Impact of machining process on the flexural strength of a composite resin block for CAD/CAM dental restorations

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Introduction

CAD/CAM composite blocks, generally composed of a polymer matrix, glass particle fillers and a silane coupling agent, are recent materials designed for milling indirect dental restorations [1]. Their industrial manufacturing provides higher biocompatibility, mechanical properties and reliability than direct composites (placed and polymerized by dentists in patient's mouth) and traditional indirect composites (hand-fabricated by technicians). Compared to ceramics, they are preferred for thin restorations because of their better machinability. However, numerically controlled milling generates surface roughness that depends on the tool-material couples and on the tool orientation over the milled surface [2]. To make a dental crown, the tool covers a large range of orientations: from 0° (end milling) on occlusal surfaces to 90° (flank milling) on peripheral surfaces. The initial surface flaws introduced during milling may significantly reduce flexural strength of the restorative material and, consequently, prosthesis lifetime [3].
The objective of this study is to quantify the impact of the machining process on the flexural strength of Coltene Brilliant Crios CAD/CAM composite. Its flexural strength is measured for different values of surface roughness in order to correlate flexural strength to surface roughness and material microstructure. This study may help manufacturers improve the mechanical properties of restorative materials and the machining strategies of dental CAD/CAM systems.

Methods

3-point bending tests were performed on 28 Coltene Brilliant Crios highly polished bend bars. Weibull strength distribution and fractography analysis were performed on these samples in order to characterize fracture origins for an ideal material without initial surface flaws. Using fracture mechanics, the critical flaw size was estimated and compared to the measured flaw size. This analysis will also be conducted on samples obtained by CAD/CAM machining for 3 different orientations of the milling tool corresponding to flank, end and intermediate milling.

Results

Coltene Brilliant Crios showed a flexural strength of 233 MPa and a Weibull modulus of 9.5. Fracture origins were diverse: pores, inclusions, polishing damage near the center or at corners of the specimen (Fig. 1). The average calculated flaw size was 26.7 µm whereas the average measured flaw size was 27.1 µm. A satisfying correlation was observed between calculated and measured flaw sizes (Fig. 2). The analysis of CAD/CAM machined specimens is currently in progress.

Conclusion

Coltene Brilliant Crios showed higher mechanical properties than traditional direct and indirect dental composites, encouraging new treatment options such as implant-supported crowns [1]. Its reliability should be improved to reach Weibull modulus values observed for ceramics or more recent CAD/CAM composites such as the polymer infiltrated ceramic network, Enamic [4]. Manufacturing parameters could be optimized to reduce the pore size and the number of inclusions and, therefore, further enhance mechanical properties and durability of composite restorations. However, CAD/CAM machining can create surface flaws whose size is comparable with internal flaws. It is then essential to quantify the impact of surface roughness on material strength and to understand the potential interaction of internal and surface flaws in order to better predict mechanical failure of the prosthesis.

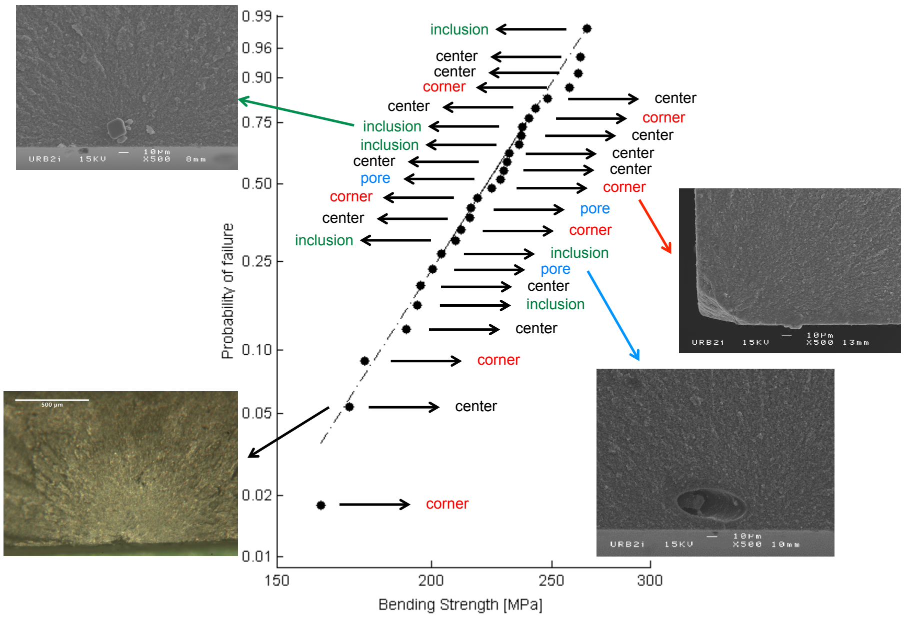

Figure 1 : Weibull analysis for Coltene Brilliant Crios CAD/CAM composite

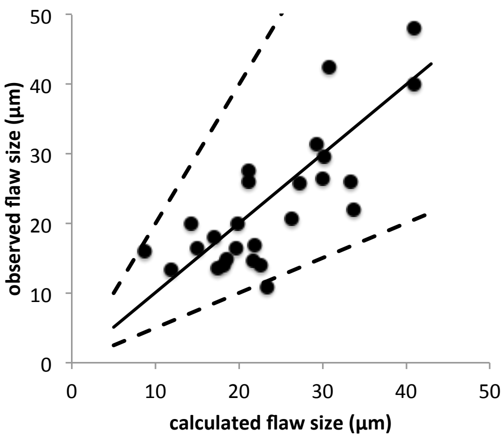

Figure 2 : Correlation between observed and calculated flaw size responsible for specimen fracture in 3-point bending

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