The Effects of Margin Curvature on Load at Fracture of Ceramic Crowns

Marit Øilo, DDS, PhD[a]/Ketil Kvam, MSc[b]/Kjetil Reisegg, DDS[a]/Nils Roar Gjerdet, DDS, PhD[a]

Purpose: Despite the high fracture strength of modern dental core ceramics, fractures are a common cause of clinical failures. The aim of this study was to use a clinically relevant test method to evaluate the effect of the curvature of the cervical crown margins on load at fracture. ***Materials and Methods:*** Thirty zirconia crowns and 30 glass-ceramic crowns were produced for three premolar preparations with variation in the approximal crown margin curvature: low curvature (r = 12 mm), moderate curvature (r = 2.5 mm), and high curvature (r = 1.5). The crowns were loaded until fracture with a method that mimics clinical fracture modes. ***Results:*** Statistically significant differences were found among both crown margin curvature and material groups ($P < .001$). Most fractures originated from pre-existing flaws. ***Conclusion:*** A moderate to low curvature of the crown margins increases crown strength compared with a high curvature. *Int J Prosthodont 2015;28:357–359. doi: 10.11607/ijp.4191*

Advanced, modern high-strength dental ceramic materials have been developed to reduce fracture rates by increasing fracture strength. Yet fractures of all-ceramic dental crowns are still observed in clinical use.[1] The reasons for the unexpected core fractures are not readily understood.

The aim of this study was to evaluate whether the curvature of the cervical crown margin affects load at fracture for dental ceramic crowns using a clinically relevant test method.[2]

Materials and Methods

Sixty full-contour monolayer crowns were made to fit three different chamfer preparations of 0.6 mm. Thirty glass-ceramic crowns (IPS e.max, Ivoclar Vivadent) and 30 yttria-stabilized zirconia polycrystal crowns (Zerion HT, Straumann) were produced by CAD/CAM technique. The variation was in the curvature of the finish line in the mesial and distal regions (Fig 1). Images of all crowns were taken at 10 and 20 times magnification. The crowns were cemented with zinc phosphate cement to one epoxy copy of the tooth cast each and stored in distilled water at 37°C for 36 hours (± 2 hours).

The crowns were subjected to occlusal load of 0.5 mm per minute from a steel ball of 12-mm diameter cushioned with a 2-mm-thick rubber disk of hardness 90 shore A to avoid contact damage and with the specimens immersed in water at 37°C.[2]

The fractured crowns were inspected in an optical microscope to determine the origin and propagation path of the fracture by fractographic analysis.[3,4]

A statistical software package (IBM SPSS Statistics 19) and nonparametric statistics were used for the analyses, the Kruskal-Wallis test for overall comparison, and the Mann-Whitney U test for comparison between groups. Spearman's rho was used for correlation analysis. The level of significance was .05.

Results

Five of the zirconia crowns with a low curvature crown margin did not break at the limit of the test machine (2,500 N). There were statistically significant differences in load at fracture among the different preparation designs in both material groups ($P < .01$) (Fig 2). All fractures in the moderate and curved groups started in the crown margin's approximal curvature (Fig 3). The crowns in the low group fractured with multiple fracture lines located around the whole circumference of the crown and with contact damages occlusally (Fig 3). It was difficult to pinpoint the initiating fracture due to small fragments.

[a]Department of Clinical Dentistry, Faculty of Medicine and Dentistry, University of Bergen, Norway.
[b]NIOM, Nordic Institute of Dental Materials, Oslo, Norway.

Correspondence to: *Dr Marit Øilo, Faculty of Medicine and Dentistry, Department of Clinical Dentistry, Aarstadveien 19, NO-5009, Bergen, Norway. Fax: +4755586489.*

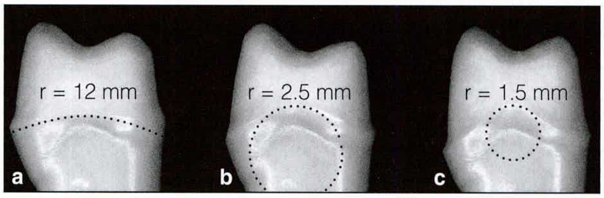

Fig 1 *(above)* The three cast premolar teeth with different all-ceramic preparation designs. Circumferential chamfers were made on all three casts but the curvature of the finish line in the approximal region varied. **(a)** Low, **(b)** moderate, and **(c)** high curvature. The radii of the approximal curvatures are marked.

