IMPORTANCE OF SIMULATING THE POLYMERIZATION SHRINKAGE OF MATERIALS IN FINITE ELEMENT MODELS

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Introduction

- The literature[1] shows models built from extracted teeth data where a subjective force is applied to analyze the stress distribution. In several models, the construction is partial and does not represent all the anatomical structures around the tooth. The mandibular movement is never included in the analysis even though it is the phenomenon which conditions the dental contact of each patient and can provide important information[2].
- The most important cause of failure for composite restorations is the loss of the cohesion of the joint between the material and the tooth during the polymerization phase, but many models do not take into account the polymerization phase in their analyzes.

Objectives

- Analyze the behavior of a patient's maxillary second molar restored with a composite MOD onlay during chewing time.
- Observe the effects of the variation in size of the MOD onlay composite restoration and the thickness of the adhesive layer on the distribution of stresses, with inclusion or omission of the simulation of material polymerization shrinkage by thermal analogy.

Materials et Methods

Segmentation of anatomical elements of 17 and 47 from cone-beam acquisition and masks creation for each structure with AMIRA® software.

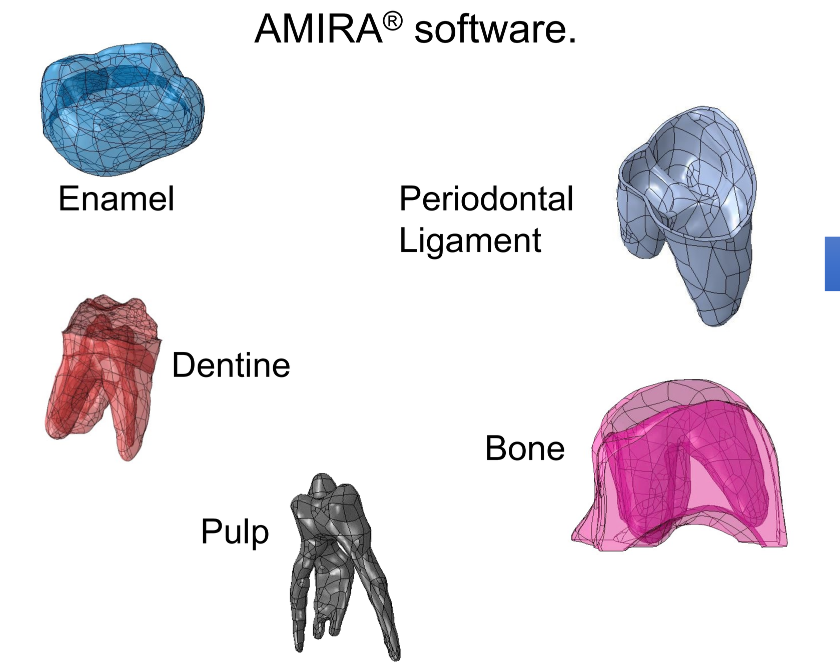


Fig. 1 : Masks of different materials for tooth 17

Geometric construction in RAPIDFORM® with all materials for each teeth.

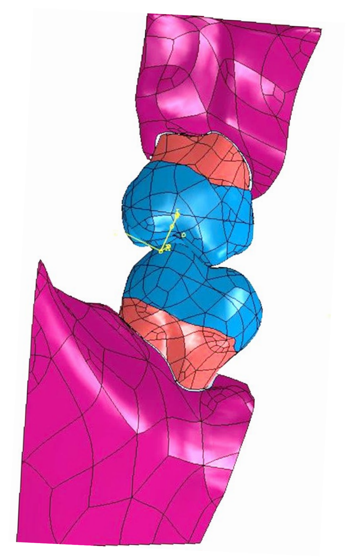
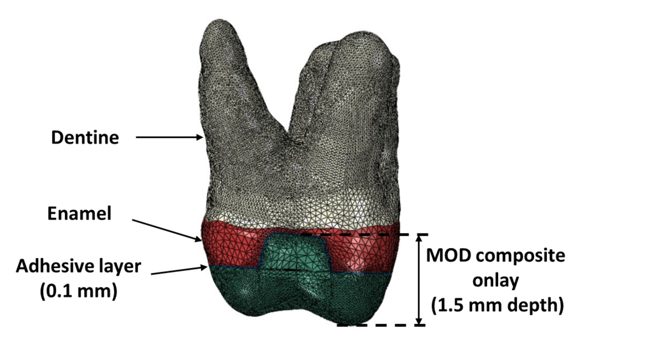
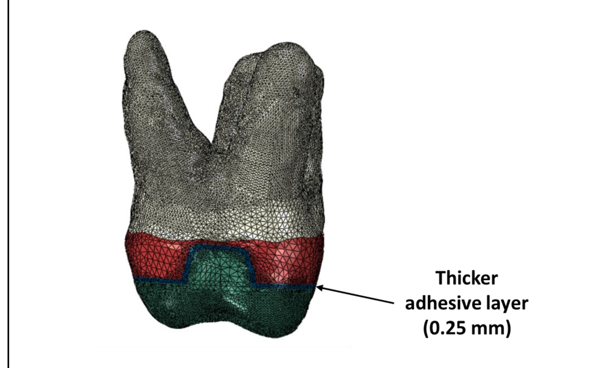
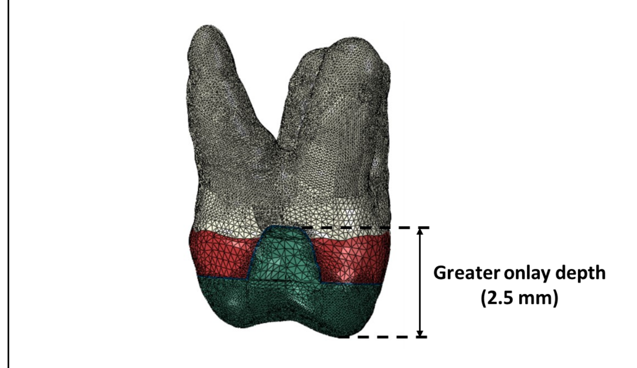


