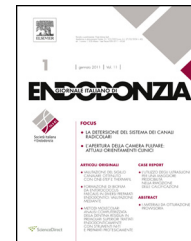




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## CROSS-SECTIONAL STUDY/STUDIO TRASVERSALE

33° CONGRESSO NAZIONALE VINCITORE PREMIO MIGLIOR TESI DI LAUREA IN AMBITO ENDODONTICO

# Analysis of the apical constriction using micro-computed tomography and anatomical sections



*Analisi della Costrizione Apicale con Micro-Tomografia Computerizzata e Sezioni Anatomiche*

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### KEYWORDS

Apical constriction;  
Apical foramen;  
Working length;  
Micro-computed tomography;  
Endodontic anatomy.

### Abstract

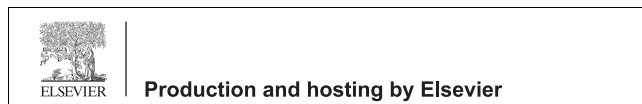
**Objectives:** The aim of this study is to assess the morphology, the prevalence and the topography of the apical constriction (AC) through a tridimensional analysis and compare the results with the available data reported in the literature.

**Materials and methods:** 15 teeth were selected. The teeth were intact and atraumatically extracted, without signs of radicular resorption or previous root canal treatments. Each tooth was scanned with the micro-computed tomography at a resolution of 9  $\mu\text{m}$ . Through computer reconstruction the roots were made transparent, in order to reveal the endodontic anatomy; two calibrated examiners assessed the prevalence and the morphology of the AC on two different projections for each tooth. The AC was classified as present (single, multiple, tapered) or absent (flaring, parallel, apical delta). Inter-rater agreement was computed applying Cohen's kappa.

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**PAROLE CHIAVE**

Costrizione apicale;  
Forame apicale;  
Lunghezza di lavoro;  
Micro-TAC;  
Anatomia endodontica.

The distance between the AC and the apical foramen was determined by means of a digital ruler. *Results and conclusion:* 52.6% of the observed ACs was ambiguous (present on one projection but not on the other one). Only 21.0% of the canals showed a tridimensional AC (present on both projections). Inter-rater agreement was very good ( $k = 0.839$ ). The morphology, from greater to least, was flaring (25%), single (21.1%), parallel (21.1%), tapered (19.7%), apical delta (10.5%) and multiple (2.6%). Inter-rater agreement was again very good ( $\kappa = 0.869$ ). Root canal anatomy as described in the literature is more conceptual than real. The presence of AC appears to be an exception rather than a canon.

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**Riassunto**

*Obiettivi:* l'obiettivo di questo studio è valutare attraverso un'analisi tridimensionale, la prevalenza, la morfologia e la topografia della costrizione apicale (CA) e paragonare i risultati ottenuti con quelli riportati dalla letteratura classica.

*Materiali e Metodi:* sono stati selezionati 15 denti estratti integri ed in modo atraumatico, i quali non mostrassero segni di riassorbimento radicolare, né di precedenti trattamenti canalari. Ogni dente è stato sottoposto ad una scansione con micro-tomografia computerizzata ad una risoluzione spaziale di  $9 \mu\text{m}$ . Sono state generate ricostruzioni 3D rese poi semi-trasparenti in modo tale da rendere visibile l'anatomia canalare. Due esaminatori, precedentemente calibrati, hanno determinato la prevalenza e la morfologia della CA su due differenti proiezioni per ogni dente. La CA è stata classificata come: presente (singola, multipla, conica) o assente (a clessidra, parallela, delta apicale). La concordanza inter-esaminatore è stata testata tramite il test kappa di Cohen. La posizione della CA rispetto al forame apicale è stata calcolata grazie ad un righello digitale. *Risultati e Conclusioni:* il 52.6% delle CA osservate era ambiguo (CA presente in una proiezione, ma non sull'altra). Solamente il 21.0% dei canali osservati presentava una CA tridimensionale (presente su entrambe le proiezioni). La concordanza inter-esaminatore è stata molto buona ( $k = 0.839$ ). Le morfologie osservate, in ordine di prevalenza sono state: a clessidra (25.0%), singola (21.1%), parallela (21.1%), conica (19.7%), delta apicale (10.5%) e multipla (2.6%). La concordanza inter-esaminatore è stata ancora molto buona ( $k = 0.869$ ). L'anatomia apicale, com'è descritta in letteratura, è più concettuale che reale. La presenza della CA sembra essere un'eccezione piuttosto che una regola.

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**Introduction**

Traditionally, the apical constriction (AC) has been considered the ideal landmark to determine the working length during root canal treatment (RCT).<sup>1,2</sup> However, the prevalence, the morphology, and the topography of the AC have not been assessed precisely and the tridimensional features of the AC have been hardly investigated.<sup>1,3–5</sup>

Recently, some researchers have suggested the idea that the AC may not be universally present. If this was true, new landmarks for RCT should be further investigated.<sup>6</sup>

The aim of this study is to assess the morphology, the prevalence and the topography of the AC through a tridimensional analysis and compare the results with the available data reported in the classical literature. Finally, the validity of the AC as a clinical landmark is been questioned.

