# Mechanical behaviour of dental treatments based on an anatomic-functional geometry (AFG) technique

D. Bianchi[1], C. Lorenzi[2], D. Severino[3], L. Arcuri[2], A. Dolci[2] and G. Vairo[1]

[1]*University of Rome "Tor Vergata"- Department of Civil Engineering & Computer Science (DICII), Rome - Italy, e-mail: d.bianchi@ing.uniroma2.it, vairo@ing.uniroma2.it*

[2]*University of Rome "Tor Vergata"- Department of Clinical Science and Translational Medicine, Rome - Italy, e-mail: claudia.lorenzi@uniroma2.it, lorenzo.arcuri@uniroma2.it, alessandro.dolci@uniroma2.it*

[3]*Private Practice in Rome, Rome - Italy, e-mail:info@darioseverino.com*

***Abstract*— In this study a computational model, formulated by means of a nonlinear finite-element strategy, is developed for the evaluation of mechanical behaviour of dental treatments. The proposed computational framework is employed to analyse different techniques in the field of prosthodontics practice, in order to highlight the influence of dental preparation on the mechanical response of treated teeth. To this aim, a comparative analysis between the anatomical-functional-geometry (AFG) preparation and the standard one is carried out. Proposed results disclose soundness and effectiveness of the computational approach in order to highlight possible drawbacks in load transfer mechanisms induced by the dental preparation.**

***Keywords* - Dental treatment, finite element modelling, anatomic-functional-geometry technique.**

## I. INTRODUCTION

THE aim of this study was to evaluate the influence of preparation geometry and design of the tooth on stress/strain distribution. Considering that failure rates of posterior all-ceramic crowns are significantly higher than anterior ones, this study tries to furnish a contribution towards the improvement of mechanical performances in posterior teeth by changing the framework design. The improved physical properties of newer ceramics enabled reduced axial preparation depth and new preparation design [1]. The inspiration of the new shape design comes from the anatomic-functional-geometry (AFG) modelling technique [2]. By extrapolating the geometric basis of this modelling technique, a framework design standardized and reproducible from each clinical has been developed. One of the advantages of such an approach is associated to the fact that, the presence of standardized anatomical landmarks allows preparing teeth in a more conservative and anatomical way.

In this context and in order to assess effectiveness of AFG technique and/or possible related criticisms, finite-element-based numerical analysis (FE) can be retained a proper tool for the multi-causal evaluation of mechanical performances of all-ceramic restorations [3]. Specifically, in this study FE has been adopted to assess the influence of the preparation shape on stress/strain distributions in all-ceramic crowns.

## II. MATERIAL AND METHODS

### *A. Sample preparation for geometry reconstruction*

Out of 112 human extracted teeth, including first and second premolars and first molars, 12 were selected. The exclusion criteria were the presence of caries and several occlusal abrasions. Selected teeth were extracted because of periodontal disease or orthodontics reasons. The study group included one first premolar, one second premolar and one first molar from each quadrant. Each selected tooth was duplicated two times by using a stainless-steal master die filled with polymethyl-metacrylate resin. The 24 duplicate teeth were divided in two groups (A and B) and prepared to receive a complete crown restoration (group A and group B including one first premolar, one second premolar and one first molar from each quadrant).

One operator with a constant water spray and using the same specific sequence of burs executed all preparations manually. In the group A, the preparation design chosen was considered the typical one of the minimal preparation suggested for ceramic crowns. A 1 mm groove was cut along the central fissure. A line was marked on the buccal and palatal cusps from the cusp tips. This line was connected to the bottom of the groove prepared in the first step with a tapered diamond bur [4]. A wall taper of 6 degrees was applied to the preparation until the CEJ that was completed with a finishing margin. In the group B, the preparation design was based on the principles of AFG modelling. The first phase included the identification of the anatomical details and of geometric landmarks belonging of AFG modelling technique. The second step consisted with the elimination of the superficial anatomical design and the preparation of triangles on the sides of the primary crests, which have a very repetitive pattern. One millimetre grooves were cut on the top of the crests and on the furrows according to the AFG modelling guidelines. The same lines were applied to the axial walls until the CEJ. After the elimination of undercuts the preparation was completed with a finishing margin.

