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UNIVERSITY of VAASA

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Inlay Fixed Partial Denture Framework 3-D Structural Integrity Validation Using COMSOL Multiphysics 3.5a

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Introduction

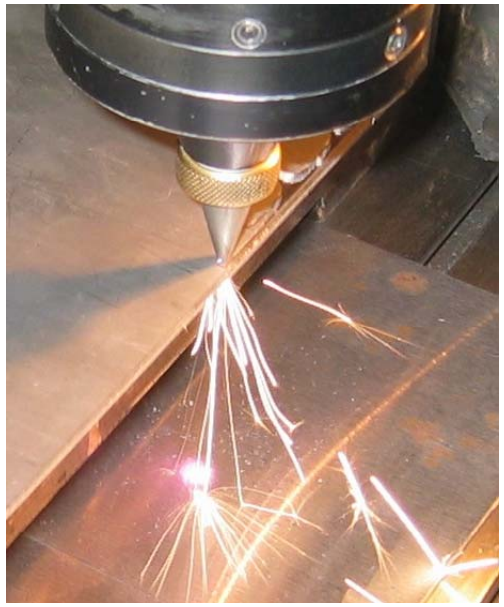
- Manufacturing dental prosthesis is delicate and time consuming work
  - Usually they are hand-made in a laboratory
    - Manufacturing only the framework by metal casting will take hours for an experienced dental technician
    - Can take all day for an inexperienced technician…
  - It is possible to order the framework from a company which has a 3-D milling machine – delivery times vary but can take up to a week
    - Doesn't speed things up…
  - Plus manufacturing the crown around the framework takes hours as well.

Introduction

- Could it be possible to add a little automation?
  - Pre-manufactured frameworks could definitely speed things up.
- Impossible to design a single framework that could be used in all situations without excessive customization by a dental technician.
- Framework for incisor area is difficult to manufacture (3D object with varying thickness)
  - Prosthesis is attached to the back side of the abutment teeth to minimize the esthetic damage.

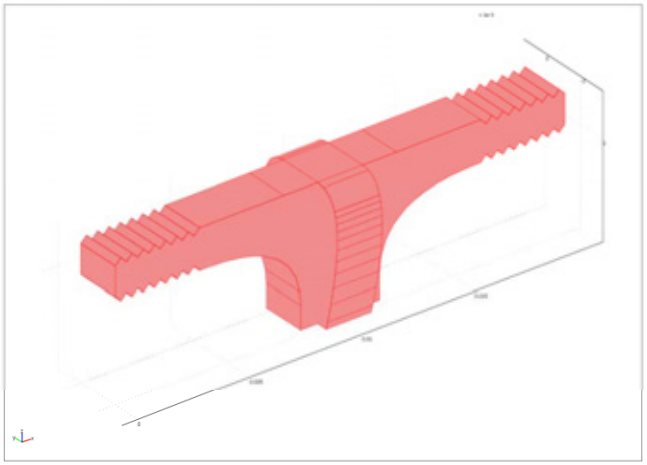
Introduction

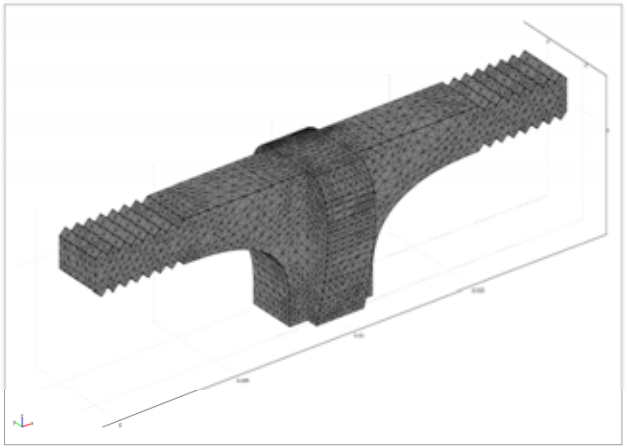
- Framework for posterior area is quite simple (simplest design is 2D object).
  - Prosthesis' attachment wings are embedded into the abutment teeth.
  - Manufacture process easily automated.



Simulations
- General Info

- The simulations consists 3D structural integrity simulations of more advanced version of the Inlay Fixed Partial Denture (IFPD) frameworks.
  - A middle part is added to the design to give more surface to attach the crown.
  - Assembly is made in two parts.



