specimens were placed into a labeled disc holder and immersed in deionized water and stored in a bacteriological incubator (Boekel Scientific, Feasterville, PA) at 37°C for 24 hours, to promote maximum polymerization and water sorption, and to simulate the oral environment.

INITIAL SHADE ANALYSIS

After 24 hours, the samples were removed from the distilled water, dried completely and an initial shade determination was collected. Each specimen was visually compared by the same operator, to the VITA Classical Shade Guide to a corresponding shade tab. Then, each specimen was assessed with a calibrated reflectance spectrophotometer (Vita Easy Shade V) utilizing a black background with each sample directly on the background in a dark chamber and dimly-lit room, eliminating background light. These shade values were recorded.

STAINING PROTOCOL

Specimens of each composite material (30 total samples) were immersed in a staining solution (Dunkin Donuts coffee) for 15 days and kept in an incubator at 37°C. Coffee was prepared fresh with bottled water and changed daily. 12.75 tablespoons of coffee were placed into a coffee filter and 50 ml of water were placed into a traditional coffee maker (Black and Decker) for brewing.

FINAL SHADE ANALYSIS

After 15 days, the samples were removed from the staining solution and dried. Discs were placed on the same black background, same room as previously described, with the finished side facing upwards. Each disc was compared to the VITA Classical Shade Guide with its most closely matching color shade, selected by the same operator. Following shade guide matching, each sample was measured with the spectrophotometer to measure staining. The tip was placed in the center of the resin discs and recorded. These values were recorded and compared to their initial values to determine the value of staining that occurred.

DATA INTERPRETATION

Significant differences in proportions between groups were assessed via a Chi-square analysis. Alpha was set to 0.05.

CHAPTER 3: Results

Finishing and Polishing

Ten samples of each composite, Control, Universal 1, and Universal 2, were not finished and polished. Their final cure was done through a clear Mylar matrix strip directly on their surface. These samples yielded a high-gloss finish. Ten samples of each composite were finished and polished with sequential Sof-Lex plastic discs under wet conditions. Control and Universal 1 yielded a semi-gloss finish, whereas Universal 2 yielded a matte finish. Ten samples of each composite were finished with Enhance Points under wet conditions and polished with PoGo points. Control and Universal 2 yielded matte finishes while Universal 1 yielded a semi-gloss finish (Table 1, Figure 1).

Initial Shades

Initial shades were recorded following all finishing and polishing, after 24 hours of submersion in deionized water at 37°C, mimicking the oral environment. Initial shade values were recorded comparing to the VITA Classical Shade Guide tabs and using the Easy Shade V spectrophotometer (Figures 2 and 3). All initial values for all samples were recorded as A1, including the Control composite, whose manufactured shade was A2 (Table 2).

Final Shades

All unfinished and unpolished composite samples of the Control, Universal 1 and Universal 2 groups, yielded a C4 shade. Of unfinished samples of Universal 2, nine samples yielded C4 Shade and one sample yielded D4 shade. Of the Control samples that were finished and polished with Sof-Lex discs, four samples yielded C4 and six samples yielded D4 shade. Of the Universal 1 samples, two yielded C4 and eight yielded D4 shades. All Universal 2 samples yielded C4 shade. Of the samples that were finished and polished with Enhance/PoGo system, all Control samples yielded C4 shade. Universal 1 samples yielded six C4 shade and four D4 shade. Universal 2 samples all yielded C4 shade (Figure 4).

CHAPTER 4: Discussion

Shade matching and polishing are critical components of using dental restorative composites. By attaining a color matched restoration, the satisfaction of the patient is increased, as it's "unnoticeable" that any restorations are present. In polishing, it is desirable to achieve a surface that is less susceptible to staining, thereby increasing longevity. Considering the final polish of the tooth surface, patients typically desire a surface that looks more like a natural tooth; therefore, a semi-gloss finish is preferred over a high-gloss or matte finish, which can appear too shiny or too rough, respectively, to the human eye. Different finishing and polishing systems can be used for composites, but not all yield the same result.

This study demonstrated that simply using a clear Mylar matrix strip, which is commonly used for anterior composite placement, yielded a high-gloss finish. This final surface finish is unlikely for any clinical setting as most restorations require some extent of finishing, whether it be to remove excess flash or to blend with the natural tooth due to overfill during placement. This method was only used to determine if any one composite sample stained more or less during their 15 day submersion in coffee. Based on the results, it was determined that all samples went from an initial A1 shade to a final C4 shade, with the exception of one outlying sample of Universal 2. From this, it is concluded that all composites undergo the same amount of staining when submerged in 15 days of staining solution, a simulation of the equivalent of one year of coffee drinking. These values may differ in time intervals, but for the purpose of this study, it can be concluded that all composites, shade based or universal shade, stain the same as one another.

