e-Workshop of the IRP Coss&Vita
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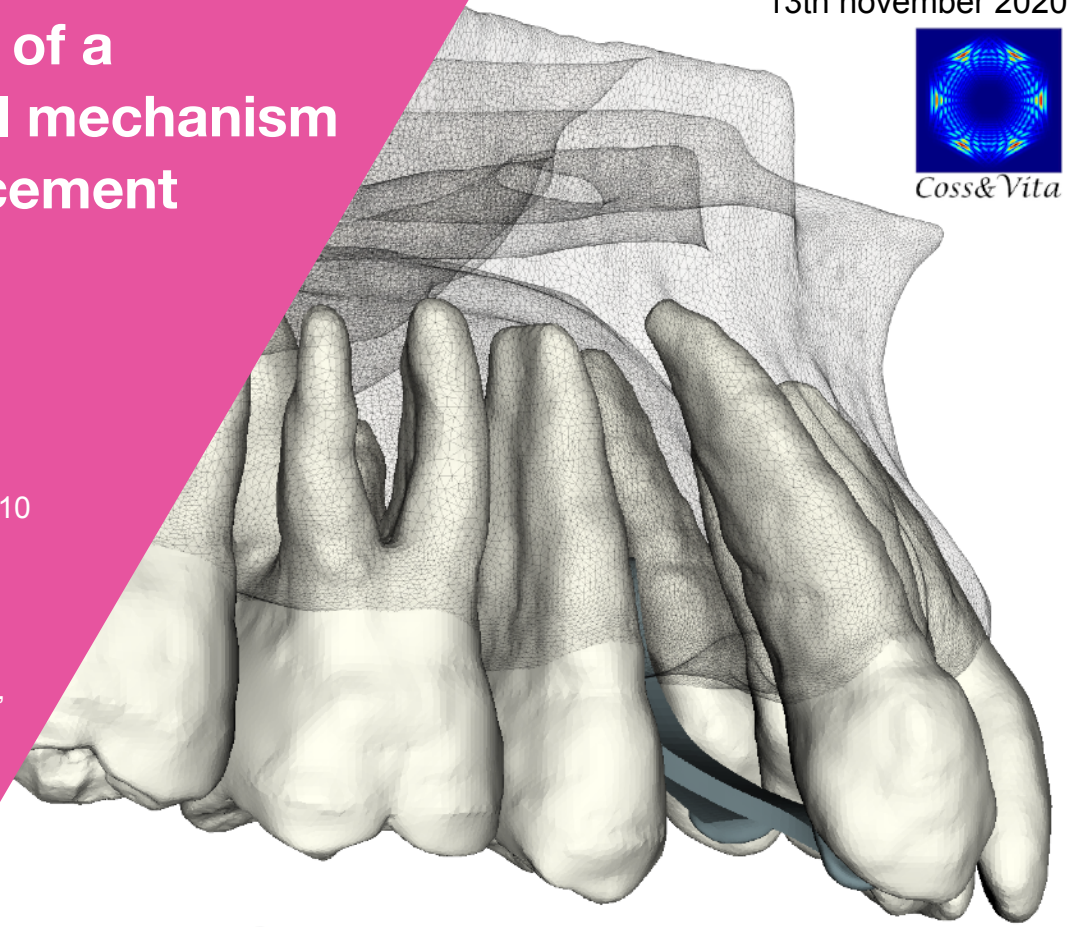
Clinical and numerical study of a statically determinate lingual mechanism for orthodontic tooth displacement

G. Dot[1,2], R. Licha[1], F. Goussard[3], V. Sansalone[1]

[1] Univ Paris Est Creteil, CNRS, MSME UMR 8208, F-94010 Creteil, France
[2] AP-HP, Hopital Pitie-Salpetriere, Service d'Odontologie, 47-83 Boulevard de l'Hopital, 75013 Paris, France
[3] CR2P, UMR 7207, Muséum national d'Histoire naturelle, CNRS, Sorbonne Université, 8 rue Buffon CP38 75005 Paris, France



Coss&Vita

MSME Laboratoire Modélisation et Simulation Multi Echelle
MUSÉUM NATIONAL D'HISTOIRE NATURELLE
ASSISTANCE PUBLIQUE HÔPITAUX DE PARIS

