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## ► To cite this version:

Jeanne Davril, Romain Hocquel, Marin Vincent, Éric Mortier, Nicolas Rauber, et al.. First predictive measurements of endodontic mechanical damage through photoelastic analysis and acoustic emission descriptors. 2024. hal-04738067

**HAL Id: hal-04738067**

**<https://hal.science/hal-04738067v1>**

Preprint submitted on 15 Oct 2024

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# First predictive measurements of endodontic mechanical damage through photoelastic analysis and acoustic emission descriptors

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**Keywords:** endodontics; nickel-titanium; rupture; acoustic emission

## 1. Introduction

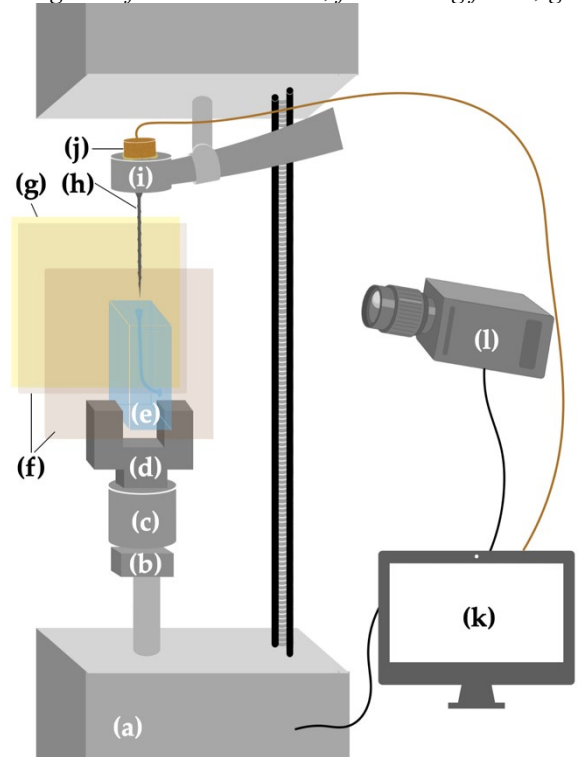
The endodontic treatment is part of the daily practice of the dentist. It consists in removing the organic content of tooth root canals using instruments called endodontic files. During treatment, the file undergoes numerous mechanical stresses that can lead to its breakage within the tooth. This incident has consequences that can be harmful for canal disinfection and obturation and therefore for the success of the treatment more generally. Indeed, this type of incident can even lead to tooth avulsion in the most extreme cases (Parashos & Messer, 2006). Despite the introduction of NiTi alloys and the clinical application of techniques that can minimize the risk of instrumental rupture, the probability of these events occurring is still too high. In the case of endodontic files, it is the state of triaxial stresses combining alternating bending and torsion that leads to the development of damage mechanisms during their use (Pillay *et al.*, 2020). The endodontic files then exhibit a mechanical response accompanied by a release of acoustic energy in the ultrasound domain (Maia *et al.*, 2015). The acoustic emission (AE) signals can be recorded and processed using an AE chain.

The aim of this work is to collect these signals and match them with their mechanical responses and observations of deformation modes. This analysis should eventually lead to the identification of early warning signals of irreversible deformation, making it possible to anticipate and avoid instrument failure.

## 2. Methods

The study consists of a campaign in which each multiphysic test is designed to reproduce the fracture of a continuously rotating endodontic file within a canal (Fig. 1).

Figure 1: a Tensile machine; b Load cell; c Torque cell; d Clamping; e geometry and the different regions of the PMMA block; f Polarizing filters; g



Light source; h File; i Motor; j Acoustic sensor; k Computer with softwares; l HD camera.

The analog tooth model was a block of PMMA containing a curved canal. As PMMA is birefringent, polarizers were placed on either side of the block to reveal isochromatics that reflect the existence of stress fields. Qualitative analysis of the isochromatics makes it possible to locate areas of high stress concentration in the tooth canal around the file. The endodontic files used (One Curve, MicroMega SA) were mounted on a Dual Move endodontic motor (MicroMega SA) and rotated at a speed of 500 rpm, with a safety torque of 4 N.cm. The motor was fixed to workbench throughout the experimental campaign. The PMMA blocks were attached to the mobile crosshead of the tension-compression machine (Ametek Lloyd LS1), fitted with force (50 N) and torque (0.3 Nm) transducers. The block moved 20 mm in the direction of the file at a speed of 1 mm/s and returned under the same conditions. The AE chain comprises a miniature

