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Name of Candidate: Donald G. Rice
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Dr. John K. Kreider
PROGRAM DIRECTOR FORT HOOD AEGD-2
Committee Chairperson

14 May 2020

Dr. Drew Krena
DEPARTMENT OF PROSTHODONTICS, FORT HOOD
Committee Member

08 JUNE 2020

COL Stefan S. Olpinski
COMMANDER, US ARMY DENTAL HEALTH ACTIVITY, FORT HOOD
Dean, Fort Hood AEGD-2

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MAJ Donald G. Rice
AEGD-2 Fort Hood
Uniformed Services University
3 June 2020

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Initiator	
1. USU Principal Author (Last, First, Middle Initial)	NORRIS, JESSE, B.
2. Academic Title	RESIDENT
3. School/Department/Center	AEGD-2 PROGRAM, FORT HOOD, TEXAS
4. Phone (512) 650-5462	5. Email jesse.b.norris.mil@mail.mil
6. Clearance	☑ Paper ☐ Article ☐ Book ☐ Presentation ☐ Other
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Name of Candidate: Jesse Benjamin Norris
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Dr. John K. Kreider
PROGRAM DIRECTOR FORT HOOD AEGD-2
Committee Chairperson

14 May 2020

Dr. Drew Krena
DEPARTMENT OF PROSTHODONTICS, FORT HOOD AEGD-2
Committee Member

08 JUNE 2020

COL Stefan S. Olpinski
COMMANDER, US ARMY DENTAL HEALTH ACTIVITY, FORT HOOD
Dean, Fort Hood AEGD-2

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Jesse Benjamin Norris
AEGD-2 program, Fort Hood, Texas
Uniformed Services University
13 May 2020

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POLISHABILITY OF FOUR COMPOSITE CAD/CAM MATERIALS

by

J. Benjamin Norris, DMD

MAJ, DC, USA

and

Donald Rice, DMD

MAJ, DC, USA

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MAJ J. Benjamin Norris and MAJ Donald Rice

Fort Hood 2-year AEGD

Uniformed Services University

15 May 2020

ABSTRACT

Background: A polished restoration surface reduces plaque retention, risks for caries, and periodontal sequelae. The objective of this study was to determine if there are significant differences in the quality of polish that can be achieved among four composite CAD/CAM materials as compared to CAD/CAM lithium disilicate.

Methods: 40 samples were milled using a CAD/CAM milling and grinding unit, and initial roughness was measured using a 3D non-contact profilometer three times per sample. Materials were then polished using a polishing protocol. Final surface roughness was remeasured for each material. Materials evaluated were four kinds of composite CAD/CAM blocks and a lithium disilicate control. Eight samples of each material were assessed.

Results: The obtained area surface roughness measurements (Sa) for each sample group were significantly different except Paradigm MZ100 and Brilliant Crios. The results in micrometers were Grandio 1.29 ± 0.21, Paradigm MZ100 0.97 ± 0.10, Brilliant Crios 0.86 ± 0.16, Shofu 0.65 ± 0.04, e.max 0.43 ± 0.15. Data were analyzed using the Oneway ANOVA followed by Tukey-Kramer Honestly Significant Difference (HSD) tests ($\alpha = .05$).

Conclusions: The results of this study showed the variability in polishability of CAD/CAM composite blocks. After our polish protocol, the Shofu composite achieved the smoothest surface. The Shofu composite performed significantly better than other composites tested. When compared to the e.max control, Shofu was not as smooth, but the polish of Shofu may be adequate for many dental applications. Manufacturer-recommended polishing systems may offer different results then the standardized polishing protocol used in this study. Further studies to determine threshold plaque adherence using Sa (3-dimensional roughness) values may be warranted.

Practical Implications: Dentists may use this study to make sound choices when choosing an appropriate CAD/CAM composite material.

