Short Communication

Probability of Failure of Machined Zirconia Dental Ceramic Core Materials

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The purpose of this study was to compare the probability of failure, expressed as B10 strength, of three systems of machined zirconia ceramics (Lava, DC-Zirkon, and Cercon) with a zirconia-reinforced aluminum ceramic (In-Ceram Zirconia). Ten rectangular specimens of each material were subjected to a three-point flexural strength test. The B10 strength of Lava was significantly lower than that of DC-Zirkon but significantly higher than that of Cercon and In-Ceram Zirconia. The B10 strength of Cercon and In-Ceram Zirconia were not significantly different from one another. The machined zirconia ceramics appeared to fail primarily with intergranular fracture. *Int J Prosthodont 2009;22:340–341.*

Yttria-stabilized zirconia (Y-TZP) dental frameworks are commonly fabricated using computer-aided design/computer-assisted manufacturing technology.[1] Machine-milling challenges the mechanical properties of zirconia. Flaws and residual compressive stresses mechanically induced during specimen preparation affect its strength.[2] To the authors' knowledge, studies undertaken specifically to compare various machined dental zirconia systems are unavailable. Therefore, the purpose of this study was to test the hypothesis that the probability of fracture under flexural load, expressed as B10 strength, of three machined zirconia ceramics was not significantly different from that of a glass-infiltrated zirconia-reinforced aluminum ceramic.

Materials and Methods

Three machined zirconia ceramics and the glass-infiltrated zirconia-reinforced aluminum ceramic were selected for the study (Table 1). Ten rectangular (20 mm × 6 mm × 1 mm [± 0.1 mm]) specimens of each material were fabricated. The flexural strength was calculated from the results of a three-point flexural strength test and statistically analyzed using the Weibull method.[3] The mean flexural strength, the characteristic strength (μ), the shape parameter/Weibull modulus (β), and the B10 strength were reported. B10 strength is defined as the strength at which 10% of the specimens would fail at 90% confidence.[3] The mode of specimen fracture was analyzed using scanning electron micrographs (SEM) of representative fractured specimens.

Results

There was a significant difference in B10 strength among the materials used. Therefore, the hypothesis that the probability of fracture of the materials under flexural load would not be significantly different was rejected. The B10 strength of the Lava zirconia ceramic was significantly lower than that of DC-Zirkon, but significantly higher than that of Cercon or the zirconia-reinforced aluminum ceramic, In-Ceram Zirconia ($P < .05$). There was no significant difference in B10 strength between Cercon and In-Ceram Zirconia ($P > .05$). The shape parameter (β) of the ceramics analyzed ranged from 3.9 (Cercon) to 12.2 (In-Ceram Zirconia) (Table 1). β values higher than 1 indicate that there were no premature or random failures.[3]

Discussion

It was unexpected that the B10 strength of DC-Zirkon, a postsintered machined Y-TZP, was higher than those of the other two presintered machined Y-TZPs (Lava and Cercon). In this context, presintered machined ceramics have the advantage that many surface flaws

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Table 1 Weibull Analysis of Zirconia Core Materials

Material	Manufacturer	Shape parameter (β)	Mean strength (MPa)	SD	Characteristic strength (μ)	B10 strength (MPa)	90% CI at B10 strength (MPa)*
Cercon (n = 10)	Dentsply	3.9	447	128	493	278	205–376[a]
Lava (n = 10)	3M ESPE	8.9	788	105	832	647	568–736[b]
DC-Zirkon (n = 10)	DCS Dental	7.6	1,129	176	1,201	894	760–1,051[c]
In-Ceram Zirconia (n = 10)	Vita Zahnfabrik	12.2	452	45	472	392	355–433[a]

*Data indicated with same letter showed no significant difference ($P < .05$).

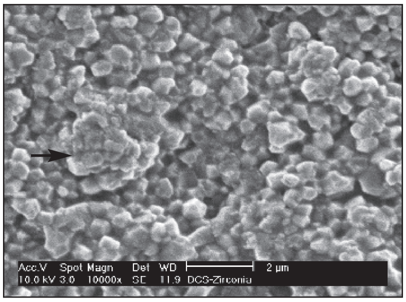

Fig 1 SEM of fractured surface of DC-Zirkon (×7,000). Arrow indicates intergranular fracture of the zirconia.

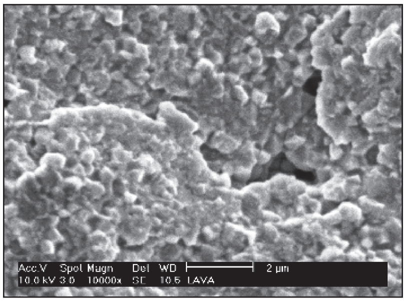

Fig 2 SEM of fractured surface of the Lava core material (×7,000).

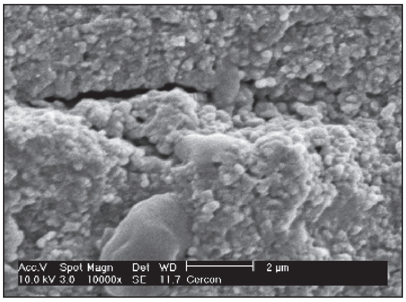

Fig 3 SEM of fractured surface of Cercon (×7,000); finer-grained zirconia shows intergranular fracture.

that are created during the milling process might be eliminated after sintering. Surface grinding of sintered Y-TZPs also compromise their strength. Grinding generates radial surface cracks and increases the effective critical defect size, thus decreasing the ceramic's strength.[2] Sintering conducted after machining of a ceramic provides the opportunity for minor cracks and defects to heal; therefore, it helps to maintain the mechanical properties of the ceramic.

Other factors affecting the strength of Y-TZPs are operative in explaining the higher B10 strength of DC-Zirkon than its presintered counterparts. Factors that might have affected the strength of the Y-TZP include the density of the presintered pressed powder blocks, as it relates to critical flaw size population, and the sinterability of the pressed powder, as it relates to the initial particle size.[2] In addition, the strength of a Y-TZP is affected by the yttria content, as it relates to the amount of tetragonal to monoclinic (t → m) phase transformations. The exact mechanism explaining DC-Zirkon's superior strength warrants further study.

The B10 strength of the glass-infiltrated zirconia-reinforced aluminum ceramic (In-Ceram Zirconia) was significantly lower than two of the machined zirconia ceramics (DC-Zirkon and Lava), but not significantly different from the third (Cercon). The relatively lower B10 strength of In-Ceram Zirconia in comparison to zirconia ceramics is explained by its lower zirconia content (approximately 35%), which could contribute to transformation toughening.[1]

SEM of DC-Zirkon, Lava, and Cercon revealed closely compacted tetragonal zirconia granules < 1 μm in size (Figs 1 to 3) The principal mode of failure was intergranular fracture between the zirconia granules. Monoclinic zirconia is evident in DC-Zirkon but not in Lava or Cercon. The failure mode of In-Ceram Zirconia involving intergranular and transgranular fracture of aluminum platelets agrees with previously reported results (SEM not shown).[1] The present SEM observation should be taken with caution since only one specimen from each group was studied.

Conclusion

The probability of failure under flexural load of three machined zirconia dental ceramics was equal to or better than a zirconia-reinforced aluminum ceramic. Among the machined zirconia dental ceramics, the probability of failure of DC-Zirkon is significantly lower than that of Lava and Cercon.

References

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