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Structural optimization of fiber-reinforced composite dental bridges

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Structural Optimization of Fiber-Reinforced Composite Dental Bridges

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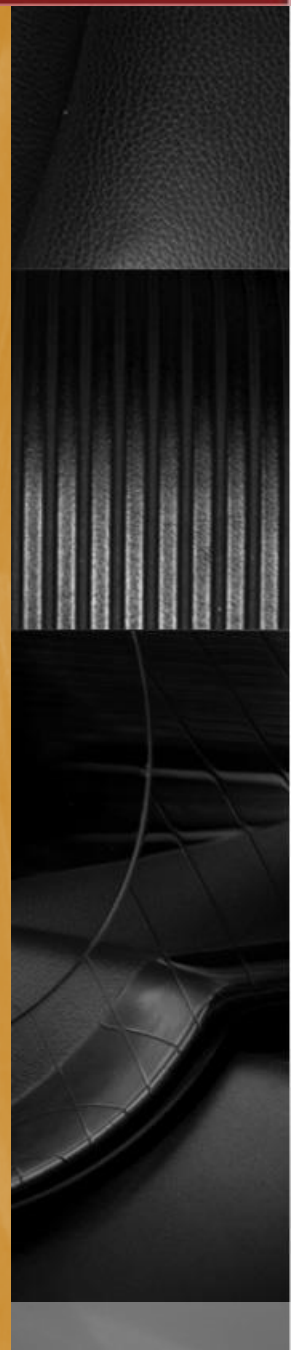
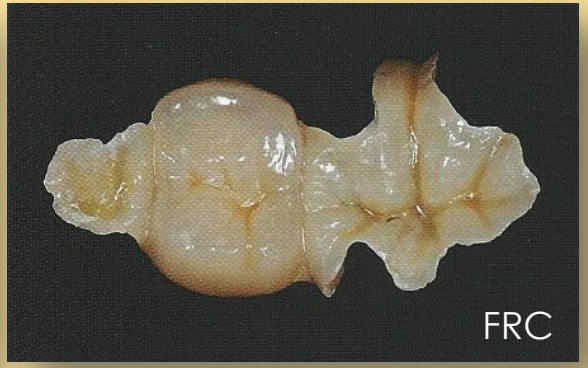


MDRCBB
Minnesota Dental Research Center for Biomaterials and Biomechanics

Replacing lost teeth

Dental implant

Dental bridges

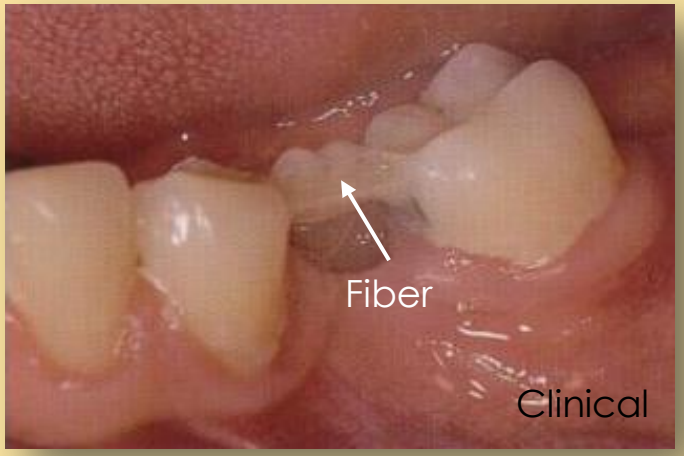


Failure of FRC bridges

High failure rates

73.4% after 4.5 years

- Heumen et al., European Journal of Oral Sciences, 2009. **117**(1): p. 1-6.



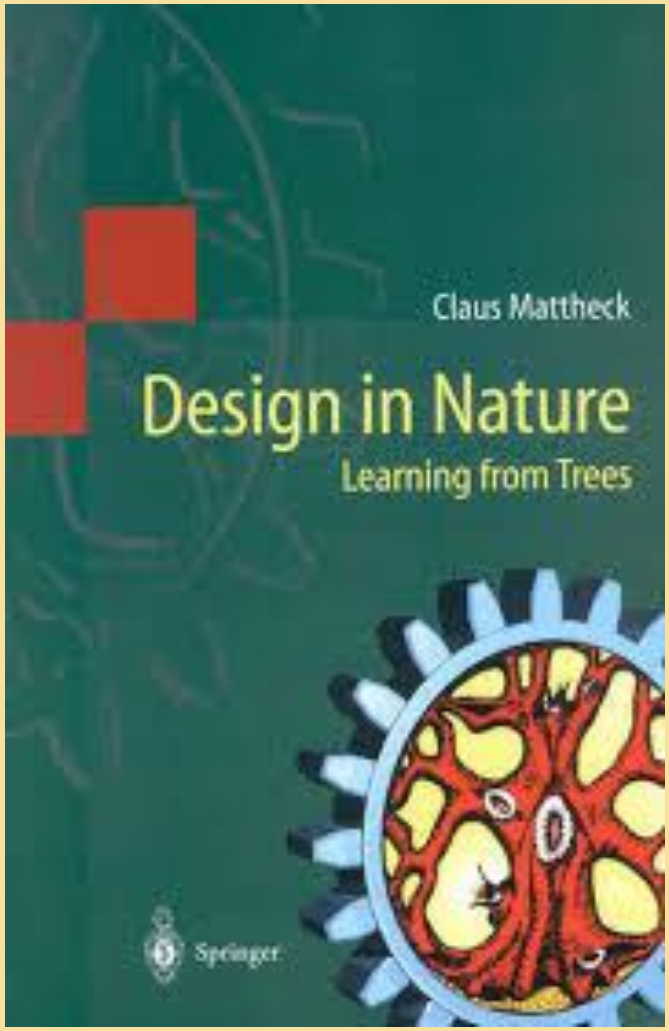
Main failure modes

- Fracture and delamination of veneering composite
- Fracture of connectors
- Debonding from supporting tooth

Aim of this study

- To create stronger dental bridges using bio-inspired structural optimization techniques

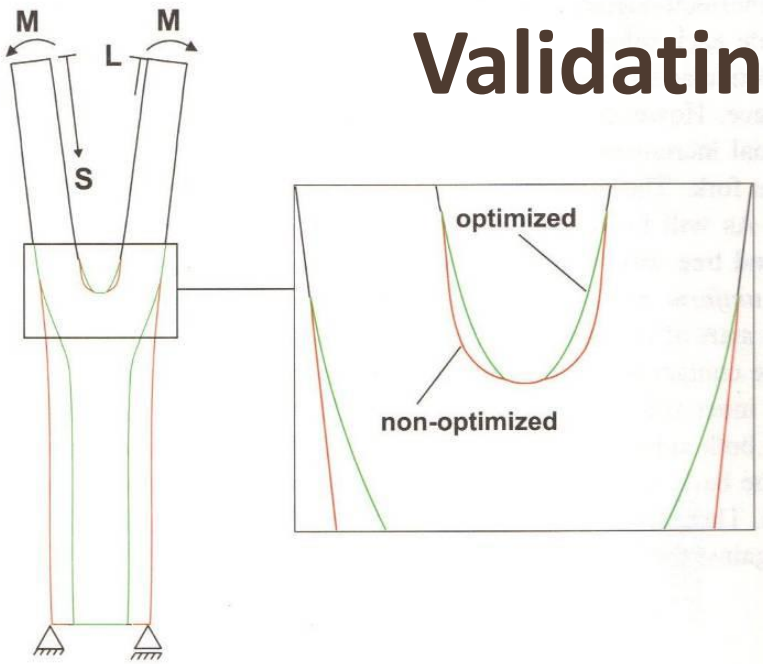
Learning from trees ...

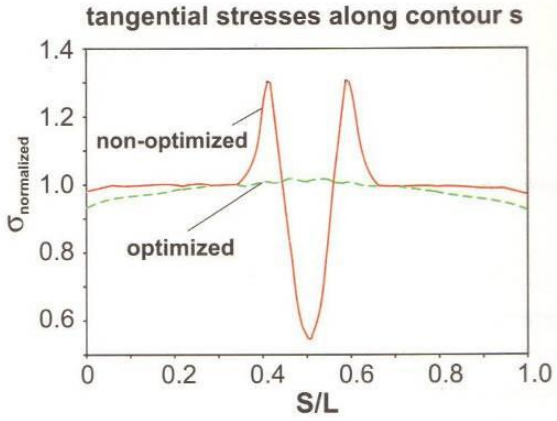


Axiom of Uniform Stress - Claus MATTHECK

- Build-up of material in overloaded zones
- No build-up (or even reduction) in underloaded zones
- Derived structures are uniformly stressed

