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Monolithic zirconia dental crowns. Internal fit, margin quality, fracture mode and load at fracture

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ABSTRACT

Objective. Dental all-ceramic restorations of zirconia, with and without an aesthetic veneering layer, have become a viable alternative to conventional metal-ceramic restorations. The aim of this study was to evaluate whether factors of the production methods or the material compositions affect load at fracture, fracture modes, internal fit or crown margins of monolithic zirconia crowns.

Methods. Sixty crowns made from six different commercially available dental zirconias were produced to a model tooth with a shallow circumferential chamfer preparation. Internal fit was assessed by the replica method. The crown margin quality was assessed by light microscopy on an ordinal scale. The cemented crowns were loaded centrally in the occlusal fossa with a horizontal steel cylinder with a diameter of 13 mm at 0.5 mm/min until fracture. Fractographic analysis was performed on the fractured crowns.

Results. There were statistically significant differences among the groups regarding crown margins, internal fit and load at fracture ($p < 0.05$, Kruskall Wallis). Fracture analyses revealed that all fractures started cervically and propagated to the occlusal surface similar to clinically observed fractures. There was statistically significant correlation between margin quality and load at fracture (Spearman's rank correlation, $p < 0,05$).

Significance. Production method and material composition of monolithic zirconia crowns affect internal fit, crown margin quality and the load at fracture. The hard-machined Y-TZP zirconia crowns had the best margin quality and the highest load at fracture. Reduction of margin flaws will improve fracture strength of monolithic zirconia crowns and thereby increase clinical success.

1. Introduction

The production methods for dental ceramics have improved greatly over the years [1–3]. Increased proportion of crystalline particles has led to higher resistance to functional loads, but also changed the optical properties of the material [2,4]. An yttria-stabilized tetragonal zirconia polycrystal (Y-TZP) popularly called "zirconia" has been the most common dental high-strength ceramic for some years. Y-TZP contains only polycrystalline particles in a metastable tetragonal crystal structure, and is the dental ceramic material with the highest fracture strength available today [5,6]. Dental zirconias are mainly used for crowns, fixed dental prostheses and implant components. The strength of zirconia depends on the density of the polycrystalline particles and quality of the product [7–10]. The manufacturing process among the zirconia restorations differs with regard to material composition, processing and machining process of the

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Table 1 – The materials used with brand name, production method, material composition and grain size. Data from the manufacturers. N/A = not available.

Code	Brand name, manufacturer	Production method	Material composition	Grain size
BX	Prismatik BruxZir Milling Blank Glidewell laboratories	Soft-machined	ZrO_2, Yttria, N/A Temp: 1530 °C	N/A
DD	Dental Direkt DD Bio ZX[2] Dental Direkt GmbH	Soft-machined	$ZrO_2 + HfO_2 + Y_2O_3 > 99\%$, $Al_2O < 0{,}5\%$, other oxides < 0,25%, $Y_2O_3$3% Temp: 1450–1550 °C	0,26–0,38 μm
ZZ	ZirkonZahn, ICE Zirkonia—Prettau Zirconia	Soft-machined	ZrO_2, Y_2O_3 4–6%, $Al_2O_3 < 1\%$ $SiO_2 < 0.02\%$, $Fe_2O_3 < 0.01\%$ $Na_2O < 0.04\%$ Temp: 1600 °C	0,3 μm
PZ	NobelProcera Crown Zirconia Nobel Biocare	Soft-machined	$ZrO_2 + Y_2O_3 + HfO_2 \geq 99.0\%$, $Y_2O_3 > 4.5$ to ≤ 6.0, $HfO_2 \leq 5\%$, $Al_2O \leq 0.5\%$. Other oxides $\leq 0.5\%$. Temp: N/A	0,3–0,5 μm
DY	Denzir Y-TZP Denzir AB	Hard-machined,	>99,95 wt%: $ZrO_2 + Y_2O_3 + HfO_2 + Al_2O_3$ Temp??	<0,5 μm
DM	Denzir Mg-PSZ Denzir AB	Hard-machined	99,95 wt% av $ZrO_2 + MgO$ Temp: 1800 °C	30–40 μm

milling blanks [11,12]. The machining process can be "hard-machining" or "soft-machining". The hard-machined crowns are milled from a fully sintered milling blank of zirconia. In the soft-machining procedure a partially sintered milling blank of zirconia is used, which is fully sintered after the milling [13]. The soft-machined restorations are milled 20% oversized to compensate the subsequent shrinking during sintering [13].

Traditionally, zirconia has been used as a core material covered entirely with a weak, veneering ceramic. This bi-layered core-veneer structure is prone to chipping and also requires excessive removal of tooth substance [14,15]. Most dental zirconias can, however, be produced as monolithic restorations, without veneering ceramic. The monolithic structure reduces the chipping problems of veneering ceramic and reduces the need for removal of sound tooth substance. In order to achieve aesthetically acceptable monolithic restorations some alterations in translucency, colour and appearance of the normally very white Y-TZP have been necessary [16,17]. To achieve clinically tooth-like translucency and colour of the zirconia materials, several different alterations in the manufacturing process can be applied [7,18]. For instance, smaller crystals increase translucency [18]. A larger proportion of cubic crystal structure achieved by higher sintering temperature and increased yttria content, will also increase translucency [18]. Inclusion of other oxides will alter colour and increase opacity [16]. It is uncertain to what extent the differences in the manufacturing process affect the properties and clinical success of the final dental restorations.

The aim of this study was to assess whether factors of production methods and material composition affect load at fracture, fracture modes, internal fit and crown margins of monolithic zirconia crowns.

2. Material and method

A synthetic premolar tooth was prepared with a circumferential shallow chamfer of 0.5 mm, a taper of 9–12° and rounded edges. An A-silicone impression (Affinis, 3M Espe, Minneapolis, USA) was taken of the preparation and sent to a dental technician laboratory (Tannlab). The laboratory made a cast model and digitally scanned the model and designed a full-contour crown. The file was sent to 5 different manufacturers who made 10 identical crowns from 6 different brands. The crowns were tooth colored, monolithic zirconia crown material. The materials differed with regard to both composition and manufacturing method (Table 1).

2.1. *Internal fit*

Internal fit was measured by the replica method [19]. Two compatible impression materials (Fit-checker, GC Corporation Tokyo, Japan and Xantropren, Heraus Kulzer, LLC) were used to make an impression of the gap between the abutment and the crown with low viscosity silicone material. The thin silicone cement film was stabilized with a contrast colored silicone material after separation from the abutment and this unit was removed from the crown and cut in two and the thickness was measured by light microscopy (Leica M205C, Heerbrugg, Switzerland). The internal fit was measured at seven points. Five crowns in each group were measured in a transverse cut in the mesio-distal direction and five in the bucco-palatinal direction. Four measurements were measured from the gap on the axial walls and three from the occlusal part of the preparation in each crown.