Bridging the Gap: Integrating a virtual, 3D model with Finite Element Analysis to examine fixed dental prosthesis materials under combined loading

Nicholas Evans[1], BS; John Caldwell[1,3], PhD (Additional Member); Caley Orr[1,3] (Committee Chair), PhD; Thomas Greany[2], DDS (Mentor)

[1]Modern Human Anatomy Program, University of Colorado Anschutz Medical Campus, Aurora, CO U.S.A
[2]School of Dental Medicine, University of Colorado Anschutz Medical Campus, Aurora, CO U.S.A
[3]Department of Cell and Developmental Biology, University of Colorado Anschutz Medical Campus, Aurora, CO U.S.A

Modern Human Anatomy Program
UNIVERSITY OF COLORADO **ANSCHUTZ MEDICAL CAMPUS**

Background

- Ceramic and monolithic zirconia are common fixed dental prosthesis materials that have been suboptimally studied.
- Combined loading scenarios of the oral cavity have not been well documented.

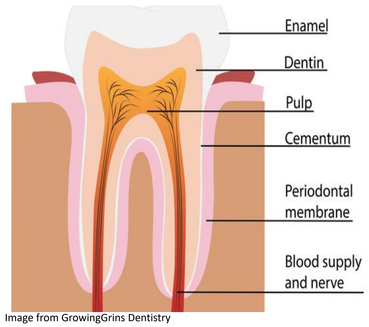


Image from GrowingGrins Dentistry

Tooth layers vary in mechanical and physical properties.

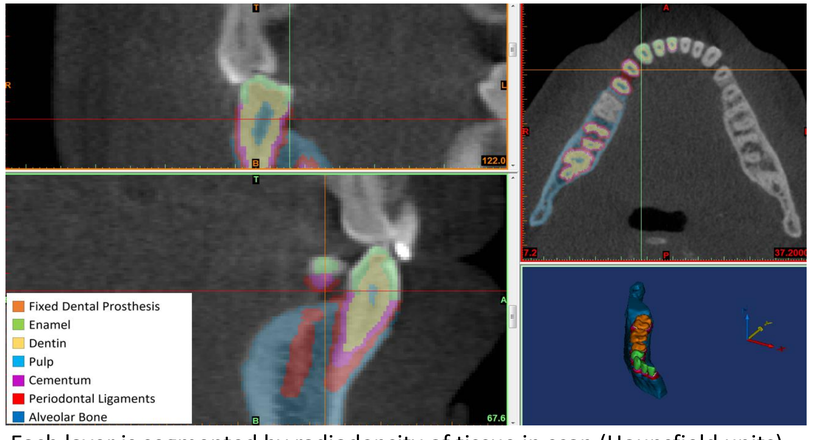
- Finite Element Analysis (FEA) investigates stress patterns by subdividing a structure into smaller “finite elements” and solving a system of equations.
- FEA research fails to accurately describe stress flow because clinicians may not understand essential biomechanics.
- A dental model containing realistic boundary conditions may not exist.

Purpose: Analyze stress patterns of dentition by:

- Creating a novel, 3D model with accurate dental layers that allows internal stresses and induced strain to be studied.
- Employing mechanical FEA to yield precise results in an effort to improve dental prostheses.

Segmentation

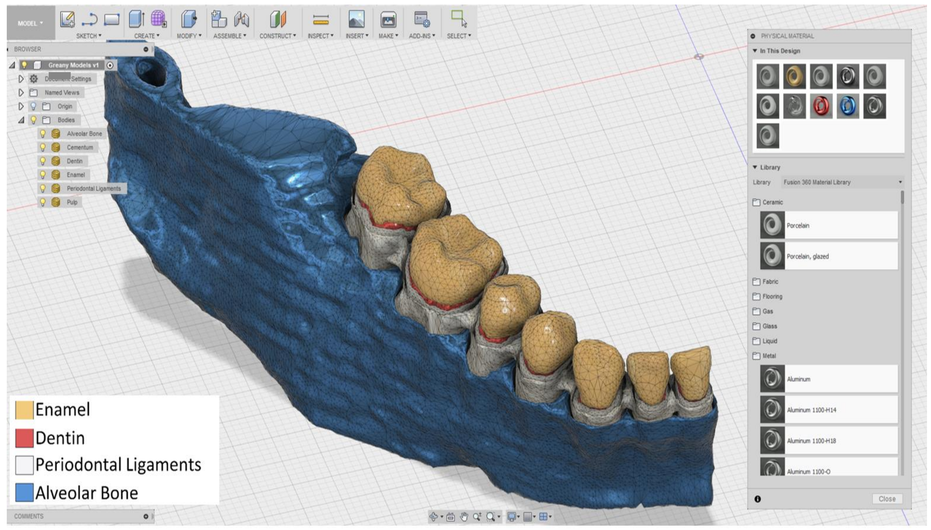
- Teeth and right lower jaw segmented from CT scan of head using Materialise Mimics (Materialise NV, Belgium).