No conflict of interest to declare

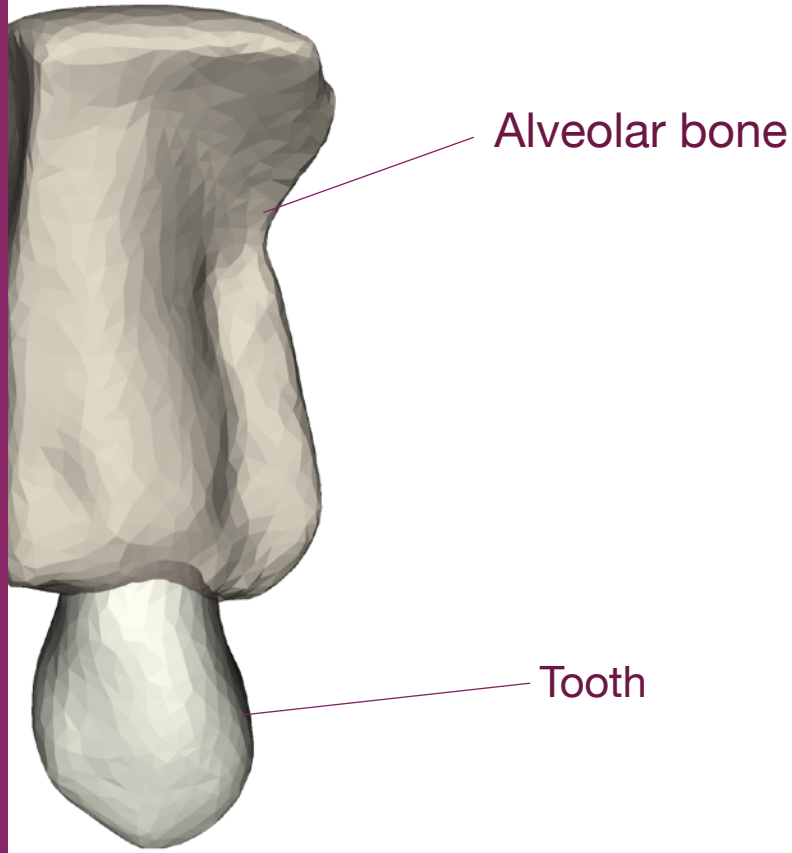
Clinical experience

Treatment planning

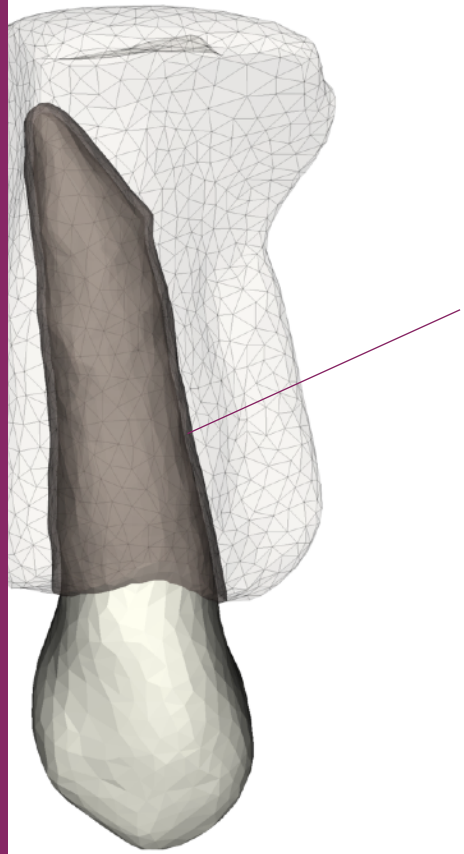
Side effects

Pain

Mechanobiology

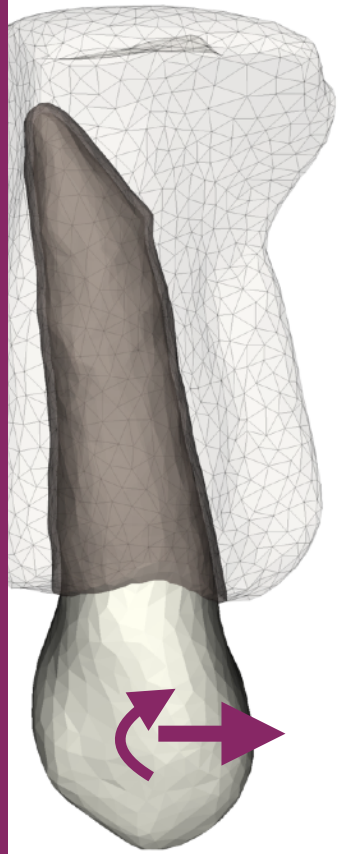


Mechanobiology



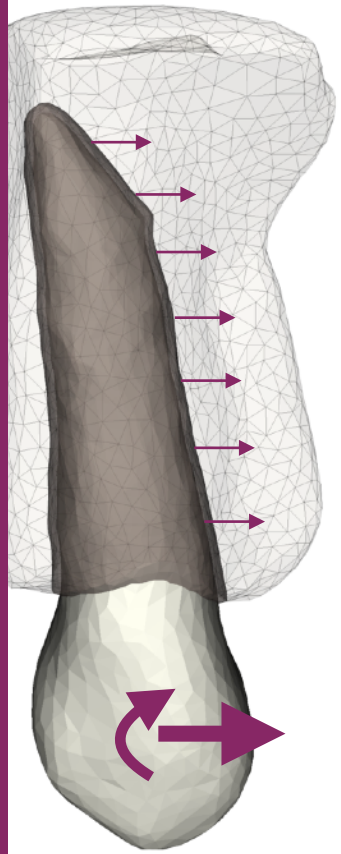
Periodontal ligament (PDL) ~0.3 mm

Mechanobiology



forces and moments at the bracket level

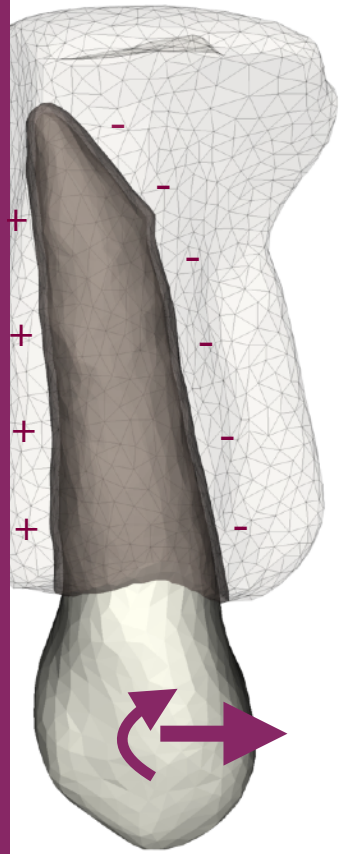
Mechanobiology



forces and moments at the bracket level

stresses and strains in the PDL and bone

Mechanobiology



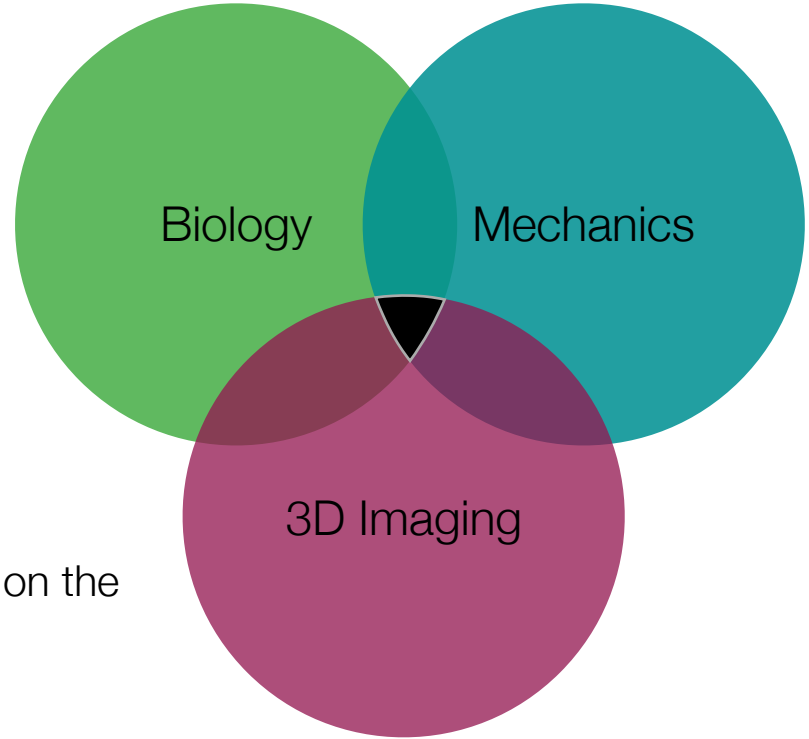
forces et moments au niveau des brackets

stresses and strains in the PDL and bone

bone remodeling

Modeling by the Finite Element (FE) method

Growing use in orthodontics



Numerical simulation based on the **construction of a model**

Modeling by the Finite Element (FE) method

Schematic view of reality

Depends on the data provided

