Alumina Additions May Improve the Damage Tolerance of Soft Machined Zirconia-Based Ceramics

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The aim of this study was to evaluate the damage tolerance of different zirconia-based materials. Bars of one hard machined and one soft machined dental zirconia and an experimental 95% zirconia 5% alumina ceramic were subjected to 100,000 stress cycles (n = 10), indented to provoke cracks on the tensile stress side (n = 10), and left untreated as controls (n = 10). The experimental material demonstrated a higher relative damage tolerance, with a 40% reduction compared to 68% for the hard machined zirconia and 84% for the soft machined zirconia. *Int J Prosthodont 2011;24:172–174.*

Zirconia-based dental ceramics are machined to individual structures by "hard machining" or "soft machining."[1,2] Hard machining implies that the structure is milled from an industrial densely sintered block of yttria-stabilized tetragonal zirconia polycrystal (Y-TZP). The soft machining technique mills the structure from a partially sintered block of Y-TZP, which is subjected to a second sintering after milling. Knowledge regarding which of the available methods is best suited for shaping dental zirconia-based restorations is not evident. The aim of the present study was to evaluate whether different zirconia-based materials, shaped by either hard or soft machining methods, differ with respect to damage tolerance.

Materials and Methods

Two dental zirconia materials, one shaped by hard machining and the other shaped by soft machining, were chosen. Additionally, one experimental zirconia material strengthened with 5% alumina and shaped by soft machining was chosen (Table 1). From each material, 30 bar-shaped 2 × 5 × 20-mm specimens were produced according to the manufacturers' recommendations (n = 90). All specimens were ground and polished with diamond disks (Struers) under water cooling to final dimensions of 1.2 ± 0.06 × 4.0 ± 0.05 × 20 mm. The specimens were cleaned ultrasonically and randomly allocated into two test groups and one control group, which was left untreated (n = 10 each).

Ten specimens of each material were subjected to 100,000 bending cycles at 1 Hz with a maximum load of 100 N (approximately 365 MPa) in distilled water at 37°C. The remaining test specimens (n = 10 each) were subjected to a Vicker diamond indenter with a load of 98 N (approximately 10 kg) in the center of the tensile surface. The diagonal length in both directions of the indent and the length of the cracks radiating from the indent were measured using a light microscope (Leica DM IRM) (Fig 1).

Flexural strength measurements were performed on a servohydraulic testing machine (MTS 810) using a three-point bending jig with 14 mm between bearers and immersed in distilled water (37°C). Specimens were loaded in the middle until fracture. The crosshead speed was 1 mm/min, and load at fracture was recorded. The flexural strength (MPa) was calculated according to the following equation:

$$M = 3Wl/2bd^2$$

where "W" is the breaking load in N, "l" is the length between test bearers in mm, "b" is the width of the specimen in mm, and "d" is the thickness in mm.

The Kruskal-Wallis test, Mann-Whitney test, and Spearman rank correlation *(r)* were all performed using the statistical package SPSS 15.0 for Windows (IBM).

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Table 1 Study Material Characteristics

	Material	Machining method	Product
Hard machined zirconia	Y-TZP	Machined to correct shape from fully sintered (white) blanks	DC Zircon, DCS Dental
Soft machined zirconia	Y-TZP	Machined to enlarged shape from partially sintered (green) blanks; final sintering after machining, which induces a shrinkage of approximately 20%	Lava, 3M ESPE
Soft machined experimental zirconia	95% Y-TZP and 5% alumina	Machined to enlarged shape from partially sintered (green) blanks; final sintering after machining, which induces a shrinkage of approximately 20%	EZ A5, Ceram Tools

Y-TZP = yttria-stabilized tetragonal zirconia polycrystal.

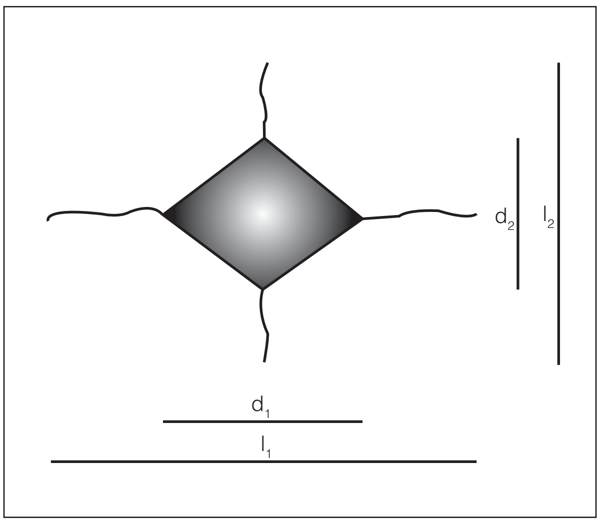

Fig 1 Schematic illustration of the indent and crack measurement procedure. d = the diagonal length of the indent; l = the length of the cracks radiating from the corners of the indent. The mean of the perpendicular measurements $(d_1 + d_2) / 2$ and $(l_1 + l_2) / 2$ were used in the analyses.