Shade matching using the VITA Classical Shade Guide is achieved by arranging the tabs in alphabetical and numerical order. The shade guide is held directly in front of the patient's tooth at approximately 10-12 inches and an alphabetical shade group is quickly chosen, followed by a numerical value within that shade group. (A1-D4). The "A group" represents red-brown colors, "B group" represents red-yellow color, "C group" represents gray color and "D group" represents red-gray colors. When arranged in value order, the shade tabs are arranged from highest value of B1, A1, B2, D2, A2, C1, C2, D4, A3, D3, B3, A3.5, B4, C3, A4 to C4 having the lowest value of all the shade tabs (Figure 5).

The initial shade for all samples was a high-value, red-brown A1 shade. All final shades were either C4 or D4. C4 represents a gray color hue with the lowest value on the VITA Classical Shade Guide. D4 represents a red-gray color hue represented in the middle of the value ordered shade guide. When the two shades are observed within the value ordered shade guide, we see that D4 represents a more similar value shade to A1 than that of C4. Comparing A, C and D shade groups we see the commonality of the hue, red, shared between A and D, whereas C solely represents the hue, gray. To the dentist, terms such as value, hue and chroma are key to shade matching, but to the lay person, dark and light are more descriptive of tooth shades. Thus, a higher value restoration is more important than a lower value shaded restoration.

Of the samples that were finished and polished with Sof-Lex discs, the Control composite and Universal 1 yielded semi-gloss polishes. These samples yielded a split result in final shade between C4 and D4. The Control yielded six D4 samples and Universal 1 yielded eight D4 samples. Comparing C4 and D4 shades, C4 is the lowest value shade and thus results in the most value change from A1 as it is on the opposite side of the value spectrum of the VITA Classical Shade Guide, whereas the D4 shade is in the middle of the shade guide and is therefore not as noticeable of a stain change from A1.

Of the samples that were finished and polished with the Enhance/PoGo system, Universal 1 was the only composite to yield a semi-gloss finish. The final shade resultant of these samples included four D4 shade samples and six C4 shade samples. While all samples of the Control and Universal 2 yielded matte samples, all yielding C4 final shades.

From the summation of these results, we can conclude that a semi-gloss finish yielded a higher value shade change to D4 over C4 than those of a high-gloss or matte finish which all yielded C4 final shades.

Limitations for this study include being an in vitro simulation versus a clinical prospective study. The disc samples picked up stain accumulation in areas that would be surrounded by tooth structure in a clinical scenario, and therefore may impact final stain results. Hygiene may play an important role in removing stain daily but was not performed as part of this simulation. Future studies should be conducted to evaluate the impact of different staining solutions and conditions on these composites, as well as further examination of other polishing systems.

CHAPTER 5: Conclusions

This study determined that shade-based composites and universal composites stain comparably to one another, and there is no preferable choice when only comparing the degree of staining over a specified period of time. The secondary objective of this study was to evaluate the effect of finishing and polishing systems on the degree of staining. The results of this study showed that a semi-gloss final polish was more likely to yield final shades of D4, which is higher in value than C4 and more closely resembles that of the A1 initial shade.

In comparing universal composites and their outcomes, Universal 1 and Universal 2 yielded very different results in their final polishing outcomes. Universal 1 outperformed with both Sof-Lex and Enhance/PoGo systems, yielding semi-gloss finishes for both and a D4 final shade, whereas Universal 2 remained matte finish for all finishing/polishing systems, therefore yielding a darker value final shade of C4.

Table 1. Finishing and polishing systems resulting finish for each composite system.

	Control	Universal 1	Universal 2
Mylar Matrix Strip	High-Gloss	High-Gloss	High-Gloss
Sof-Lex Discs	Semi-Gloss	Semi-Gloss	Matte
Enhance/PoGo	Matte	Semi-Gloss	Matte

Table 2. Initial shades using shade tabs and spectrophotometer

	Control		Universal 1		Universal 2	
	Shade Tab	Spec.	Shade Tab	Spec.	Shade Tab	Spec.
Mylar Matrix Strip	A1	A1	A1	A1	A1	A1
Sof-Lex Discs	A1	A1	A1	A1	A1	A1
Enhance/PoGo	A1	A1	A1	A1	A1	A1

Figure 1. Samples of high-gloss, semi-gloss and matte finishes (left to right).