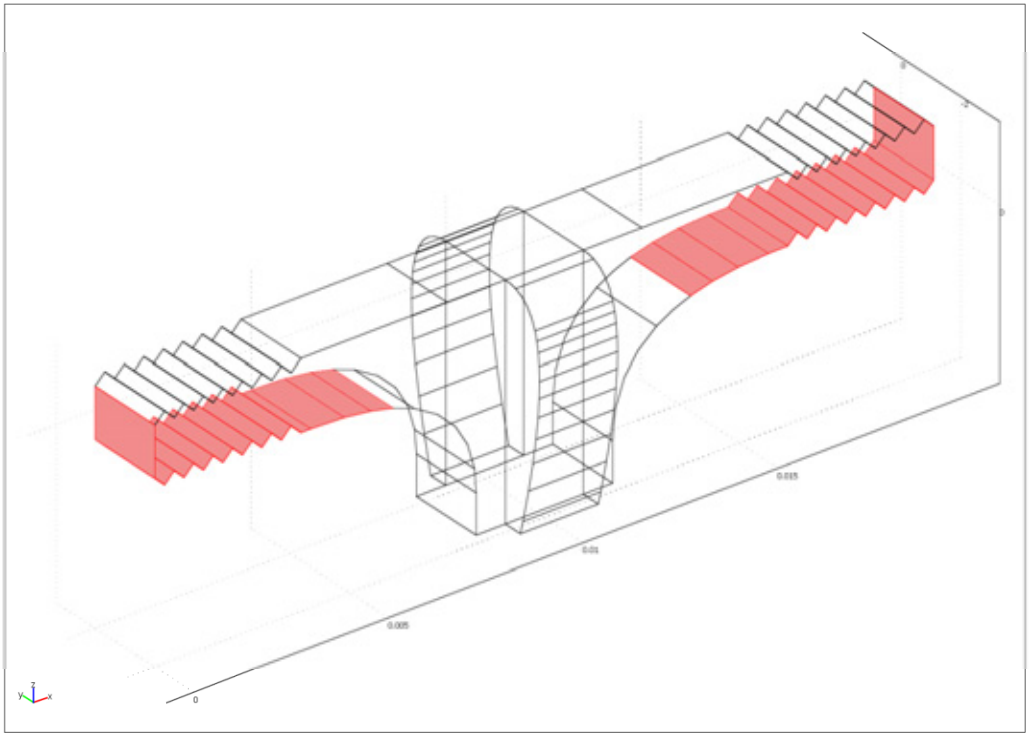


Simulations
- General Info

- Simulation computer:
  - Mac Pro with 64-bit Leopard OS
  - 8 64-bit Intel Xeon 2.8 GHz processor cores
  - 64 GB 800 MHz RAM
- This enables to have 480 000+ degrees of freedom in the 3-D simulation model and run complex 3-D time-depended simulations.