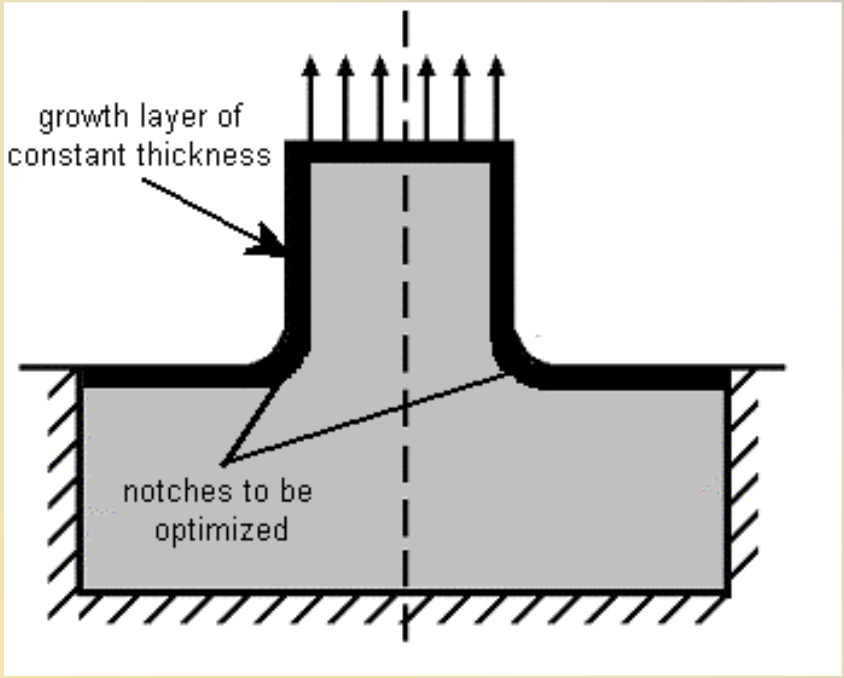
Validating using trees



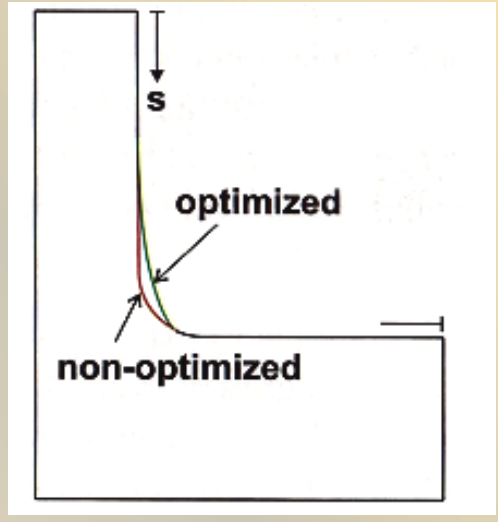


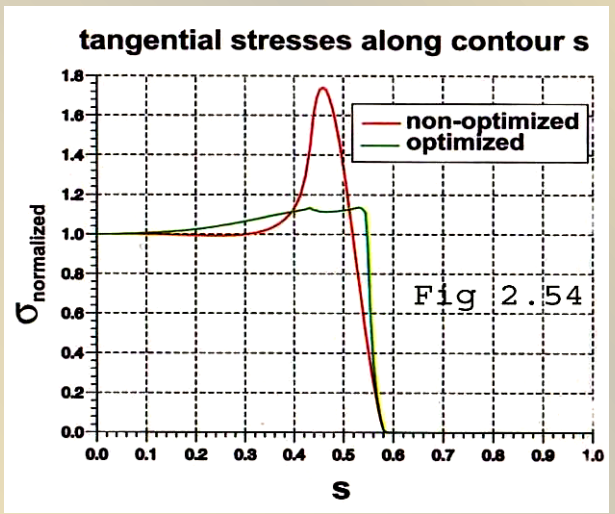
Claus MATTHECK, 1998, *Design In Nature,* Springer

Applying axiom to engineering components

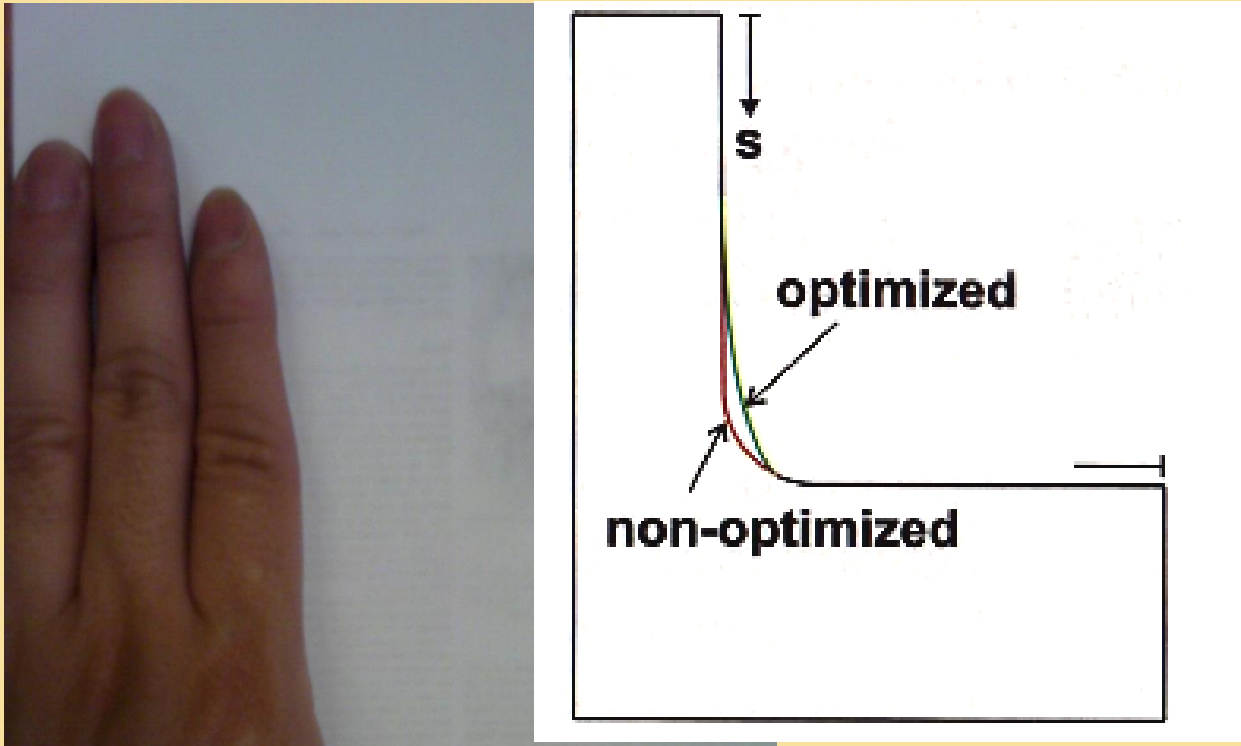


Claus MATTHECK, 1998, *Design In Nature,* Springer



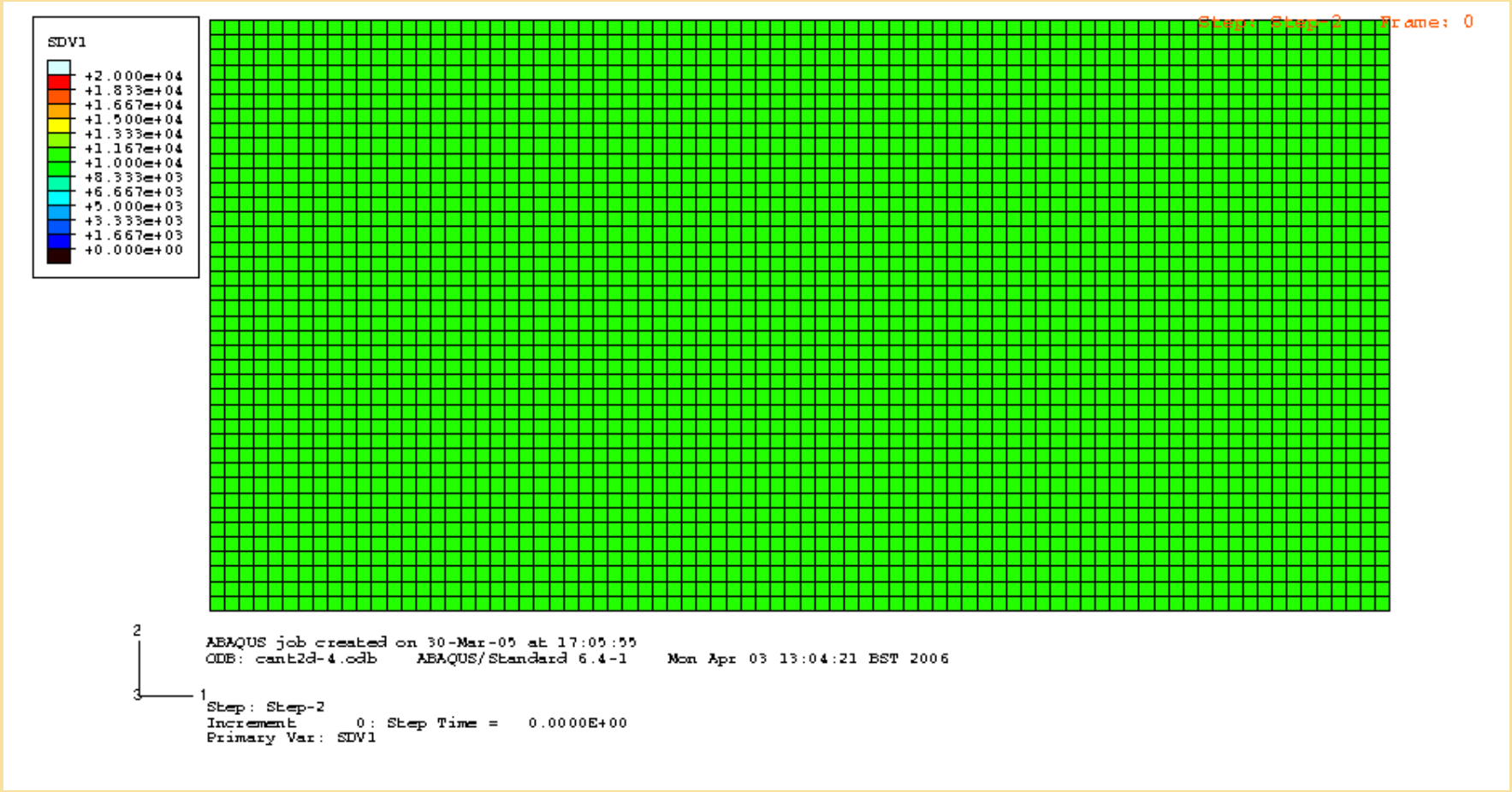


Fatigue life greatly increased



Nature got there first!