Numerical simulation based on the
construction of a model

Modeling by the Finite Element (FE) method

Schematic view of reality

Depends on the data provided

Orthodontic publications often have two major limitations:

- validation of results (clinical data)

- loading conditions (friction/contacts…)

Main objective

Propose a new strategy for the development of a FE model of orthodontic displacement based on:

- precise patient-specific data,

- statically determinate force system.

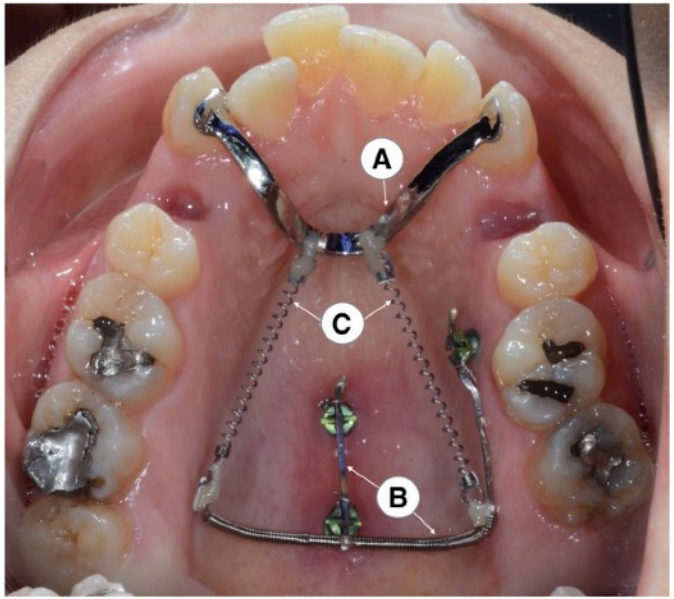
MATERIALS AND METHODS

Clinical procedure

Ethical committee approval (CPP IdF-1)

Inclusion of a patient (28 years old), treated by an original device :

- Custom-made lingual appliance for canine retraction *(homemade design)*
- Known loading conditions : 2 distalization forces, no friction



A - CAD-CAM rigid individualized arch

B - Rigid arch attached to 3 temporary screw

C - 2 Ni-Ti open springs (1.0 N each)

