Cutting efficiency evaluation of Quantec Series 2000 orifice openers with computed tomography (CT)

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Abstract

Introduction: Orifice openers or orifice shapers are used to shape the coronal part of the root canals during endodontic treatment. Objectives: The aim of this work was to analyse the cutting efficiency of Quantec Series 2000 system orifice shapers by means of computerised tomography (CT). Materials and methods: Mandibular molars were selected, preoperative CT was performed and the cross-sections and surface area of the root canals were measured. Following access opening and preparation of the coronal part of the canals with Quantec Series 2000 orifice shapers, a further CT was obtained of all the teeth, the previous measurements were repeated and the two sets of measurements were compared. Results: Although the canals suffered modifications due to the action of the instruments, they remained centred and retained their original morphology; the changes were greater in the most coronal part of the canals. Conclusions: the orifice shapers of the system under study kept the canals centred on their original position, so they do not present great aggressiveness during endodontic treatment; the canals that were initially the widest were those that showed the greatest modification; the CT system employed in the study showed itself to be an effective, non-invasive system for studying the changes that had taken place inside the root canals.

***Key words**: Orifice openers, orifice shapers, computerised tomography, endodontics, Quantec Series 2000.*

Introduction

Biomechanical techniques for preparing root canals have evolved from manual methods to rotary techniques employing nickel-titanium instruments. Many of the new nickel-titanium instruments known as orifice openers or orifice shapers are more conical in shape, so their wider active part creates the necessary widening of the canal (1). Moreover, this coronal widening can reduce the risk of modifying the anatomy of the canal, although the instruments should be used with care to avoid weakening the tooth. These instruments initially prepare the coronal portion of the canal, followed by preparation of the middle and apical thirds (2).

The evolution of the instruments has been paralleled by that of the systems to study them (from conventional radiology to taking impressions of the root canals, making serial cuts or using blocks of resin), with different levels of complexity and of sample precision. Research is currently directed to analysing the modifications that the different rotary instrumentation systems bring about in the root canals, employing reconstruction and visualisation methods that allow the canals to be observed three-dimensionally both before and after treatment without destroying the specimen under study (3-6).

The objective of this work is to analyse the dental tissue removal behaviour of Quantec Series 2000 system orifice openers through comparison with the initial morphology of the untreated canal, using CT.

Materials and Methods

When designing this study, questions arose which had to be solved empirically, owing to the scarcity of the existing literature, such as the necessity or otherwise of using a contrasting material to visualise the interior of the canal and differentiate it from the air density of the exterior, the enamel and the dentine; or the ability of CT to visualise the entire length of the root canal from the canal entrance to the root apex. Consequently, a CT was taken of each of eight teeth, prepared as follows: tooth without treatment, tooth opened but without contrast, teeth opened and with contrast, teeth with shaped canals with and without contrast, tooth with shaped canals filled only with gutta-percha and filled with gutta-percha and cement. On viewing the samples, it was found that under the conditions of this prior study, and given the capacity of the CT that was to be used, the following situations became apparent: firstly, that the apical third of the root could be seen but could not be measured either before or after preparation, even when filled with radio-opaque materials such as gutta-percha and sealing cement, whereas the coronal part of the root canal was perfectly visible and measurable; secondly, that the root canals do not need to be opened with files before preoperative CT for the canal to be visible, and lastly, that it is not necessary to use contrast in order to see the canal. In fact, using contrast caused distortions in the images and the appearance of artefacts. As a result, it was decided to centre the study on the anatomical modifications of the coronal part of the root canal; to perform the preoperative CT without opening the canals, thus avoiding the introduction of another possible variable; and not to use contrast to view the canals.

The 19 canals chosen for this study corresponded to mandibular molars (kept in a saline solution after removing the remaining soft tissues) that had intact roots even if there were restorations to the crown (if metallic, these were removed before the study began). Before preparing the canals, 4 horizontal marks were made on one of the proximal faces of each tooth with a diamond bur to serve as reference points for the subsequent measurements. The first mark was made at the amelo-cement junction and the other three at 2 mm intervals in the direction of the apex. The three most apical were named a, b and c, the most apical of the cross-sections to be measured being a. They were then set in resin blocks at root level (taking the labial face as the reference point in all cases) to facilitate handling. At this point, the preoperative images were acquired with the GE Medical Systems Lightspeed 16 CTS1_OC0 (General Electric Medical Systems, Frankfurt, Germany) CT system under the following conditions: 120 kV, 290 mA, slice thickness = 0.625 mm, SFOV = 25 cm, edge filter, matrix = 512 x 512; the workstation was the Advantage Workstation AW4.1_04 made by the same company, with a resolution of 0.2 mm, DFOV = 1.4 cm, WW = 7500 and WL = 2800). The helical multi-detector CT machine obtains up to 16 sections per rotation (around six sections per second), achieving images with better resolution (with 0.625 mm sections) and faster gantry rotation. The images have isotropic voxels. It can obtain images in all three spatial planes.