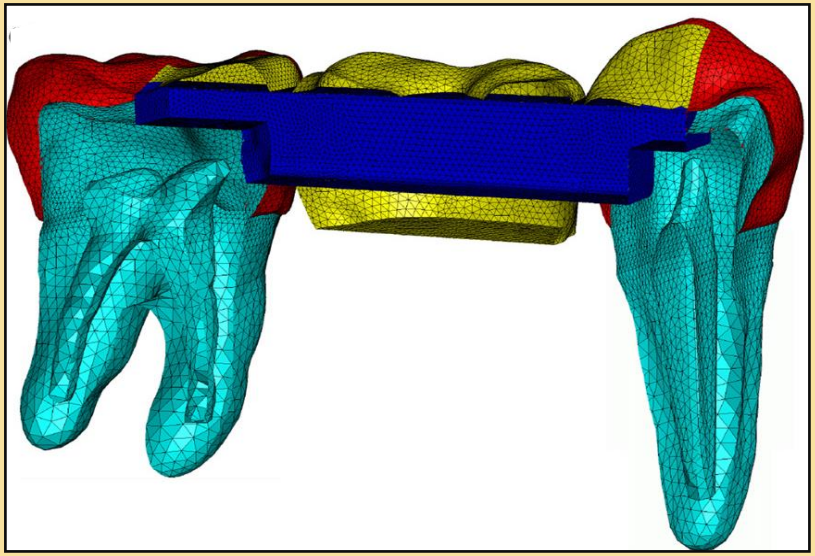
Optimization of a cantilever beam

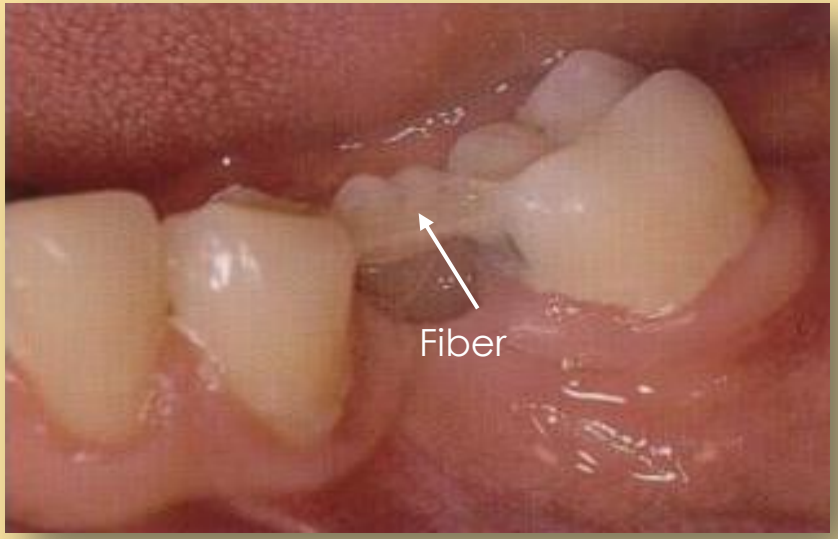


Real-world examples

Nature, again, got there first!

3-unit FRC bridge



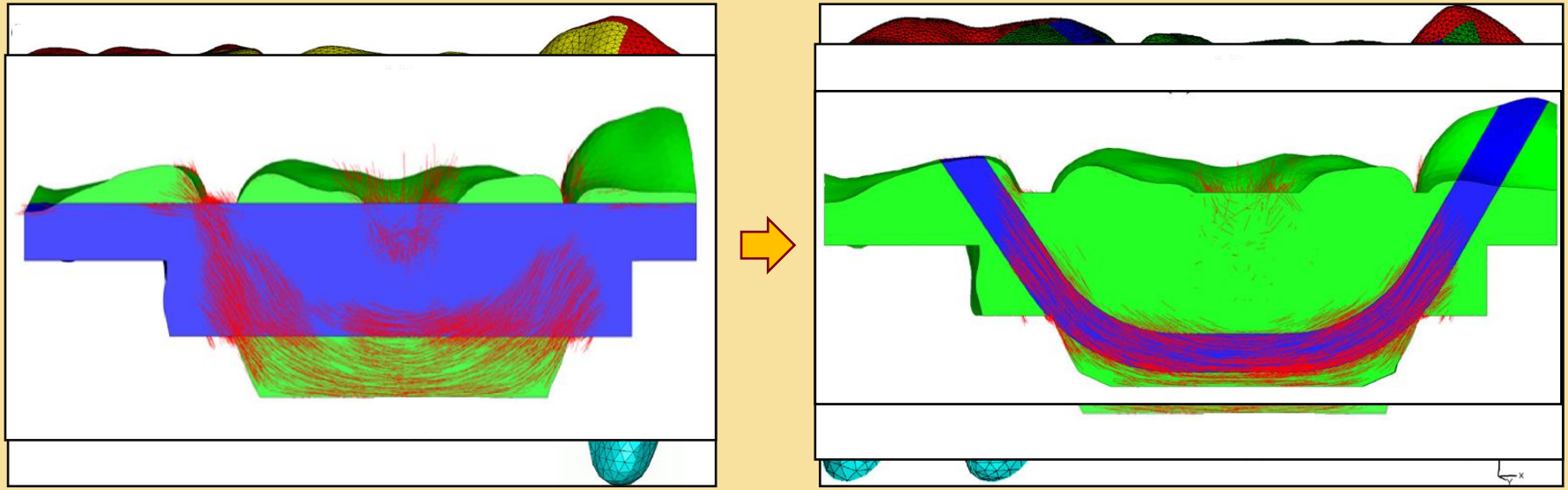


Conventional design

Optimization of a 3-unit FRC bridge

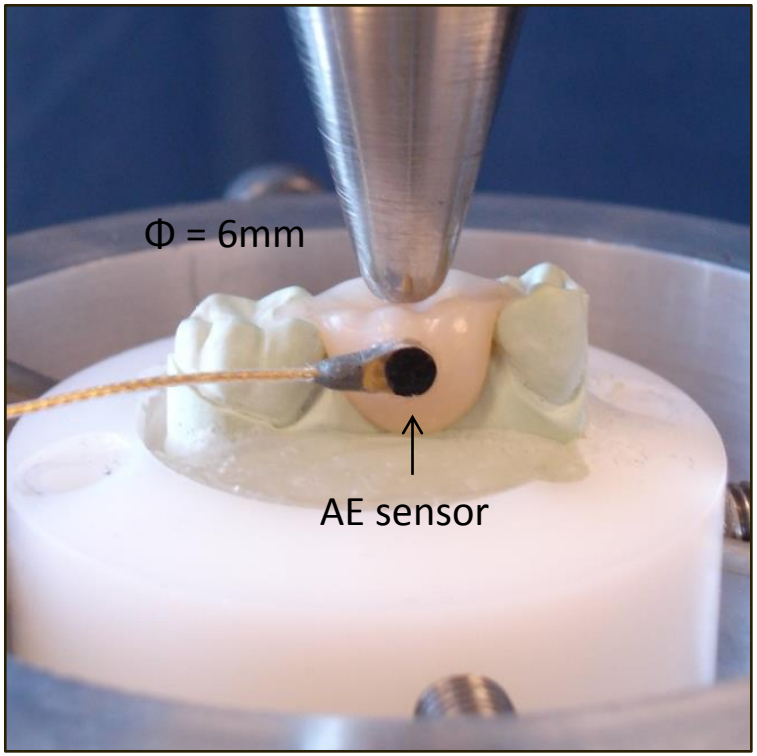
After optimization:

1. 30% reduction of maximum principal stress
2. 30% volume reduction of fiber substructure



