3D PRINTED CERAMIC CROWN

SCIENTIFIC STUDIES SUMMARY

SprintRay Ceramic Crown has undergone the following studies:

- Fracture Load and Abrasion Resistance
- Occlusal Wall Thickness Effect on Fracture Load
- Chewing Simulation Abrasion Resistance
- Bonding Strength with Luting Composite
- Shear Bond Strength Luting Workflow Comparison

CONTENTS

3D Printed Crowns 2
SprintRay Ceramic Crown 3
Fracture Load with 10 Year Chewing Simulation 4
Abrasion Resistance with 10 Year Chewing Simulation 7
Occlusal Wall Thickness Effect on Fracture Load 9
Bonding Strength with Luting Composite 11
Shear Bond Strength Luting Workflow Comparison 13
Additional References 15

3D PRINTED CROWNS

Composite Technology Advancement

Materials science has been integral to dentistry since the formation of the profession. Since the introduction of composite materials in the 1960s, professionals across the industry have sought to improve the quality and patient experience for indirect restorations.[1]

The introduction of next-generation composite materials in the 1990s brought a breakthrough in the form of dominant ceramic composites. These new materials used fine refractory fillers to improve the mechanical characteristics of the composite, creating indirect restorations that were incredibly long-lasting and aesthetic.[2]

Early Chairside Fabrication

With composite materials sufficiently strong and aesthetic, many dental clinics were interested in providing same-day restorations. The benefits were clear: an improved patient experience, good ROI on the equipment, and huge time savings.

CEREC by Dentsply Sirona, pioneered early in-office milling and digital imaging, creating a commercially viable system for scanning, designing, and milling definitive restorations out of composite blocks. This system introduced a new way to deliver high-quality indirect restorations to patients, raising the standard of care and providing clinics with newfound flexibility.[3]

3D Printing Reaches Maturity

Stereolithographic 3D printing, which uses liquid resin and a high-frequency light source to build 3D objects, experienced two major breakthroughs in the early twenty-teens. First, they achieved a desktop form factor, meaning they could be placed in any office. Second, the FDA tested and cleared the materials for intraoral use.[4]

These two developments, combined with the outstanding accuracy of the technology, created a new technology vector for dentistry. As the technology improved, companies like SprintRay created full-workflow solutions that covered every aspect of in-office 3D printing, from design services to denture production. 3D printing brought solutions across myriad treatment types but was material-limited when it came to composite restorations.

---

1 – O'Brien WJ. Dental materials and their selection. 3rd ed. Chicago: Quintessence; 2002.

2 – Kahler B, Kotousov A, Swain MV. On the design of dental resin-based composites: a micromechanical approach. Acta Biomaterialia 2008;4:165–72.

3 – Fasbinder DJ. The CEREC system. The Journal of the American Dental Association. 2010;141:3S-4S.

4 – Anadioti E, Kane B, Soulas E. Current and emerging applications of 3D printing in restorative dentistry. Curr Oral Health Rep. 2018;5(2):133-139.

Ceramics Unlock Restorative 3D Printing

In 2021, SprintRay released OnX, a revolutionary 3D printing material that used inorganic refractory compounds to achieve a dominant ceramic formulation. This material was first indicated for denture teeth, but it was clear that 3D printing was coming to restorative dentistry.

In late 2022, the American Dental Association announced that the CDT code for ceramic restorations would be amended by removing the language around fabrication methods. In 2023 and beyond, 3D printed crowns formulated with predominantly ceramic can be qualified for reimbursement as a full ceramic restoration.

SPRINTRAY CERAMIC CROWN

SprintRay Ceramic Crown is the first ceramic dominant 3D printing resin designed as part of a comprehensive chairside restoration ecosystem. It is designed for use in tandem with the groundbreaking Crown Kit, a compact 3D printing build platform and resin tank system designed to fabricate multiple restoration types in 10–15 minutes. It addresses the updated definition of ceramic with its ceramic-dominant formulation and is FDA-cleared for placement as definitive single-unit crowns, inlays, onlays and veneers.

Ceramic Crown has been studied by renowned institutions worldwide to prove its excellent mechanical properties and efficacy as a definitive restoration.

SprintRay Ceramic Crown has undergone the following studies:

- Fracture Load and Abrasion Resistance
- Occlusal Wall Thickness Effect on Fracture Load
- Chewing Simulation Abrasion Resistance
- Bonding Strength with Luting Composite
- Shear Bond Strength Luting Workflow Comparison

SprintRay Ceramic Crown Technical Data

Density	1.6 - 1.7 g/cm^3
Viscosity	2,500–6,000 mPa·s at 30°C
Flexural Strength	150 ± 25 MPa
Flexural Modulus	7,800 ± 500 MPa
Hardness	82 Shore D
Water Solubility	2.16 ± 1.30 µg/mm^3
Water Uptake	17.35 ± 2.56 µg/mm^3
Layer Thickness	100 µm and 50 µm
Cytotoxicity / Biocompatibility	Passes DIN EN ISO 10993-3, -5, -10, and -11

Ceramic Crown Chemical Composition

This innovative material is composed of methacrylate monomers and oligomers, acrylic monomers, photoinitiators, and inorganic fillers; with a total content of inorganic fillers exceeding 50% by mass. The goal in developing this resin was to create a hard, strong material that mimics the mechanical performance of surrounding dentition. The high ceramic content provides strength and hardness, while the polymer matrix establishes durability and shock absorption. This unique combination of properties ensures excellent performance in fracture resistance, polishability, and fabrication efficiency.