Nine different measurements were made of the sections at each of the three more apical marks on each of the canals (the most coronal mark was only used as a reference point for locating the other three). All the measurements were made in millimetres except for the canal surface area (which was measured in mm^2) and were identified as follows (Figure 1): A. maximum length or bucco-lingual diameter of the canal; B. maximum width or mesio-distal diameter of the canal; C. canal surface area; D. total width or mesio-distal diameter of the root measured at the level of maximum canal width; E. distance from the point of intersection of the maximum length and maximum width of the canal to the exterior of the root, measured horizontally; F. distance from the exterior of the canal to the exterior of the root measured horizontally at the same level as measurements D. and E.; G. total length or bucco-lingual diameter of the root measured at the level of maximum canal length; H. distance from the point of intersection of the maximum length and maximum width of the canal to the exterior of the root, measured vertically (if the root had only one canal, the distance was measured taking the upper wall as the reference point. If the root had two canals, the reference point was the nearest wall); I. distance from the exterior of the canal to the exterior of the root, measured horizontally at the same level as measurements G. and H., taking the same wall as in measurement H. as the reference point.

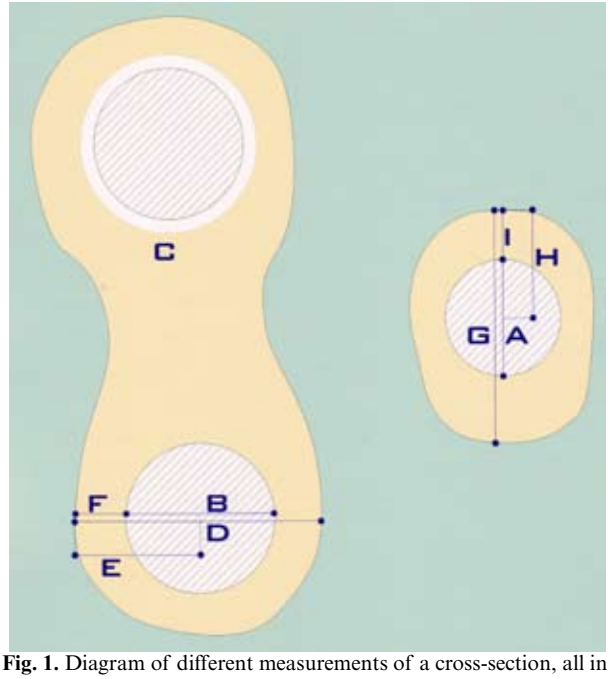

Fig. 1. Diagram of different measurements of a cross-section, all in mm except for surface area (mm^2).

After opening, locating the canals and establishing a glide path, the coronal portion of the canals was prepared with the Quantec Series 2000 system orifice shapers (Tycom Inc, Irvine, CA, USA). The system is made up of 10 instruments (numbered from 1 to 10) with a slightly positive cutting angle. For recognition purposes, all the files have four coloured rings. Their taper ranges from 0.02 to 0.06 and their length from 21 to 25 mm. Their 30° helical cutting angle allows effective cutting. They have two radial surfaces that keep them centred along the axis of the root canal when in contact with the dentine walls. Although the flat external radial surface (radial land) may avoid instrument breakage, it may cause greater friction on the root canal walls. These instruments have a relatively small cutting edge and reduced peripheral surface (7,8). They have two types of tips: the LX (non cutting tip), which remains in the centre of the canal and has two penetration guides, and the SC (safe-cutting tip), which is suitable for opening spaces in an apical direction, particularly in calcified and obstructed canals.

Fig. 2. Orifice shapers (Flare series files) from the Quantec Series 2000 system.

There is also a Flare series of instruments, in 17 and 21 mm lengths with 8%.10% and 12% tapers, used for working in the coronal third of the canal, with an asymmetrical cross-section. They have cutting angles of 23° in the neighbourhood of the active part and 35° in the vicinity of the base of the active part, cutting more during instrumentation. These are the instruments used for orifice shaping.

