

## Mechanical behaviour of a nickel-titanium root canal instrument: a non-linear finite element approach

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**INTRODUCTION:** The study of the mechanical behaviour of Ni-Ti endodontic instruments is a difficult challenge for many reasons: the instrument geometries are complex, the mechanical behaviour of Ni-Ti SMA is strongly non-linear and very much affected by the multiaxiality of the mechanical loading [1-2]. Some interesting experimental investigations have been performed in recent years to determine the effect of different parameters (rotational speed, curvature of root canals, microstructure, etc. [3]) on the failure of endodontic instruments. These indispensable studies are time-consuming and can be performed only on existing instruments. Our investigations concern an alternative and complementary approach based on non-linear finite element simulations to evaluate the effect of the cross-sectional shape on the mechanical behaviour of Ni-Ti endodontic instruments.

**METHODS:** Since the geometry of endodontic instruments is complex, three-dimensional computation based on the finite element method is required to determine the stresses, the strains and the behaviour of root canal instruments. Some results have already been published concerning the study of the mechanical behaviour of endodontic instruments by numerical methods [4]. In all cases, the mechanical behaviour of Ni-Ti has been considered as elastic. This hypothesis allows the duration of simulations to be reduced but it does not take into account the real mechanical behaviour of Ni-Ti (*i.e.*, superelastic non-linear behaviour). In this study, an *ad hoc* model recently proposed by Bouvet *et al.* [1] was implemented in the finite element code CAST3M<sup>®</sup> developed by the CEA (Commissariat à l'Energie Atomique), and used in the simulations. This model takes into account the martensite transformation, the effects of cyclic loading and the effects of the multiaxiality of the loading.

**RESULTS:** Figures 1 and 2 show the cross section and the finite element mesh of the endodontic instrument respectively. The finite element mesh consists of 6210 elements and 8281 nodes. It takes into account both the cross sectional size and the thread variations. The left face was blocked and

bending was applied to the right face. Figure 3 shows the stress and the martensite volume fraction distributions in the instruments.

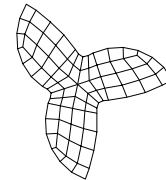


Fig. 1: Cross section of the instrument.



Fig. 2: Finite element mesh of the instrument.

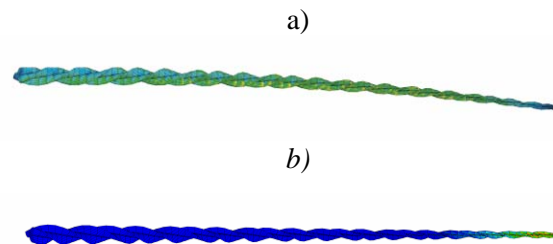


Fig. 3: von Mises stress and martensite volume fraction distribution in the instruments.

**DISCUSSION & CONCLUSIONS:** The results obtained show that it is now possible to estimate the stress field and the phase transformation rate in the complex geometry of a Ni-Ti endodontic instrument. The next step of this work will concern failure prediction under representative mechanical loading.

**REFERENCES:** <sup>1</sup>C. Bouvet, S. Calloch, C. LExcellent (2004) *Eur J Mech* **23**:37-61. <sup>2</sup>C. Bouvet, S. Calloch, C. LExcellent (2002) *JEMT* **124**:112-124. <sup>3</sup>G. Kuhn, L. Jordan (2001) *J Phys IV* **11**:553-557. <sup>4</sup>YL. Turpin, F. Chagneau, JM. Vulcain (2000) *J Endodontics***26**:414417.

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