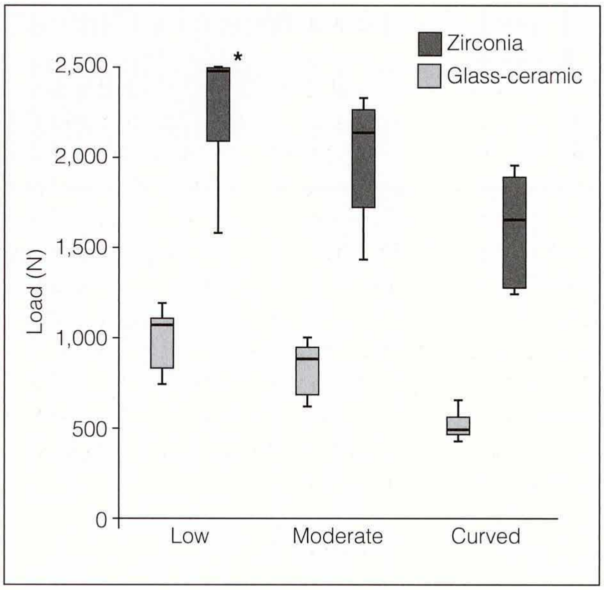

Fig 2 *(right)* A box-plot diagram of the load at fracture. The boxes represent 75% of the results, the horizontal lines within the box represent the median value, and the vertical bars the min/max values.* Five crowns in the low zirconia group did not break at maximum load. Their values were set to 2,500 N.

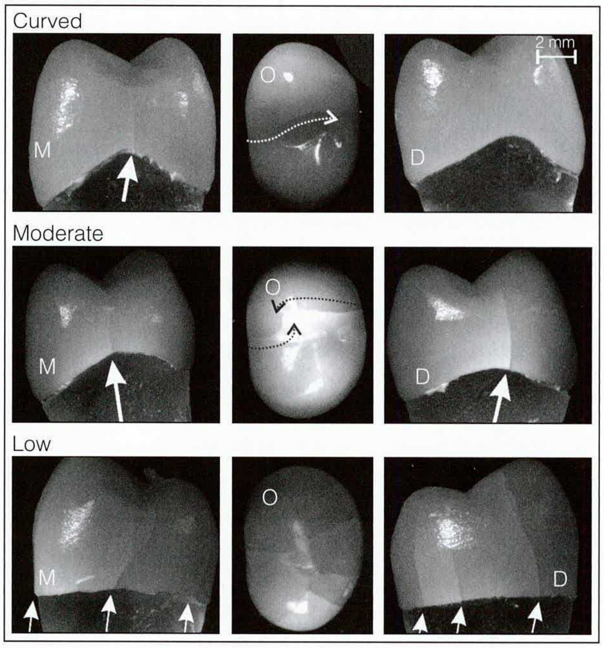

Fig 3 Typical fracture modes for the three test groups. Each crown is presented from the mesial (M), occlusal (O), and distal (D) views. The white arrows indicate fracture lines. The dotted arrows indicate the crack propagation on the occlusal surface.

