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STRESS TESTING OF 3D PRINTED VARSEOSMILE CROWN PLUS RESIN

A manuscript

Presented to the Faculty of the Advanced Education in General Dentistry, Two-Year Program,

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And the Uniformed Services University of the Health Sciences—Post Graduate Dental College

In Partial Fulfillment of the Requirements for the Degree of

Master of Science in Oral Biology

By

Robert Van Wagenen, CPT(P), DC, USA

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DISCLAIMER

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DEDICATION

Before I begin, I'd like to dedicate this research to my co-residents who contributed overwhelmingly to this project with their constant support and motivation. I hope to one day repay their kindness, even though they offered me their help while asking zero favors in return. The assistance my residency class has given to me has earned them my respect and admiration.

ABSTRACT

Stress Testing of 3D Printed VarseoSmile Crown Plus Resin

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Objective: To measure the flexural strength and flexural modulus of VarseoSmile Crown Plus Resin to evaluate suitability of the material as a permanent full-coverage dental restoration.

Method and Materials: A Formlabs 3D printer was used to fabricate 30 bars of VarseoSmile Crown Plus Resin sized 15 x 4 x 2 mm. Samples were then subjected to a three-point flexural test and the resulting stress-strain values were used to calculate flexural strength and flexural modulus. These values were compared to published values of other similar CAD/CAM milled materials[7] and to ISO 6872:2015[8] to determine indications for clinical use.

Results: The mean flexural strength of the 3D printed samples was measured at 106.67 MPa and the mean flexural modulus was 5,376.08 MPa.

Conclusions: The 3D printed samples had lower flexural strength compared to IPS Empress CAD, but greater strength when compared to Vitablocs Mark II. No difference was noted between the 3D printed samples and published values for Paradigm C in terms of flexural strength. The mean flexural modulus of the 3D printed samples was found to be significantly higher than reported by the manufacturer[1] however and lower compared to IPS Empress CAD, Paradigm C, and Vitablocs Mark II.

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BACKGROUND

With the advent of affordable 3D printing, there is a shift from subtractive to additive manufacturing in many fields and dentistry is no exception. Additive manufacturing promises greater material efficiency and less waste. 3D printing has been successfully applied to many aspects of dentistry including fabrication of mouthguards, surgical guides, diagnostic and working casts, temporary restorations, and removable dentures. 3D printable resin hybrid crowns are being introduced to the market and advertised as permanent restorations and internal studies show material properties consistent with requirements for clinical use[1], but little independent research is available to support their use. One such material is VarseoSmile Crown Plus, a Ceramic Filled Hybrid 3D Resin from BEGO Bremer Goldschlägerei Wilhelm Herbst (BEGO).

These new materials need to be evaluated for clinical effectiveness and financial and operational practicality before implementation in US Army dental clinics. Changing from milling to 3D printing permanent fixed dental restorations could save significant time and money for US Army dental clinics and dental labs in many areas including the following:

1) Lower equipment costs
2) Less equipment maintenance
3) Lower material costs
4) Faster post-processing time
5) Less lab space
6) Superior portability of equipment

However, previous resin hybrid crowns have had unpredictable results when used as full-coverage restorations, particularly in posterior regions of the mouth. One noteworthy instance was the removal of the full coverage crown indication from 3M's Lava Ultimate in 2015 after the product struggled with frequent debonding.[2]

Assessing a material's suitability as a permanent prosthesis involves many different characteristics. Interest in 3D printing dental restorations is obvious from the volume of studies being published on the subject. Other authors have studied the dimensional accuracy and color stability of 3D printed restorative materials compared to milled materials. Tahayeri et al[3], when evaluating a temporary crown resin, measured the fidelity of 3D printed bars to infer accuracy of the fit of 3D printed restorations. He also measured elastic modulus and peak stress and concluded that, though there were discrepancies in printing accuracy, the material had adequate physical properties for clinical use.[3] Shin et al[4] compared color stability of two different 3D printed resins against three CAD/CAM blocks and found that the 3D printed materials stained significantly worse than the milled materials.

This study will measure flexural strength and flexural modulus of VarseoSmile Crown Plus Resin to allow for comparison with milled resin hybrid materials currently available on the market.