SprintRay Ceramic Crown is designed for the fabrication of restorations that are wear-resistant, while also being gentle on opposing dentition. The material is capable of withstanding heavy occlusal forces, while remaining gentle on the opposing teeth. This results in a longer-lasting, functional restoration that is comfortable for the patient. It is a perfect choice for fabricating full-contour crowns, providing long-lasting wear resistance and gentle contact with opposing teeth.

FRACTURE LOAD WITH 10 YEAR CHEWING SIMULATION

Comparison of Milled and 3D Printed Materials

Objective

This study aimed to evaluate the long-term performance of 3D printed dental crowns made using the SprintRay Ceramic Crown material, specifically focusing on the breaking load after a 10-year chewing simulation. To establish a benchmark, other products were tested, including a 3D printed competitor crown resin (30–35% ceramic), as well as milled lithium disilicate and milled hybrid ceramic. The study provides valuable insights into the suitability and durability of 3D printed dental crowns compared to traditional milling techniques.

Materials and Methods

For this evaluation, full-contour crowns were fabricated from two milled materials and two 3D printed materials. The CAD designs for all four crowns were identical except for the support structures used during fabrication. The milled crowns were prepared by Paramount Dental Studio (Huntington Beach, CA) according to manufacturer IFU, and the 3D printed materials were prepared using a SprintRay Pro55 S printer and SprintRay ProCure 2 also according to manufacturer IFU.

3D Printed Crowns	Milled Crowns
SprintRay Ceramic Crown (>50% Ceramic)	Lithium Disilicate
Competitor Crown Resin (30–35% Ceramic)	Hybrid Ceramic (70–75% Ceramic)

Four crown replicates were made for each experimental group and cemented with Panavia SA to 3D printed stumps designed to mimic a clinical prep scan. The crowns were subjected to thermal cycling and antagonist loading with steatite material which mimics the mechanical properties of natural enamel. The chewing simulation comprised 400,000 cycles with a vertically applied load of 50N, with thermal cycling of 10,700 cycles alternating between 5°C and 55°C.

The fracture load was evaluated using a universal testing machine. The specimens were loaded with a 5mm diameter steel antagonist in the middle of the occlusal surface, with load applied until failure (tested in accordance with DIN EN ISO 7500-1). Failure load was evaluated with and without chewing simulation to determine the effect of this simulated wear on functional mechanical performance. Statistical analysis was performed using two-factor ANOVA and post-hoc Tukey pairwise comparison.

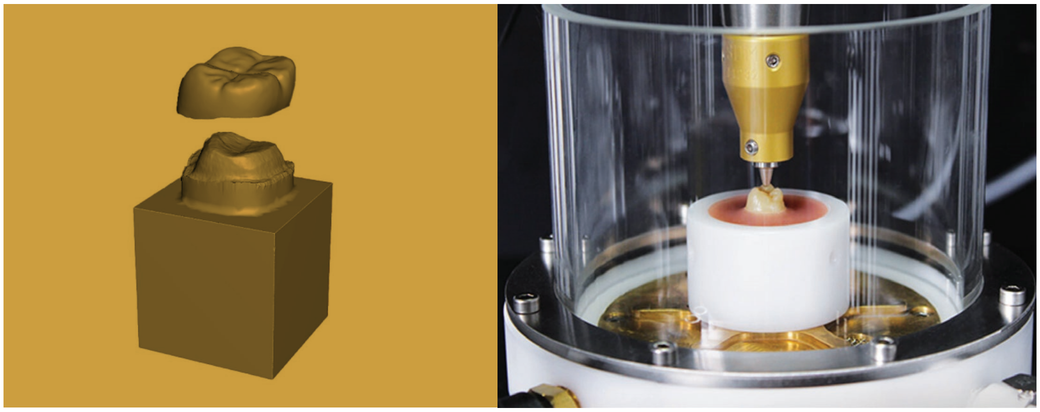
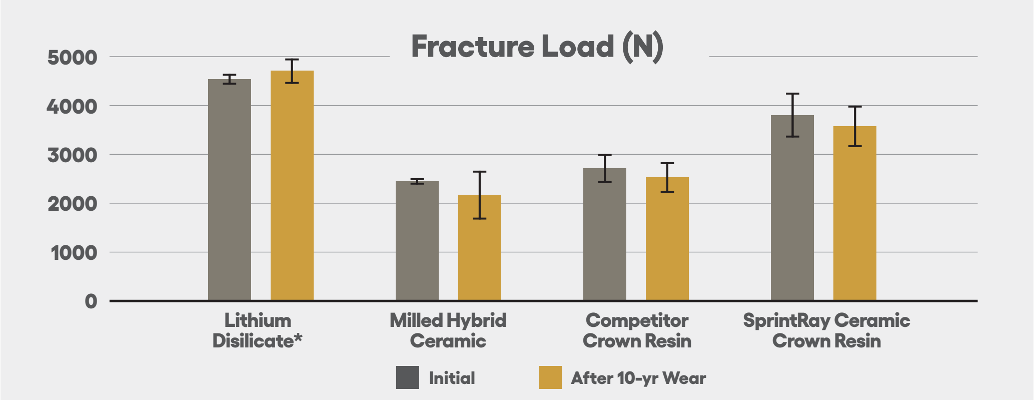


