Sujet de thèse

Numerical abacuses applied to the orthodontic field, a tool dedicated to the practitioners for the optimization of the choice of shape memory alloys archwires

Abaques numériques appliqués au domaine orthodontique, un outil dédié aux praticiens pour l'optimisation du choix des arcs AMF (alliages à mémoire de forme)

Directeurs de Thèse

Siham TOUCHAL : Associate professor, HDR, member of MMB research team

Delphine WAGNER : Associate professor and practitioner, orthodontist, member of MMB research team

Hamdi JMAL : Associate professor, member of MMB research team

Contacts : touchal@unistra.fr delphine.wagner@unistra.fr jmal@unistra.fr

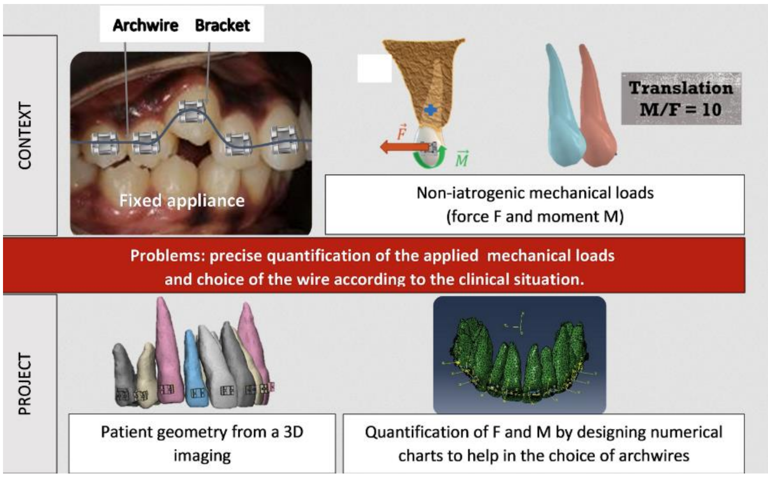
Application deadline: **Mai 2, 2023**

Application method: **by email to the contacts above accompanied by a CV and a cover letter**

Thesis start: **September 2023**

Short summary of the project

Orthodontics aims at treating malocclusions mainly with fixed appliances, composed of brackets and archwires. Wires' sections and dimensions evolve with the leveling of the dental arches according to a sequence of archwires chosen by the practitioner. Mechanical loads initiate dental displacement but can also be iatrogenic if they are excessive. The scientific problem is that practitioners do not have a precise way to quantify and to control these mechanical loads.



Presentation of the project

Context

Orthodontic appliances are used to correct a malocclusion using brackets and archwires. With the progression of leveling, their dimension and size evolve, called an archwire sequence. Shape memory alloys (SMA) are the most democratized to perform this first step of treatment due to their mechanical properties (Jian et al., 2013; Wang et al., 2018; Nucera et al., 2014). The wires are the promoters of the mechanical loads transmitted to the teeth. It is the moment/force ratio present inside the slot of each bracket that will determine the type of movement expected (Storey and Smith, 1952; Smith and Burstone, 1984).

Different archwire sequences are described in the literature (Papageorgiou et al., 2014) without consensus, leaving the practitioner with a choice to make depending on the clinical situation to be treated. The use of numerical models attempts to help (Haddadpour et al., 2019) but their use has not yet gone as far as correlating a real situation with an archwire sequence recommendation.
It is important to note that the application of inadequate mechanical forces can cause side effects, as discomfort, pain, and even root resorptions (Casteluci et al., 2021; Villaman-Santacruz et al., 2022). It is essential for orthodontists to be able to accurately determine the action of their device.
The theoretical range of values is given in the literature (Proffit et al., 1993; Wu et al., 2018). However, Burstone and Koenig (1974) evaluated the 2-dimensional force and moment present on 2 adjacent coplanar teeth. These intensity values were estimated based on idealized geometry, without considering the periodontal environment.
Accurate, three-dimensional quantification of all the teeth in an arch is complex, if not clinically impossible. Practitioners can rely on their experience and the use of dynamometers.
Only one German team has attempted to develop brackets to record the forces and moments applied within the bracket, but this device has not reached the market (Lapatki et al., 2007). Measurements made by a dynamometer are the most widely used but unreliable and difficult to reproduce.
Our proposal is in line with one of the three main research axes of the MMB research team, multi-scale modeling. A preliminary science thesis has already been completed with the objective of quantifying the forces and moments deployed by a multi-attachment device. This work was limited to the study of one type of device and a single round archwire and one single dimension. Its originality was to propose and validate an experimental protocol whose results were used to implement a first numerical model realized in collaboration with the LEM3 laboratory, Metz.
The project has allowed us to consider areas of improvement, in particular the desire to universalize the devices tested and to model them, in order to be representative of orthodontic practices on an international level (the different types of brackets available on the market, conventional and self-ligating, and the 2 most popular sizes of slots).
It is in this context that the abacuses can be designed. The initial numerical model will be used as a working tool and will have to evolve with this new project. Indeed, obtaining a second model integrating the different types of attachments commonly used by orthodontists, as well as the entire range of sections and dimensions of SMA wires that can be used, would allow the simulation of most clinical situations that can be encountered. In addition, an experimental campaign, supported by the INSERM SFODF grant in 2021, has already made it possible to acquire part of the input data for this second model.
The acquisition of the patient's geometry, subject to the agreement of the ethics committee of the Faculty of Medicine of Strasbourg and the DRCI of the HUS, can be done using a cone beam imaging.
The project will benefit from the experimental and digital means available within the Imaging, Robotics and Innovation for Health (IRIS) platform.