### *B. Numerical modelling*

Each selected tooth is regarded as a continuum body, i.e. a regular region in the Euclidean space. The solid domain is composed of three subregions: prepared tooth, ceramic crown and cement region. The cement region, is defined as the volume region separating tooth and crown. The three-dimensional geometry of each sample is reconstructed in an automatic way, by combining CAD techniques and optical scanner technology, and by employing –for generating surface meshes of each sample– Rhinoceros, Optical RevEng and Exocad software. Each material region is assumed homogeneous and to behave as a linearly-elastic material with isotropic constitutive symmetry, whose mechanical properties are set fully in agreement with the specialized literature [5]. All interfaces are assumed perfectly bonded.

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Numerical simulations are carried out by considering the tooth model undergoing physiological load conditions (as sketched in Fig. 1), and accounting for the presence of the periodontal ligament (PDL). In detail, following the modelling strategy proposed in [5], PDL nonlinearities and anisotropy are described via a discretized distribution of non-linearly elastic spring elements, acting along the normal direction to the constrained tooth surface (Fig. 1) and whose tangent stiffness value locally depends on the local level of strain. In particular, the PDL nonlinear modelling is based on the multiscale formulation proposed in [6,7].

As a result, nonlinear numerical simulations are performed by adopting an incremental approach, based on an updated Lagrangian formulation and implemented via a home-made Matlab code which exploits the finite-element capabilities of COMSOL Multiphysics.

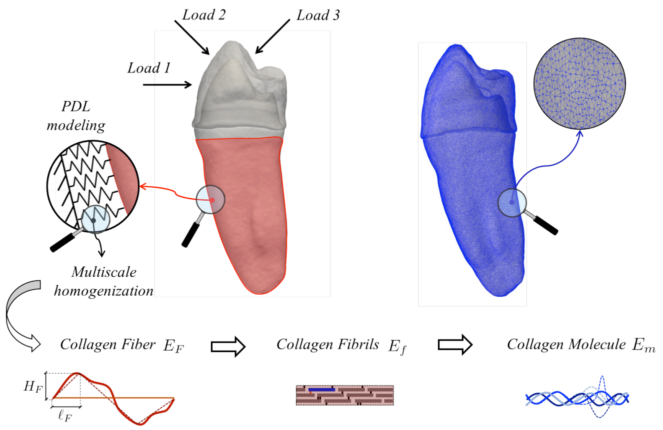


Figure 1: Schematic representation of loading conditions and of PDL-based boundary conditions considered in the present study.

## III. Results

In order to carry out a comparative analysis of different dental preparations, the mechanical interaction between ceramic crown and prepared tooth is mainly assessed by evaluating the stress distribution at the crown-tooth interface (namely, into the cement region). As an example, the spatial distribution of Von Mises stress measure at the crown-tooth interface, in the first molar and for both standard and AFG preparation techniques, is shown in Fig. 2(a). Moreover, Fig. 2(b) highlights differences in terms of surface area at the crown/prepared-tooth interface in both cases, such a measure being able to be considered as an index of stability for the treated tooth.

## IV. Conclusion

In this work, a computational model formulated by means of a nonlinear finite-element strategy is developed. A comparative study between two different dental preparation (standard and AFG-based) is presented. Proposed model integrates a fine description of periodontal ligament obtained via a multiscale approach. Moreover, different physiological load patterns are investigated in order to contribute towards the proper assessment of the influence of dental preparation type on the mechanical response arising in tooth-bone load-transfer mechanisms.

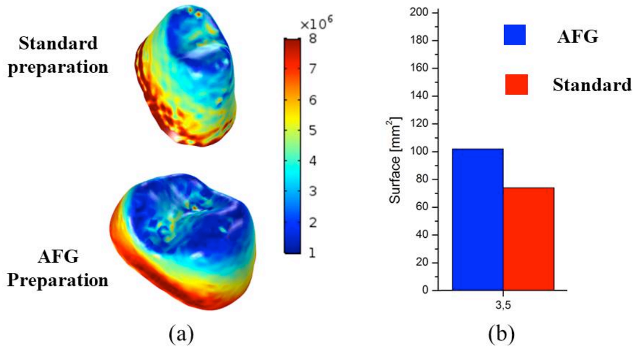


Figure 2: (a) Spatial Von Mises stress distribution in first molar for both standard and AFG preparation; (b) surface area between crown and prepared tooth in standard and AFG preparations.

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