Figure 1:
3D design used for crowns and cemented stumps (left) and testing apparatus (right).



* Note that the differences in mean between lithium disilicate conditions are not statistically significant, as determined by two-factor ANOVA and post-hoc Tukey pairwise comparison ($p > 0.1$).

Figure 2:
Fracture load of cemented crowns before and after chewing simulation demonstrated significant differences between all materials tested ($p < 0.01$).

Results

The fracture load of SprintRay Ceramic Crown averaged 3815 N prior to the chewing simulation, and there was no significant change in this value after the simulation which indicates no detectable material fatigue ($p > 0.1$). The 3D printed competitor crown resin had a significantly lower fracture load of 2693 N ($p < 0.01$).

The milled lithium disilicate and hybrid ceramic materials had average fracture loads of 4560 N and 2460 N, respectively. Milled lithium disilicate had a greater fracture load compared to SprintRay Ceramic Crown, while milled hybrid ceramic had a significantly lower fracture load. For all materials, the differences in fracture load following the chewing simulation were not statistically significant ($p>0.1$).[5]

---

[5] – Study conducted SD Mechatronik GmbH, Germany.

Discussion

SprintRay Ceramic Crown achieved fracture loads more than seven times the average maximum human masticatory forces of 522 N.[6] Crowns printed in this material had an average fracture load of 3815 N before the 10-year chewing simulation and showed no significant change in fracture load following simulated wear. This indicates no significant material fatigue in SprintRay Ceramic Crown printed restorations after the simulated wear. The marginal difference in average fracture load with chewing simulation was within sample variance and differences in means were not statistically significant as determined by post hoc Tukey pairwise comparison.

Compared to other tested materials, SprintRay Ceramic Crown had a significantly higher fracture load relative to 3D printed competitor crown resin and milled hybrid ceramic. While the milled hybrid ceramic has higher flexural strength reported at 274MPa, it failed at a 38% lower fracture load compared to Ceramic Crown. This highlights the need reported for flexural properties in predicting material performance. Fracture load measurement takes into account multiple factors such as bond strength and modulus mismatch.

The milled lithium disilicate showed approximately a 20% higher fracture load than SprintRay Ceramic Crown despite having a substantially higher reported flexural strength of 380MPa.[7] This is likely due in part to the stiffness of lithium disilicate. Due to its significantly greater flexural modulus (70–84 GPa) than the underlying dentition (12–21 MPa), loads applied to milled lithium disilicate crown material may not be distributed to the dentin beneath. This can result in stress concentrations that cause failure in these milled crowns.

6 – Apostolov N, Chakalov I, Drajev T. Measurement of the maximum bite force in the natural dentition with a gnathodynamometer. MedInform. 2014;1(2):70-75.

7 – Al-Thobity AM, Alsalman A. Flexural properties of three lithium disilicate materials: An in vitro evaluation. The Saudi Dental Journal. 2021;33(7):620-627.

ABRASION RESISTANCE WITH 10 YEAR CHEWING SIMULATION

Objective

To evaluate abrasion resistance of 3D printed crowns made using SprintRay Ceramic Crown compared to other predicate photopolymer resins. This test focused on volumetric loss of material after a 10-year chewing simulation. Competitor 3D printing resins with different levels of ceramic content were tested to set a benchmark.

Materials and Methods

In this study, abrasion resistance of samples was evaluated using the following procedure. Testing specimens were prepared as flat discs printed from four different resins, processed according to the manufacturer's instructions for use. A stainless steel antagonist was used with a linear actuator, which applied a 15 N load and dragged the antagonist 1.5mm for 400,000 cycles at a frequency of 1 Hz. The volumetric loss of each specimen was evaluated using a profilometer. Statistical analysis was performed using one-way ANOVA, followed by post-hoc Tukey pairwise comparison to determine significant differences between the materials.

