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3D-Printed Dental Restorations: Present Challenges and Emerging Promise

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INTRODUCTION:

With the floodgates open for dozens of 3D-printed resins being marketed for use in full-coverage crowns and even bridges, there is a lot of concern in the scientific community that these materials are being used inappropriately and without significant clinical data proving efficacy. There is also the concern that insufficient testing has been conducted for each product on the market with aging studies or by independent parties, which can lead to a higher probability of quality control issues for products on the market. There is a huge spectrum of properties, filler content, and resin types within these products, which will have an impact on their performance in the oral environment, which can lead to fractures, debonding, and an increase in surface roughness, which increases microbial attachment compared to other ceramic options available.

DENTAL ADVISOR has conducted several testing projects this year examining the In Vitro performance of some of the products on the market in an effort to understand how these products fit into the prosthodontic landscape of restorative options. A few of the definitive resin ceramics we examined include ***Rodin Sculpture 2.0*** (Pac-Dent), which reportedly includes up to 60% filler by weight. Increasing filler content is a direction that the manufacturers of these products are striving toward in an attempt to bridge the gap between other ceramics with higher strength and increased stiffness and resin ceramics, which tend to be weaker and more flexible. We also examined ***VarseoSmile TriniQ*** (Bego), which was the first additively manufactured resin indicated for 3-unit bridges and ***Pro Resins Crown X*** (Straumann).



Asiga Max 2 printer

First, we'll look at the spectrum of physical properties as it relates to resin ceramics indicated for definitive restorations.

Flexural Strength is the force that a material can withstand as it bends, which creates tensile stresses on the underside of the material. During chewing, the complex bending that occurs in the restoration leads to tensile forces on the bottom of the restoration, and this is usually where cracks will form, as the tensile strength of most materials is lower than their compressive strength. The flexural strength relates to how thin a material can be made for a restoration, as stronger materials can be made thinner without fracturing under maximum chewing forces.

Flexural Modulus is an important property that relates to the stiffness of the material. How the modulus of the restoration matches the underlying dentin is an important factor in how a restoration can ultimately fail, by how it stresses the bonding interface or underlying tooth structure. For reference, human enamel modulus ranges from ~75-100 GPa, and human dentin ranges from ~15-25 GPa. As a general rule, for considering how to design restorations, and materials; minimizing stresses from concentrating in any one spot can help prevent failures, as fractures tend to form at the weakest link in a system.

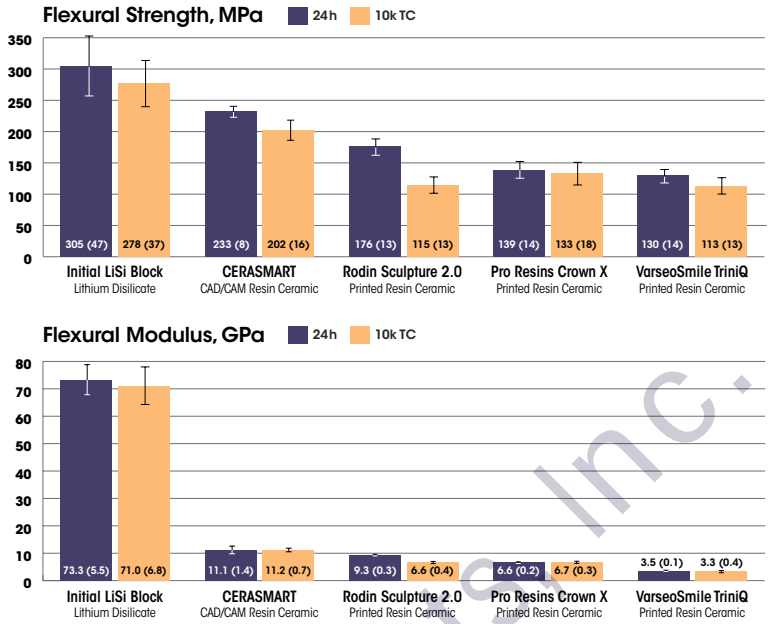
High-modulus ceramics such as zirconia (>200 GPa) are stiff and absorb the forces from chewing in the restoration without deforming, which compresses the cement layer and bonding interface while the dentin underneath flexes. The relative mismatch in modulus is one of the factors that leads to debonds, as the cement interface can take the brunt of the stresses that concentrate on a relatively small area.

CAD/CAM Resin ceramics have a modulus that is usually 10-18 GPa, which can be similar to dentin. Matching the modulus of the restoration to dentin causes stress from chewing to distribute as evenly as possible, which allows the restoration and underlying dentin to flex together as a single unit.

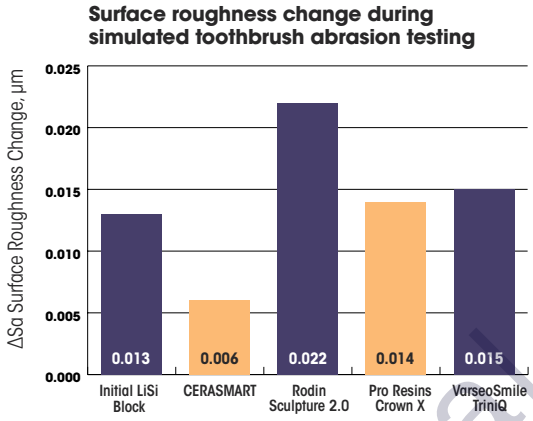
The advent of additively manufactured resin ceramics has brought to market some products with very low modulus materials <4 GPa, which are even lower modulus than flowable direct composites. The difference with these products is that they deform significantly more than dentin, and this causes increased stress at the margins as the crown tries to fold on itself, which may cause marginal debonds leading to microleakage. Also, while the flexible restoration absorbs more of the stress, the chewing stresses which are transferred are less evenly distributed to the underlying dentin, which can cause stress concentration during peak chewing forces. These materials may also be subject to increased cyclic fatigue as they deform more per chewing cycle and will rely on the stability of their resin to prevent developing micro-cracks over time as they deform thousands of times a day. It remains to be seen with clinical data what the efficacy of these restorations will be, as there is a tradeoff in protecting tooth fractures by the crown breaking more easily at the risk of increased crown fractures and potential microleakage leading to secondary caries.