The Flare series shapers used to prepare the coronal third of the root canals in this study have two coloured rings on their shanks (Figure 2):

Number 1: two red rings (.12/25)
Number 2: two yellow rings (.10/25)
Number 3: two blue rings (.08/25)

These rotary instruments were mounted in an Endodontic Contra Angle 16:1 hand piece and driven by a TCM Endo motor at a speed of 300 rpm.

After preparing the canal, postoperative images were obtained under the same conditions as the preoperative ones and the two were compared (Fig. 3).

To analyse inter-observer agreement, 10% of the measurements (of both the preoperative and the postoperative observations) were repeated at random and the intra-class correlation coefficient was used.

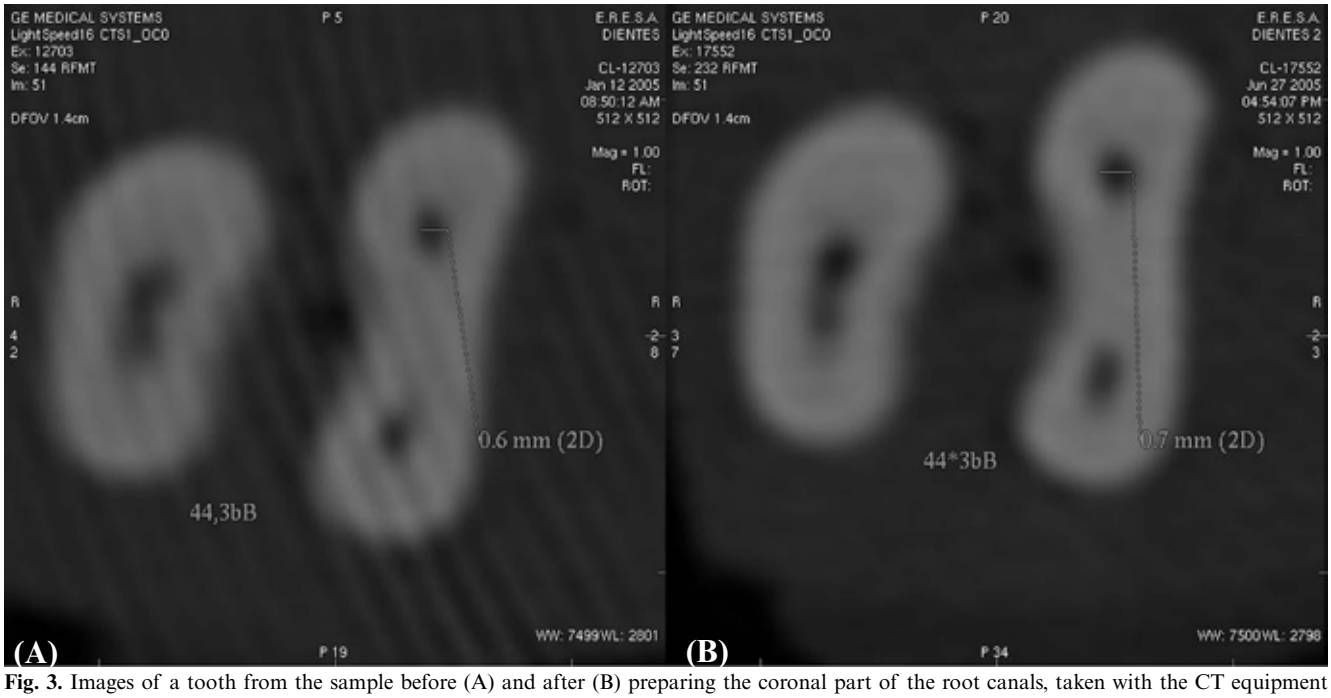

Fig. 3. Images of a tooth from the sample before (A) and after (B) preparing the coronal part of the root canals, taken with the CT equipment employed.

Table 1. Results in canals prepared with the Quantec 2000 system (n = 19).