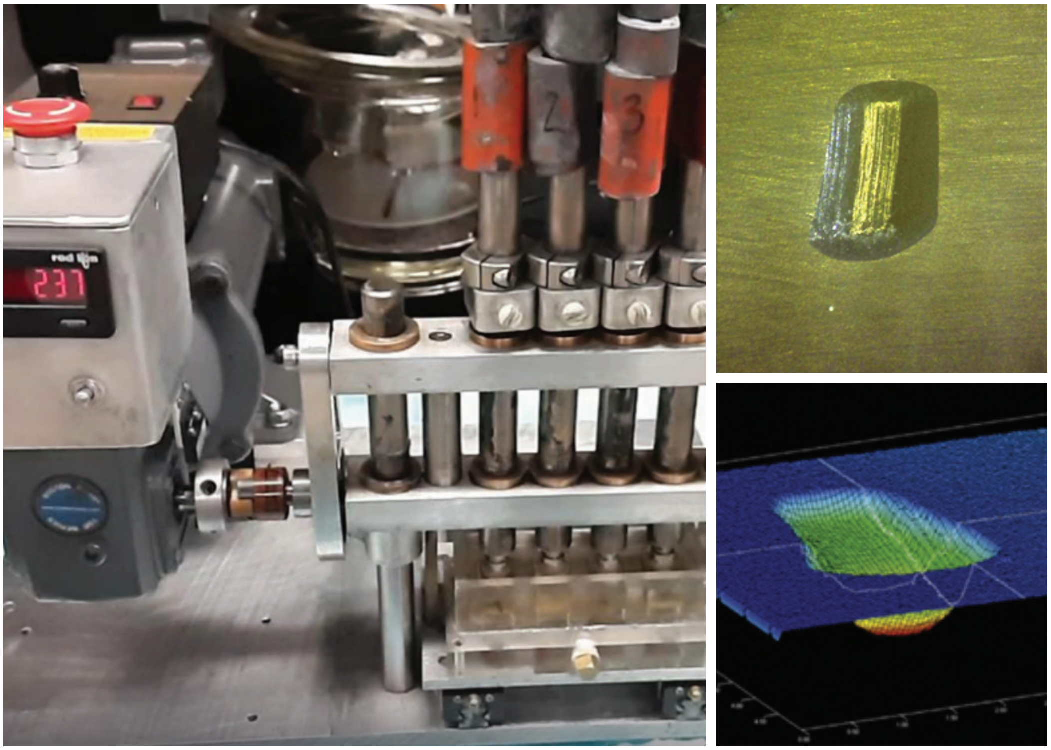


Figure 3: Chewing simulator, test piece, and profilometer output.

Results

The abrasion resistance and volumetric wear of dental restorative materials were evaluated following a 10-year chewing simulation. The results showed that the competitor crown resin with 20–25% ceramic exhibited the highest volumetric wear of 0.051 mm^3; whereas SprintRay Ceramic Crown showed the lowest volumetric wear of 0.023 mm^3. Statistical analysis by one-way ANOVA indicated significant differences between the groups ($p<0.05$). However, post-hoc Tukey pairwise comparison showed no significant difference between the competitor crown resins with 30–35% and 50–55% ceramic, and SprintRay Ceramic Crown ($p>0.05$). These findings suggest that, although there are differences in the volumetric wear between the tested materials, some of them have comparable performance. Further studies are needed to investigate the clinical significance of these differences and their impact on the longevity of dental restorations.

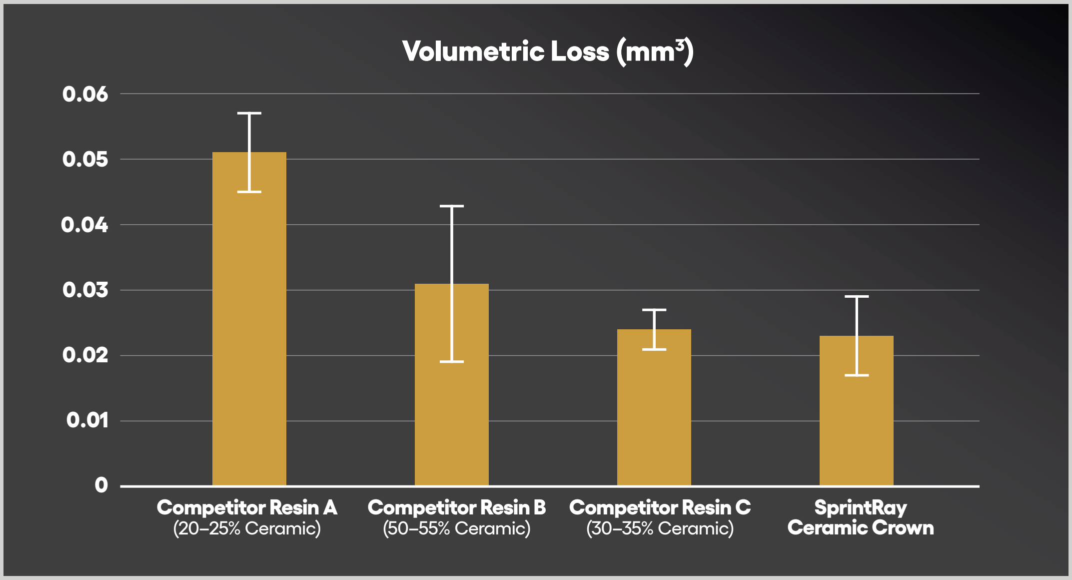


Figure 4: Volumetric wear comparison of 3D printed crown materials.[8]