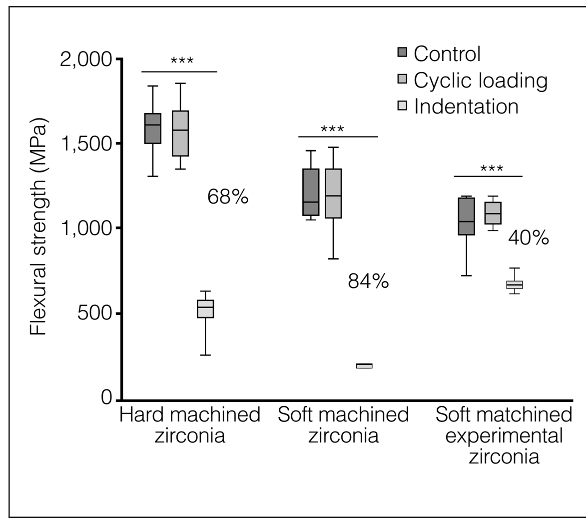

Fig 2 Box plot diagram of the results from the flexural strength test of the control specimens, specimens subjected to cyclic loading, and specimens subjected to indentation. Percentages represent the relative reduction in strength for each material. $^{***}P < .001$.

Results

Flexural strength differed significantly among the materials for both test procedures (Kruskal-Wallis, $P < .001$; Fig 2). No effect was observed on the specimens subjected to cyclic loading compared to the controls regarding flexural strength. There was a significant reduction in flexural strength after crack provocation compared with the controls for all materials (Mann-Whitney, $P < .001$). Statistically significant differences were found in the diagonal length of the indent and the length of the cracks radiating from the indent among the different materials (Kruskal-Wallis, $P < .03$; Table 2). A statistically significant correlation was found between the length of the provoked cracks and flexural strength for the hard machined zirconia ($r_s = -0.930$, $P < .001$), but not for the soft machined materials. No correlation was found between the diagonal length of the indent and the flexural strength of the indented specimens.

Table 2 Median (Minimum–Maximum) Indent and Crack Lengths for the Three Different Materials

Material	Indent (µm)	Crack length (µm)
Hard machined zirconia	115 (114–116)	137 (130–160)
Soft machined zirconia	115 (113–117)	202 (179–234)
Soft machined experimental zirconia	119 (117–123)	146 (143–151)

Discussion

The present results reveal that zirconia specimens subjected to crack-inducing indentations showed a distinct reduction in flexural strength compared with controls, while a limited cyclic loading process caused no effect on flexural strength. Defects seem to be the most important detrimental factor for dental zirconia-based materials. The present results indicate that both shaping method and material composition affect a material's ability to withstand defects introduced after the material has reached its final shape. This is in accordance with previous studies.[1–5] The zirconia materials seemed to achieve the best damage tolerance when shaped by hard machining, but the addition of alumina into the zirconia material may allow for better damage tolerance after soft machining, as has been shown for orthopedic materials.[4,5] It may be beneficial to further investigate the applicability of these materials for dental restorations.

Conclusions

Soft machined zirconia had a lower damage tolerance than both hard machined zirconia and an experimental soft machined zirconia-alumina ceramic. Care must be taken to avoid inducing cracks during processing and clinical handling of dental zircona restorations.

Acknowledgments

The authors would like to thank 3M ESPE for donating specimens, DC Dental for reducing the price of the blanks, and Ceram Tools for their cooperation. Thanks to Odd Johan Lundberg for assisting with the technical procedures and Assoc Prof Olav Bøe for assisting with the statistical analyses.

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Literature Abstract

Analysis of primary risk factors for oral cancer from select US states with increasing rates

The incidence and mortality rates for oral cancer have been steadily declining in the US over the past 30 years. Despite the overall decline, new evidence suggests that there have been increases in some specific geographic areas and specific demographic subgroups. The purpose of this study was to identify the geographic areas with increased risk for oral cancer so that public health intervention may be directed more effectively. Population-based data on oral cancer morbidity and mortality were obtained from the National Cancer Institute's Surveillance, Epidemiology, and End Results (NCI-SEER) database. Measurement for current and former trends of tobacco usage was obtained from the Centers for Disease Control and Prevention Behavioral Risk Factor Surveillance System (CDC-BRFSS). Evaluation and comparison of previous state tobacco use and tobacco-related policies were measured using the Initial Outcomes Index (IOI) and the Strength of Tobacco Control Index (SoTC). The NCI-SEER data confirmed the previous report of geographic increases in oral cancer and demonstrated that they are state-specific. These include the states of Nevada and Idaho. The data from the CDC-BRFSS also revealed that these states had relatively higher percentages of smokers currently, as well as historically. Analysis of the IOI and SoTC suggested that cigarette pricing, taxes, and home or workplace bans may have a significant influence on smoking prevalence in these areas. For example, states with increasing oral cancer incidences have lower IOI scores, indicating higher rates of smoking and lower rates of tobacco control (ie, lower cigarette prices and fewer smoking bans). Conversely, states with decreasing oral cancer incidences scored lower on the IOI scale, suggesting these states had lower smoking rates and higher overall tobacco controls, including higher cigarette prices and more extensive smoking bans. This study provides evidence of state-specific increases in oral cancer. With a better understanding of the primary and secondary factors, local state public health professionals may be able to formulate effective prevention and education programs directed to the residents of specific geographic areas to reduce and eliminate such health disparities.

Bunnell A, Pettit N, Reddout N, et al. *Tob Induc Dis* 2010;8:5. **References:** 43. **Reprints:** Karl Kingsley, Department of Biomedical Sciences, School of Dental Medicine, University of Nevada, Las Vegas, USA. Email: karl.kingsley@unlv.edu—*Beatrice Leung, Toronto Ontario, Canada*