Key Words. Polishability, composites, lithium disilicate, CAD/CAM

INTRODUCTION

Diverse bacterial species are known to cause both caries and periodontal disease. Plaque can harbor microorganisms responsible for caries (e.g., Streptococcus mutans and Lactobacillus) and periodontitis (e.g., Actinobacillus actinomycetemcomitans and Porphyromonas gingivalis).[1] A rough surface can also cause attrition to opposing dentition.[2] A surface roughness above R_a=0.2 µm has been shown to increase bacterial accumulation. Plaque has been shown not to adhere to a surface below a threshold roughness of R_a= 0.2 µm whether it is a supragingingival restoration or subgingival implant-supported abutment.[3]

Since CEREC 1 milled the first feldspathic porcelain block chairside in 1985, there has been an acceleration of innovation in hardware, software, and materials available for use within the dental CAD/CAM industry.[4] CAD/CAM blocks available today include leucite-reinforced ceramics, lithium disilicate ceramics, feldspathic glass ceramics, aluminum-oxide and yttrium tetragonal zirconia polycrystals, and more recently composite resins.[5] Dental ceramics, however, often require additional firings, modification of contacts and staining and/or glazing, reducing productivity.

Composite CAD/CAM materials offer good alternatives to ceramics in many clinical situations. CAD/CAM composites have similar elastic moduli to tooth structure, have good strength, are less brittle, and are less abusive to opposing enamel than their ceramic counterparts.[6] High temperatures and pressures required for indirect fabrication of CAD/CAM composites, result in superior polymerization and offer many advantages such as less porosity and greater wear resistance, and they require less chair time than ceramic CAD/CAM blocks.[7] CAD/CAM composite restorations also offer the advantage of being easily adjusted, polished and repaired.[8]

Finished restorations of all types benefit from polishing. As previously mentioned, restorations attract plaque and pathologic bacteria, which can increase caries risk and potentiate periodontal sequelae.[1,9-10] Finishing is the contouring of a restoration while polishing refers to the reduction of roughness created by the instrument used in the finishing process.[11] There are many ways to finish and polish restorations including carbide and diamond finishing burs, rubber cups and points, and aluminum oxide-coated abrasive disks. Each type of instrument leaves the surface with varying roughness.[12]

In previous studies, surface roughness (Ra) exceeding 0.2 μm has been shown to increase plaque accumulation in vitro. Ra is a two-dimensional average of a surface's microscopic peaks and valleys. Common methods for determining surface roughness in vitro include the use of the profilometer and scanning electron microscope.[5] Newer 3-D non-contact profilometers record three-dimensional roughness, a variable represented by Sa.

The CAD/CAM milling process for ceramic and composite resin blocks roughens the surface.[13] It is then necessary to polish the restoration to avoid plaque adhesion and disease previously mentioned. It is then clinically relevant that the provider examine which materials can be smoothed most effectively to provide the best care for the patient. To date, few studies have been undertaken to compare polishability of various CAD/CAM composite materials with materials known to polish well such as e.max using three-dimensional surface roughness as a means for comparison. This study compares polishabilty of four composite CAD/CAM materials with e.max using a 3-D non-contact profilometer.

MATERIALS AND METHODS

Five materials were evaluated for this study: Four composite CAD/CAM materials and one lithium disilicate control. Lithium disilicate blocks were e.max (Ivoclar Vivadent) while composite blocks studied were the Grandio Bloc (VOCO), Brilliant Crios (COLTENE), Paradigm (3M), and Shofu Block HC (SHOFU). Eight samples were evaluated from each group for a total of 40 samples.

Typodont tooth #8 of an Operative Jaw Model (Nissin) was prepared with a heavy shoulder to allow adequate material for the upcoming polishing process. The prepared typodont tooth was scanned and a crown was designed using a Cerec Omnicam (Dentsply Sirona) using Cerec Software 4.6. 40 CAD/CAM samples were fabricated using a CAD/CAM grinding/milling unit CEREC MC XL (Dentsply Sirona). Eight IPS e.max samples were crystallized in a ceramic oven (Programat P510, Ivoclar Vivadent). A vinyl polysiloxane jig was fabricated using medium-bodied Aquasil Monophase (Dentsply Sirona). Each sample was mounted in the jig and scanned three times with a 3D Laser Scanning Confocal Microscope (VK-X200, Keyence). In groups of four samples per puck, material samples were then placed in a form (Buehler) and immersed in epoxy resin (EpoxiCureTM, Buehler). The pucks of epoxy resin cured for 24 hours before initiating the polishing protocol. The samples embedded in the cured epoxy pucks were then polished by a polishing machine (Ecomet 6 variable speed grinder/polisher, Buehler) using a series of silicon-carbide discs (Buehler) with water cooling. The machine held six pucks while applying 2 pounds of force during the polishing sequence. In groups of six pucks, samples were polished 15 minutes in a clockwise direction followed by 15 minutes in a counterclockwise direction. When changing revolution direction of the polishing machine, a new polishing paper was used. A 400, 600, 800, 1000 and 1200 grit silicon-carbide grinding paper sequence was followed with initial revolutions of 100rpm for the first minute and 180 rpm for the remaining 14 minutes. Each puck was then hand-polished on the same polishing machine in a slurry of polishing powder mixed with water (MicroPolish Alumina 1.0 micrometer, Buehler). After polishing, the specimens were then ultrasonically cleaned in distilled water for five minutes using an Elmasonic P60H (Elma), followed by rinsing with distilled water before measuring surface roughness.