Measurement level	Measure	Distal canal		Mesio-Buccal canal		Mesio-Lingual Canal	
		Medium	SD.	Medium	SD.	Medium	SD
a	A	0,27	0,16	0,05	0,05	0,09	0,04
	B	0,07	0,05	0,05	0,05	0,09	0,04
	C	0,12	0,08	0,05	0,05	0,09	0,07
	D	0,02	0,04	0	0	0	0,06
	E	0,10	0,15	-0,03	0,05	-0,09	0,11
	F	-0,03	0,05	-0,08	0,08	-0,13	0,10
	G	-0,07	0,10	0,03	0,14	0,01	0,07
	H	-0,07	0,16	0,02	0,13	0	0,08
	I	-0,12	0,08	-0,07	0,08	-0,07	0,05
b	A	0,33	0,48	0,12	0,04	0,09	0,04
	B	0,08	0,08	0,10	0,06	0,11	0,07
	C	0,18	0,15	0,10	0,09	0,07	0,05
	D	0	0,13	0,02	0,12	0	0,10
	E	-0,08	0,20	-0,03	0,05	-0,06	0,10
	F	-0,08	0,10	-0,10	0,06	-0,10	0,08
	G	0,02	0,13	0,05	0,24	0,04	0,18
	H	0,02	0,15	0	0,11	0	0,13
	I	-0,08	0,08	-0,12	0,04	-0,09	0,12
c	A	0,60	0,63	0,22	0,18	0,17	0,14
	B	0,45	0,49	0,25	0,16	0,21	0,07
	C	1,08	1,50	0,28	0,28	0,19	0,13
	D	-0,02	0,08	-0,05	0,08	-0,04	0,10
	E	-0,12	0,17	-0,07	0,10	-0,05	0,11
	F	-0,35	0,44	-0,18	0,12	-0,11	0,09
	G	0,08	0,17	0,08	0,20	0,09	0,15
	H	0,08	0,20	-0,10	0,19	0,06	0,17
	I	-0,20	0,22	-0,30	0,32	-0,09	0,09

n: number of elements
SD.: standard desviation

Results

As may be seen in table 1, at level 'a' (the most apical) the modification in the bucco-lingual diameter of the distal canals was three times as great as in the mesio-distal diameter, whereas in the two groups of mesial canals these modifications were equal in both directions. As regards surface area (measurement C.), the distal canals were those to show the greatest increases, particularly compared to the mesio-labial canals. In the distal canals, the widest point moved towards the centre of the root in a mesio-distal direction and towards the external wall of the root in a bucco-lingual direction, whereas in the mesial canals the widest point of the canal shifted towards the external wall of the root in the mesio-distal direction and towards the interior in the bucco-lingual direction. The means for measurements F. and I. were negative for all the groups of canals.

At level 'b', the distal canals show the same situation as regards diameters as at level 'a'. However, the situation was different in the mesial canals, as while the bucco-lingual diameter increased more in the mesio-buccal canals, in the mesio-lingual canals the difference was greater in the mesio-lingual diameter. In terms of surface areas, the increase was greater in the distal canals. At this level, the mean differences in the F. and I. measurements were also negative (i.e. the canals increased in size towards the exterior of the roots), but the widest point of the distal canals moved towards the exterior of the root in a mesio-distal direction and towards the interior in a bucco-lingual direction, whereas in the mesial canals the widest point moved towards the exterior of the root in a mesio-distal direction but there was no displacement in a bucco-lingual direction.

As regards measurement level 'c', the bucco-lingual diameter again increased more than the mesio-distal diameter in the distal canals whereas in the two mesial canals the increase was greater in a mesio-distal direction; as at the more apical levels, here too the increase in surface area was far greater in the distal canals than in the mesial canals. The E., F. and I. measurement means were negative in the three canals (i.e. the reference points shifted towards the exterior of the root); however, the widest point of the canals measured in the bucco-lingual direction moved towards the external wall of the root in the mesio-labial canals and towards the internal wall in the others.

It was at level 'c' that the greatest differences in means compared to levels 'a' and 'b' was found, particularly in the mean surface areas and mean canal diameters.

As regards the reliability of the results, 87.9% of the preoperative measurements were identical, with an intra-class correlation coefficient of 0.9. In the postoperative measurements, 89% were identical and the intra-class correlation coefficient was 0.91.

Discussion

When considering this study, it was decided to investigate the possibility that computerised tomography might be capable of differentiating between dental tissues and of measuring the root canal, as although according to Lloyd et al. (9) magnetic resonance is a good method for studying dental anatomy, other authors (10) have shown that CT has a greater capacity for differentiating the hard tissues of bones and teeth.

