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Published in:
Proceedings of the 14th euspen International Conference

Publication date:
2014

Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
Yagüe-Fabra, J. A., Tosello, G., Ontiveros, S., Jiménez, R., & Rasmussen, J. (2014). Dimensional quality control of Ti-Ni dental file by optical coordinate metrology and computed tomography. In Proceedings of the 14th euspen International Conference (pp. 102-105). euspen.

Dimensional quality control of Ti-Ni dental file by optical coordinate metrology and computed tomography

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Keywords: Dental file; Computed tomography; Optical coordinate metrology

Abstract

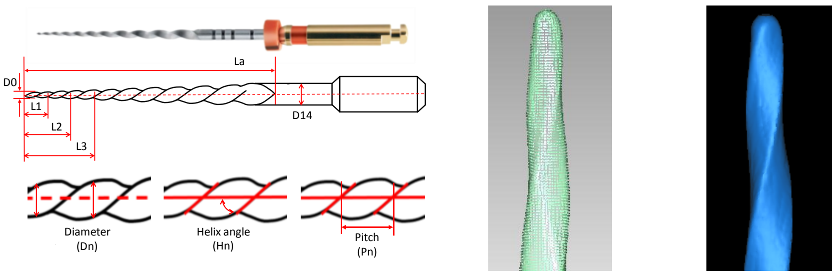
Endodontic dental files usually present complex 3D geometries, which make the complete measurement of the component very challenging with conventional micro metrology tools. Computed Tomography (CT) can represent a suitable alternative solution to micro metrology tools based on optical and tactile techniques. However, the establishment of CT systems traceability when measuring 3D complex geometries is still an open issue. In this work, to verify the quality of the CT dimensional measurements, the dental file has been measured both with a µCT system and an optical CMM (OCMM). The uncertainty of measurements performed with both technologies is assessed. The estimated uncertainty is eventually compared with the component's calibration and tolerances to validate the measuring capability of the µCT system.

1. Introduction

The manufacturing of micro 3D components with complex geometries increasingly requires high accuracy metrological tools for process optimization and product tolerance verification. Tactile micro coordinate measuring machines (µCMM) can provide the required metrological performances, but are limited in terms of measuring capability because of accessibility limitations, deformations due to the probing force, etc. Non-contact measuring instruments based on optical techniques have limitations in measuring vertical walls and high aspect ratio structures, etc. A viable solution to these limitations is represented by the use of microcomputed tomography (µCT) for coordinate measurements. Currently, one limitation for the complete acceptance of computed tomography for metrology purposes is the possibility of performing a reliable establishment of traceability. However, recent research efforts have shown the possibility of performing an experimental uncertainty assessment of CT dimensional measurements using calibrated workpieces as described in the ISO/TS 15530-3 [1].

2. Materials and methods

A complex miniaturized component for medical application (dental endodontic file) was measured both by an OCMM and a µCT system in the present study (see Fig. 1). A ProTaper F2 finishing file by Dentsply Maillefer (USA) was used. This instrument is manufactured in a Ti-Ni alloy and its characteristic dimensions are lengths, diameters, helix angles and pitches (according to the standard on root-canal instruments ISO 3630-1:2008) [2]. The dimensions to be verified in the working part are the following: (1) length of the active cutting part (La); (2) diameter (Dn, n=0,1,2,…,14), variable along the file length, being D0 the diameter at the file tip and D1, D2, etc the diameters at 1, 2, etc mm along the file axis respectively; (3) helix angle (Hn, n=1,…,10), is the angle formed between the helix and the file axial axis, being the first one (H1) the angle formed between the tip and the base of the file; (4) helix pitch (Pn), is the distance between a point in the forward edge and its corresponding point in the adjacent edge along the file longitudinal axis, being P1 the first helix pitch, starting from the tip of the file.



(a) (b) (c)

Figure 1. (a) Dental file and characteristic dimensions: length of the active cutting part (La); diameter (Dn); helix angle (Hn); helix pitch (Pn); (b) point cloud and (c) surface obtained from the CT scanning.

The nominal dimensional values available for this dental file are: 21 mm in length, a cutting segment (La) of 16 mm in length, a tip diameter (D0) of 250 µm, a fixed conicity of 8% between D0 and D3 and a variable conicity from D3 to D14 along its axis; and a maximal flute diameter (D14) of 1.20 mm. The ISO 3630-1:2008 [2] provides guidelines to specify tolerances for diameters and length.