Main objective
To design a tool based on a digital model from a real clinical situation (geometry acquired from a patient). It must allow the quantification of the mechanical loads applied to all the teeth. The aim is to enable the practitioner to choose the successive archwires during the first phase of an orthodontic treatment, the levelling, in a reasoned and individualized manner.

Secondary objective
To propose the best benefit/risk ratio to the patient during the levelling phase of orthodontic treatment.

Originality of the project
- Transversal project where mechanics, engineering and orthodontics are implicated
- To develop a digital twin applied to the orthodontic field.
- First quantification of the mechanical efforts extended to a full 3D dental arch.
- The project has a clinical aim, to limit iatrogenic risks.

Expected candidate profile:

Skills required of the candidate:

- Knowledge and mastery of DICOM image segmentation software (imaging format dedicated to the medical field)

- Knowledge and mastery of Abaqus software

- Ability to code in Abaqus

References

- *Storey E, Smith R. Force in orthodontics and its relation to tooth movement. Aust J Dent 1952: 11–8.*
- *Smith RJ, Burstone CJ. Mechanics of tooth movement. Am J Orthod 1984;294-307.*
- *Jian F, Lai W, Furness S, McIntyre GT, Millett DT, Hickman J, Wang Y. Initial arch wires for tooth alignment during orthodontic treatment with fixed appliances. Cochrane Database Syst Rev. 2013 Apr 30;2013(4):CD007859.*
- *Wang Y, Liu C, Jian F, McIntyre GT, Millett DT, Hickman J, Lai W. Initial arch wires used in orthodontic treatment with fixed appliances (Review). Cochrane Library 2018.*
- *Nucera R, Gatto E, Borsellino C, Aceto P, Fabiano F, Matarese G, Perillo L, Cordasco G. Influence of bracket-slot design on the forces released by superelastic nickel-titanium alignment wires in different deflection configurations. Angle Orthod. 2014 May;84(3):541-7.*
- *Papageorgiou SN, Konstantinidis I, Papadopoulou K, Jäger A, Bourauel C. A systematic review and meta-analysis of experimental clinical evidence on initial aligning archwires and archwire sequences. Orthod Craniofac Res. 2014 Nov;17(4):197-215.*
- *Haddadpour S, Motamedian SR, Behnaz M, Asefi S, Bagheban AA, Abdi AH, Nouri M. Agreement of the clinician's choice of archwire selection on conventional and virtual models. Angle Orthod. 2019 Jul;89(4):597-604.*
- *Casteluci CEVF, Oltramari PVP, Conti PCR, Bonjardim LR, de Almeida-Pedrin RR, Fernandes TMF, de Almeida MR, de Castro Ferreira Conti AC. Evaluation of pain intensity in patients treated with aligners and conventional fixed appliances: Randomized clinical trial. Orthod Craniofac Res. 2021 May;24(2):268-276.*
- *Villaman-Santacruz H, Torres-Rosas R, Acevedo-Mascarúa AE, Argueta-Figueroa L. Root resorption factors associated with orthodontic treatment with fixed appliances: A systematic review and meta-analysis. Dent Med Probl. 2022 Jul-Sep;59(3):437-450.*
- *Proffit W, Fields H, Ackerman J, Sinclair P, Thomas P, Tulloch JFC. Contemporary Orthodontics. 5th ed. Mosby Year Book; 1993.*
- *Wu JL, Liu YF, Peng W, Dong HY, Zhang JX. A biomechanical case study on the optimal orthodontic force on the maxillary canine tooth based on finite element analysis. J Zhejiang Univ Sci B. 2018 Jul;19(7):535-546.*
- *Burstone CJ, Koenig HA. Force systems from an ideal arch. Am J Orthod. 1974 Mar;65(3):270-89.*
- *Lapatki BG, Bartholomeyczik J, Ruther P, Jonas IE, Paul O. Smart bracket for multi-dimensional force and moment measurement. J Dent Res. 2007 Jan;86(1):73-8.*