Influence of sepiolite and silica on the mechanical and viscoelastic properties of urethane acrylate- based resin for 3D-printed denture teeth

Hyebin Ahn, D.D.S, M.S.
Seoul St. Mary's Hospital

INTRODUCTION

Three-dimensional printing technology has led to a new approach to fabricating dentures as the popularity of digital dentistry grows, allowing simpler fabricating process of dentures and reproducing complex geometries. However, previous studies have reported on the limitations of the mechanical properties of 3D-printed denture. Also, a few studies dealed with mechanical properties of 3D-printed denture teeth compared to denture base. The purpose of this study was to evaluate the effect of adding silica and sepiolite nanofillers to 3D-printed urethane acrylate as denture teeth material.

MATERIALS

Matrix

Double-cross linked urethane acylate resin
(TC-80, Graphy Inc, Seoul, Republic of Korea)

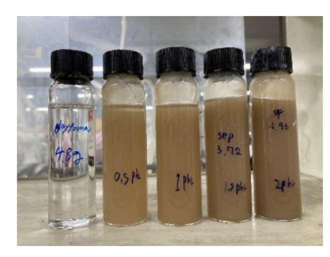
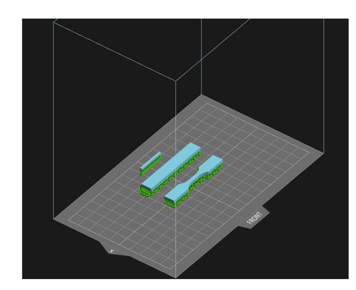
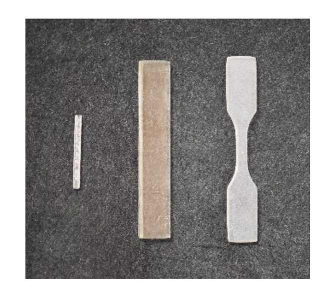
Nanofiller

Sepiolite (Sepiolite, Sigma-Aldrich, USA)
- $Mg_2H_2Si_3O_9 \cdot xH_2O$ unit
- diameter of 10–30nm, length of 1–2µm

Silica (SC5500-SMJ, YC100C-SM2, Admatechs, Japan)
- surface treated with methacrylate
- 0.5µm of fumed-silica (SC2500-SMJ), 100nm of fumed-silica (YC100C-SM2)
- mixed in a ratio of 9:1

Sample preparation

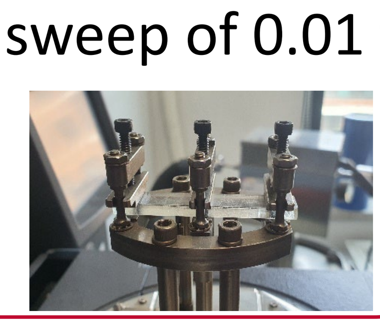
The raw materials composing urethane acrylate resin was mixed with sepiolite or silica at concentrations of 0, 0.5, 1, 1.5, and 2 parts per hundred resin (phr) for sepiolite and 0, 0.5, 1, 1.5, 2, and 5 phr for silica. The specimens were designed by computer-aided design software (Rhinoceros 7.0; McNeel, Seattle, USA), printed by a digital light-processing 3D printer (Pro95; SprintRay, CA, USA), and post-cured for 15 min.

Strength test, dynamic mechanical analysis

In flexural and tensile strength tests, 77 specimens per strength test (7 specimens for each ratio) and 154 specimens in total were prepared and independently assessed. The mean value and standard deviation of the tests were used. Flexural strength and elastic modulus were measured in three-point bending tests in accordance with ISO 10477. Tensile strength and elastic modulus were measured in accordance with ASTM D638. A specimen with dimensions of 63 × 10 × 3.5 mm was prepared for dynamic mechanical analysis. The viscoelastic properties were evaluated by measuring the storage modulus, loss modulus, and loss tangent using a dynamic mechanical analyzer (Q800; TA Instrument, New Castle, USA) at 35 °C over a frequency sweep of 0.01 to 100Hz in a dual cantilevered condition at a strain of 0.1%.
Statistics- one-way analysis of variance with Scheffe's test and Dunnett's T3 test