Reference measurements of the endodontic file were performed with an optical coordinate measuring machine (OCMM) DeMeet 220 using a diascopic illumination with a light ring, a magnification lens 2x and a field of view of 3111 µm x 2327 µm. The dental file was measured in four different positions, according on the orientation of a reference cube applied at the bottom of the cutting area of the file. A General Electric eXplore Locus SP cone-beam micro-CT machine was used for the CT measurements. The scanning parameters used were the following: voltage = 90 kV, intensity = 80 µA, increment angle = 0.4 degrees, object position = 100 mm and voxel size = 28 µm. The CT system MPE was experimentally determined by using several calibrated reference artefacts. Two different techniques were applied for the surface extraction to perform the measurements: (a) CT1, based on the local threshold method [3]; (b) CT2 based on the 3D Canny method [4]. The MPE obtained for CT1 and CT2 were respectively: MPE_{CT1} = 7.2 µm + (L/6.8) µm (L in mm) and MPE_{CT2} = 7.0 µm + (L/5.7) µm.

3. Results

The procedure described in ISO 15530-3 [1] was used to estimate the measurement uncertainty for the CT measurements. Expanded uncertainties $U_{95,CT1}$ and $U_{95,CT2}$ have been estimated by using equation 1, extracted from [1].

$$U_{95} = k \times \sqrt{u_{cal}^2 + u_p^2 + u_b^2 + u_w^2} \quad (1)$$

Table1: Uncertainty contributors and maximum expanded uncertainty (U_{95}, k=2, confidence level = 95%) obtained by the CT system with both surface extraction techniques used (CT1: threshold and CT2: 3D Canny) for the dimensions selected.

	D11 [µm]		La [µm]		P4 [µm]		H5 [deg]	
	CT1	CT2	CT1	CT2	CT1	CT2	CT1	CT2
u_{cal}	4.2	4.1	5.6	5.8	4.3	4.2	0.06	0.07
u_p	1.3	0.7	1.1	0.4	0.7	0.4	0.20	0.08
u_b	0.005	0.005	0.1	0.1	0.01	0.01	0.01	0.01
u_w	0.005	0.005	0.1	0.1	0.01	0.01	0.01	0.01
U_{95}	8.8	8.3	12	12	8.7	8.4	0.4	0.2

In Table 1 the uncertainty contributors and maximum expanded uncertainty (U_{95}, k=2) obtained by both CT1 and CT2 are shown for some of the dimensions (e.g., D11, La, P4, H5). As can be observed the $U_{95,CT1}$ and $U_{95,CT2}$ values for lengths mainly depend on the calibration uncertainty (u_{cal}) term in equation 1, which is conservatively estimated from the MPE of the CT system. For angle measurements, the repeatability term (u_p) was the most influent. These uncertainty values are slightly higher than those obtained with the OCMM system, where the maximum expanded uncertainty U_{MAX} (k=2) estimated for the four selected measurands were: U_{MAX}(Dn)(n=1,…,14) = 4.0 µm, U_{MAX}(Pn)(n=1,…,14) = 5.7 µm, U_{MAX}(Hn)(n=1,…,14) = 0.1 deg, U_{MAX}(La) = 5.8 µm.

An analysis of the CT measuring capability was also carried out by analyzing the ratio between the uncertainty (2U) and the tolerance zone (T) for those dimensions where tolerance values are available (e.g. D0 to D14 and La). Results show that the ratio obtained with the OCMM for the diameters is always smaller than 40%, which is the limit allowed when the tolerances are tight, as in the case of micro-manufactured products. In the case of both CT1 and CT2 measurements, for dimensions D0 to D6, where the tolerances are smaller, the ratio 2U/T is slightly above 40%. However, for dimensions D7 to D14, where the tolerances are larger, the ratio is in the range of 20%. For the active length, with a wider tolerance, all the three techniques meet the requirement. Despite higher uncertainties and challenges in performing CT scanning metrology, its applicability towards tolerance verification on complex geometries appears promising.

4. Conclusions

Results obtained by a µCT system for the verification of dimensions of an endodontic dental file with complex 3D geometries and the calibration procedure proposed in order to provide traceability have been presented. The values are comparable to those obtained by an OCMM. Challenges are still present for complex measurand such as the helix angle, and for geometrical characteristics with a critical measurand definition such as the length of the active cutting edge. Nevertheless, uncertainties of CT measurements on the considered complex geometry were at the same level of results obtained for regular geometries in the same range in previous works.

References:

[1] ISO 15530-3, 2011, GPS – CMM: Technique for Determining the Uncertainty of Measurement – Part 3: Use of Calibrated Workpieces or Measurement Standards.

[2] ISO 3630-1, 2008, Dentistry - Root-canal instruments - Part 1: General requirements and test methods.

[3] Ontiveros, S., Yagüe-Fabra, J.A., Jiménez, R., et al., 2012, Dimensional measurement of micro-moulded parts by computed tomography, Measurement Science and Technology, 23, 125401, 9 pages.

[4] Yagüe-Fabra JA, Ontiveros S, Jiménez R, et al., 2013, A 3D edge detection technique for surface extraction in computed tomography for dimensional metrology applications, CIRP Annals, 62/1:531-534.