The inclusion criteria for the teeth demanded intact roots without endodontic treatment. As regards the crown of the teeth, caries lesions or coronal fractures were not important provided that the pulp chamber was intact, so that the part of the tooth to be studied would be unaffected; in cases where any silver amalgam filling was present, however, this was removed as the metal can cause artefacts in the images. Some studies (11) have used computer systems to remove the artefacts caused by metallic fillings, using an interpolation system to replace the area in question with another of the same characteristics without such an artefact. Nonetheless, as these authors comment, this process can generate new artefacts if the surface to be studied is complex. In the present case, moreover, it would not be possible to carry out this process as substituting one surface for another would alter the results totally; for example, if the area that was altered involved part of a canal, substitution would give a neoformed canal that would not necessarily coincide with the original morphology of that canal.

A prior x-ray was taken of all the teeth analysed, irrespective of whether or not they were restored. This was done for two reasons: on the one hand, to confirm that the teeth had not received endodontic treatment, and on the other, to acquire an idea of the anatomy and size of the roots and eliminate teeth with calcified roots that could not subsequently be cleared.

As already mentioned, a preliminary study was conducted to establish the conditions in which the work should be carried out; it was observed that with the CT equipment employed, the entire length of the canals could be seen, as noted by Ohishi et al. in 1999 (12), but the apical third could not be measured. It was therefore decided to centre the study on the orifice openers. Nonetheless, other authors who have conducted the same type of analysis maintain that it is possible to measure the entire canal to the apical third (3, 4) although these same authors state that the spatial distortion of the canal at apical level makes it impossible to obtain precise measurements from the CT images.

The preoperative CT was performed before opening the canals in order not to introduce any more variables, as in the studies of other authors (13, 14).

The CT equipment was selected as being that with the most advanced commercially-available technology that could be procured; in this case, a helical multi-slice CT machine with improved characteristics compared to conventional CT. This CT system has also been used by other authors (15) for studies of tooth and bone anatomy. The resolution matrix in this study was 512 x 512, as in other studies of similar characteristics (16). The acquisition resolution in this study was 0.625 mm and the reconstruction resolution was 0.2 mm, a thinner cross-section than in other studies (5, 11), where the slice thickness was 1 mm. All these characteristics give the images greater resolution, since the section is thinner.

Many studies have been conducted to investigate modifications in the apical third of root canals (8, 17) and although most of them study the modifications that have taken place throughout the length of the canal (18, 19), few focus on studying modifications in the coronal part (4, 20, 21) or the consequences of this widening on the subsequent therapeutic shaping of the rest of the canal (22). The widening of the canals in the coronal area is also of great importance because excessive enlargement could lead to fracturing of the teeth. This was another reason for studying the modifications that these instruments make at this level and the way in which they bring them about.

In order to avoid instrument breakage, each instrument was employed (as recommended by the manufacturer) five times, in other words, in five canals, following the recommendations published by Buchanan in 2001 (23) and by Veltri et al. in 2004 (24). None of the instruments broke during use.

In the table mentioned in the Results it may be seen that some of the measurements gave a negative result; this is a consequence of displacement of the points of reference used to take the measurements. On observing the measurement levels, 'c' was the level to show the greatest modifications in the anatomy of the canals.

The appearance of undesirable effects after preparing canals with conventional instruments and methods has led to the development of the new nickel-titanium instruments (25). Preparation with these instruments leaves the canals centred in the root, respecting the anatomy of each and achieving a gradual taper without displacing the foramen (26).

Displacement of the canal in the apical, middle and coronal thirds has been seen with different instrumentation systems; however, it has been shown that this tendency to canal displacement can be reduced by using nickel-titanium instruments (27). The results of the present study corroborate these findings.

According to other authors (28), nickel-titanium instruments cause fewer changes in the anatomy of the canals than stainless steel instruments, so they also reduce changes in working length during the process of cleaning and shaping the canals.

Thompson and Dummer (7, 8) studied the Quantec Series 2000 system and commented that it left smooth surfaces without step-backs throughout the length of the canal (including the coronal third).

Peters et al. (29) concluded that the definitive morphology of the canals after instrumentation depended more on the initial anatomy than on the techniques employed. The initial size of the canals can influence the final result, as the same results are not obtained in the distal and mesial canals: the anatomical changes that take place are greater when the canals are larger.

The Quantec Series 2000 instruments keep the canals centred, with a minimum tendency to displacement, without causing any excessive widening that could facilitate the appearance of root fractures.

The original morphology of the canal influences the work done on it by the instrument, so the canals that were widened most by the instruments used in this study were those that were originally the widest.

The greatest wear on the tissues, among the levels studied, took place in the most coronal portions. Lastly, the CT system used in this study is a non-invasive method that makes objective comparison of the images possible, with good reproducibility of the results.

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