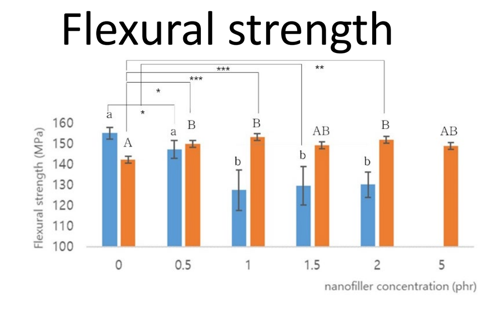


RESULTS

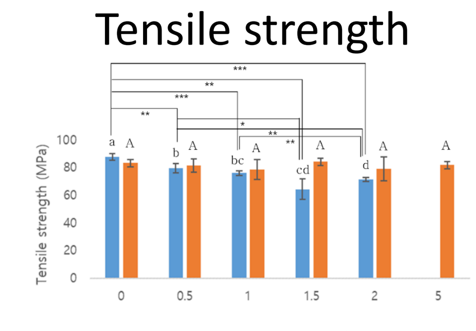
Flexural strength and tensile strength: An urethane acrylate matrix mixed with sepiolite filler exhibited lower flexural and tensile strength compared with a control. The flexural elastic modulus decreased until a sepiolite concentration of 1.5 phr was reached and it increased at 2 phr sepiolite. Tensile elastic modulus decreased until 1 phr sepiolite was reached and increased at 1.5 and 2 phr sepiolite. The addition of silica resulted in an increase in flexural strength and tensile elastic modulus, and constant flexural elastic modulus and tensile strength.
Viscoelastic properties: The storage modulus, loss modulus, and tanδ increased with the addition of sepiolite and silica in comparison with the control group. The storage modulus also increased with the frequency of sepiolite or silica. The addition of silica to urethane acrylate material therefore produced more favorable results compared with sepiolite.

RESULTS

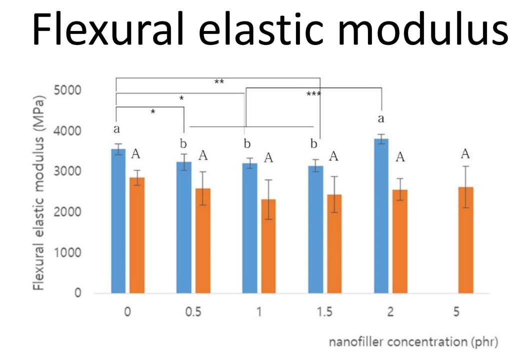
Flexural strength



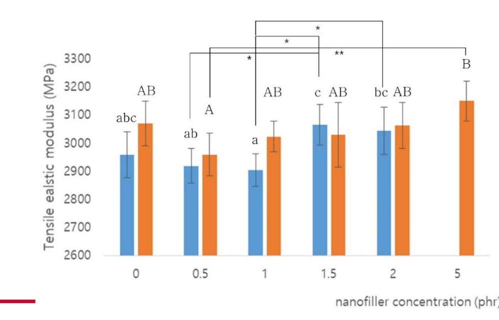
Tensile strength



Flexural elastic modulus

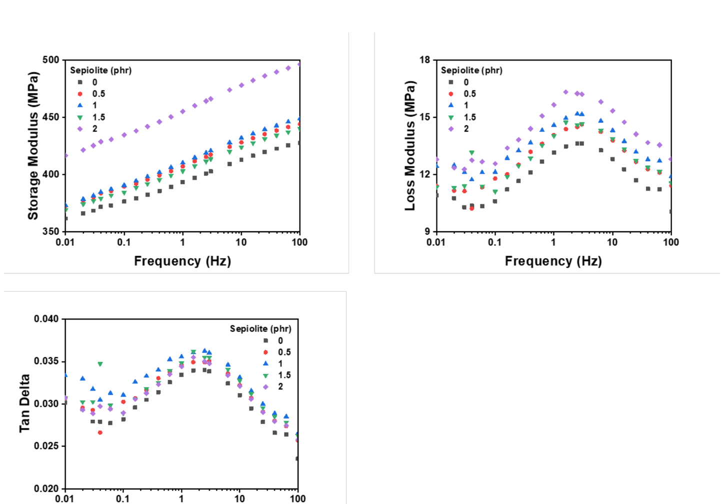


Tensile elastic modulus

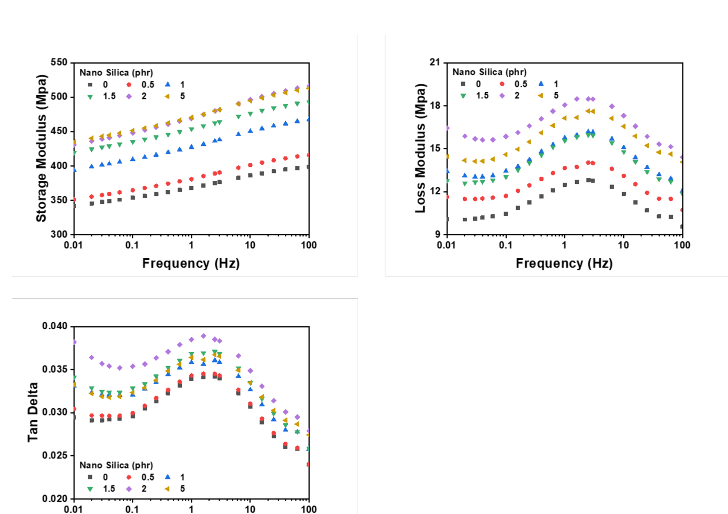


RESULTS

DMA with sepiolite



DMA with silica



CONCLUSION

A nanofiller can improve the mechanical and viscoelastic properties of 3D-printed urethane acrylate resin. The addition of a nanosilica filler to urethane acrylate resin achieved greater improvements in mechanical properties compared with a nanosepiolite filler. A methacrylate surface treated with fumed nanosilica is a potential nanofiller to reinforce the mechanical properties of 3D-printed urethane acrylate resin in denture teeth.

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