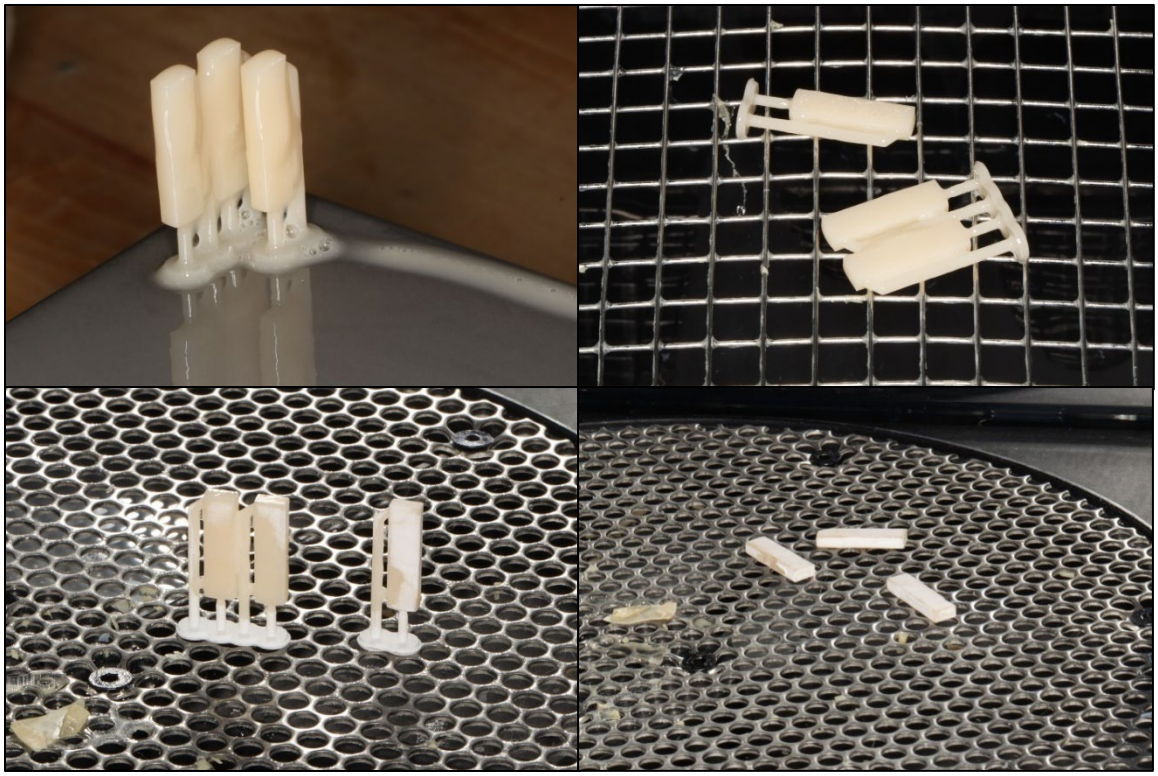
METHOD AND MATERIALS

Sample preparation

Samples of VarseoSmile Crown Plus Resin sized 15mm x 4mm x 2mm were 3D printed from an STL file using a Formlabs Form 3B+ printer using a stainless steel build platform. Post-processing was performed according to Formlabs specifications,[5-6] consisting of the following steps:

1) Isopropyl alcohol solvent rinse in Formlabs Form Wash for 3 minutes
2) Cure in a Formlabs Form Cure appliance (405nm) for 20 minutes at 60 °C
3) Removal of supports
4) Cure in a Formlabs Form Cure appliance (405nm) for 20 minutes at 60 °C

Following post-processing, samples were measured in all three dimensions using a Mitotoyo Absolute AOS Digimatic digital caliper, accurate to 0.01 mm. Initially, 40 samples were fabricated and the 10 with the greatest dimensional variability were excluded. Fine adjustments were made to the remaining 30 samples until all were within 0.05 mm of target size in each dimension.



Figures 1-4. Samples after 3D printing, alcohol bath, first cure, and second cure.

Data collection

Samples were subjected to a three-point flexural test using a MTS858 Mini Bionix II tensiometer. Load was applied at a rate of 1.0 millimeters per minute until failure.

Flexural strength and flexural modulus

Force at failure was determined by locating the point of greatest force applied to the sample immediately before the applied force dropped, indicating failure of the material. Flexural strength was calculated by the equation:

$$\sigma = 3FL / 2bd^2$$

where F is axial load (force), L is length of the sample, b is width, and d is depth.

Deflection at time of sample failure was determined by noting the point at which stress measured by the tensiometer returned to baseline. Flexural modulus was calculated by the equation:

$$E = (\sigma 2 - \sigma 1) / (\varepsilon 2 - \varepsilon 1)$$

where stress (σ) is force divided by the specimen's cross-sectional area and strain (ε) is the change in length of the material divided by the material's original gauge length.

Comparison of data

Flexural strength and flexural modulus of the VarseoSmile Crown Plus Resin samples were compared to the flexural strengths and flexural moduli of IPS Empress CAD, Vitablocs Mark II, and Paradigm C, as published in *Measurement of select physical and mechanical properties of 3 machinable ceramic materials*.[7]

Material	Flexural Strength	Flexural Modulus
IPS Empress CAD	125.10 ±13.05	16.10 ± 5.94
Vitablocs Mark II	102.77 ± 3.60	8.65 ± 2.24
Paradigm C	109.14 ±10.10	9.09 ± 2.96

Table 1. Flexural strength and flexural modulus of comparison materials.