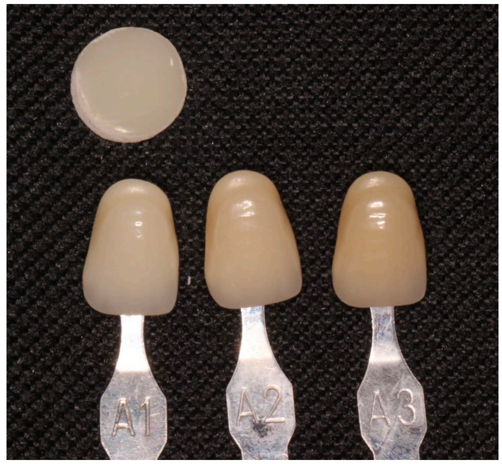

Figure 2. Composite disc comparison to shade tabs for initial measurements.

Figure 3. Easy Shade V spectrophotometer display of initial sample.

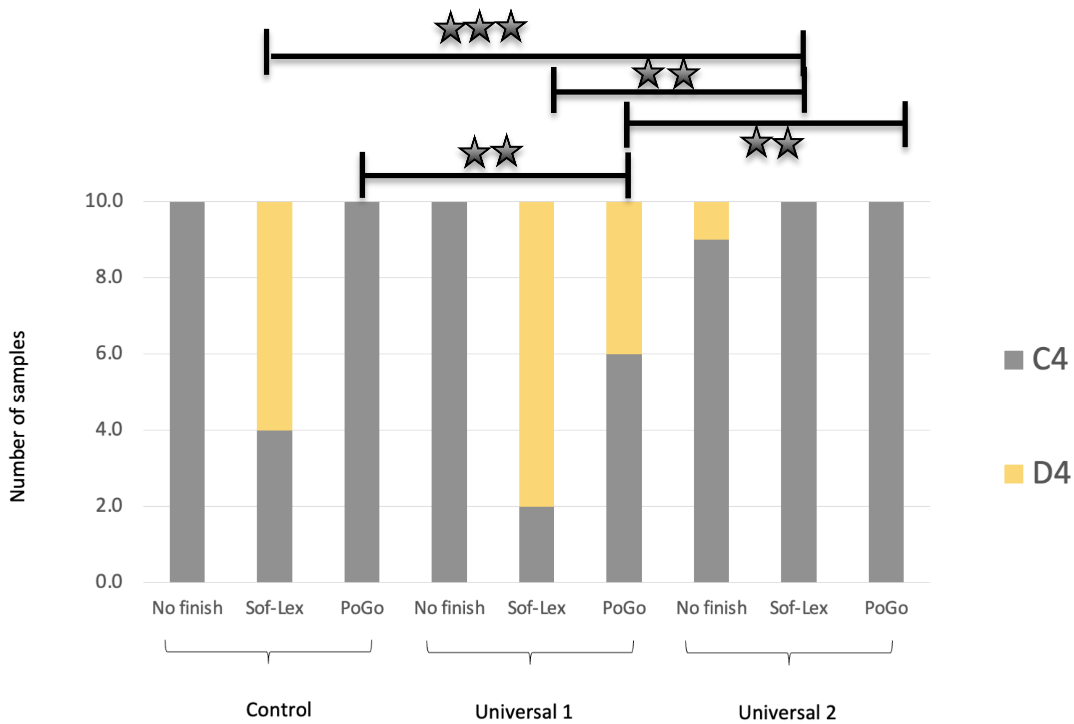

Figure 4. Final shade values. ** denotes $p < 0.01$ and *** denotes $p < 0.001$

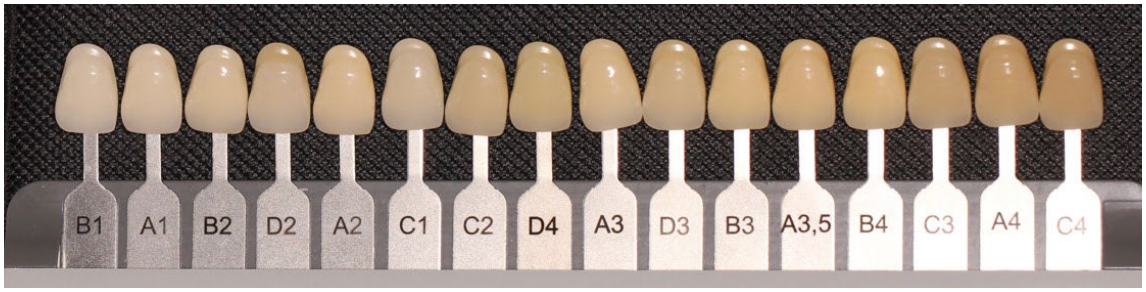

Figure 5. VITA Classical Shade Guide tabs in value order.

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