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Visualization of mechanical properties in alumina dental crowns fabricated by using laser scanning stereolithography[†]

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KEY WORDS: (Dental crown) (Alumina) (Stereolithography) (Flexural strength) (Sintering behavior)

1. Introduction

Ceramic dental crowns to cover human teeth or dental implants are investigated and developed actively in worldwide medical industries in order to realize advantages of aesthetic sensuousness and to avoid serious risks for metallic allergies. In this investigation, the dental crown models of acrylic resins including ceramic particles were fabricated by using laser scanning stereolithography of a computer aided design and manufacturing. Graphic data of the crowns were obtained through a computer tomography scanning. Dense objects of alumina ceramics as biomedical components were fabricated successfully through powder sintering processes [1,2]. Moreover, the formed crowns were coated by dental glasses to improve aesthetic and mechanical properties.

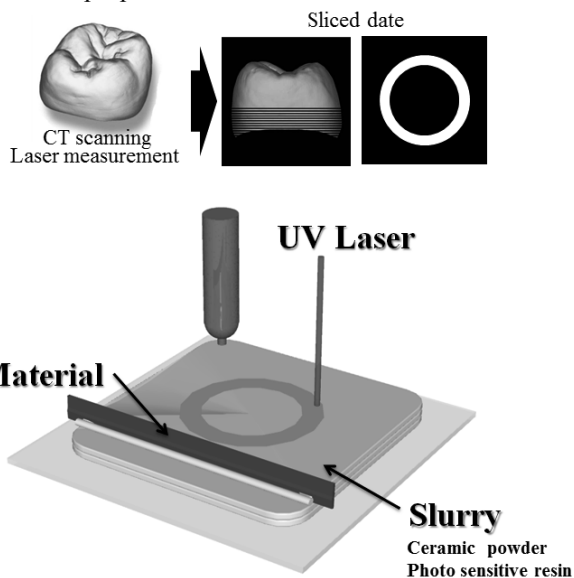


Fig. 1 Schematic illustrations of data processing and laser scanning in stereolithography technique of a computer aided design and manufacturing (CAD/CAM) procedure.

2. Experimental Procedure

The dental crown models and flexural test specimens of 4.5×22×1.0 mm in dimensions were fabricated by using

stereolithography. **Figure 1** shows schematic illustrations of the fabrication system. Three dimensional model data was converted into the stereolithography file format, and sliced into a series of two dimensional data with uniform thickness.

These files were transferred into the process equipment (D-MEC, SCS-300P). Slurry material was prepared through mixing photo sensitive acryl resin and alumina powder (Showa Denko, AL-170) at 60 to 70 volume %. The mixed paste was spread on a flat substrate and smoothed. An ultra violet laser beam of 355 nm in wave length was scanned over the deposited layer to create cross sectional planes. After these layer stacking processes, solid components were fabricated. These precursors were de-waxed at 600 to 800 °C for 2 hs and sintered at 1400 to 1600 °C for 2 hs in the air atmosphere. The sintered ceramic components were coated with La₂O₃-B₂O₃-Al₂O₃-SiO₂ glass (Zahnfabrik, In-Ceram-Alumina) for the dental use and heated at 1100 °C for 2 hs. The ceramic microstructures were observed by using a scanning electron microscope. And the flexural strengths of plate specimens were measured by using a three point bending test machine.

3. Results and Discussion

The stereolithographic composite model and the sintered alumina crown are shown in **Fig. 2**. Macroscopic damage and deformations are not observed. Cross sectional micro-structures of sintered bodies and glass infiltrate samples are shown in **Fig. 3**. The large cracks propagate parallel to the stacked layers formed in the stereolithographic processes. Through the glass infiltrate treatments, these cracks become inconspicuous. The maximum flexural strength is achieved 587±91 MPa by sintering at 1500 °C and glass infiltration. This mechanical property is acceptable level for dental crown use. Subsequently, we considered sintering behaviour at each temperature for the non-keeping times. **Figure 4** shows the ceramic microstructures at each heating temperature. The sintered sample at 1300 °C shows the powder-like microstructure. Comparing with this, by the sintering at 1400 to 1500 °C, the neck growths between the particles were considered to be started.