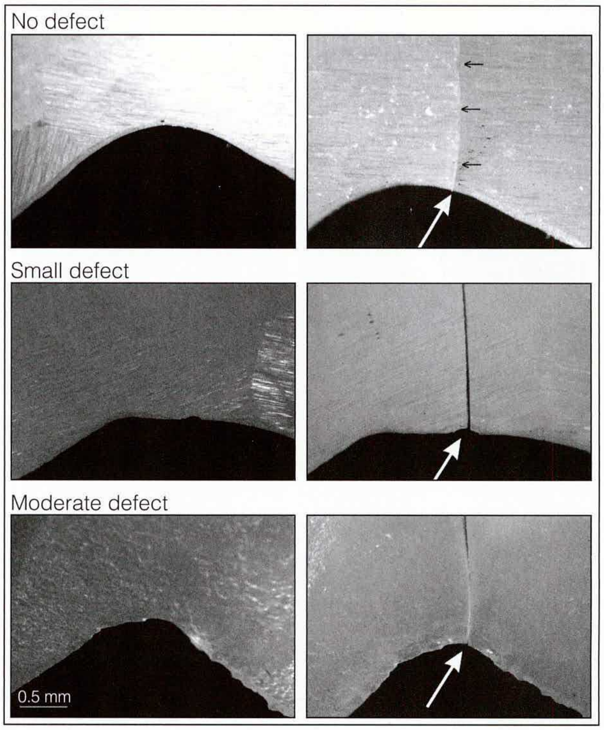

Fig 4 Images of crown margins before *(left)* and after *(right)* being subjected to the axial loading leading to fracture. *(Top)* A zirconia crown with no visible defect at fracture start. *(Middle)* A zirconia crown with a small defect at fracture start. *(Bottom)* A glass-ceramic crown with a moderate defect at fracture start. The white arrows indicate the fracture origin. The black arrows indicate the crack.

No crowns had major flaws before being subjected to the test, but all had imperfections, including minor to moderate-sized flaws or defects at the crown margin. Most fractures (zirconia 85%, glass-ceramic 65%) in the curved and moderate groups originated from an existing flaw at the crown margin (Fig 4). Fracture origin on the mesial side was found in 26 crowns and on the distal side in 14 crowns. There was no statistically significant correlation between the presence of flaws or location of origin and load at fracture.

Discussion

The findings show that the curvature of the finish line strongly influences the load at fracture and the fracture modes of all-ceramic crowns. Most fractures originate from pre-existing flaws. The findings can explain why all-ceramic crowns fail in clinical use even though the in vitro fracture strengths indicate that they should be able to withstand mastication forces.[5] The loads at fracture in many in vitro studies are based on tests performed on crowns with leveled crown margins, and usually by inducing occlusal contact damages.[2,5] In vivo, preparations are adjusted for tooth anatomy, previous damages, and the gingival contour, resulting in asymmetric crowns.

Conclusions

This report shows that the presence of margin flaws in all crowns indicates that the manufacturing method is not optimal. The finding that most fractures originated from existing flaws in the crown margin suggests that flaws function as stress concentrators and contribute to lower loads at fracture. The clinical implication of the results is that the preparation margins should be as leveled and even as possible without jeopardizing the vitality of the tooth or the gingival papillae.

Acknowledgments

The authors thank Torkildsen, Thunes og Olsen Tannteknikk, Bergen, Norway, who manufactured all crowns at a reduced cost. The authors reported no conflicts of interest related to this study.

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Literature Abstract

Longevity of posterior composite restorations: A systematic review and meta-analysis

This review paper investigated the failure rates, failure reasons, and influence of patient-, materials-, and tooth-related variables on posterior composite restorations (PCR) survival. Out of 1,551 papers identified, 12 longitudinal studies with at least 5 years' follow-up were included, using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The authors constructed a comprehensive database of restorations from original datasets consisting of 2,816 restorations (2,585 Class II and 231 Class I), and performed a regression analysis based on patient (age, gender, caries risk), tooth (location, restored surfaces), and material (composite, glass-ionomer, adhesive type, presence of base/liner) variables. Failure rates for all composites demonstrated a mean annual failure rate of 1.8% and 2.4% after 5 and 10 years of service. Failure reasons in the first year revealed that it was mainly endodontic complications, while in later years, caries and fractures were the main failure reasons. For premolars, hazard ratios demonstrated more failure for teeth with high caries risk (HR 2.44, $P < .001$), presence of lining cement (HR 4.9, $P < .001$), and number of restoration surfaces (HR 1.45 for every extra surface, $P < .001$). For molars, this outcome was similar, with HR 3.04 for caries risk ($P < .001$), 2.87 for lining ($P < .001$), and 1.24 for surfaces ($P = .002$). This study showed a significantly higher risk of failure for restorations in individuals with high caries risk and those with a higher number of restored surfaces. It is important to note that this study included mostly Class II restorations, encompassed data from different practice settings, had different survival criteria, and 10 of the 12 studies were delivered by only three research groups, which may have led to possible bias and restrictions on its generalizability.

Opdam NJ, van de Sande FH, Bronkhorst E, et al. *J Dent Res* 2014;93:943–949. **References:** 36. **Reprints:** N.J.M. Opdam, Radboud University Nijmegen Medical Centre, College of Dental Sciences, Preventive and Restorative Dentistry, Ph van Leydenlaan 25, PO Box 9101 6500HB Nijmegen, The Netherlands. Email: niek .opdam@radboudumc.nl—*Loke Weiqiang, Singapore*