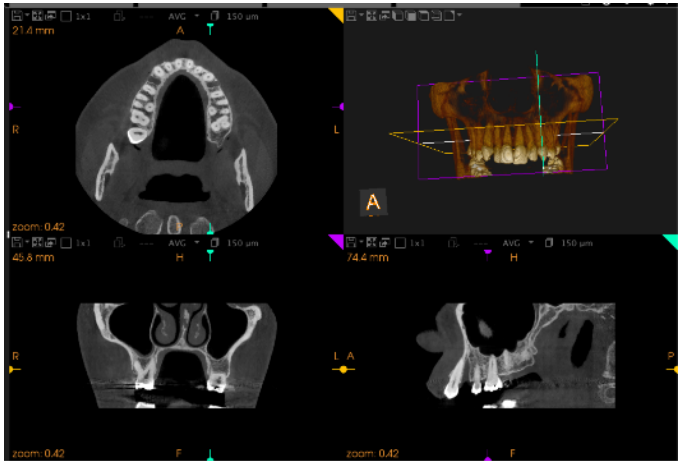
MATERIALS AND METHODS

Clinical procedure

Clinical steps	T0	T1	T2	T3	T4	T5	T6	T7
Days	*0*	*29*	*64*	*92*	*126*	*155*	*190*	*218*
CBCT	x							x

Cone beam CT (CBCT) of maxillary arch

*NewTom VGi EVO - 12*8 cm field of view ; 0.15 mm3 voxel size*



MATERIALS AND METHODS

Clinical procedure

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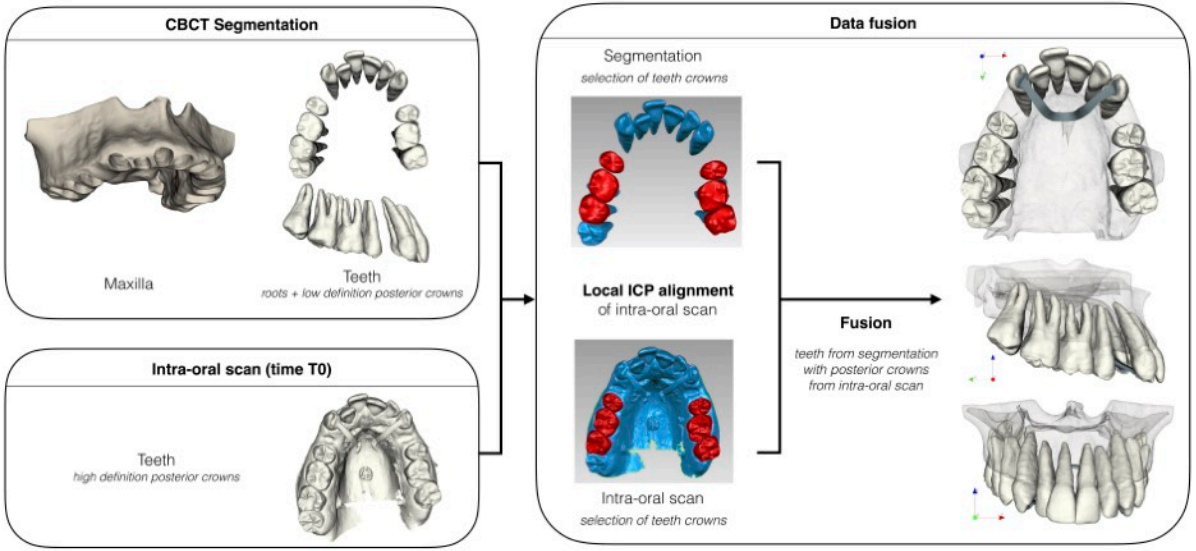
Days	*0*	*29*	*64*	*92*	*126*	*155*	*190*	*218*
CBCT	x							x
Intra-oral scan	x	x	x	x	x	x	x	x

Intraoral scan
performed monthly

MATERIALS AND METHODS

Personalized 3D surface models

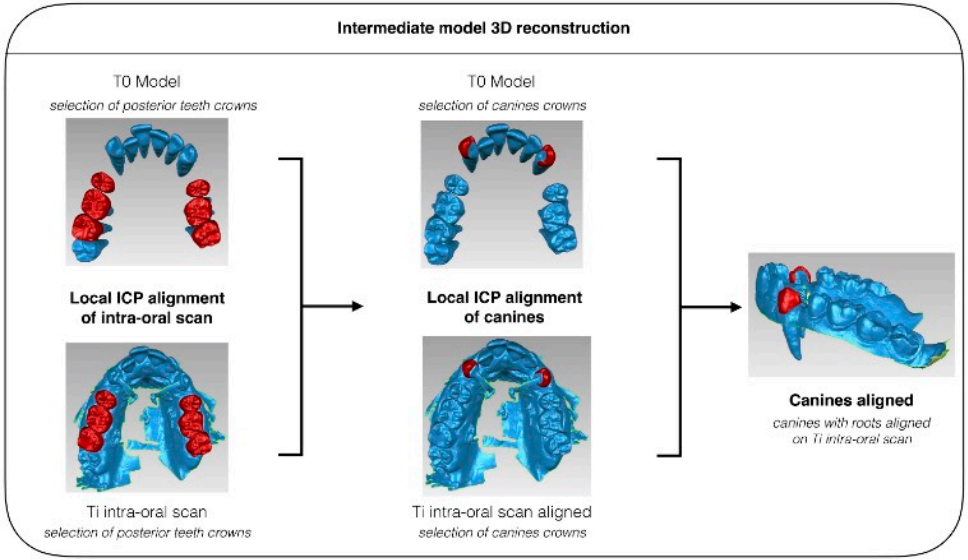
Clinical steps	T0	T1	T2	T3	T4	T5	T6	T7
Days	*0*	*29*	*64*	*92*	*126*	*155*	*190*	*218*
CBCT	x							x
Intra-oral scan	x	x	x	x	x	x	x	x