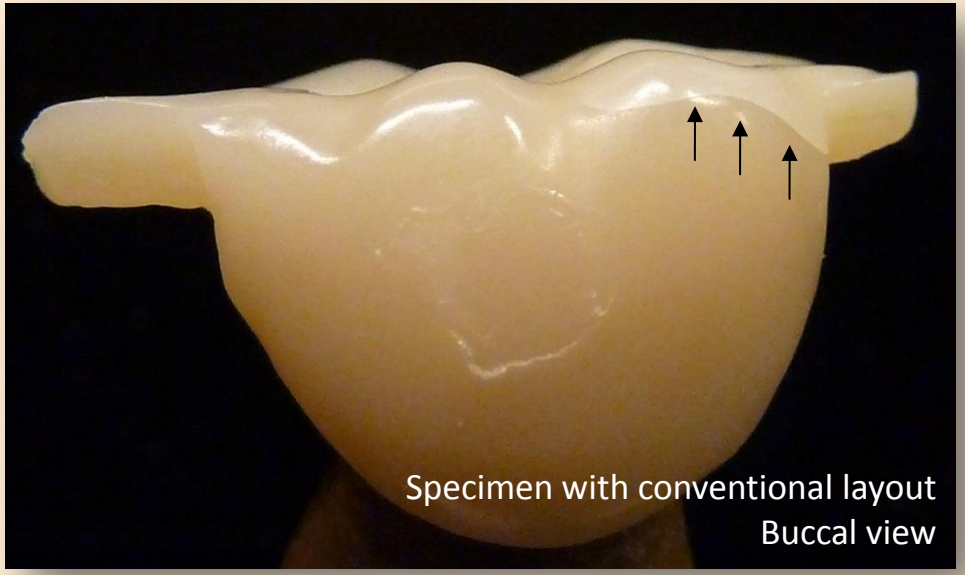
Shi, L. and A.S.L. Fok, Dental Materials, 2009. 25(6): p. 791-801.

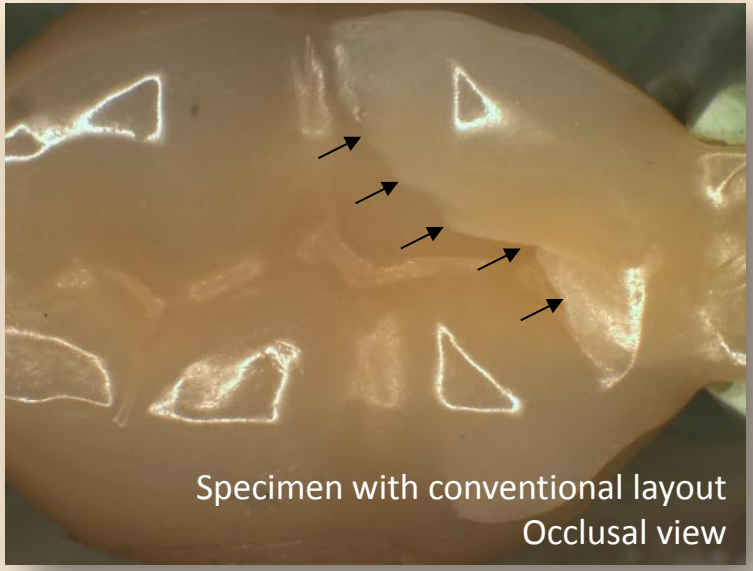
Mechanical testing



Loaded to 400 N

Visual inspection


Specimen with conventional layout
Buccal view


Specimen with conventional layout
Occlusal view

Cracking

Location

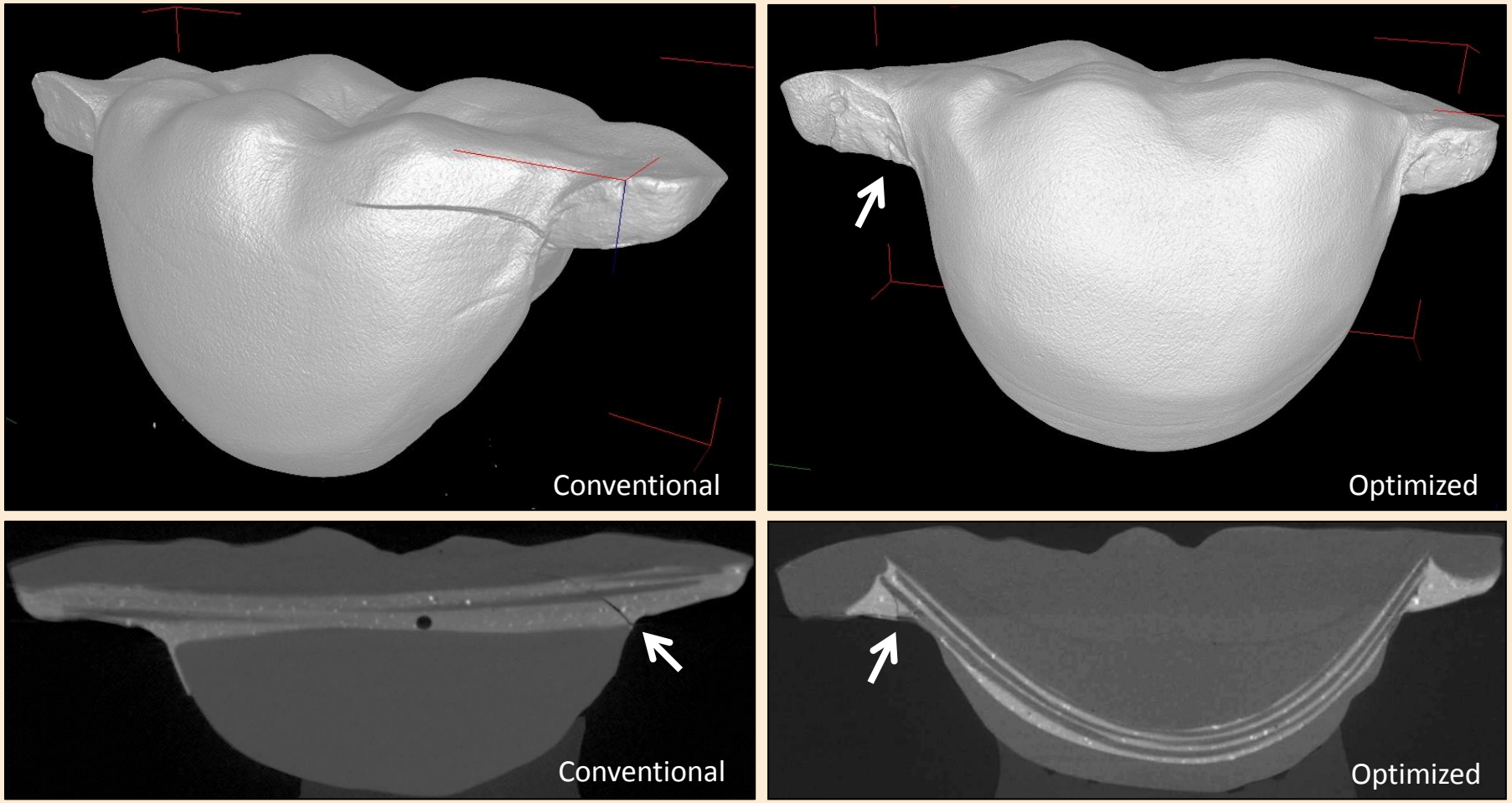
- buccal surface
- lingual surface
- loading point

Percentage of failure

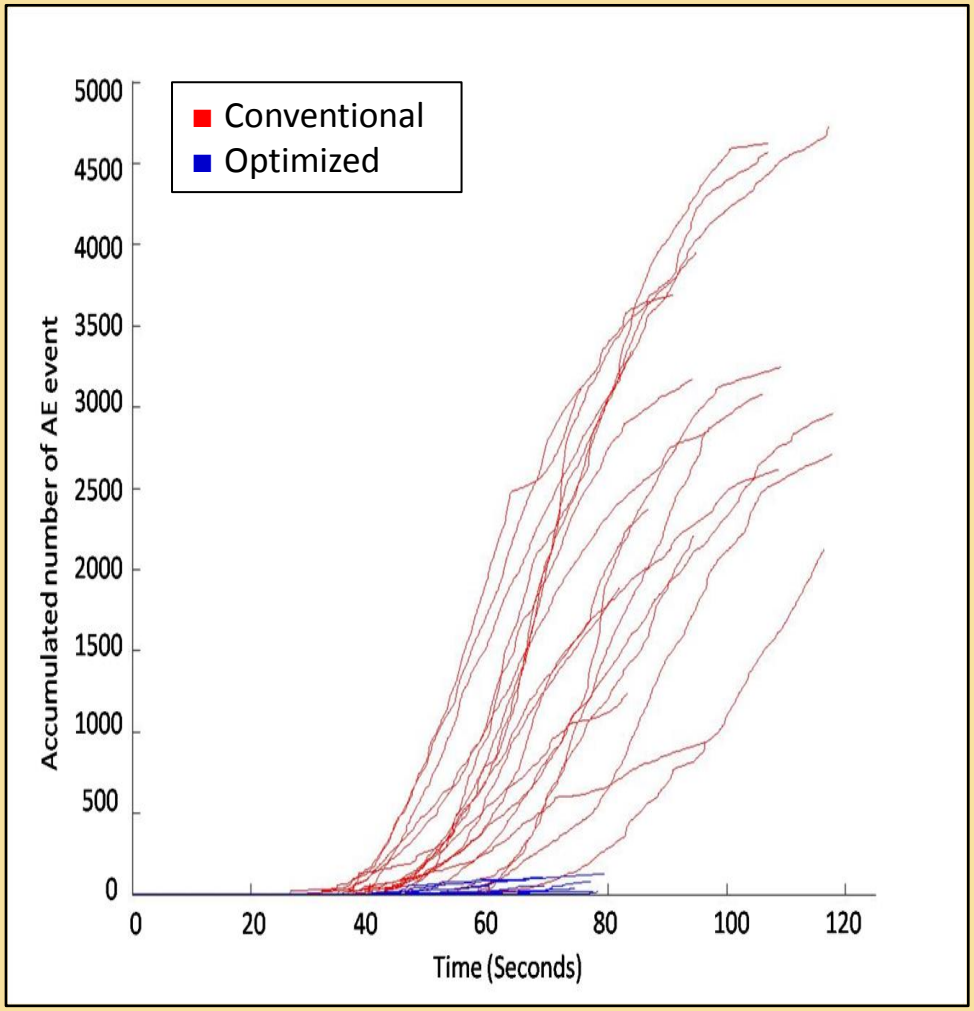
- Conventional layout
  → **100 % (20/20)**
- Optimized layout
  → **28.5 % (6/21)**