Three-dimensional surface roughness (Sa) of each specimen was then remeasured after completion of the polishing sequence using the same non-contact 3D Laser-Scanning Confocal Profilometer (Keyence). Each of the three samples mounted in the epoxy puck were scanned three times.

RESULTS

Three profilometer readings of each of the 40 samples were taken at baseline and after polishing protocol was complete for a total of 240 readings. Statistical analysis was performed using JMP software (version 13, SAS Institute). Arithmetic average roughness (Sa) and maximum height (Sz) measurements were calculated for each sample. Mean Sa and Sz values were then calculated for each sample group. Surface roughness (Sa) of the polished groups were all significantly different from each other except for the Paradigm MZ 100 and Brilliant Crios blocks. In addition, the Sz of the Grandio Blocs were significantly different from the Shofu block HC group and the e.max group.

The results of the ANOVA test for the baseline of each group showed no significant differences for the Sa or Sz measurements ($p = 0.1053$, $F = 2.074$ for Sa; $p = 0.2329$, $F = 1.468$ for

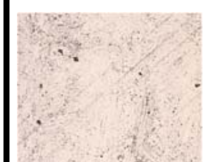
Sz). With both p values greater than 0.05 they are not significantly different. After completion of the polishing the surface roughness was reduced enough between the groups to become significant. After completion of the polishing protocol, surface roughness measurements were evaluated with the ANOVA and Tukey-Kramer tests utilizing statistical software (JMP, version 13, SAS) which revealed significant differences between the test groups. The Sa of the polished samples resulted in $p < 0.0001$ and $F = 40.8392$ showing their statistical significance. The Tukey-Kramer HSD test comparing the different sample groups with an $\alpha = 0.05$ revealed significant differences between each of the sample groups except the Paradigm MZ100 and the Brilliant Crios. (Table 1). The Sz of the polished samples was significantly different for the Grandio Blocs compared to the Shofu block HC and the e.max block sample groups. The Sz sample groups of Brilliant Crios and Paradigm Mz 100 were not significantly different from the Grandio blocs, Shofu block HC, or the e.Max sample groups. (Table 1).

Table 1. Means and standard deviation of surface roughness (Sa and Sz) for each group

	Mean	Sa µm		Sz µm		SD	Sa µm		Sz µm	
		Baseline	Polished	Baseline	Polished		Baseline	Polished	Baseline	Polished
Grandio Blocs	G	6.76	1.29	62.35	18.15	G	2.05	0.21	15.13	6.99
eMax CAD	E	6.91	0.43	68.77	7.27	E	0.92	0.15	5.17	3.76
Shofu Block HC	S	7.01	0.65	61.40	8.26	S	1.63	0.04	8.76	0.76
Brilliant Crios	B	7.58	0.86	69.30	12.48	B	1.08	0.16	7.37	4.76
Paradigm MZ100	P	8.93	0.97	74.08	12.23	P	2.52	0.10	19.28	2.93

Profilometer images show surface topography before and after the polishing sequence. Baseline images (Fig. 1) are prior to polishing which show the surface texture with each sample group's irregularities, scratches, and roughness as a result of the milling process with the CAD/CAM diamond burs. Images after polishing (Fig. 1) show a smooth homogeneous surface with minimal surface irregularities. The null hypothesis of the study assumes there are no differences in surface polishability between groups. Significant differences in polishability between material groups reject this null hypothesis. The surfaces of the samples in the images (Fig. 1) show the variability in surface roughness. Each sample type represented shows unique surface irregularities with shallow scratches and pores.