Statistical analysis

Data were screened for normality using the Shapiro–Wilk statistic. Consequently, measures of central tendency and dispersion are reported as means with associated standard deviations. One-sample T tests were used to assess potential differences between samples of 3D printed VarseoSmile crown plus resin and reported values for IPS Empress CAD, Paradigm C, and Vitablocs Mark II with respect to flexural strength and flexural modulus. A value of $P < 0.05$ was considered significant for all tests. All data were analyzed with the IBM SPSS version 25 (IBM Corporation, Armonk NY, USA).

RESULTS

A total of 30 assessed samples were included in this study.

Flexural strength

The mean flexural strength of the 3D printed samples was measured at 106.67 MPa (SD = 17.48) and the mean flexural modulus was 5,376.08 (SD = 518.89). Analysis results indicate the 3D printed samples had lower flexural strength compared to IPS Empress CAD, but greater strength when compared to Vitablocs Mark II, both $P < 0.001$. No difference was noted between the 3D printed samples and published values for Paradigm C in terms of flexural strength, $P = 0.91$.

Flexural modulus

The mean flexural modulus of the 3D printed samples was found to be significantly higher than reported by the manufacturer (4,090)[1] whilst significantly lower compared to IPS Empress CAD (16,100), Paradigm C (9,090), and Vitablocs Mark II (8,650), all $P < 0.001$.

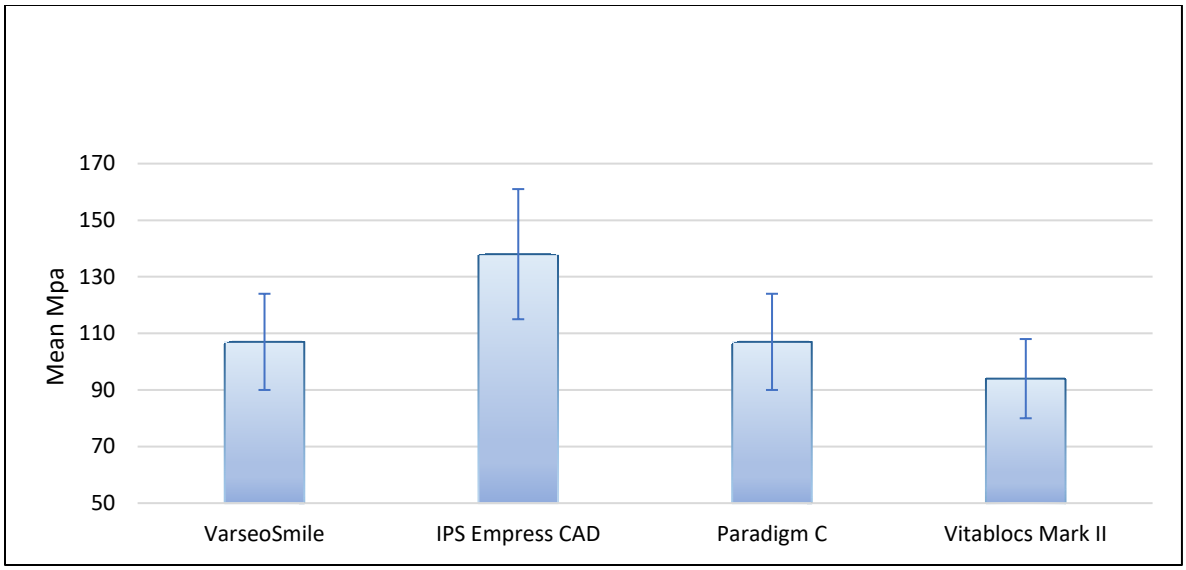


Figure 5. Mean Flexural Strength by Material Type.