Specimen with optimized layout
buccal view

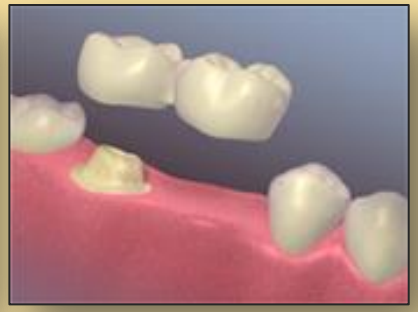
Micro-CT



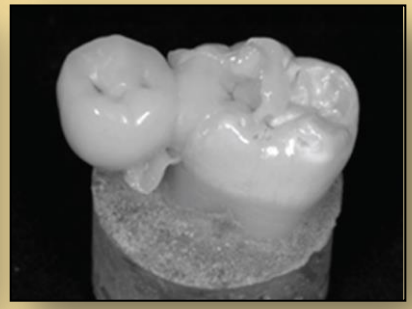
Acoustic emission



Two-unit cantilever bridge

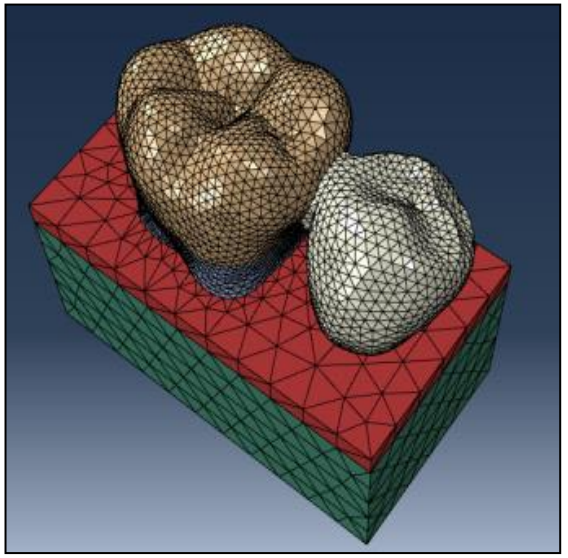







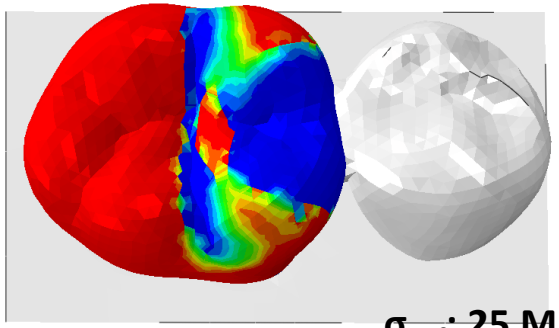
- **Advantages:**
  - Less tooth tissue removal
  - Easier to clean
  - Less expensive