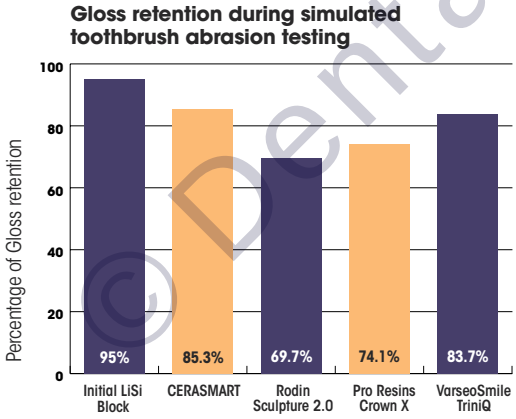
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We performed over 200 flexural strength tests in 3-point bend with artificial aging to simulate approximately a year of water exposure and cold-hot stress cycles. 3D-printed specimens were made according to manufacturer instructions with ***Asiga Max 2*** printers. As expected in our testing, the CAD/CAM version of the resin ceramic ***CERASMART*** has higher strength and modulus than the printed resin ceramics, with significant differences in the properties of the printed resin ceramics. One of the printed resins with the highest filler load had the largest decrease in flexural strength and modulus after artificial aging, indicating an issue with a buildup of stress and hydrolytic degradation leading to a weaker resin matrix. A higher filler load and more complete polymerization of CAD/CAM laboratory-made resin ceramic blocks are possible compared to additively manufactured resin ceramics, as the high heat and pressure used during the formation of the blocks lead to higher polymerization and they are not limited to the extrusion of the material during printing, allowing a higher inorganic filler content.



Next, we'll look at the resistance of these materials to simulated toothbrush abrasion and how it relates to long-term gloss retention and surface roughness changes. Materials were subjected to 5 years of simulated toothbrush abrasion, and surface roughness (Sa) was characterized with a high-resolution laser confocal microscope (VK-X1000 Series, KEYENCE) and change in gloss was measured with a spectrophotometer (CI7600, X-Rite).





CERASMART again had significantly less surface roughness change compared to the additively manufactured resins, while the Initial ***LISI Block*** had the best gloss retention. The ***VareoSmile TriniQ*** had the highest gloss retention among the 3D-printed resin ceramics. Similar to the strength testing above, ***Rodin Sculpture 2.0***, despite having the highest filler content of the 3D printed materials tested, had the biggest deleterious effect from toothbrush abrasion. Continued testing of this new class of materials will be ongoing throughout the scientific community as well as at DENTAL ADVISOR testing centers.

DENTURE BASE RESINS

Additively manufactured denture materials are also on the rise, as the ability to quickly produce new dentures as they break is a great advantage for patients and clinicians. We performed some testing comparing several 3D-printed denture base resins to a CAD/CAM PMMA resin to see the differences in performance.

There are ISO 20795 requirements for strength and modulus for materials used as a denture base, and the first test we performed was to compare the materials to those requirements. Of the 4 materials we tested, only the ***Aidite Pink Denture PMMA*** and ***Lucitone Digital Denture Print*** from Dentsply had over the 65 MPa requirement for flexural strength in this standard.

A key provision of the testing to ISO 20795 requirements is that the actual flexural strength test needs to be conducted while immersed in water compared to most flexural strength testing in other areas that is conducted while dry. One of the printed resins had dry strength before water immersion of 87 MPa, which is similar to the value listed on the product technical specification sheet. However, after 50 hours of water immersion, that strength dropped to 50 MPa while tested dry, indicating a weakening of the resin due to water sorption. When tested after 50 hours of water immersion and tested while under water, this dropped further to 19 MPa, far below the ISO requirements. ***Lucitone***, in contrast, had a strength of 98 MPa after 50 hours of water immersion tested in the dry condition, which still dropped to 72 MPa when tested wet.

Stain Resistance testing in coffee and tea also showed the CAD/CAM PMMA material having significantly less color change than the 3D-printed materials, with Lucitone having the smallest overall change for the 3D-printed materials. This data will be presented at the 2026 IADR/AADOCR/CADR conference..

Final Thoughts: Whenever a new class of dental material comes to market, there is a rapid growth in development and improvement for each generation. 3D printed material restoratives are already showing extraordinary increases in strength, accuracy, esthetics and wear resistance within the last several years, but they still behind their CAD/CAM resin ceramic and traditional ceramic counterparts in most performance categories. We are cautiously optimistic that as these materials mature, they will be a useful component of the restorative playbook as the cost effectiveness of their use is likely to be unmatched by other restorative options. As it stands, these materials blur the line between long term provisionals and definitive restorations, with a large spectrum of performance even among similar 3D printed materials.

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