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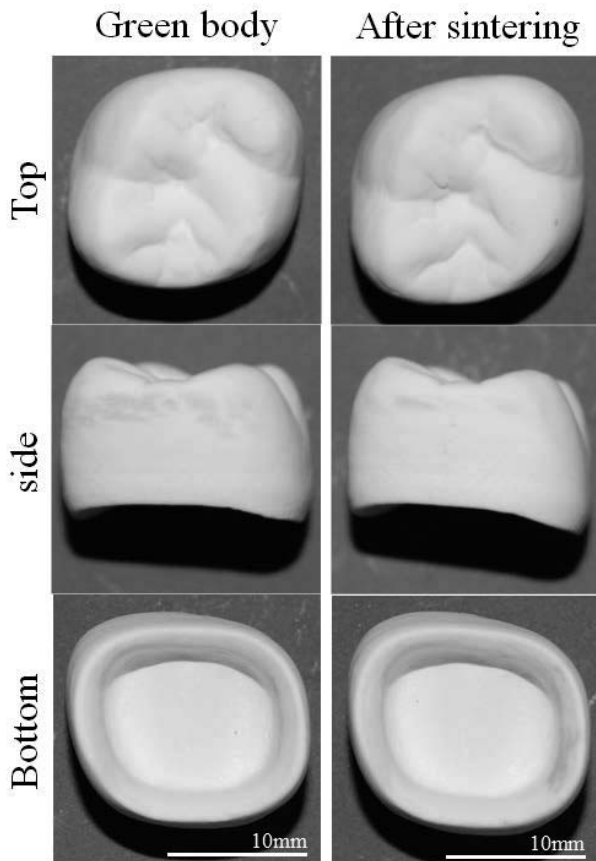


Fig. 2 Dental crown models of green bodies composed of acrylic resin with alumina particles formed by the stereolithography and sintered ceramic components.

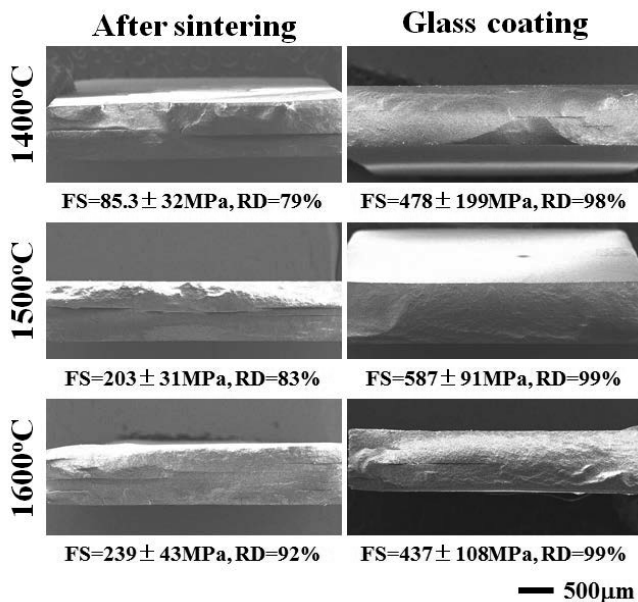


Fig. 3 Cross sectional ceramic microstructures of alumina flexural test samples with or without glass infiltrations. The plate specimens were formed by stereolithography and heat treatment processes. FS and RD mean the flexural strength and relative density, respectively.

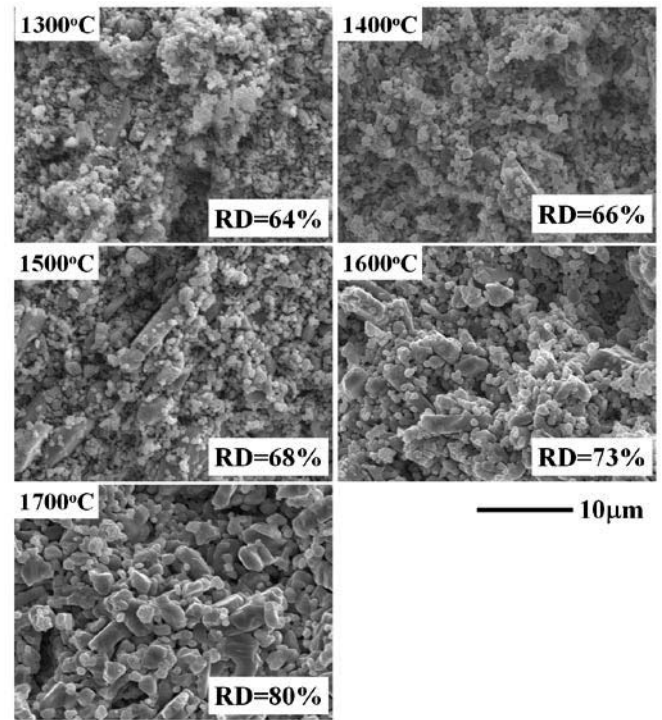


Fig. 4 The ceramic microstructures of the sintered alumina. The composite precursors formed by the stereolithography were de-waxed and sintered at 1300 to 1700 °C without time keeping for the necking growth observations.

4. Conclusion

Three dimensional alumina components of dental crowns and mechanical test plates were fabricated successfully by using stereolithography. Flexural strength of glass infiltrated sample is achieved about 600 MPa as an acceptable level for dental crown use. Subsequently, sintering behaviours of the alumina components were investigated, and the obtained results will serve as a guide to material designs.

5. Acknowledgments

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