Discussion

The present study investigated the abrasion resistance and volumetric wear of four dental restorative materials following a 10-year chewing simulation. The results indicate that the SprintRay Ceramic Crown material showed one of the lowest volumetric wear rates amongst the 3D printed materials tested. This finding is significant as low wear rates have been linked to clinical durability, meaning that restorations made with this material may be expected to have a longer lifespan. Abrasion resistance is a critical aspect of material performance that is directly related to the longevity of dental restorations. The results of this study provide valuable information that can assist clinicians in selecting materials with optimal abrasion resistance for their patients' dental restorations.

8 – Study conducted by the University of Alabama at Birmingham, Division of Biomaterials.

OCCLUSAL WALL THICKNESS EFFECT ON FRACTURE LOAD

Objective

The present study aimed to evaluate the performance of 3D printed dental crowns made using SprintRay Ceramic Crown with different occlusal wall thicknesses. Fracture load testing of crowns cemented to a stump was used as a functional test of maximum load, with a focus on the effects of thin features on the material's performance. Ceramic restorations typically recommend a minimum wall thickness of 1mm to ensure optimal performance. Thin features resulting from inadequate preparation of the tooth structure are a leading contributor to the failure of crown restorations. Stress concentrations can occur in thin regions of the material, leading to fractures that compromise the integrity of the restoration. The evaluation presented in this study was designed to investigate the performance of SprintRay Ceramic Crown in thin regions, an essential factor for assessing the material's suitability for use in dental restorations.

Materials and Methods

This study aimed to evaluate the fracture load of dental restorative materials at different occlusal thicknesses. Crowns were cemented to 3D printed stumps designed from a clinical prep scan, with the crown STL file modified to have 0.5, 1, and 1.5mm occlusal thickness. Four crown replicates were tested per experimental group. To assess the fracture load of the specimens, an antagonist in the form of a 5mm diameter steel sphere was loaded in the middle of the occlusal region, with the load applied until failure. Testing was conducted in accordance with DIN EN ISO 7500-1 standards to ensure accurate and reliable results. Fracture load was then compared between the experimental groups to evaluate the performance of the different occlusal thicknesses. Statistical analysis was conducted using ANOVA to determine any significant differences between the experimental groups.

Figure 5: Cross sections of crown designs for 0.5mm, 1.0mm, and 1.5mm occlusal wall thickness.

Results

The fracture loads of SprintRay Ceramic Crown materials at different occlusal thicknesses were evaluated in this study. The results show that the fracture loads averaged 3865 N, 3978 N, and 4012 N for occlusal thicknesses of 0.5 mm, 1 mm, and 1.5 mm, respectively. Statistical analysis using one-way ANOVA indicated that there were no significant differences between the experimental groups. These results suggest that the fracture load of 3D printed crowns made using SprintRay Ceramic Crown does not vary significantly across different occlusal thicknesses.

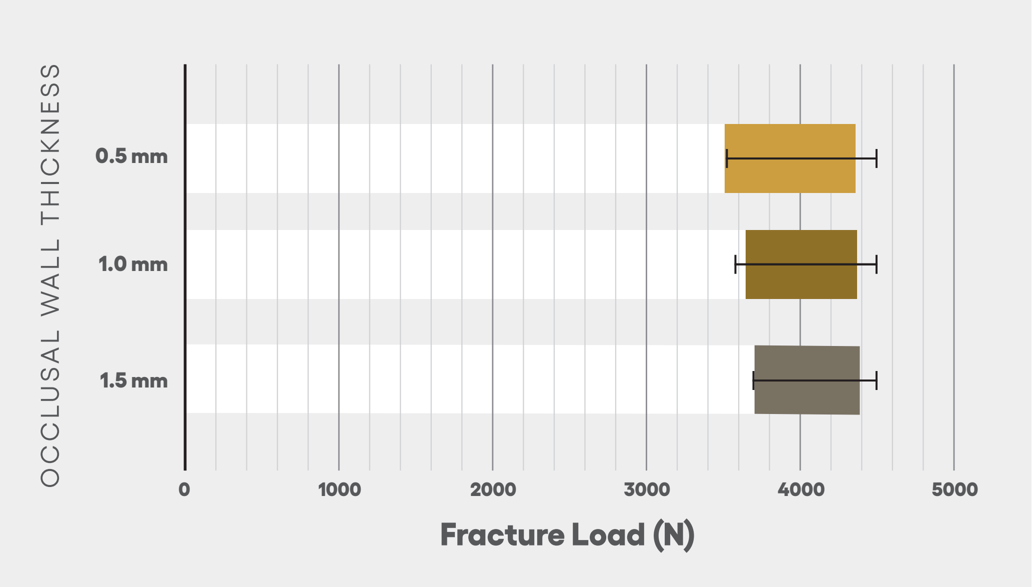


Figure 6: Fracture load of cemented crowns with different wall thickness[9]