MATERIALS AND METHODS

Personalized 3D surface models

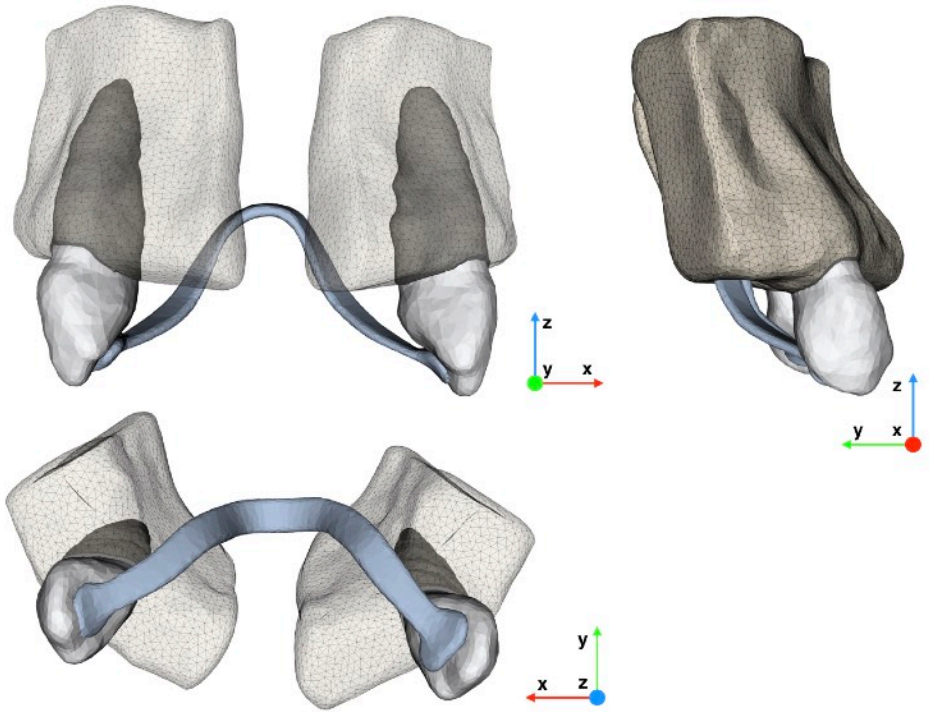
Clinical steps	T0	T1	T2	T3	T4	T5	T6	T7
Days	*0*	*29*	*64*	*92*	*126*	*155*	*190*	*218*
CBCT	x							x
Intra-oral scan	x	x	x	x	x	x	x	x



MATERIALS AND METHODS

Finite Element model

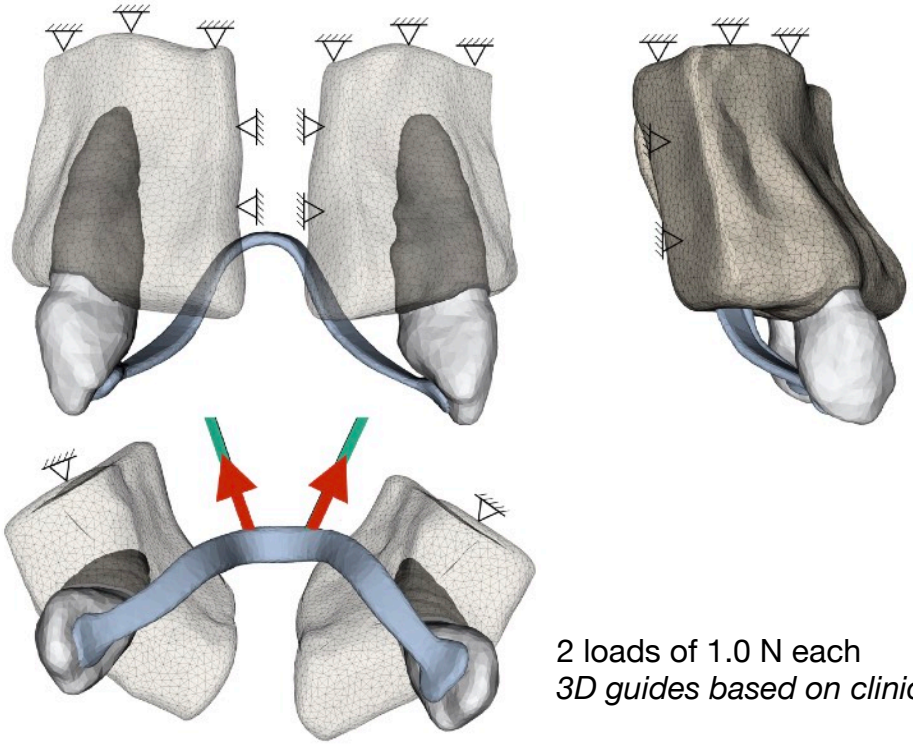
Personalized 3D geometry (selection of 3D areas of interest)