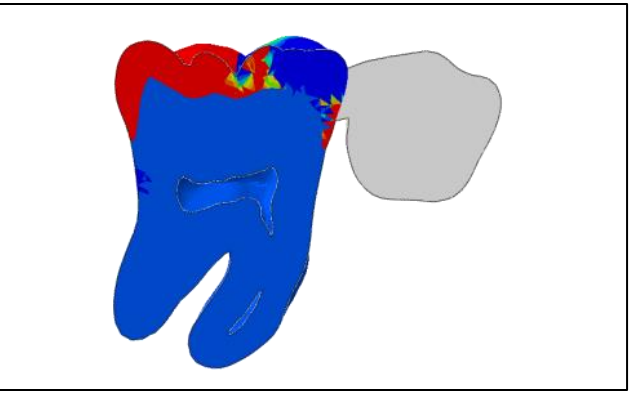
Materials & Methods

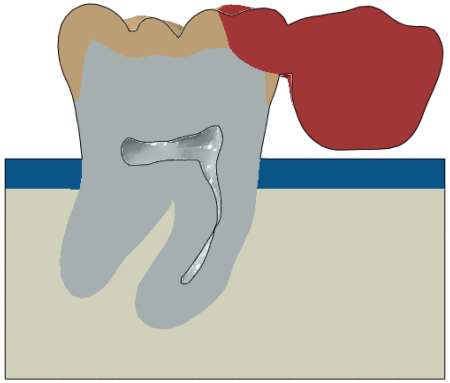


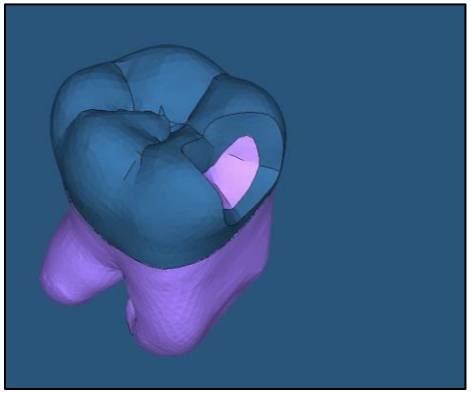
Two-step optimization

1st STEP: Using isotropic SMT UMAT to obtain the cavity design



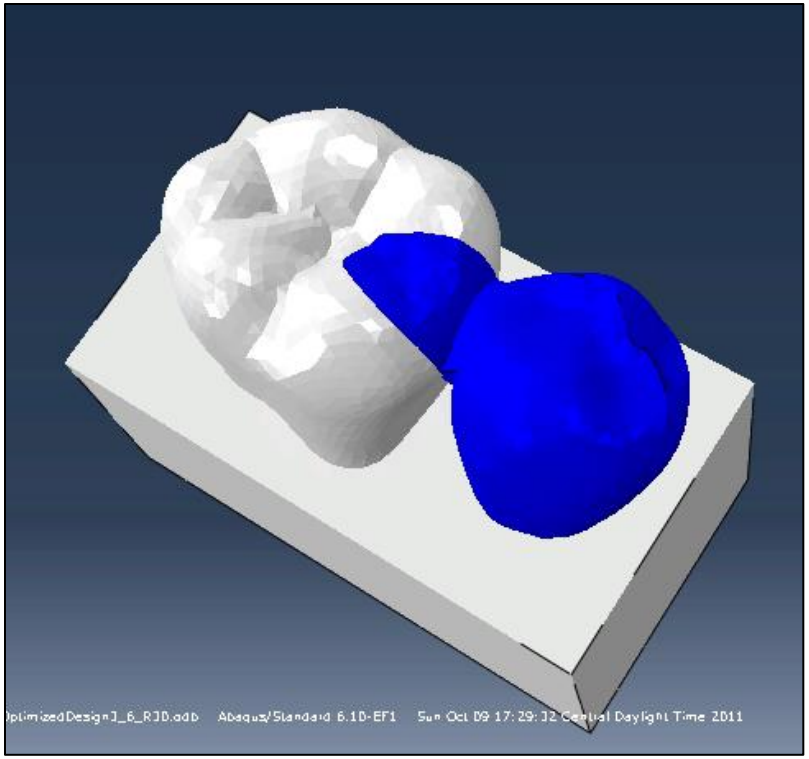


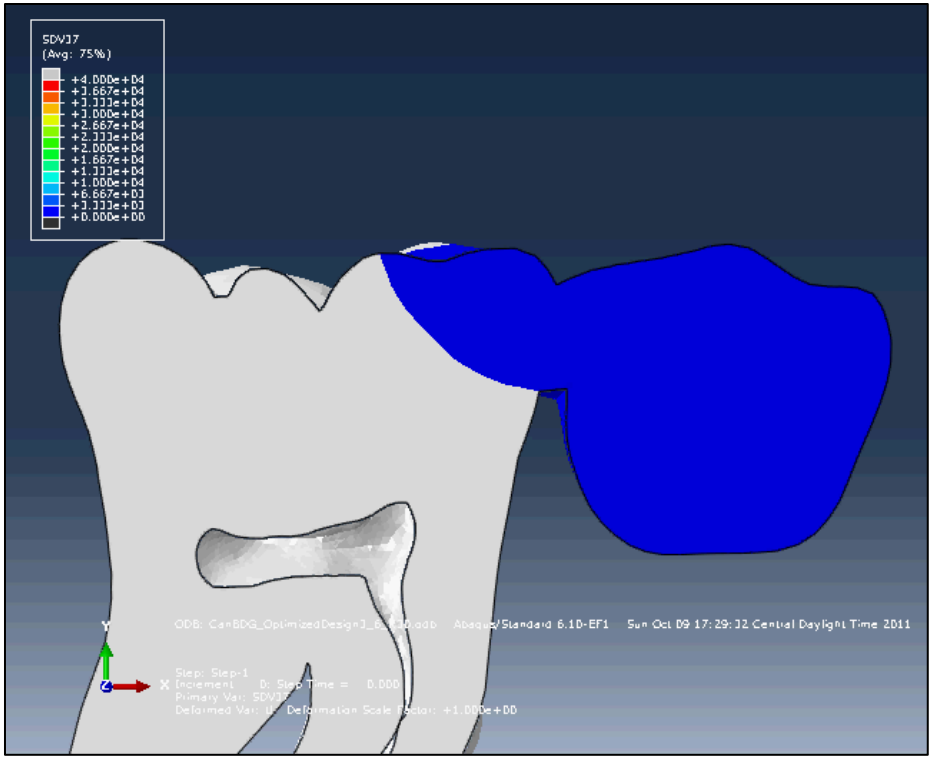




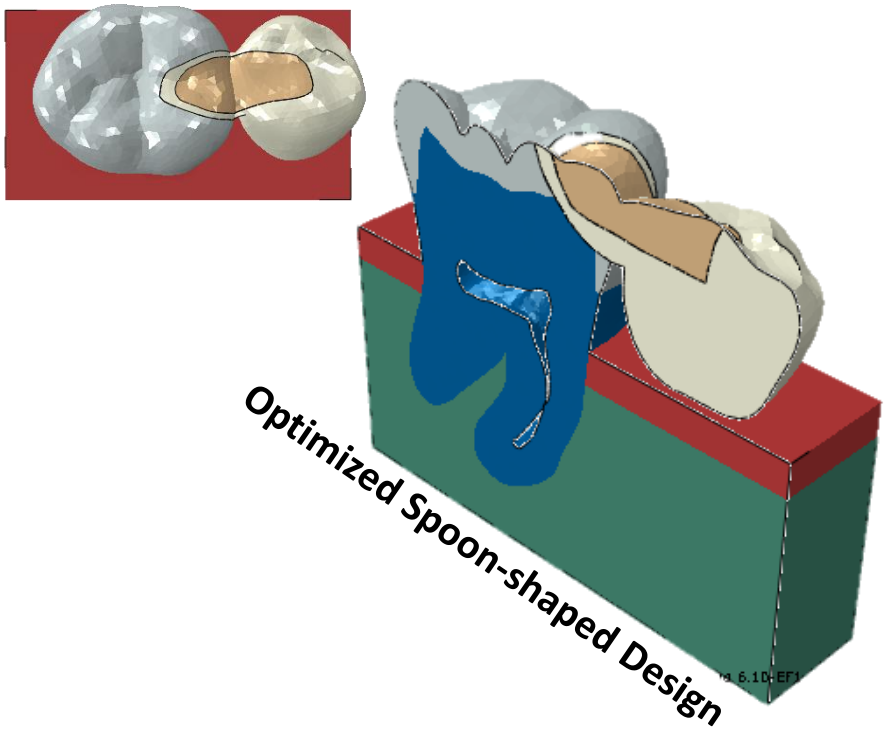
Two-step optimization

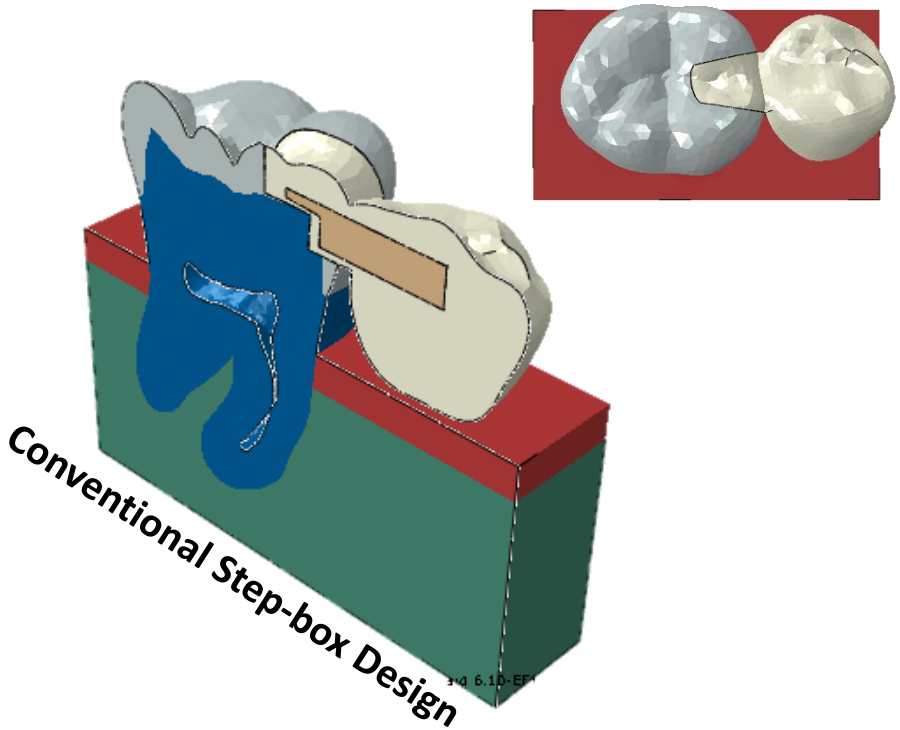
2nd STEP: Using orthotropic SMT UMAT to obtain the fiber layout





