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# Milling Evaluation of Amber Mill®

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## Introduction:

Important properties evaluated in this study that may be affected by the combination of mills and materials while producing restorations include flexural strength, machinability (chipping), milling accuracy, and initial surface roughness. This study used a five-axis mill, the ***VersaMill 5X400*** with a lithium disilicate milling strategy to evaluate the machinability of a recently released lithium disilicate block, ***Amber Mill®*** (Hass Corp). ***Amber Mill*** has a unique feature that allows the material to be very transparent before heat treatment, and the temperature of the heat treatment modulates the translucency from high translucency to opaque reducing the need for multiple blocks of different translucencies for any given shade.

## Polishability and surface roughness:

Flexural strength specimens were used to examine the initial surface condition of the materials after milling. The specimens were evaluated with a scanning electron microscope under various magnifications and a *Bruker Dimension Icon Atomic Force Microscope* for qualitative and quantitative evaluation of the surface topography. The initial gloss was measured with a *Novo-Curve Glossmeter,* with three measurements per specimen every 120° and the surface roughness with a *Bruker Dimension Icon Atomic Force Microscope* with an 80 x 80 µm area scanned to generate a 3D topographic map and calculate the average surface roughness (Ra). The specimens were polished with a ***Luster Twist Polishers*** (Meisinger) for 20, 40 and 120 seconds and the change in gloss and roughness measured for a time dependent polishing measurement.

| Polishing, means (standard deviations) | | | | |
|---|---|---|---|---|
| Parameter | Milled | 20s | 40s | 120s |
| Gloss, gu | 3.0 (0.3) | 52.6 (4.6) | 82.9 (2.3) | 99.0 (1.5) |
| Roughness, Ra, nm | 1580 (260) | 410 (300) | 109 (33) | 9.0 (6.4) |

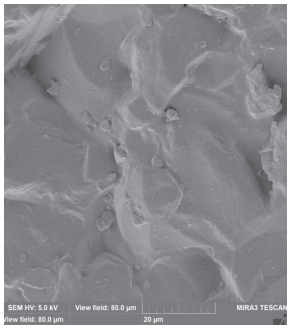
The polishing rate is similar to other glass ceramics, and extended polishing time can achieve an almost glass like appearance with a surface roughness of less than 10 nm. The total peak to trough height after milling was 10.4-11.4 mm. Adequate polishing with an Ra below 200 nm (or 0.2 µm) to minimize bacterial adhesion was achieved within 40 seconds of polishing.


**MATERIALS:**

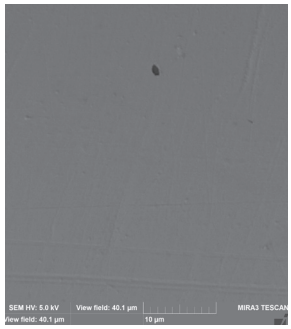
**CAD/CAM Materials:** ***Amber Mill*** block A1 (Hass Corp.)
**Mills:** ***VersaMill 5X400*** with Lithium Disilicate milling strategy
**Burs:** 2.5 mm, 1.5 mm and 1.0 mm OEM diamond burs (Versamill Part Number: DG-52, DG-53, DG-54)
**Oven:** ***Ivoclar Programat 300*** using the MO heat treatment profile

**TESTS:**

Flexural Strength, Milling Accuracy, Chipping of Machined Blank Specimens, Surface Roughness, and Polishability.

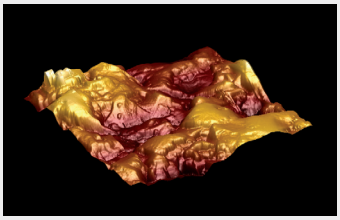


SEM image of the representative appearance of an 80 x 80 µm area of initial surface evaluated by AFM

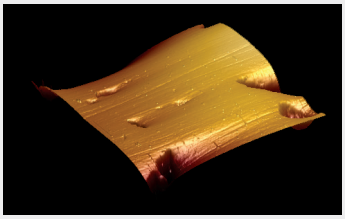


SEM image of a highly-polished surface showing a mirror-like image

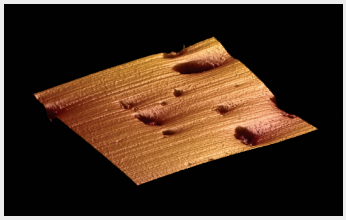
**Atomic Force Microscope Scans over 80 x 80 µm**



