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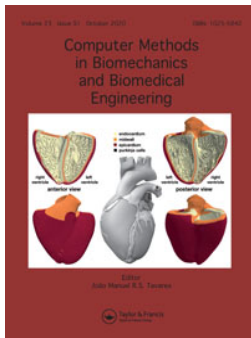
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Impact of machining process on the flexural strength of CAD/CAM blocks for dental restorations

Aurélié Benoit^a, Hiba Issaoui^a and Nicolas Lebon^b

^aUniversité de Paris, URB2I, UR 4462, Montrouge, France;

^bUniversité Paris 13, URB2I, UR 4462, Bobigny, France

1. Introduction

Thanks to the advent of CAD/CAM technology in dental practice and to the increased bonding strength of adhesives, dentists can now offer to their patient new types of restorations (inlays, onlays, overlays, veneers) with reduced dimensions, complex shapes and diverse materials (composites and ceramics) in order to preserve healthy tissues as much as possible. Dentists and/or dental technicians follow four steps to make a restoration using CAD/CAM technology (Tapie et al. 2015):

- Intraoral scan of the patient's prepared tooth
- Computer-aided design (CAD) of the prosthesis using dedicated software
- Computer-aided manufacturing (CAM) and numerically controlled milling of the prosthesis.
- Finishing: sandblasting and/or acid etching of the basal surface for adhesive infiltration; polishing and glazing of the external surface for aesthetic and biological requirements.

Fracture of the restoration is the first cause of clinical failure for restorations in ceramics (Pjetursson et al. 2007) and the second cause, after secondary caries, for restorations in composite (Opdam et al. 2014). Curran et al. (2017) have shown that manual adjustment of the prosthesis after machining - grinding with diamond discs followed by polishing - introduced chipping damage responsible for a decrease in strength by 10 to 70% depending on the considered material. This study focuses on numerically controlled milling that may also introduce initial local damage. Lebon et al. (2015) have shown that milling

parameters such as the tool-material couple or the tool orientation generated different surface roughness.

The objective is to evaluate the impact of numerically controlled machining on surface topography and on flexural strength for various restorative materials and milling conditions.

2. Methods

Four restorative materials were included in this study:

- Coltene Brilliant Crios composite composed of a reticulated methacrylate resin reinforced by dental glass and amorphous silica
- Cerasmart composite composed of a Bis-MEPP, UDMA and DMA resin reinforced by silica and baryum glass particles
- Enamic polymer infiltrated feldspathic ceramic network
- LRF leucite reinforced feldspathic ceramics.

Two milling conditions were investigated:

- FL: Flank milling with Lyra milling bur (grain size $78 \mu\text{m} \pm 18 \mu\text{m}$)
- EC: End milling with Cerec milling bur (grain size $44 \mu\text{m} \pm 10 \mu\text{m}$)

For Coltene Brilliant Crios composite, two additional conditions were investigated: high polishing (HP) ($1 \mu\text{m}$) and flank milling with Cerec milling bur (FC). Surface roughness was estimated using Alicona focus variation microscope.

Table 1 shows the number of samples subjected to 3-point bending tests and analysed using Weibull statistics. Fractography analysis was performed for Coltene groups in order to characterize fracture origins for each surface condition. Using fracture mechanics, critical flaw size is also calculated from fracture toughness and flaw location.

3. Results and discussion

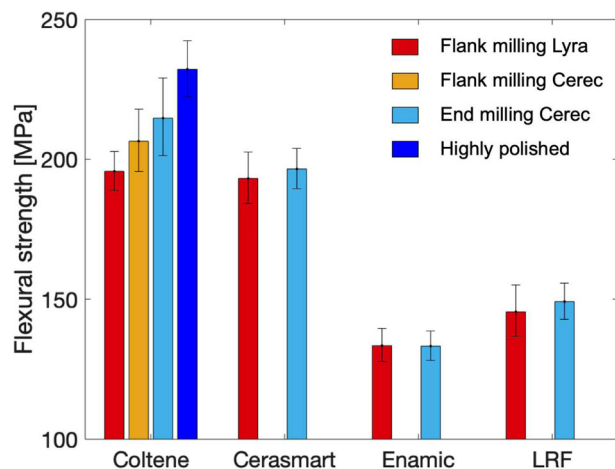
Figure 1 shows the flexural strength of the studied restorative materials, which ranked as follows:

Coltene > Cerasmart > LRF > Enamic.

No significant impact of milling condition was observed for Cerasmart, Enamic and LRF (difference

Table 1. Number of samples per group.

	Coltene	Cerasmart	Enamic	LRF
FL	n = 9	n = 15	n = 15	n = 13
FC	n = 10	–	–	–
EC	n = 10	n = 15	n = 14	n = 14
HP	n = 28	–	–	–

**Figure 1.** Characteristic flexural strength. Error bar: 95% Weibull confidence interval.

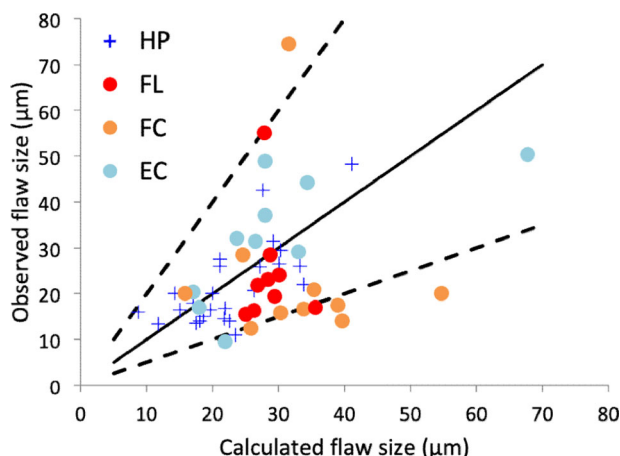
in flexural strength < 3%). This result was expected for Enamic and Cerasmart, known for their machinability but was more surprising for LRF. Indeed, strength reduction due to chipping induced by manual grinding is evaluated between 34% and 47% for a material similar to LRF (Curran et al. 2017).

For Coltene Brilliant Crios, the FL group showed 8.8% lower flexural strength than the EC group, the EC group's flexural strength being already reduced by 8% compared to the HP reference group. Damage induced by flank milling with Lyra bur is greater than grinding damage generally observed on restorative composites.

Surface roughness was significantly affected by milling conditions. For Coltene Brilliant Crios, Ra parameter increased from 0.2 µm for EC condition to 1.9 µm for FL condition. Roughness measurements are in progress for the other groups.

All Coltene groups showed diverse and similar fracture origins: pores, inclusions, machining or polishing damage near the centre or at corners of the specimen. However fracture origins were more often related to machining damage for the FL group.

A satisfying correlation was observed between calculated and measured flaw sizes (Figure 2), especially for groups with low surface roughness (EC and HP). For FL and FC groups, the measured flaw size was smaller than the calculated flaw size, suggesting an interaction between material microstructure and surface topography.

**Figure 2.** Correlation between calculated and observed flaw sizes for Coltene Brilliant Crios.

4. Conclusions

This study showed that machining parameters had little impact on the flexural strength of Cerasmart, Enamic and LRF. However, the orientation and the type of milling burs significantly affected Coltene Brilliant Crios strength. Thus, dental CAD/CAM software should adapt their machining strategy and recommendations according to the chosen restorative material.

Acknowledgements

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✉ aurelie.benoit@u-paris.fr