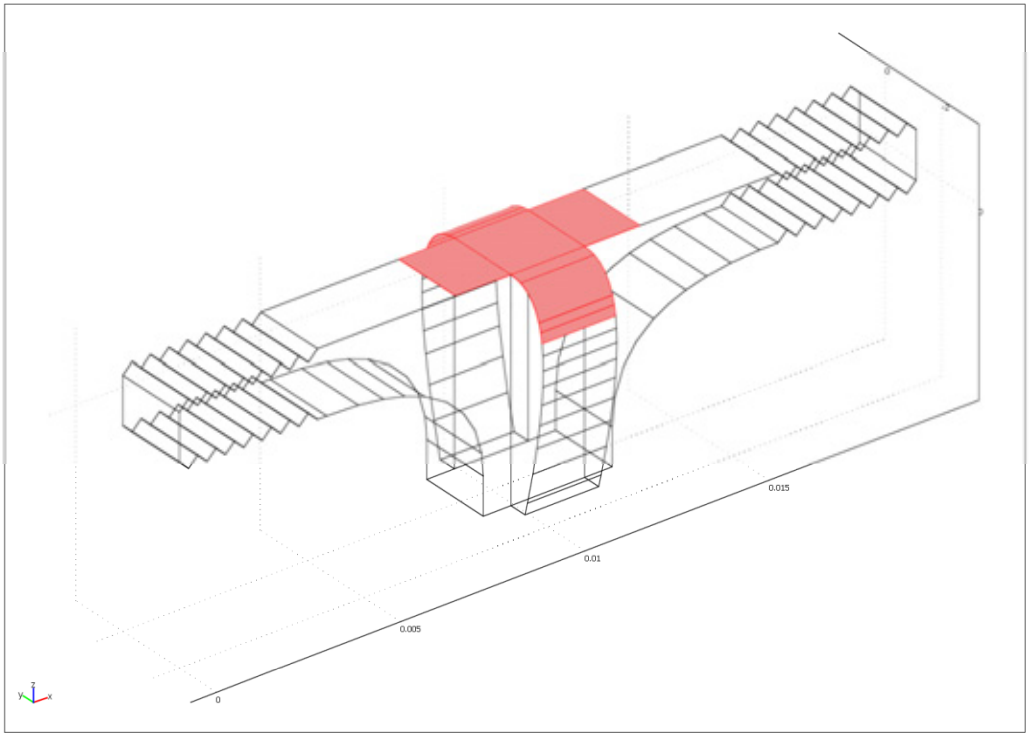
Simulations
- Boundary Conditions

- Fixed area
  - Corresponds to the area which is attached to the abutment teeth.



Simulations
- Boundary Conditions

- Force implementation area
  - Corresponds to the area where the occlusion force is affecting.



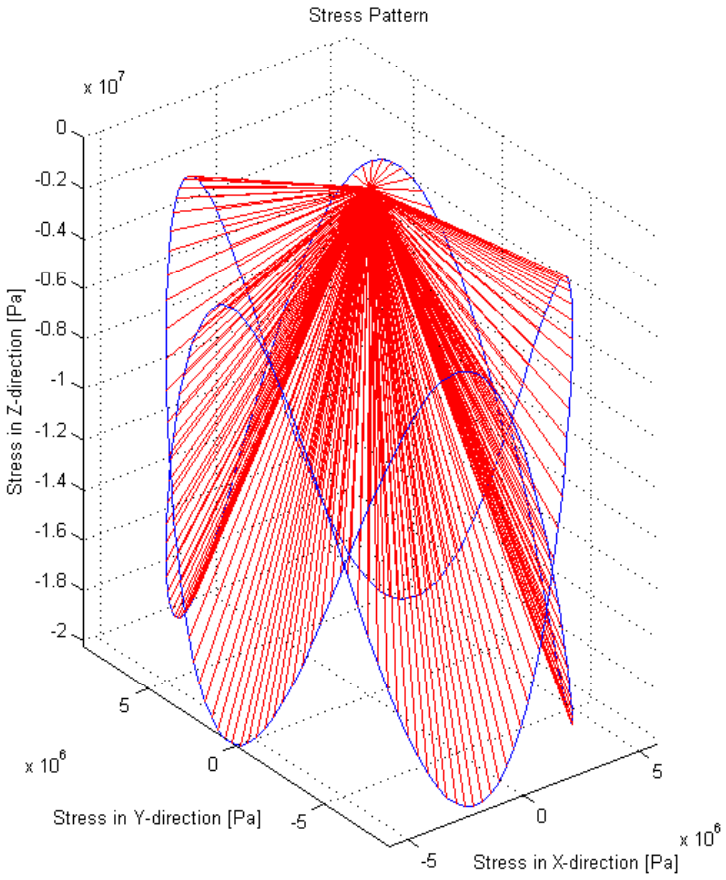
Simulations
- Forces

- In static simulation the acting force was the average maximum occlusion force for a healthy young adult male 847 N.
- In time-depended simulations there was a little more room for creativity…

Simulations - Forces

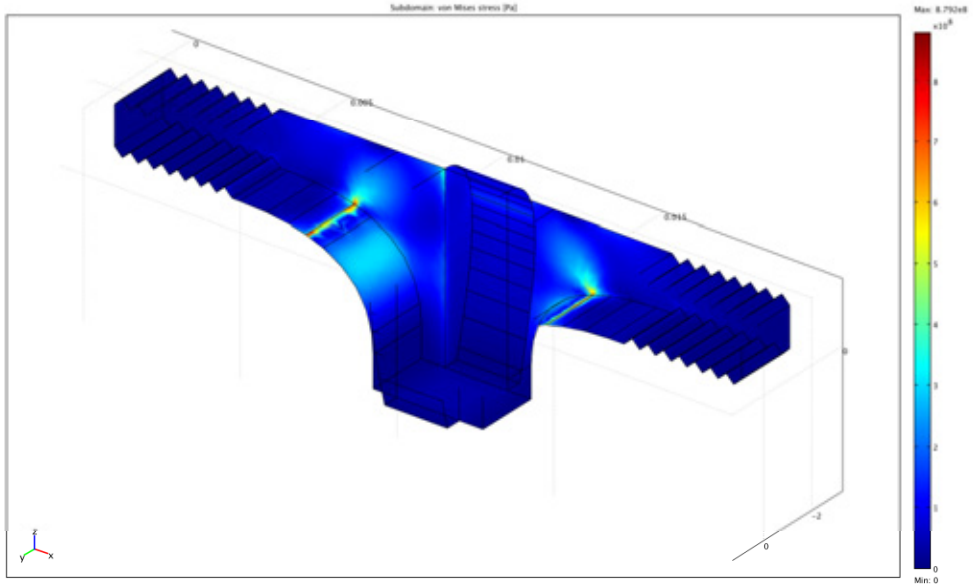
- In time-depended simulations the simulated forces were designed to mimic the masticatory cycle, where the forces are inflicted to every direction in x, y and z coordinates.