Fig. 2 : View of the two teeth in contact after construction

Simulation of the MOD onlay cavity and its composite restoration with different configurations

Group A Reference group	Group B Thicker adhesive	Group C Greater onlay depth
		
A1 (With simulation of the polymerization shrinkage for composite and adhesive)	**B1** (With simulation of the polymerization shrinkage for composite and adhesive)	**C1** (With simulation of the polymerization shrinkage for composite and adhesive)
A2 (Same model as A1 without simulation of the polymerization shrinkage for composite and adhesive)	**B2** (Same model as B1 without simulation of the polymerization shrinkage for composite and adhesive)	**C2** (Same model as C1 without simulation of the polymerization shrinkage for composite and adhesive)

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A thermal expansion coefficient of 0.001 was included for the composite and adhesive layer, and their polymerization shrinkage was simulated by a thermal stress during a temperature reduction of 1°C during an additional cooling step.

Record of the mandibular motion with Modjaw® system[3].

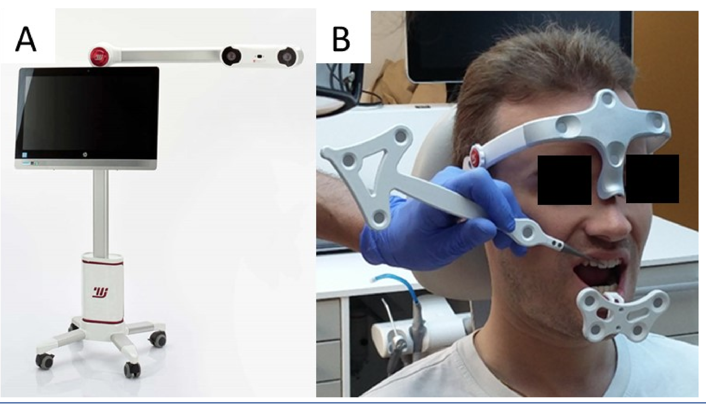

Fig. 3: Modjaw® A) The system with camera and screen, B) The preparation of the patient for motion record with the headband, the butterfly attachment of markers and the stylus.

- Pooling of the finite element model with the mandibular motion data from the Modjaw® system.
- Start of finite element tests.

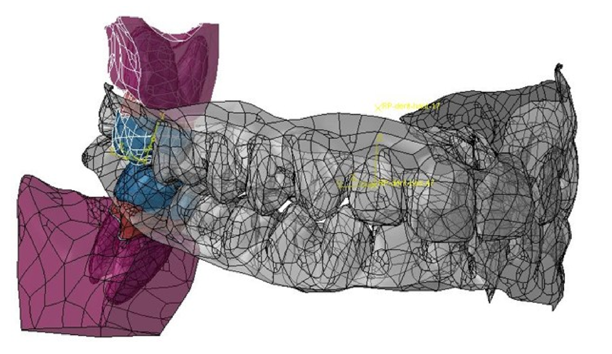

Fig. 4: Model of the two teeth from Rapidform® superimposed with the maxillo-mandibular model from Modjaw®.