MATERIALS AND METHODS

Finite Element model

Boundary conditions and personalized loading



2 loads of 1.0 N each
3D guides based on clinical data

MATERIALS AND METHODS

Finite Element model

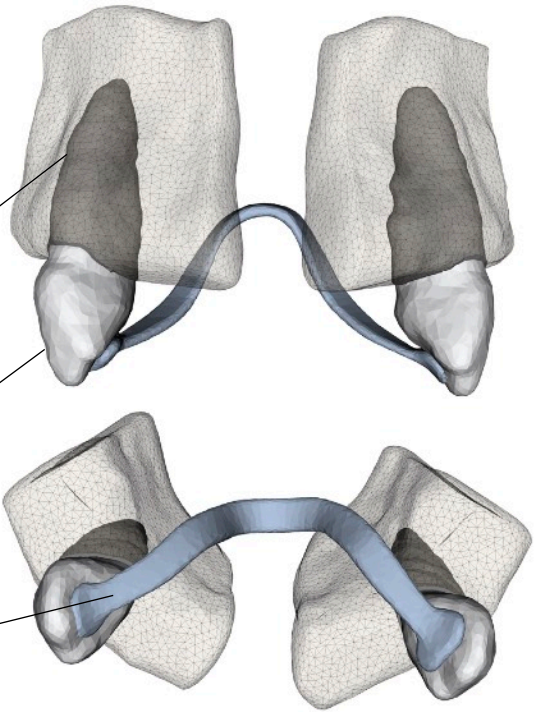
Material properties

Homogeneous, isotropic and linearly elastic

Periodontal Ligament
E = 1 Mpa
v = 0.45

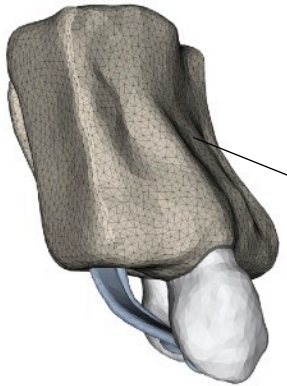
Teeth
Rigid bodies

Cobalt-Chrome
E = 200 Gpa
v = 0.3

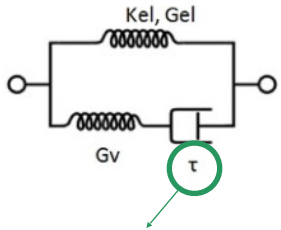


Homogeneous, isotropic and **visco-elastic**

Bone
E = 345 Mpa
v = 0.3



Zener model to mimic bone remodeling



characteristic time τ: only parameter requiring calibration

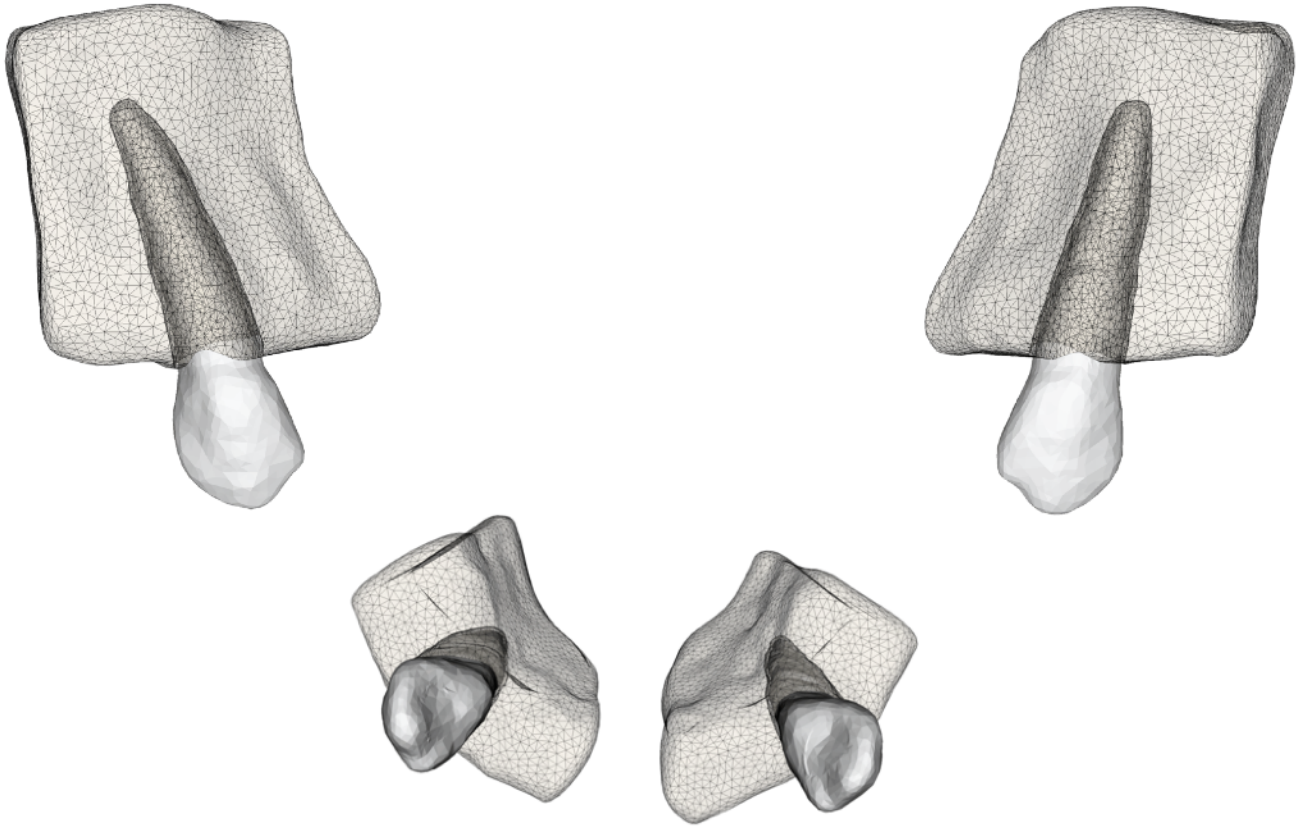
RESULTS

RESULTS

7 months of clinical tracking (T0 to T7)

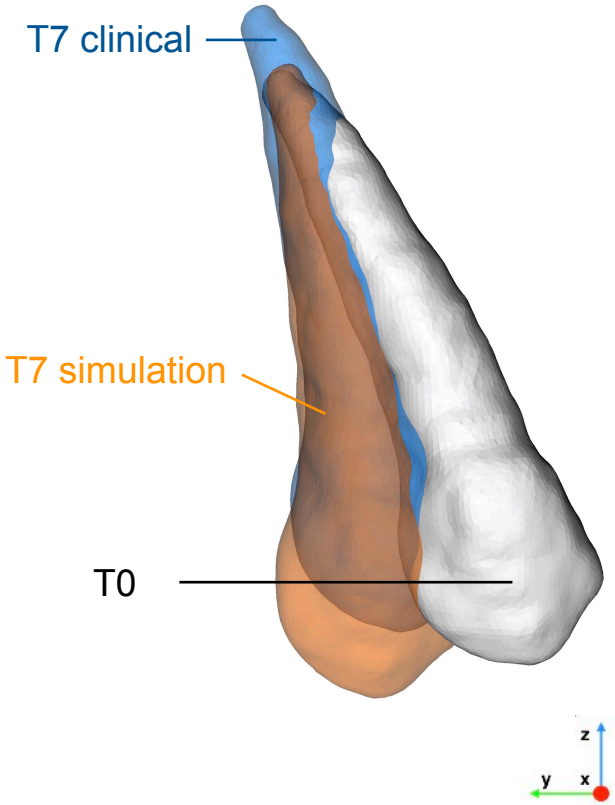
Right canine

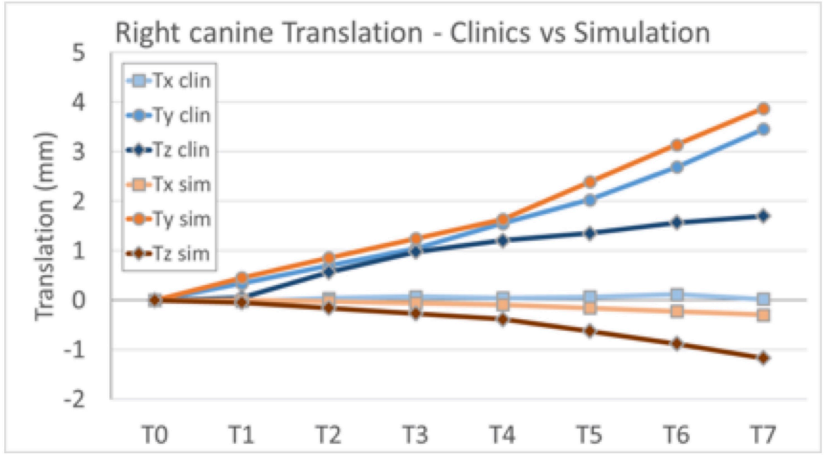
Left canine

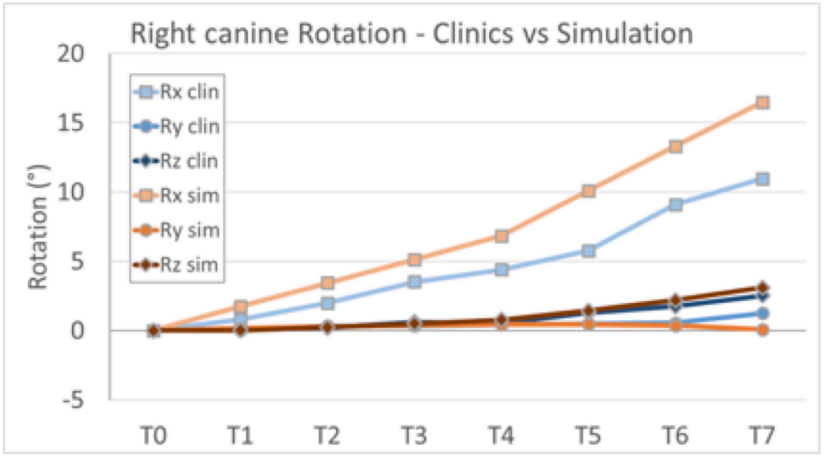


RESULTS

Right canine







DISCUSSION

State of the art

- Lack of validated FE model of orthodontic tooth movement and bone remodeling
- Lack of reliable data on the clinical displacement of teeth subjected to a known system of forces

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- Lack of reliable data on the clinical displacement of teeth subjected to a known system of forces

Main results

- Successful set up of a clinical protocol to track orthodontic tooth movement
- Collection and analysis of reliable clinical data on long-term orthodontic tooth movement
- Development of a preliminary FE model simulating this displacement

DISCUSSION

Clinical results

Customized force system based on « statically determined mechanics »

Simple and known loading conditions for 7 months

(Fontenelle 1991 ; Burstone, 2015 ; Roberts 2016)

Efficient method of tooth tracking, based on CBCT and intraoral scan

Low X-ray dose

Validation using final CBCT

Procedure remains tedious (not suitable for clinical use) (Lee, 2015 ; Bouton, 2017)

Unexpected tooth movement : rotation and intrusion (-z axis)

Line of action of forces too occlusal ?