Discussion

The findings of this study suggest that the use of SprintRay Ceramic Crown material for the fabrication of dental restorations may provide a degree of flexibility with respect to occlusal wall thickness. The comparable fracture loads observed across all thickness groups suggest that this material is resilient to occlusal thicknesses below the recommended minimum wall thickness of 1 mm. This may be due, in part, to the strength of the cementation between the crown and the underlying prep, as well as the distribution of the applied load across the underlying structure.

The modulus of Ceramic Crown is comparable to that of the underlying dentition, which enables the load to be effectively transmitted to the prep. It is worth noting that ceramic materials have a substantially higher modulus than other restorative materials, which can lead to stress concentrations at thin regions of material and contribute to higher failure rates in underprepped cases. The results of this study suggest that SprintRay Ceramic Crown material may provide a viable option for dental restorations with reduced occlusal wall thickness, while maintaining adequate strength and resilience.

9 – Study conducted SD Mechatronik GmbH, Germany.

BONDING STRENGTH WITH LUTING COMPOSITE

Objective

This study was conducted to test the bonding strength between SprintRay Ceramic Crown and a luting agent. To simulate clinical luting workflows, the study bonded a luting agent to a substrate of Ceramic Crown. This same test was evaluated with comparison to milled lithium disilicate using different adhesive primers. These further tests were completed to understand Ceramic Crown's position relative to well established market competitors.

Materials and Methods

For this study, testing specimens consisted of printed cylinders. The printed specimens were then fixed in acrylic material to ensure that they met the dimensional requirements of the testing apparatus. To prepare the surfaces for testing, they were ground flat using a wet sanding process. For the sandblasting groups, an additional sandblasting treatment was applied to the bonding surface. The bonding surface was treated with various adhesive primers according to the experimental group. A 2.5mm cylinder of Omnichroma resin cement (Tokuyama Dental) was applied to the bonding surface. A universal testing machine with a notched attachment was used to shear off the cylinder of dental cement from the printed crown material. The failure load was measured, and statistics were evaluated by two-factor ANOVA with post-hoc Tukey pairwise comparison.

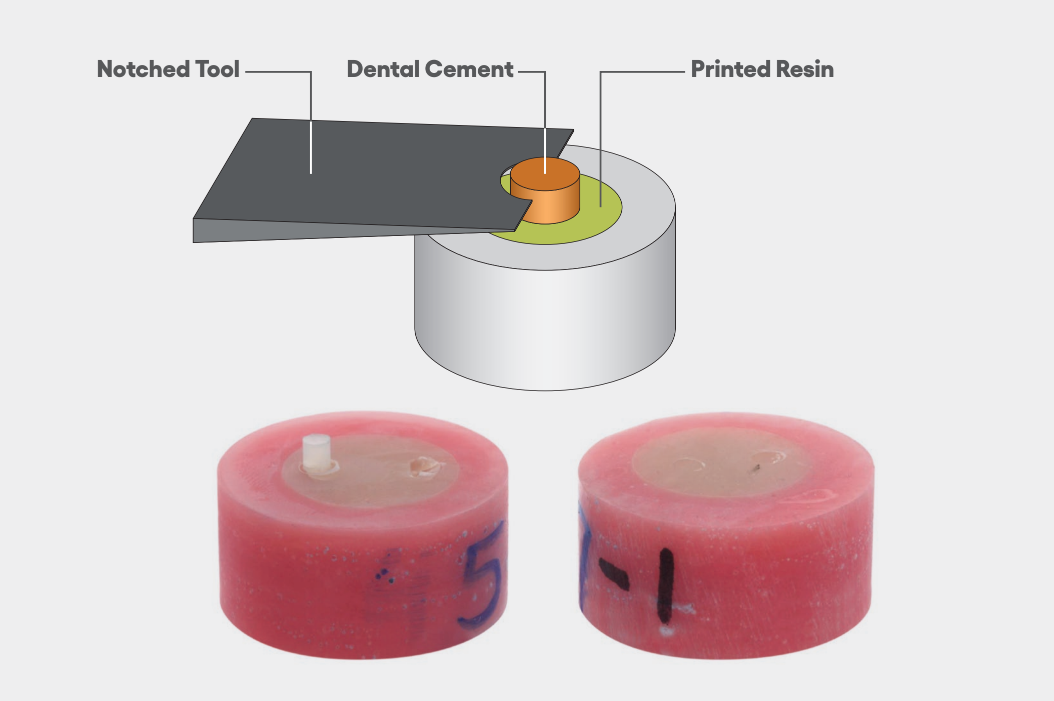


Figure 7: Shear bond testing, cohesive failure, adhesive failure. The majority of experimental conditions failed by cohesive failure.