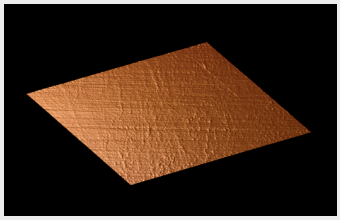
**Initial roughness**



**20s polishing**



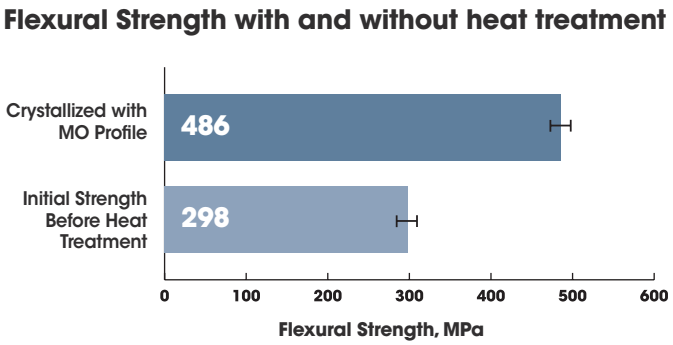
**40s polishing**

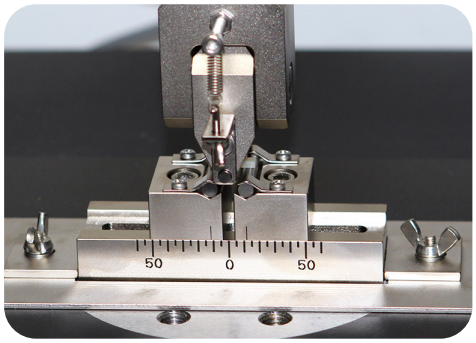


**120s polishing**

## Flexural Strength:

Flexural strength bars (n=10, 14 x 2 x 4 mm) were tested according to ISO 6872:2015 methods. One group was tested after heat treatment according to the MO profile and one group was not heat treated to test the initial strength during milling. The bars were cut with a slow-speed wafering saw and finished through 600-grit SiC paper before crystallization. Bars were loaded in 3-pt bend with a 12-mm span and 1 mm/min crosshead speed in a *Shimadzu AGX-V Universal Test Machine.*

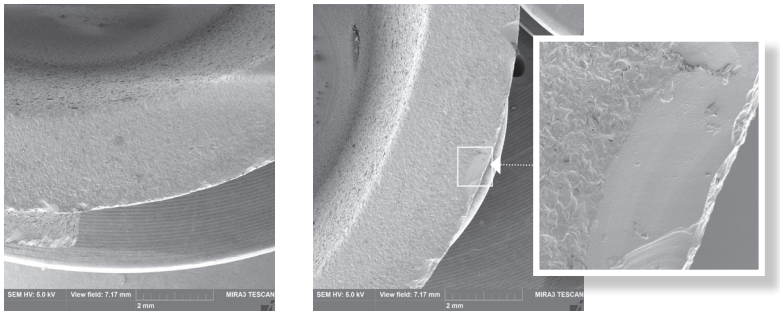



The initial flexural strength of the material was 298 MPa before heat treatment which increases up to 486 MPa after heat treatment.

## Machinability:

**Chipping of Machined Blank Specimens:** Five standardized crowns with a 2-mm occlusal thickness and 1-mm axial thickness with a shoulder margin finish line were milled with each material. The margin was examined under magnification to detect defects with a minimum size of 0.1 mm and the margin thickness measured with a digital micrometer. The total length (L) of the chipped areas and total perimeter (P) of the crowns were measured and the chipping factor for each crown was calculated (CF = L/P) and presented with means and standard deviations. The measured thickness of the margin with a calibrated digital micrometer *(Mitutoyo Absolute Digimatic)* ranged from 1.00 mm to 1.03 mm.



The chipped flakes were all less than 0.2 mm of the margin thickness and cannot be easily seen without magnification.

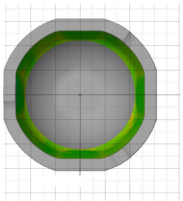
| Chipping Factor, chipped area/circumference | | |
|---|---|---|
| Material | CF | CF, % |
| Amber Mill | 0.035 (0.020) | 3.5 (2.0) |

Overall, 96.5 % of the margins were fully intact and results are typical of milling of hard ceramics. Shallow chips were visible around approximately 3.5% of the circumference of the margin. Approximate depths of the chips were between 30-100 microns.

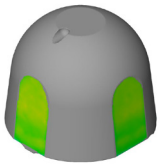
## Machining Accuracy:

**Machining Accuracy (ISO/TR 18845:2017):** Standardized crown shape specimens with a 12-mm diameter, 10-mm height, 1-mm wall thickness were milled, scanned with a ***3Shape E3*** model desktop scanner to 7µm accuracy and analyzed with *Geo-Inspect 2018* software according to ISO/TR 18845:2017 methods. Means and standard deviations were calculated of the lateral discrepancy, Z-direction discrepancy and prep-line discrepancy.

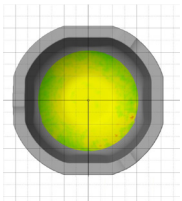
| Machining Accuracy Discrepancy | | | | | |
|---|---|---|---|---|---|
| Material | Intaglio Lateral, µm | External Lateral, µm | Intaglio Z-Direction, µm | External Z-Direction, µm | Prep-line, µm |
| Amber Mill | 31 (25) | 42 (20) | 89 (22) | 89 (26) | 20 (50) |



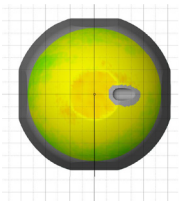
Specimen intaglio surface plane in the lateral direction.



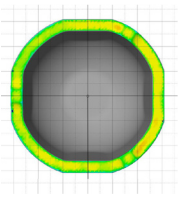
Specimen external surface plane in the lateral direction.



Specimen intaglio surface plane in the Z-direction.



Specimen external surface plane in the Z-direction.



Specimen prep-line surface in the Z-direction.

The results of the milled specimens were scanned and compared to the original design file. The mean value of the machining accuracy gives an idea of how much over/under milling there was as the comparison can give positive or negative numbers. The standard deviations describe the range of values around the mean. In comparison to the results from RR 126 using an ***inLab MC XL***, the ***VersaMill 5X400*** had similiar or better accuracy for the Intaglio Lateral, and Prep-line areas. There was less variability (smaller standard deviations) in 4/5 areas examined. The Intaglio and External Z-direction both registered higher discrepancies than the other areas, highlighting an aspect that could potentially be improved in the milling control software, or could be compensated during designing the restoration.