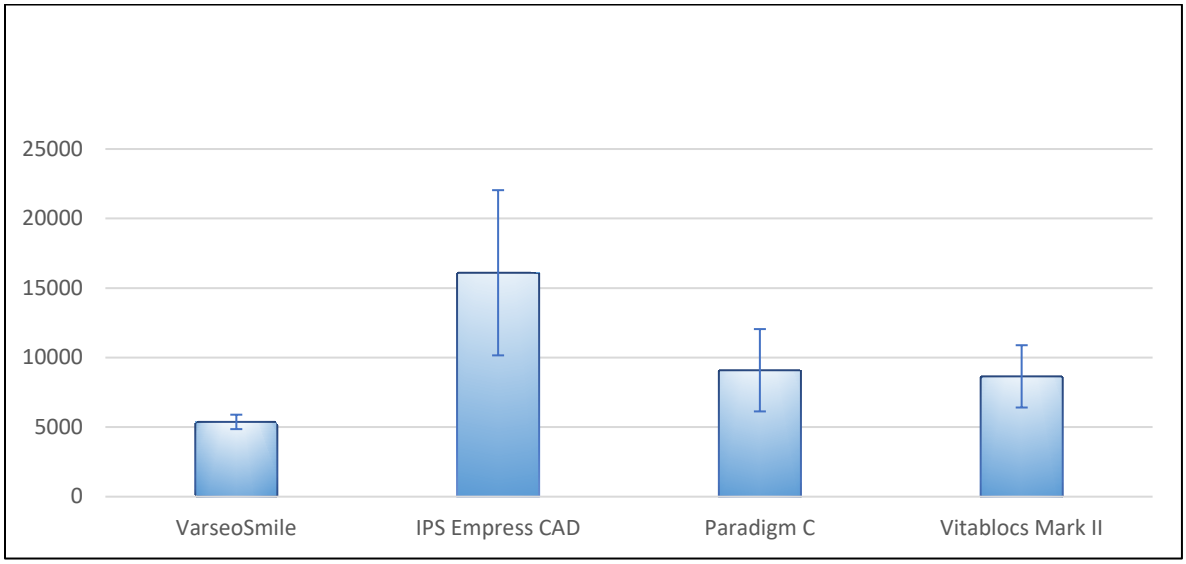


Figure 6. Mean Flexural Modulus by Material Type.

DISCUSSION

Corporations are constantly releasing new products to tap into the $172 billion dollar industry of dentistry in the United States. In the rapidly advancing field of dental materials, new products promise superior longevity, efficiency, and economics. Amid this constant barrage of new materials, pressures on individual practice owners seeking

to select materials for their clinics include overhead, dental school debt, environmental concerns, and perhaps most importantly ethical obligation to provide the best possible care to their patients. Properly testing and vetting new materials is an important part of evidence-based dentistry, which allows dental providers to select materials that fulfill the needs of their practices and patients as well as their own needs. The purpose of this study was to assess two important material properties of the newly-released VarseoSmile Crown Plus Resin to compare it to other similar materials and to determine suitability for use as a full-coverage permanent restoration as outlined by ISO 6872:2015.[8] The flexural strength of VarseoSmile Crown Plus Resin as found in this study (107 MPa) is slightly lower than the range claimed by the manufacturer (116-150 MPa).[1]

According to ISO 6872:2015[8], VarseoSmile Crown Plus Resin fulfills the flexural strength requirement of a Class II ceramic with the following indications:

1) Monolithic ceramic for single-unit anterior prostheses, veneers, inlays, or onlays adhesively cemented.
2) Partially or fully covered substructure ceramic for single-unit anterior or posterior prostheses adhesively cemented.

These clinical indication recommendations are based on the finding that VarseoSmile Crown Plus Resin exhibits a flexural strength over 100 MPa, but less than 300 MPa. In other resin-bonded Class II ceramics, additional strength is gained through bonding. A future study could investigate the changes in material properties between bonded and luted restorations.

The flexural modulus measured (5,376) was considerably higher than the modulus of elasticity claimed by the manufacturer (4,090),[1] though differences between

flexural modulus and modulus of elasticity are possible in some materials. Higher flexural modulus indicates a more rigid material, which could result in fewer incidences of debonding.

Limitations

In addition to flexural strength, chemical solubility is a factor in determining clinical indications for this type of material. Because this property was not measured in this study, an additional study on chemical solubility will be needed.

Due to limitations in accuracy of 3D printing with the Formlabs Form 3B+ printer, polishing of the samples was needed to achieve acceptable dimensional accuracy. This step could potentially have altered the physical characteristics of the material to some degree.

Comparison of the flexural modulus of the material in this study to elastic modulus as reported by the manufacturer is not a perfect comparison. Though the values should be identical in theory, some materials have exhibited differences between flexural modulus and modulus of elasticity.

CONCLUSIONS

The 3D printed samples indubitably had lower flexural strength compared to IPS Empress CAD, but greater strength when compared to Vitablocs Mark II. No difference was noted between the 3D printed samples and published values for Paradigm C in terms of flexural strength. The mean flexural modulus of the 3D printed samples was found to be significantly higher than reported by the manufacturer, however, and lower compared to IPS Empress CAD, Paradigm C, and Vitablocs Mark II. Applying this 3D printed resin to military dentistry could result in lower costs, smaller operational footprint,

and a reduction in refractory sick call patients presenting with fractured temporary crowns.

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