Results

The results of the bonding strength test are shown in the graphs below. All materials and groups met the standard criteria of minimum bonding strength of 5 MPa, with all samples exceeding this ISO requirement by a significant margin. Additionally, the majority of conditions for SprintRay Ceramic Crown resulted in cohesive failures of the underlying material. This mode of failure indicates high bond strength relative to cohesive material strength.

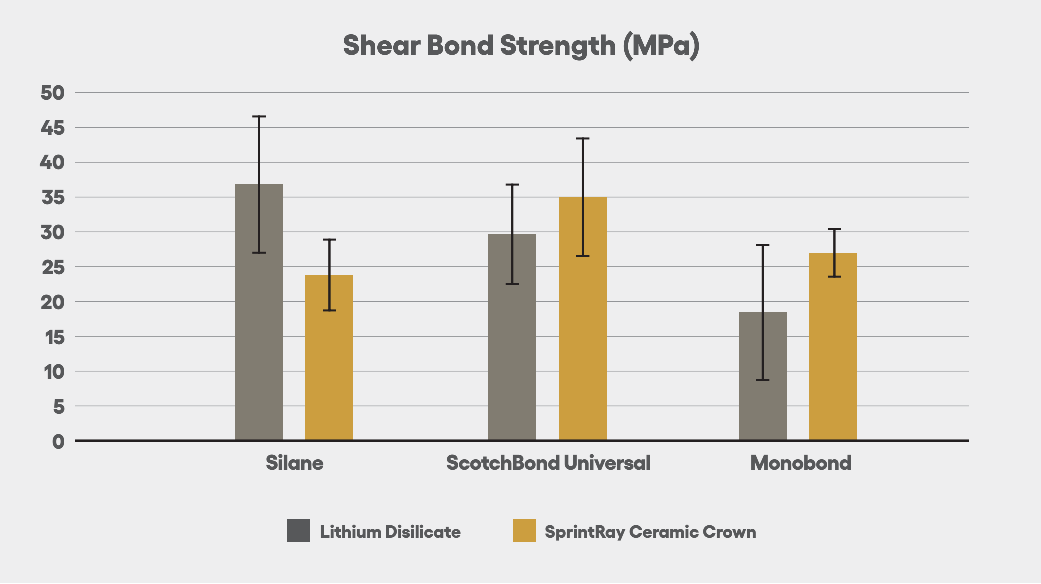


Figure 8:
Shear bond strength compared to milled lithium disilicate with different adhesive primers.[10]

10 – Study conducted by the University of Alabama at Birmingham, Division of Biomaterials

A comparison to bonding strength of milled lithium disilicate indicated comparable shear bond strength with a statistically significant difference only in the silane adhesive primer group (Figure 8). The effects of sand blasting surface treatment were also evaluated with different adhesive primers. Sand blasting showed no significant change in shear bond strength in this comparison, however it should be noted that the non sand-blasted conditions were prepared by roughing the surface with sandpaper.

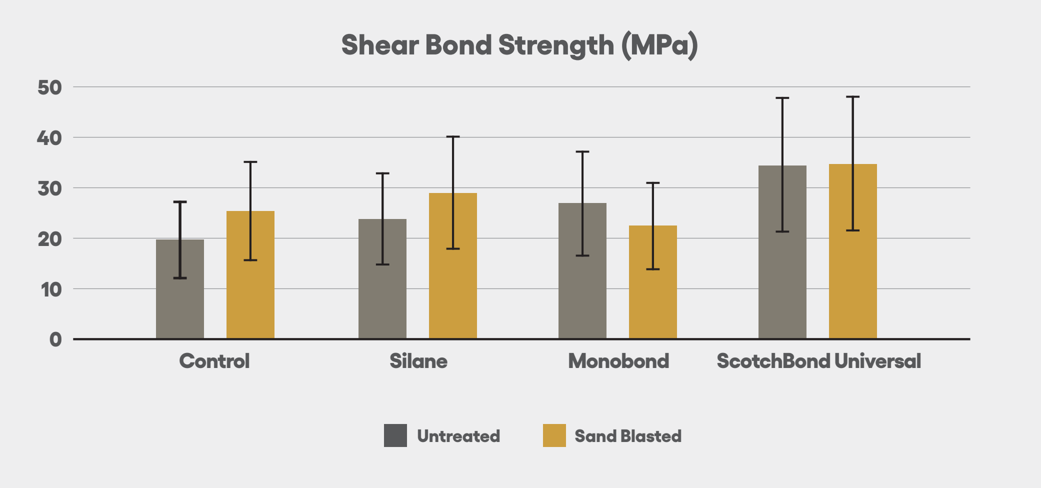


Figure 9:
Shear bond strength comparison of different surface treatments and adhesive primers.[11]

11 – Study conducted by the University of Alabama at Birmingham, Division of Biomaterials

Discussion

The shear bond strength between dental restorative material and resin cements is a crucial factor for the long-term success of dental restorations. The results of this study showed that SprintRay Ceramic Crown had comparable bond strength to milled lithium disilicate when bonded to resin cements. However, it is important to note that the large standard deviations resulted in limited statistical significance of the results for comparison of primers or surface treatment. All conditions outperformed the ISO minimum requirement of 5 MPa. However, we did not observe a significant difference in bond strength between the different primers or surface treatments. These findings suggest that SprintRay Ceramic Crown provides adequate bond strength when bonded with all different primer conditions tested.