$$\begin{cases} x = \frac{100}{A}\cos(t) \ [\mathrm{Pa}] \\ y = \frac{150}{A}\sin(t) \ [\mathrm{Pa}] \\ z = -\frac{200}{A} + \frac{150}{A}\sin\left(\frac{4\pi t}{5}\right) \ [\mathrm{Pa}] \end{cases}$$



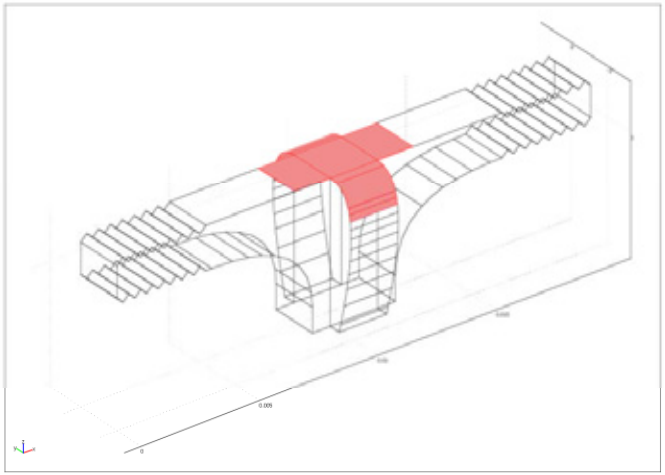
Results
- Static

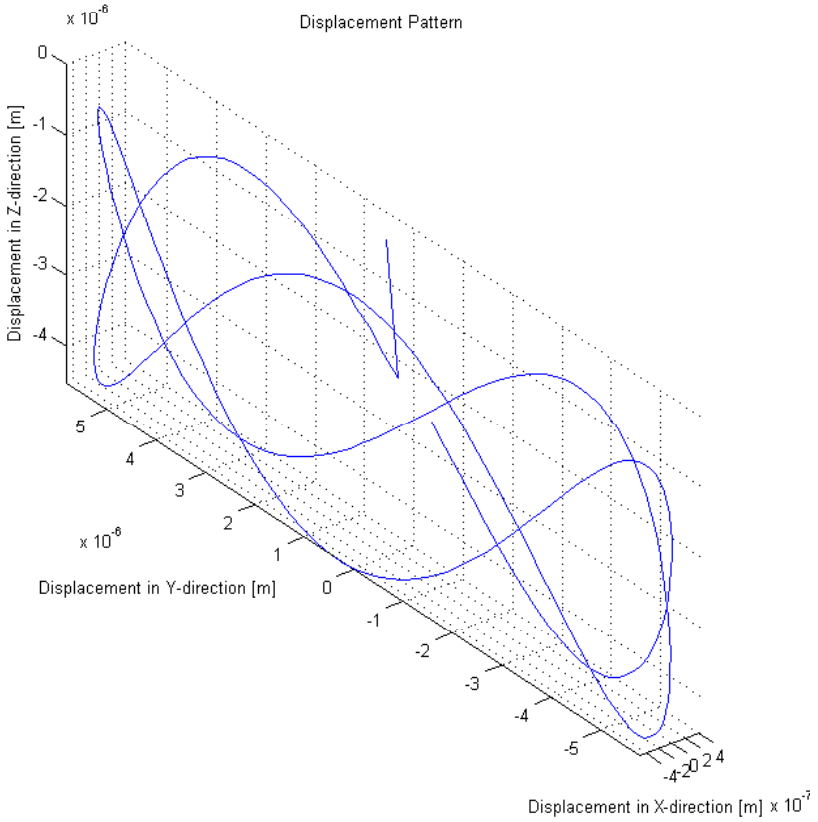
- In the static simulation we are interested in the von Mises stresses.
  - Titanium's yielding stress is 920 MPa
  - Maximum von Mises stress value from the simulations was 879.2 MPa.