Results

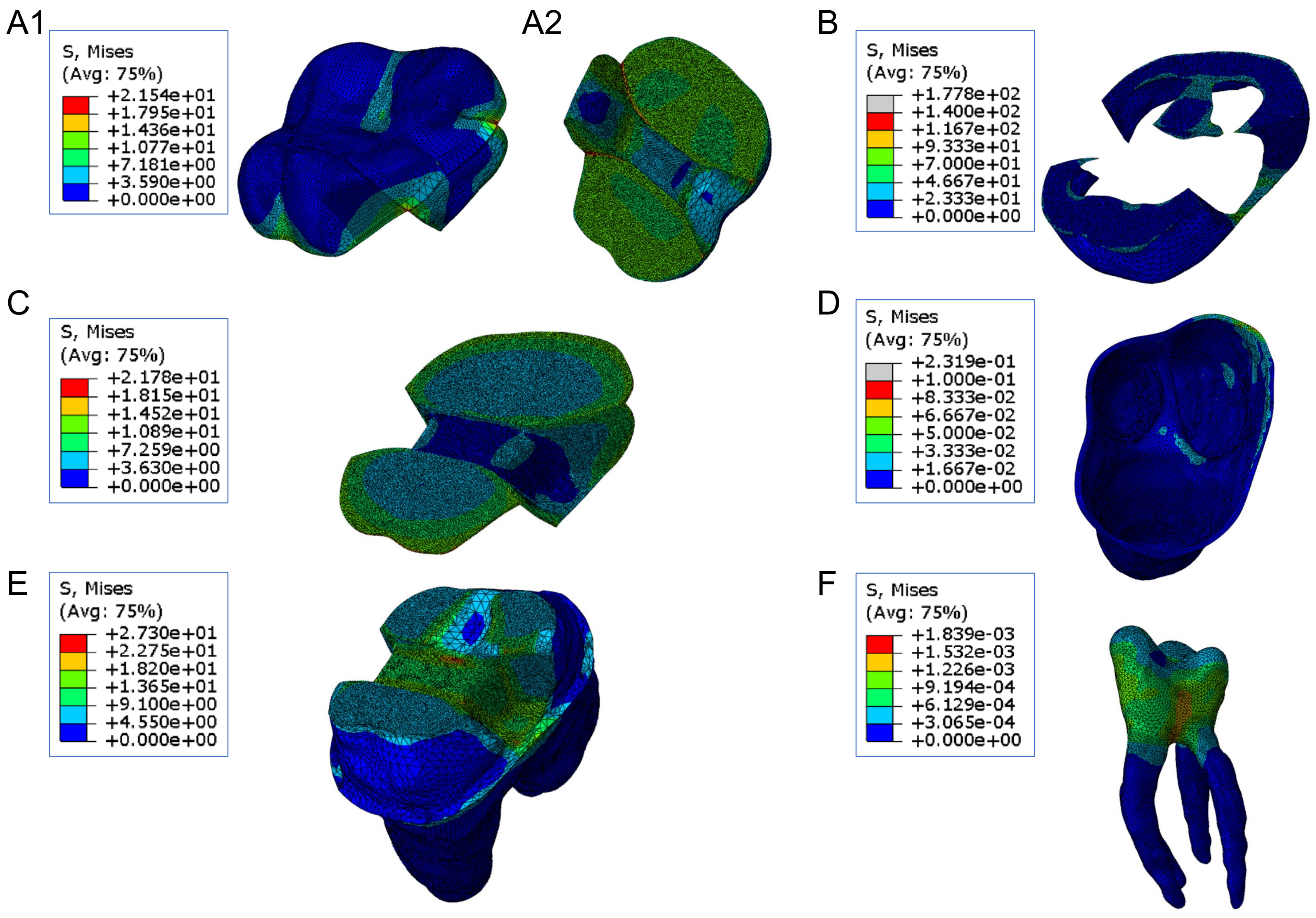

Fig. 5 : The Von Mises stresses (MPa) measured on the materials of the tooth 17 in model C1 A) Onlay Composite (A1 occlusal view, A2 Apical view), B) Enamel , C) Adhesive layer D) Bone, E) Dentine, F) Pulp.

			Von Mises Stress (MPa)						
Group		**With simulation of the polymerization shrinkage for composite and adhesive**	**Adhesive layer**	**Composite**	**Dentine**	**Enamel**	**Periodontal ligament**	**Bone**	**Pulp**
A Reference group	**A1**	**x**	21.4	137.1	77.0	147.0	17.9	25.4	0.0028
	A2		4.0	147.6	14.2	39.7	17.9	27.4	0.0014
B Thicker adhesive	**B1**	**x**	18.5	187.2	29.8	137.3	17.8	24.9	0.0027
	B2		4.4	141.7	12.4	45.7	17.8	26.9	0.0014
C Greater onlay depth	**C1**	**x**	21.1	204.3	25.3	155.0	13.5	25.5	0.0027
	C2		4.0	217.8	11.2	35.8	14.0	27.5	0.0014

- The greatest stresses were measured in the composite under the contact points with the antagonist tooth and in the group with the deepest restoration.
- With the simulation of polymerization shrinkage, the stresses observed on the enamel were 3 to 4.4 times higher and localized on the proximal zones where the thickness of the material was the lowest.
- For dentin, stress values were doubled for groups B and C and 5.5 times greater for the reference group. They was located on the external part of the proximal angles of the cavity.
- With the polymerization shrinkage simulation, the pulp also presented stresses twice as high despite values remaining very low.

Conclusions

- This model design protocol with the integration of the mandibular motion in the finite element data allowed to have a very realistic analysis of the situation for this patient. It can be used for all other patients to study the dispersion of the stresses on the dental structures during polymerization and chewing.
- The proximal edges of the restorations were an area of stress concentration due to the reduced material thickness (enamel and dentin) on these areas.
- These stresses were induced by the polymerization shrinkage of the materials. The omission of this parameter during finite element analysis can therefore induce significant errors of interpretation, especially for cyclic fatigue analysis.
- Without the simulation of the polymerization shrinkage, the only significant stresses were observed under the contact points with the antagonist tooth and were supported by the composite restoration.

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