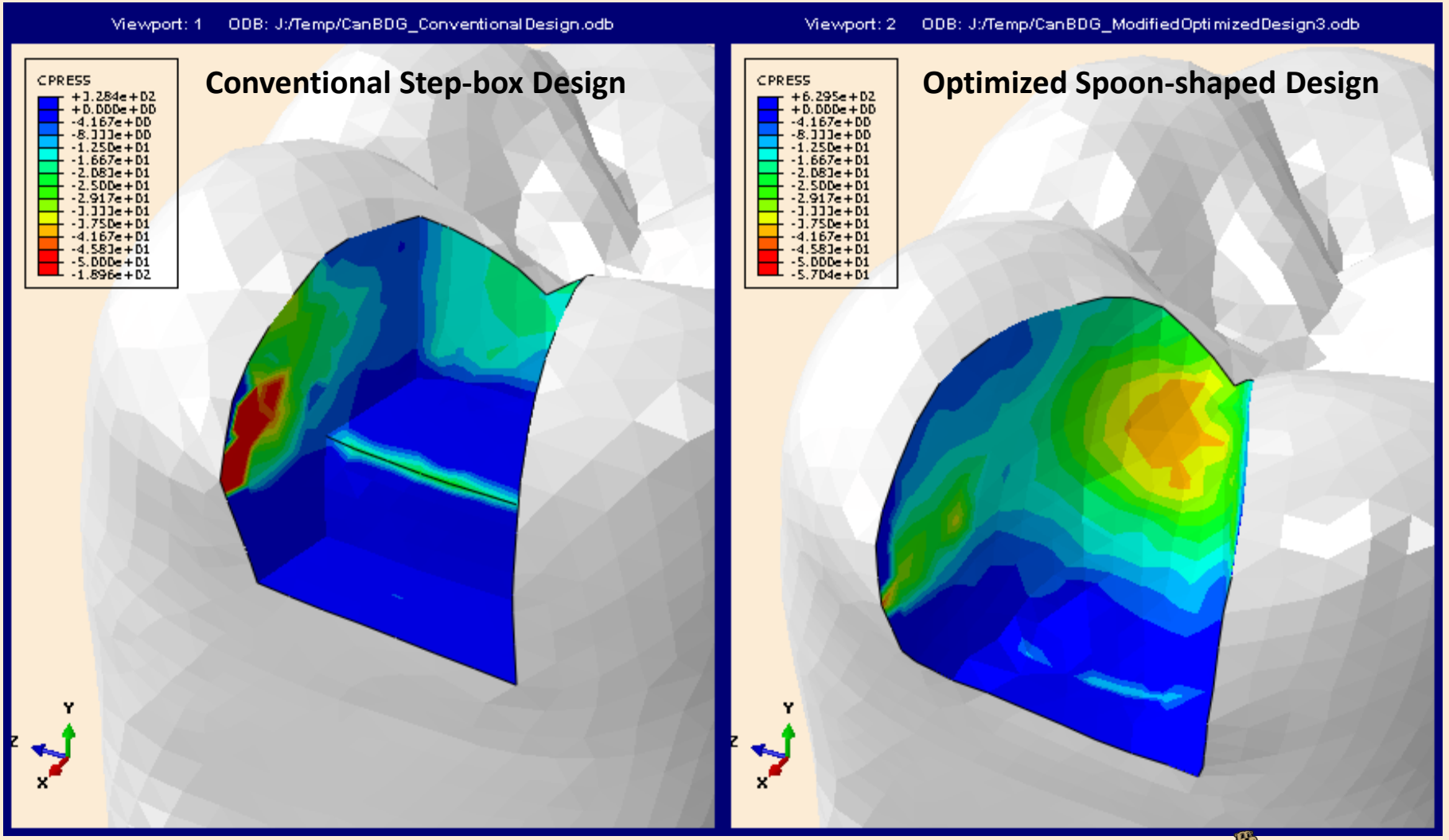
Optimized vs conventional designs



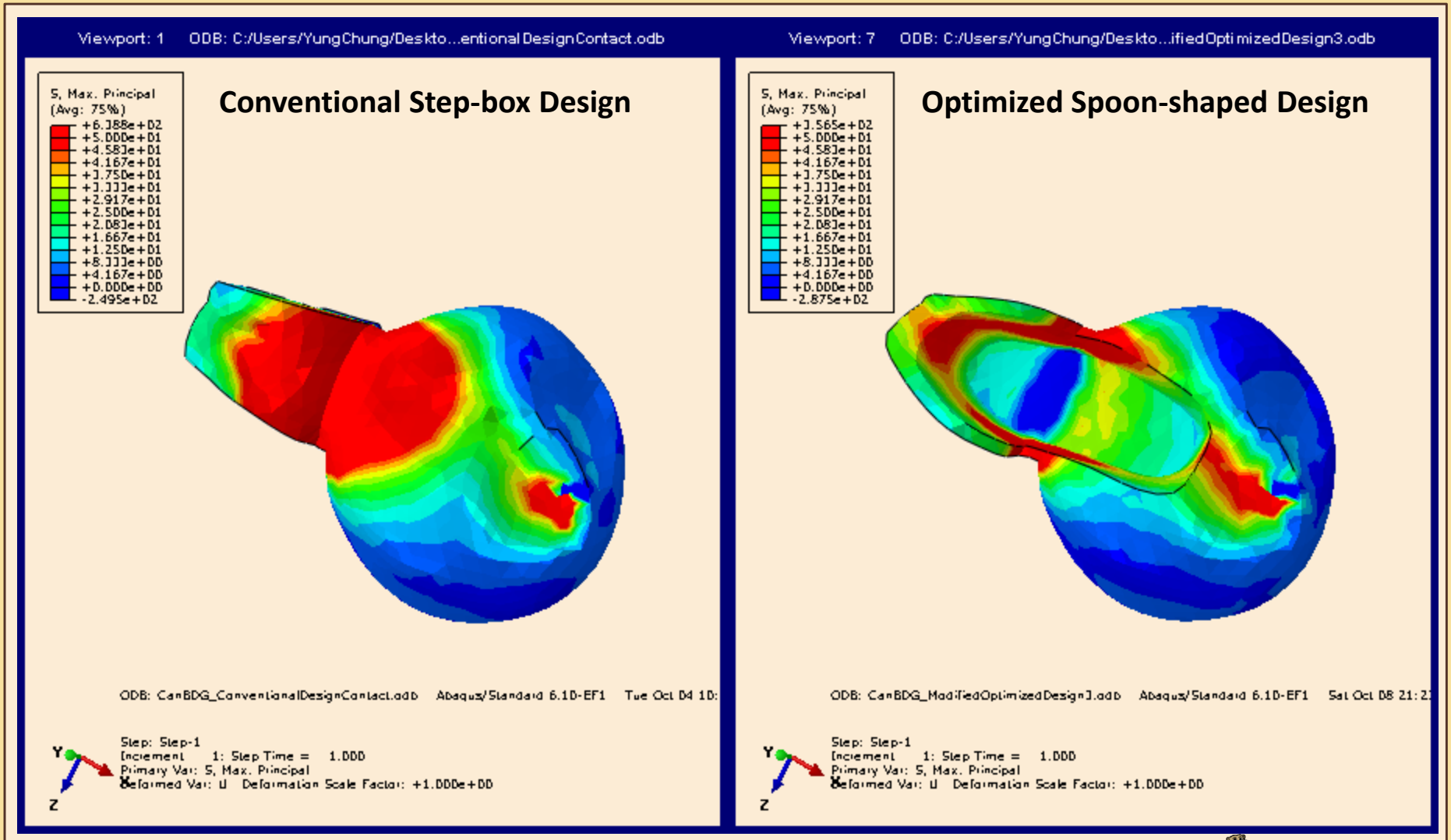


Design	Optimized	Conventional
Bonding surface area	31.314	37.980
Retainer's volume	26.122	26.226