Figure 1. Images from non-contact 3-D profilometer

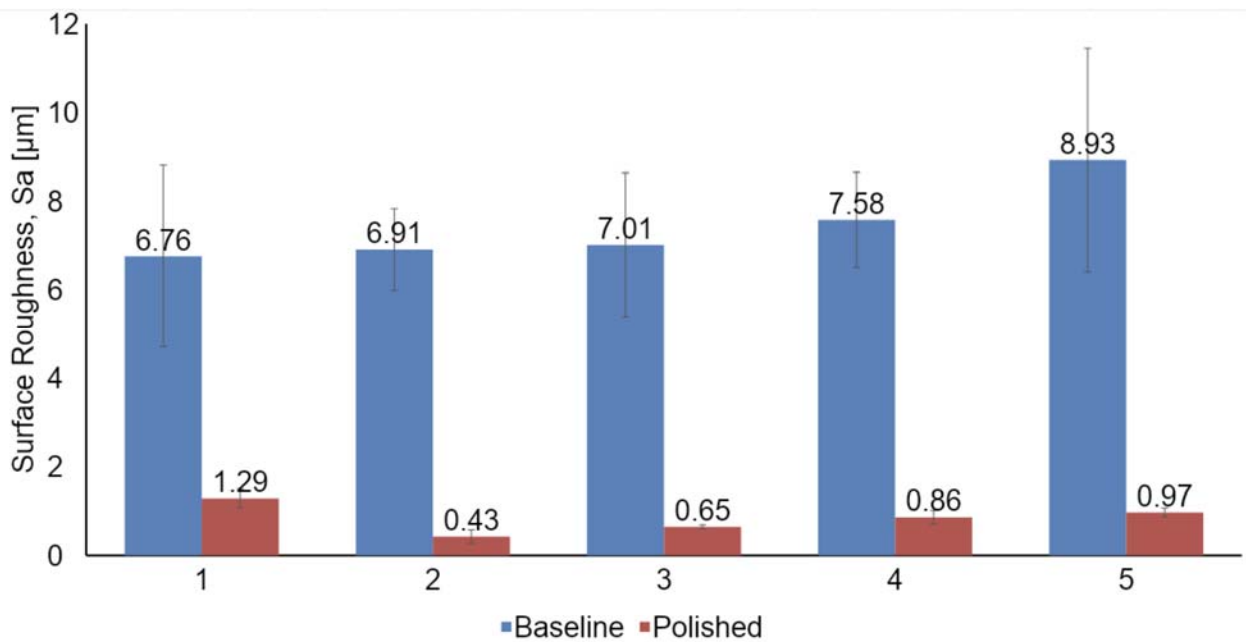
	E.max	**Grandio Blocs**	**Shofu Block**	**Brilliant Crios**	**Paradigm**
Baseline					
Polished					

Discussion:

When replacing missing or decayed tooth structure the choice of material is an important one. Material selection must not only take into account strength and esthetics, but also polishability. The purpose of this study was to determine if there is a significant difference in polishability between four composite CAD/CAM blocks when compared to lithium disilicate CAD/CAM blocks. After statistical analysis, the Sa and Sz values were significantly different. Therefore, the null hypothesis for this study was rejected.

The results of this study demonstrated that the polishability of the composite CAD/CAM blocks were significantly different. It showed that the Sa of e.max acting as a control, had the lowest surface roughness followed by the Shofu Block HC, Brilliant Crios, Paradigm MZ100, and Grandio in increasing roughness. (Graph 1).

Table 2. 1 = Grandio, 2 = e.Max, 3 = Shofu block HC, 4 = Brilliant Crios, 5 = Paradigm MZ100



In previous studies the Ra value of 0.2µm was determined to be the threshold surface roughness for bacterial retention.[1] This threshold is important because there is no plaque accumulation below 0.2µm surface roughness. The importance of minimizing the surface roughness will prevent plaque accumulation, retention of bacteria, staining of restorations, recurrent decay, periodontal inflammation, and excess wear on opposing dentition. [1,14-16] In Bollen et al 1997 they concluded that each dental material needed its own treatment modality to obtain and maintain the smoothest possible surface. This study recognizes the significance of that statement however for study purposes a single polishing system was employed to determine polishability of composite CAD/CAM blocks.

