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Development and Mechanical Evaluation of Multi-Material 3D-Printed Tooth Models for Dental Education

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Introduction

- Learning and teaching of clinical skills is always challenging for teachers and students.
- Current tooth models do not accurately replicate the natural composition and key structural layers of enamel and dentine. This makes practising tooth preparation challenging for students.
- The advancement of 3D printing technology provides the opportunity to develop improved models that can aid student training.

Aim

- Create more effective and realistic tooth models for enhancing dental education by developing a multi-layered, 3D-printed new tooth model, particularly orientated to root canal training.

Methodology

- The study focused on optimizing 3D printing conditions using stereolithography and multi-jet printing technologies. (Fig.1).
- A total of 33 circular samples (30 mm diameter, 2 mm thickness) were printed. Seven resin samples for Formlabs printer (F1: Clear resin, F2: High-strength resin, F3: Model resin, F4: Bis-acrylate temporary restoration resin, F5: Denture-base resin, F6: Ceramic-filled hybrid composite resin, F7: Aluma Core resin) and five resin samples for Stratasys J5 printer (J1: Model, J2: Clear, J3: White, J4: Magenta, Stratasys J5 : Flexible) N = 3 per resin.
- Mechanical evaluation included Vickers and Mohs hardness, surface roughness analysis and SEM imaging were used to get the initial result. According to these results, cutting tests was developed to simulate clinical rotary instrumentation using a 150 g vertical load on a modified IsoMet precision saw. The models were tested by study groups involving 59 participants (29 undergraduate, 9 postgraduate and 21 academic staff) who evaluated tactile realism and learning value via questionnaires (Ethics Ref: 064036).(Fig. 4,5).

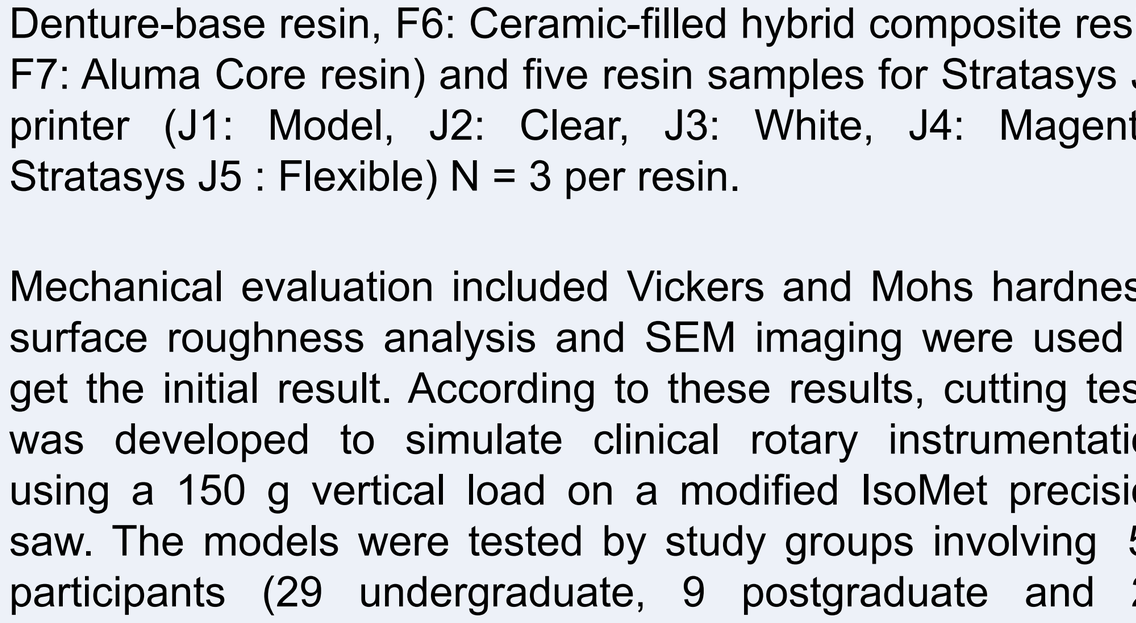


Figure (1) 3D printers used in the study, (A) Formlabs, (B) J5. (C) Schematic of layer-by-layer manufacturing.