SHEAR BOND STRENGTH LUTING WORKFLOW COMPARISON

Objective

This study evaluated the bonding strength between SprintRay Ceramic Crown and a luting agent. To simulate clinical luting workflows, the study bonded a luting agent to a substrate of Ceramic Crown. Various common luting workflows were tested in order to evaluate common resin cements.

Materials and Methods

For this study, testing specimens consisted of printed cylinders. The printed specimens were then fixed in acrylic material to ensure that they met the dimensional requirements of the testing apparatus. To prepare the surfaces for testing, they were ground flat. The bonding surface was treated with adhesive primers when indicated. A 2.5mm cylinder of resin cement was applied to the bonding surface. A universal testing machine with a notched attachment was used to shear off the cylinder of dental cement from the printed crown material. The failure load was measured, and statistics were evaluated by two-factor ANOVA with post-hoc Tukey pairwise comparison.

Results & Discussion

The shear bond strength between dental restorative material and resin cements is a critical factor for the long-term success of dental restorations. In this study, we aimed to evaluate the shear bond strength of Ceramic Crown material when bonded to resin cements under different test conditions and to assess the effect of adhesive primers on bond strength. The results showed that all test conditions, except for Temp Bond, significantly exceeded the minimum ISO requirement of 5 MPa.

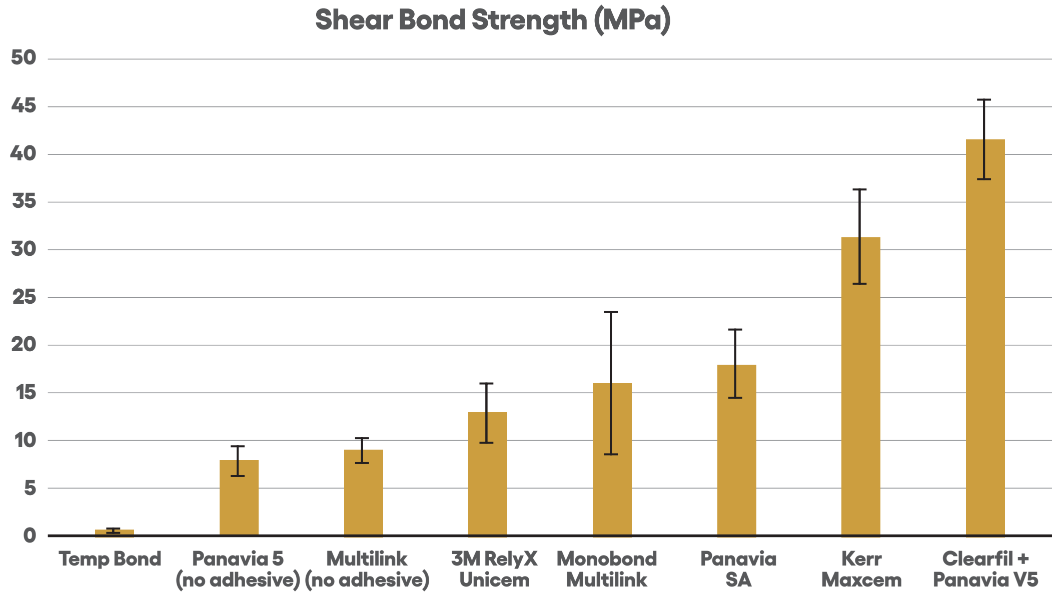


Figure 10: Comparison of workflows with common resin cements.[12]

[12] – Study conducted by SprintRay Materials Science team.

The most commonly observed fracture type among the Ceramic Crown samples was cohesive fracture patterns in the substrate, indicating that the adhesive bond strength between the Ceramic Crown material and luting composite is very high. Clearfil V5 with Clearfil adhesive primer provided the highest shear bond strength with an average value of 42.12 MPa, which was significantly higher than the other adhesive systems tested in this study. In contrast, Temp Bond had the lowest performance with a value of 0.62 MPa.

Crown restorations derive much of their mechanical strength from cementation to the underlying prep, so shear bond strength contributes significantly to durability and overall mechanical performance. These findings can guide dental practitioners in choosing appropriate luting workflows for bonding Ceramic Crown restorations to the underlying prep, which will contribute significantly to the durability and overall mechanical performance of the restoration.

REFERENCE MATERIALS

Instructions For Use (IFU)

VIEW

Safety Data Sheet (SDS)

VIEW

Workflow Guide

VIEW

SprintRay