Each Composite block recommended different polishing protocols. Grandio blocks and Brilliant Crios blocks recommend standard non-specific composite polishers.[17, 18] However, 3M-Paradigm MZ100 recommend 3M ESPE's Sof-Lex™ discs and strips for polishing and Shofu block HC recommend Ceramaster polishers, DURA Polish, and DURA Polish Dia.[19, 20] The polishing protocol used in this study attempted to eliminate the confounding influence of multiple polishing systems and focus on the comparable surface roughness of the materials themselves with one polishing protocol.

Lithium disilicate (e.max), functioned as our control. Studies of lithium disilicate have obtained Ra values between 0.046 and 0.29µm with varying polishing protocols.[21, 22] The known Ra of e.max then acts as a reference point. Although not an exact scale, it does allow us to see how the composites compare. Previous studies used Ra values (2-D roughness) due to limitations in equipment available at the time.

Table 3. CAD/CAM Composites

	Fillers	Polymer	Manufac-turer
Grandio Blocs	86% Nanohybrid fillers	14% UDMA+DMA	VOCO
Brilliant Crios	70% Glass and amorphous silica	Bis-GMA, Bis-EMA+TEGDMA	COLTENE
Paradigm MZ100	85% ultrafine zirconia-silica ceramic particles	Bis-GMA+TEGDMA	3M
Shofu Block HC	61% Zirconia silicate nano-filler	UDMA+TEGDMA	SHOFU

Our study uses Sa values taken from a 3-D non-contact profilometer. Sa values are always higher than their counterpart Ra in part because of the 3-dimensional nature of roughness and accuracy of the newer equipment. E.max, however, still serves as a benchmark for polishability and so we sought to compare to this example using 3-dimensional roughness.

In the study by de Oliveir et al. 2012, they evaluated the impact of filler size on roughness after toothbrush abrasion. They were able to conclude from their study that the roughness of the material correlates to the filler size and distribution. The nanofilled systems performed better than the microhybrid and conventional organic matrix composites.[23] Their findings can help us understand the results from this study. Of the composite materials, Shofu HC had the smoothest surface roughness measurements using a zirconia silicate nanofiller. The Brilliant Crios and Paradigm MZ100 blocks were not significantly different from each other. They had glass and amorphous silica, and ultrafine zirconia-silica ceramic particle fillers respectively. (Table 3). The ultrafine zirconia-silica particles in Paradigm MZ100 have an average particle size of 0.6 micrometers or 600nm.[21] The Brilliant Crios uses a filler of barium glass measuring <1.0micrometer and silica measuring <20nm.[20] The Grandio blocks had the roughest surface measurement and are composed of a nanohybrid filler. According to Mota EG et al. 2012 and their study of inorganic particles in composite nanofilled resins, Grandio measured at 2.05 and 3.10 micrometers for enamel and dentin shades, respectively. With the increase in filler size the surface roughness also increased.[24] This is a possible explanation for the variety of significant differences that we measured within the study.

Conclusion:

Within the limitations of this study, the evaluation of polishability of the composite CAD/CAM blocks resulted with significantly different 3-D profilometric surface roughness readings. Roughness measurements (Sa) from smoothest to roughest were e.Max, Shofu, Brilliant, Paradigm MZ100, and Grandio. Each sample group was statistically significantly different from the others except the Brilliant and Paradigm MZ100 groups. Studies have noted the importance of different recommended polishing protocols for different dental materials.[1,25] Further study for these materials could compare using manufacturer-recommended polishing methods. A comparison of surface roughness when the load volume of filler particles varies would also, be worth studying. It is also important to note that previous studies used a threshold roughness of 0.2 μm using a 2-dimensional profilometer measurement. This study was undertaken using a 3-D profilometer which will typically have higher measurements then its 2-D counterpart. New studies could focus on determination of threshold roughness of plaque adherence using 3-dimensional measurements which would make the results of this study more meaningful.

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