Results

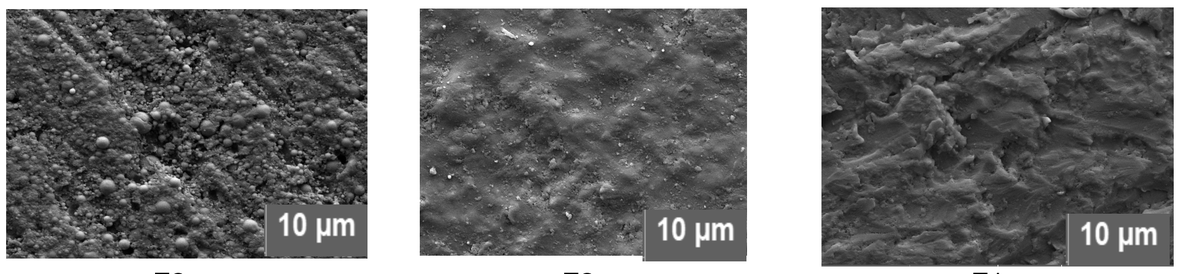
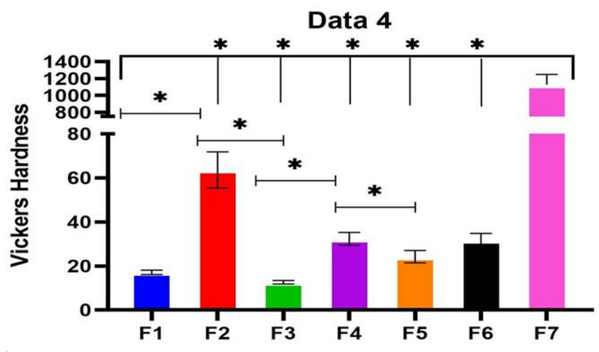


Figure (2) Representative SEM images for 3D printed samples using Formlabs printer.



Reference HV for native enamel and dentine
50-100 HV
- 290 to 450 HV *(1)*

Figure (3) Hardness of 3D-printed samples (A) created with the Formlabs printer, demonstrating that the High-strength resin material closely matches the mechanical properties of the dentine layer.