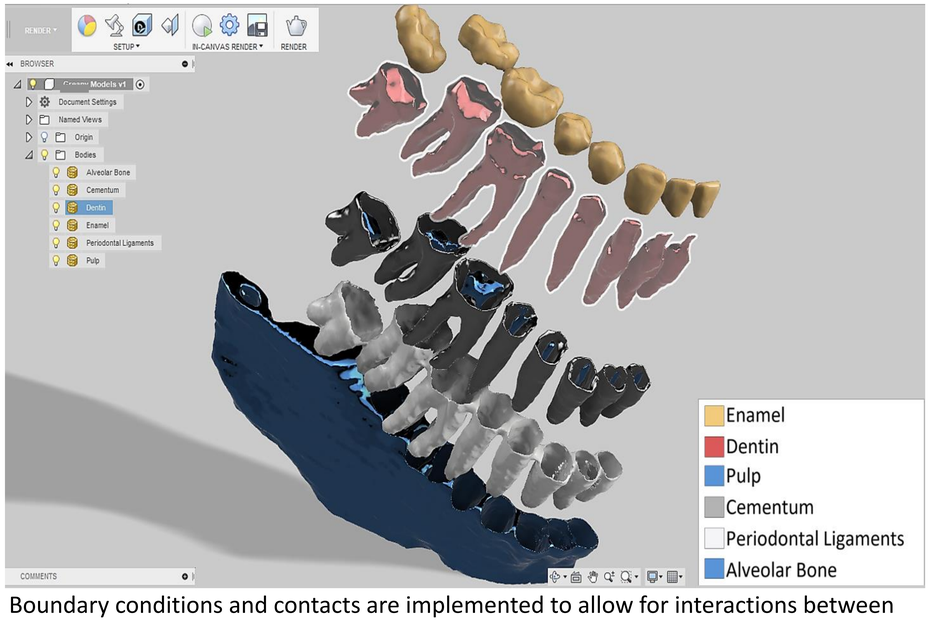
Each layer is segmented by radiodensity of tissue in scan (Hounsfield units).

Model Preparation

- The layered model is prepared to undergo mechanical FEA to assess stress and strain distribution (Autodesk Fusion 360).



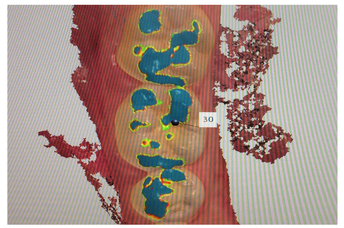
Each layer is assigned a specific material that is made using the custom materials toolbar.



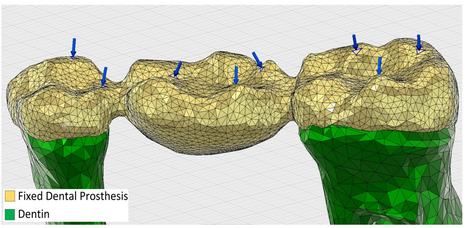
Boundary conditions and contacts are implemented to allow for interactions between layers when applied load is distributed throughout the model.

FEA Simulation

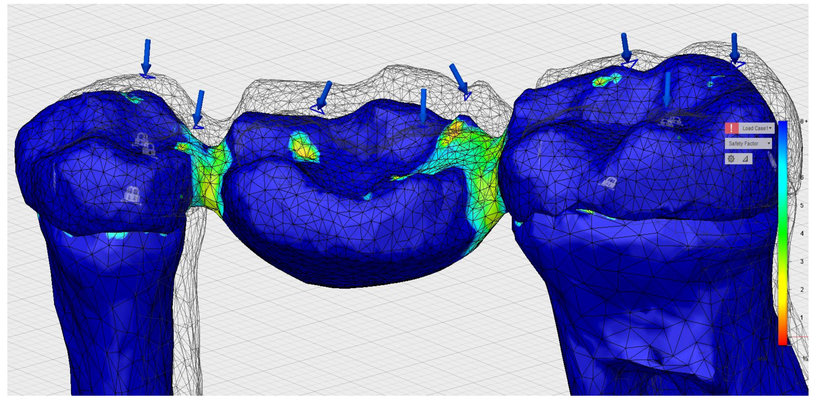
- A distributed load of 800N over eight regions is applied to the occlusal surface of the fixed dental prosthesis.



An intraoral scan depicting occlusal contact (3Shape Trios).



A lingual view of the model with the distributed load before application.



A lingual view after the force is applied in which blue represents low stress and red represents high stress – the highest stress occurs at the connectors.

Discussion

- Both layered ceramic and monolithic zirconia yield similar stress distributions at the connectors under the same loading conditions.
- Integration of mathematics, anatomy and computer imaging produced a realistic model represented by flexible layers.
- All 5 layers of the model may be utilized for stomatognathic, biomechanical research and investigations regarding strength analysis of dental prosthesis materials.

Acknowledgements

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