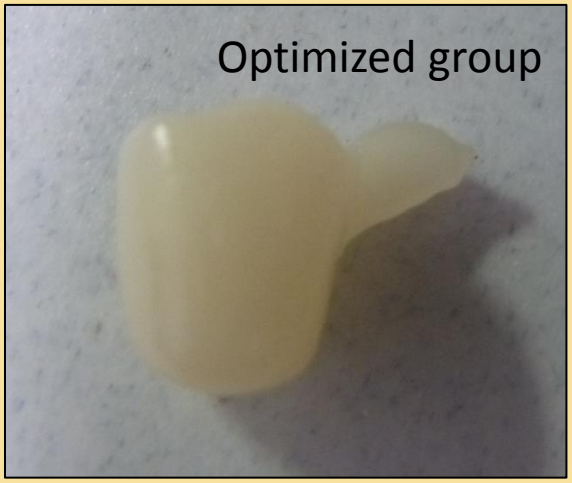
Interfacial stress distribution

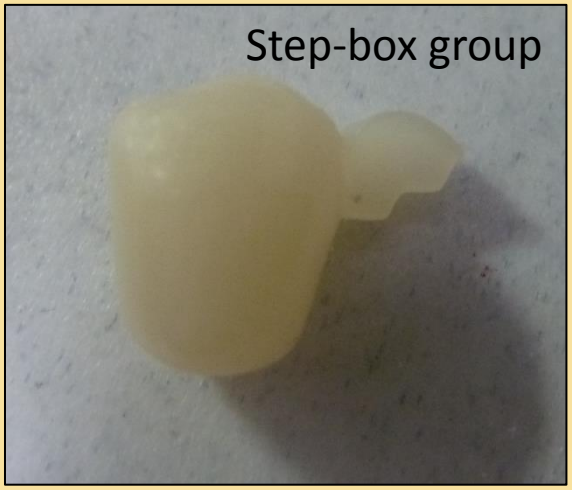


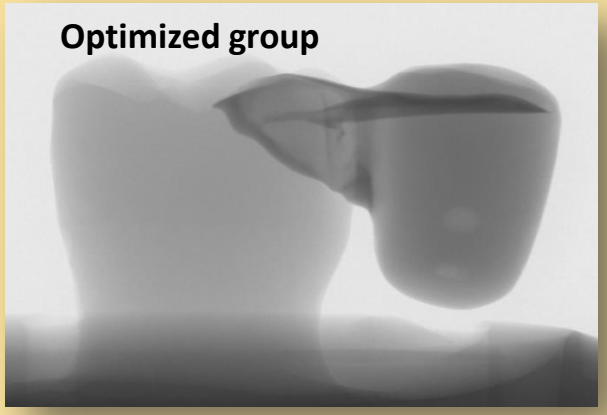
Structural stress distribution

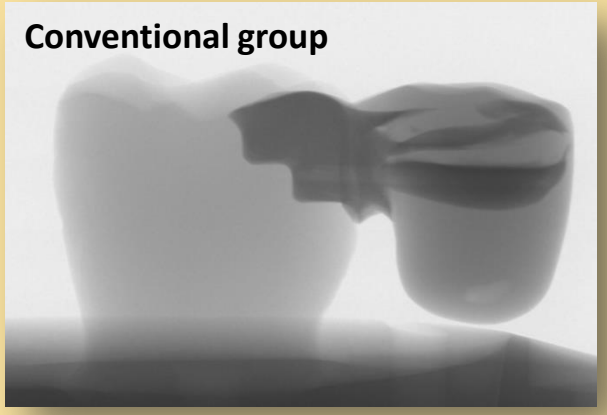


Mechanical testing

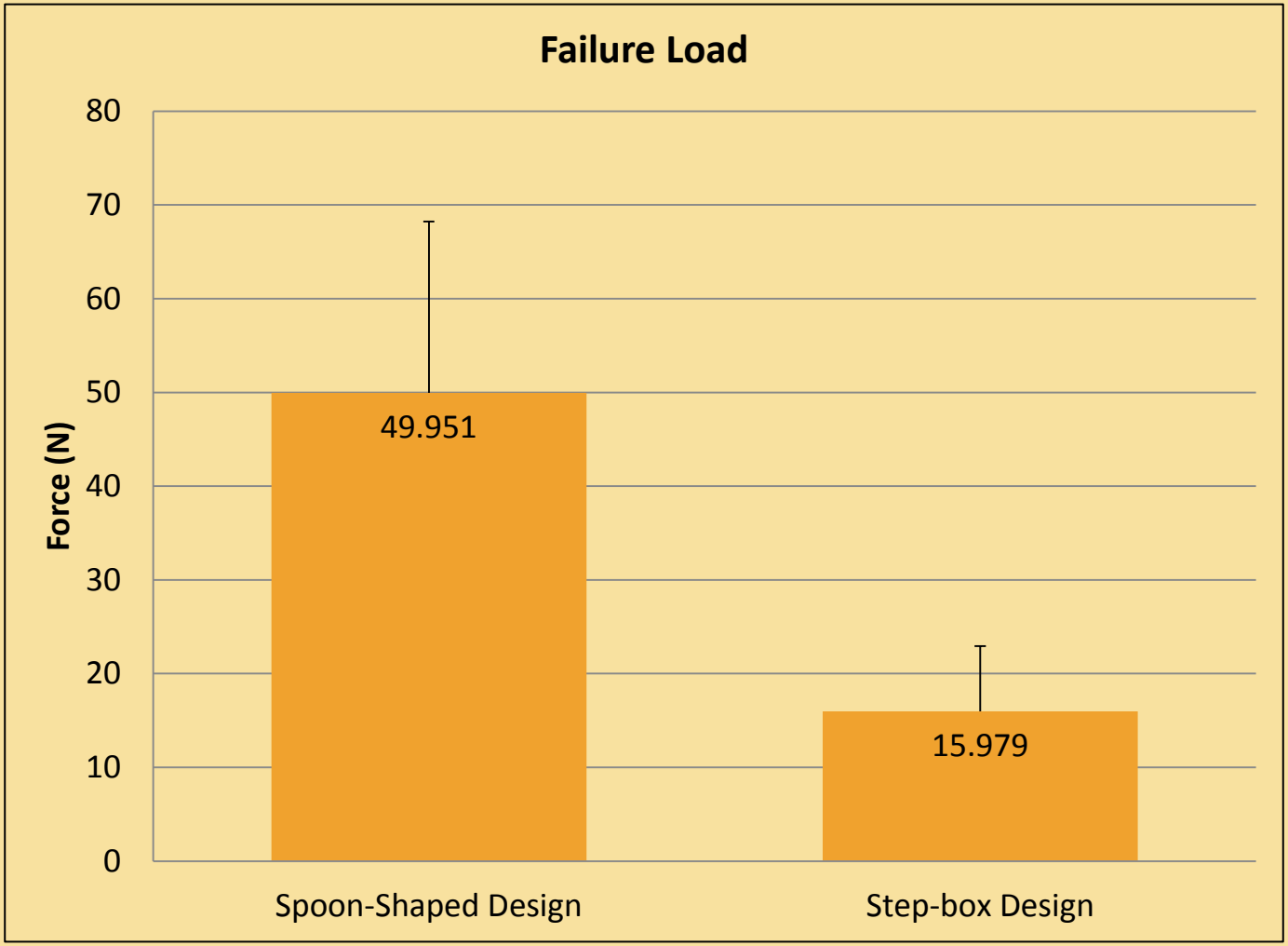




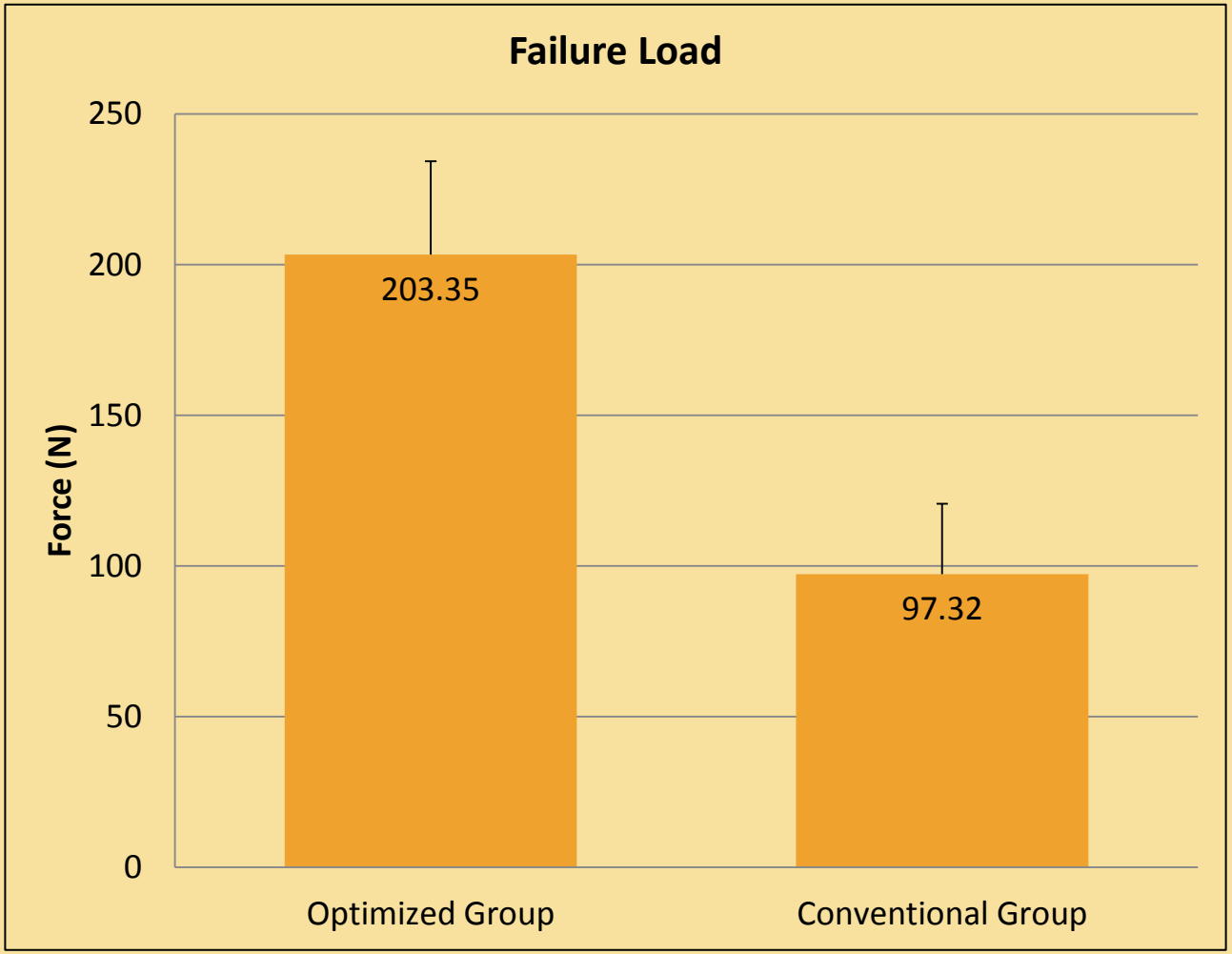




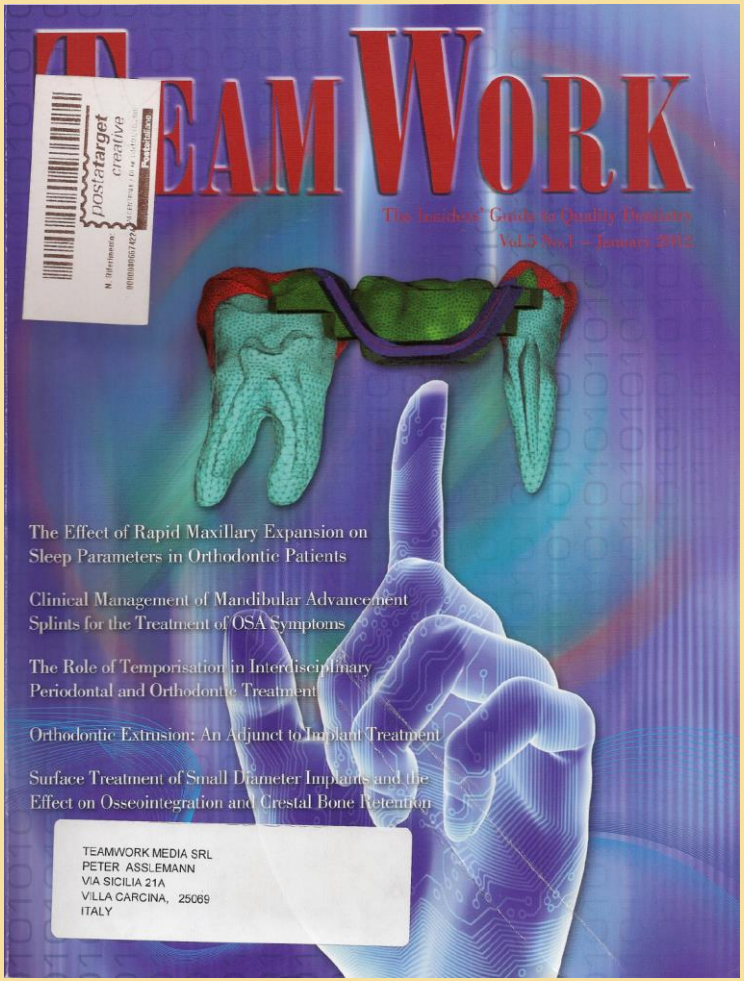
Performance without fiber reinforcement



Performance with fiber reinforcement



Translation to clinical practice



Courtesy of Gerardo Sacco, Bari, Italy

Isambard Kingdom Brunel

Clifton suspension bridge