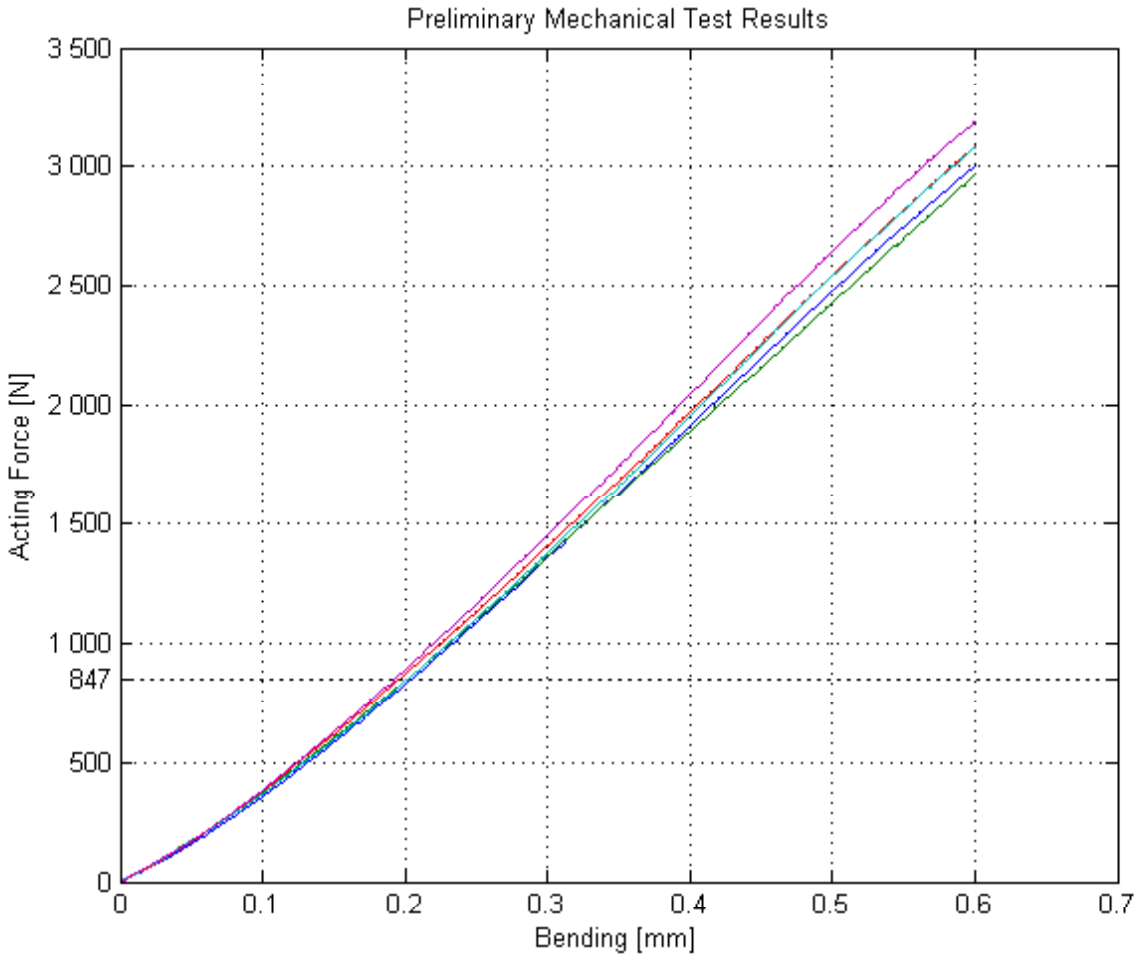
Results
- Time-depended

- In time-depended simulation the most interesting thing is the behavior of the bending.
  - No fatigue present in simulation results.





Comparing to preliminary mechanical tests



Conclusions and future work

- The simulations and preliminary mechanical tests give promising results to continue with prototype manufacturing and further studies.
  - More mechanical tests
  - Clinical trials
- The shape can be further optimized using the expertise of dental practitioners and numerical optimization methods
  - Genetic algorithms
    - Differential evolution

Acknowledgements

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