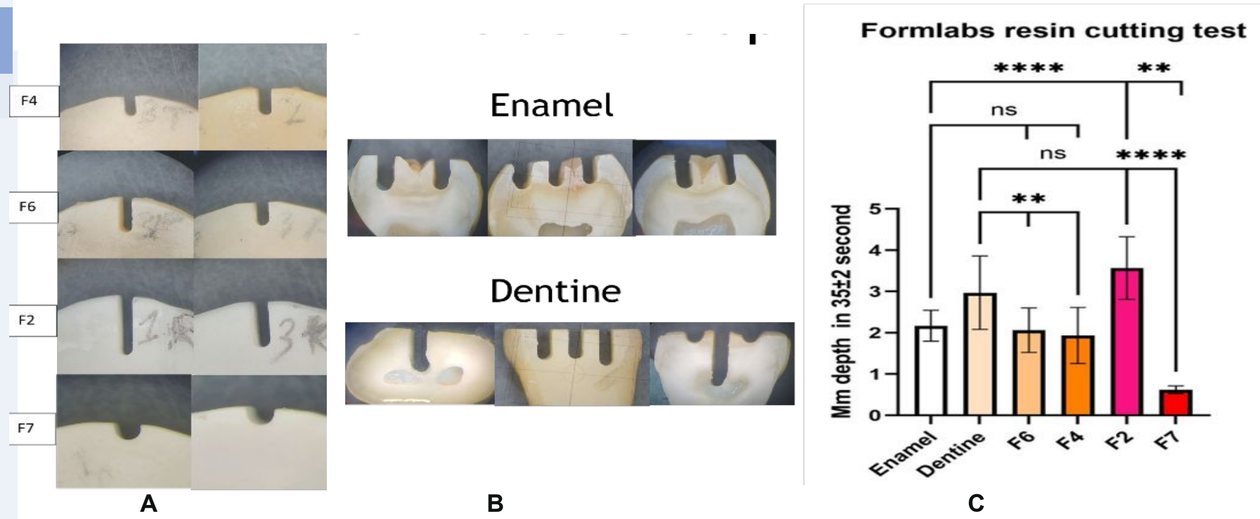


Figure (4) Representative macroscopic images and quantitative comparison of cutting performance between natural dental tissues and Formlabs 3D-printed resins. (A) Standardized bur-generated grooves produced under identical cutting conditions (35 ± 2 s) in SLA-printed resins (F2–F7). (B) Natural enamel and dentine as reference materials. (C) Mean cutting depths (mm) demonstrating material-dependent cutting resistance. Error bars represent mean ± SD; statistical significance indicated (*p < 0.05, **p < 0.01, ***p < 0.0001).*

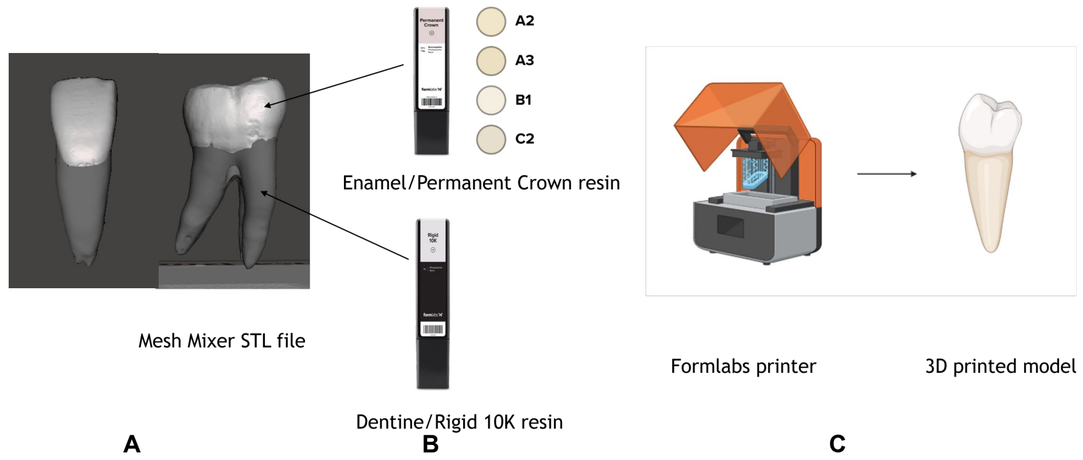


Figure (5) The process of creating a central incisor and molar model, including (A) the STL file used for 3D printing, (B) Resins to print the enamel(Permanent crown resin) and dentine (Rigid 10k), and (C) a schematic illustrating the layer-by-layer manufacturing process.



Figure (6) Representative X-ray and photographic images of biomimetic multi-layer 3D-printed tooth models fabricated using a multi-material approach. The enamel layer was manufactured using Permanent Crown resin, while the dentine layer was fabricated using Rigid 10K resin and the pulp filled with wax to mimic the structural hierarchy of natural teeth. (A) Central incisor model. (B) Molar model.

Conclusion : 3D printing enables the fabrication of biomimetic tooth models that closely replicate the mechanical properties of natural enamel and dentine. Using optimized resin selection, printing orientation, and multi-material design, the developed models improve tactile realism and have strong potential to enhance pre-clinical dental education .g (Fig.6).

References: Salehi P, et al., (2022). Dent Res J. 19(62).
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