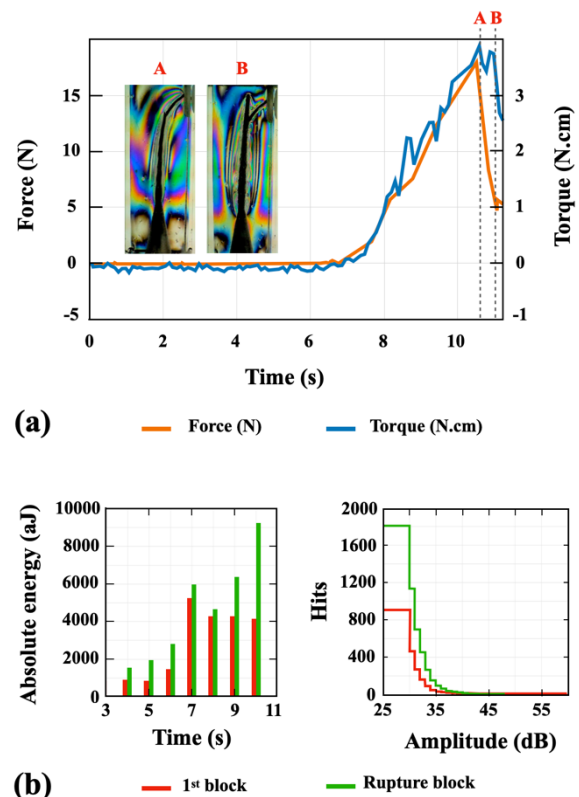
transducer linked by a cable to a preamplifier and a data acquisition chain (Mistras). The ultrasonic transducer (200-750 kHz) was coupled to the endodontic motor head. Force and torque values were processed simultaneously with AE descriptors, which were collected and analyzed using AEWIN software. Tests were repeated on the same file until breakage, each block being reamed only once. After each test leading to fracture, the files and instrumental breaks within the blocks were examined and analyzed on a profilometer.

### 3. Results and discussion

A total of 10 files were tested to failure, corresponding to 34 blocks. Real-time isochromatic analysis revealed a high concentration of stresses around the file, particularly in the "working" areas of the file (Fig. 2a). On the other hand, we observed residual stresses persisting in the blocks, even after the file had been removed, particularly at the root canal walls and around the embedded instrumental break. An inversion of the file pitch is visible on every broken file, and the fracture surface is helical in shape but slightly different from 45°, meaning that the file has mainly broken in torsion, with its tip embedded in the apical zone. Finally, after breaking (point A in Fig 2a), the file continues its movement prescribed by the choice of loading path, creating a block. new path, or bifurcation (point B in Fig.2a), along the long axis of the block.

Force and torque values increase during machining (Fig. 2a). In the various tests, the force reached maximum values of around 15 to 30 N and the torque of 3 to 4 N.cm. In tests where breakage occurred, the force decreased immediately after breakage, while the torque decreased once the return movement has been initiated. With regard to acoustic emission signals, we present in this summary, by way of example, the evolution of absolute energy (aJ) as a function of machining time and the distribution of hits as a function of their amplitude (dB) (Fig. 2b). This subfigure compares the results for the first resin block and the one during which the file break occurred. Absolute energy values were higher during the rupture test than during the first test, particularly just before rupture (at time 10.5 seconds in figure 2b). In terms of signal amplitude and distribution (hits), for all tests, there were many low-amplitude events and few high-amplitude events. Compared with the first block test, the rupture test showed lower signal amplitudes but a greater number of hits. On the other hand, the maximum amplitude reached was lower and high-amplitude signals were rarer. The increase in absolute energy and number of hits reflects an increase in the number of microstructural events leading to fracture (Nataf *et al.*, 2020).

**Figure 2. (a)** Illustration of file breakage and bifurcation of the machined canal, and associated



force and torque responses versus time during a rupture test (b) Comparison of acoustic emission descriptors of a representative file for the first and the rupture block: on the left, absolute energy (aJ) versus time (s); on the right, distribution of hits by amplitude (dB). Credit: J Davril

### 4. Conclusion

This first study made it possible to highlight acoustic emission signals just before and during the file break and to target the descriptors to be favored. Macroscopic visual analysis revealed a predominantly torsional fracture. New studies are underway, focusing on multivariate statistical analysis to establish correlations between the various data, and on a more detailed description of local deformation mechanisms. Prediction methods are also being explored.

### References

- Parashos, P., & Messer, H.H. (2006). Rotary NiTi instrument fracture and its consequences. *J Endod*, 32(11):1031-43. doi: 10.1016/j.joen.2006.06.008. PMID: 17055902.

- Pillay, M., Vorster, M., & Van Der Vyver, P.J. (2020). Fracture of endodontic instruments - Part 1: Literature review on factors that influence instrument breakage. *S Afric Dent J*, 75:553–63. doi: 10.17159/2519-0105/2020/v75no10a4.
- Maia, L.H.A., Abrao AM, Vasconcelos WL, Sales WF, Machado AR (2015). A new approach for detection of wear mechanisms and determination of tool life in turning using acoustic emission. *Tribol Int*, 92:519–32. doi: 10.1016/j.triboint.2015.07.024.
- Nataf GF, Romanini M, Vives E, Žužek B, Planes A, Tušek J, et al. (2020). Suppression of acoustic emission during superelastic tensile cycling of polycrystalline Ni<sub>50.4</sub>Ti<sub>49.6</sub>. *Phys Rev Mater*, 4:093604. Doi: 10.1103/PhysRevMaterials.4.093604.

**Received date:06/04/2024**

**Accepted date: 28/06/2024**

**Published date: XX/XX/2024**

Volume: 1

**Publication year: 2024**