Functional forces (tongue, masticatory…) non negligible ? (Viecilli, 2015)

DISCUSSION

Preliminary FE model

Good correspondence with the clinic, except on the translation along the -z axis

Even with a carefully designed clinical setup, the model does not stick to clinical data

Importance of calibration and validation of FE models using realistic clinical data

Modeling assumptions

Simplified material behavior

Visco-elastic bone properties to mimic bone remodeling (Ludwig, 2013)

First step, could be used to answer clinical questions

> *where is the center of resistance of the canines in 3D ?* (Viecilli, 2013)

> *would we have more translation by modifying the line of action of the forces ?*

Utility of finite element modeling in orthodontics

Lack of a validated model of orthodontic displacement

CONCLUSION

Utility of finite element modeling in orthodontics

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CONCLUSION

Clinical study

Long-term data for orthodontic tooth displacement of one patient

Development of a preliminary FE model simulating this displacement

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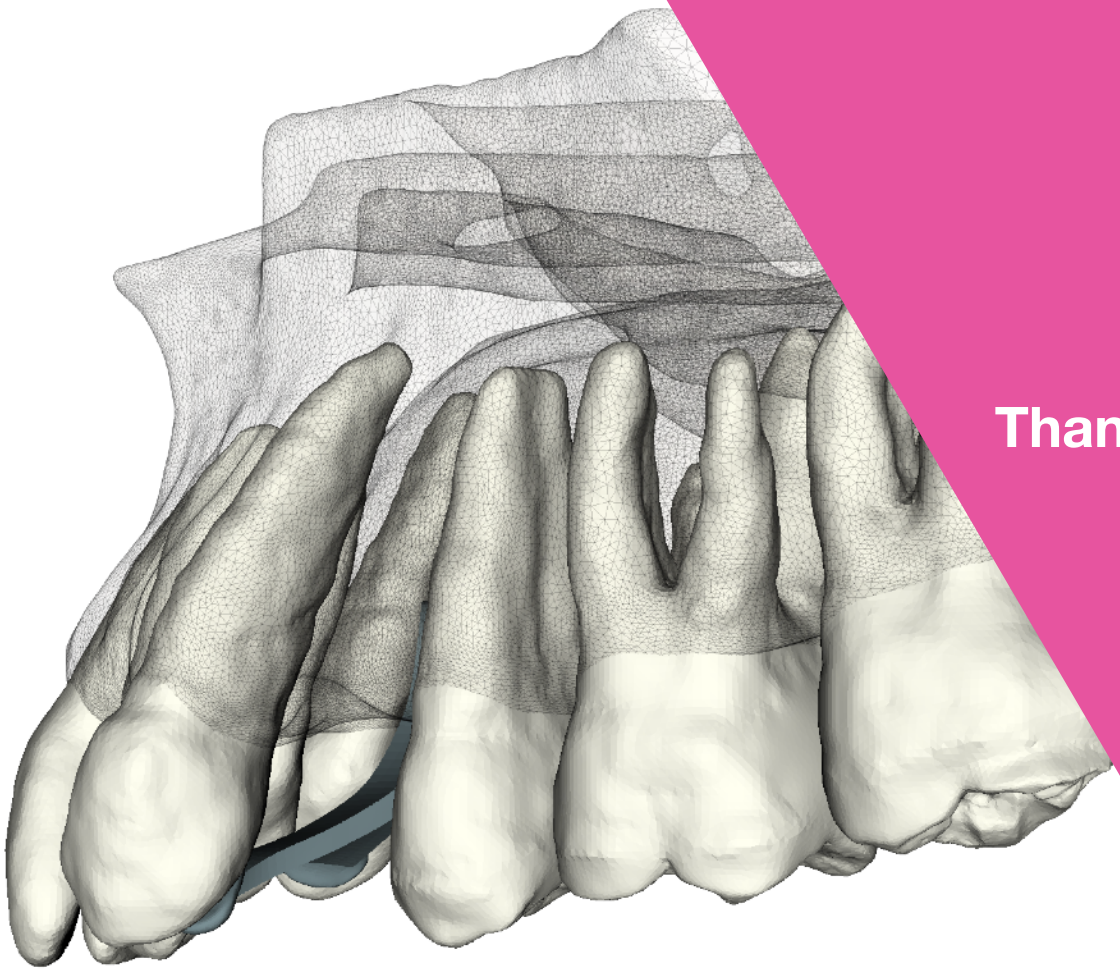
Future works

Integration of a bone remodeling algorithm

Development of a model allowing prospective simulation



Thank you for your attention

gauthier.dot@ensam.eu