**Materials and methods**

A sample of 15 teeth was selected. The teeth were intact and atraumatically extracted, without signs of radicular resorption or previous RCTs. Each tooth was disinfected, preserved in formalin and then placed in a plastic case in order to facilitate the micro-computed tomography (micro-CT) scanning. Each tooth was scanned with the micro-CT at a

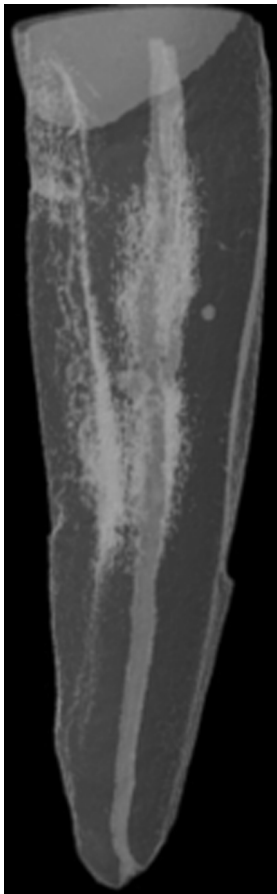
resolution of  $9 \mu\text{m}$ . After all scans were completed, individual slices were cropped. 3D images were obtained by processing the cropped slices. Through computer reconstruction, the roots were made transparent so that the endodontic anatomy was visible.

The apical region was observed in two different projections (mesio-distal and bucco-lingual projections) in order to make tridimensional assessments (Figs. 1 and 2). The presence and the morphology of the AC were evaluated by 2 different examiners, which had undergone a calibration session. Cohen's kappa was applied to evaluate inter-rater agreement of examiners.

The topography of the AC was determined measuring the distance between the AC and the apical foramen (AF) by means of a digital ruler. Finally, each observed AC was classified as a clinically valid AC, whenever it was tridimensional (i.e. observed on both projections by at least one examiner), symmetric (i.e. the plane of the AC is perpendicular to the long axis of the root canal)<sup>7</sup> (Fig. 3), and placed at a distance from the AF smaller than 2 mm.<sup>8</sup>

**Results and discussion**

Results are resumed in Table 1. Among the observed ACs, only a limited proportion (21.0%) was classified as tridimensional



**Figure 1** Tridimensional reconstruction, rendered semi-transparent on bucco-lingual projection.

by at least one examiner. More than half of the ACs (52.6%) was ambiguous (i.e. AC present on one projection but not on the other). In approximately one third of the sample (32.6%) the AC was classified as absent on both projections by at least one examiner. Inter-rater agreement of examiner was very good ( $k = 0.839$  with a 95% CI ranging from 0.665 to 1.014).

Regarding the morphology of the AC, we have distinguished the presence of AC (single AC, multiple AC, tapered AC) by the absence of AC (flaring AC, parallel AC and apical delta) (Fig. 4). The more represented morphologies were flaring (25%), single (21.1%) and parallel (21.1%), tapered (19.7%), apical delta (10.5%) and multiple (2.6%). Only 8 canals showed the same AC morphology in both projections. Among the mesio-distal projections, the single AC was the most represented (34.2%). On the other hand among bucco-lingual projections single AC appeared only in 7.9% of the cases, whereas the flaring AC was observed in 36.4% of the canals. Inter-rater agreement of the examiner was very good ( $k = 0.869$  with a 95% CI ranging from 0.747 to 0.990).

When the AC was present, symmetry was assessed. However, only 33.3% of the AC showed a symmetrical appearance. The mean AC-AF distance was:  $724.28 \pm 348.56 \mu\text{m}$ . At the end of the study, no AC met all the criteria to be classified as a clinically valid AC.

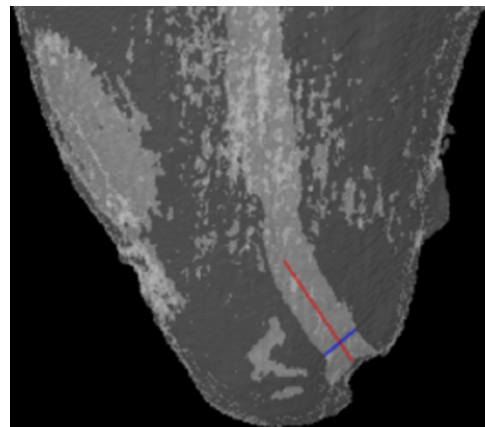


**Figure 2** Tridimensional reconstruction, rendered semi-transparent on mesio-distal projection.

Micro-CT scanning allowed a detailed analysis of the teeth included in the sample.

Most of the canals observed showed an ambiguous AC. Thus, since teeth are tridimensional structures and RCTs are tridimensional treatments, ambiguous ACs cannot be considered as reliable landmarks to determine the working length in endodontics.

The fact that our results disagreed with the results from classical studies about the AC is mainly due to the methods of



**Figure 3** Analysis of the symmetry of the AC; blue line = plane of the AC; red line = long axis of root canal.

**Table 1** Summary of results. MD = mesio-distal; BL = bucco-lingual; A = single AC; B = multiple AC; C = tapered AC; D = flaring AC; E = parallel AC; F = apical delta.

Case	Projection	Examiner 1	Examiner 2	Symmetric AC	AC-AF ( $\mu\text{m}$ )
1a	MD	A	A	NO	464.1
	BL	D	D	—	—
1b	MD	D	C	—	—
	BL	D	D	—	—
2	MD	A	A	YES	446.2
	BL	D	E	—	—
3a	MD	C	C	NO	606.9
	BL	D	D	—	—
3b	MD	A	A	YES	553.3
	BL	E	E	—	—
4a	MD	A	A	NO	908.7
	BL	A	A	YES	1106.7
4b	MD	A	A	NO	249.4
	BL	D	D	—	—
5	MD	C	A	NO	678.3
	BL	D	A	—	—
6	MD	B	B	NO	1124.5
	BL	D	D	—	—
7	MD	C	C	NO	773.4
	BL	C	E	—	—
8	MD	E	E	—	—
	BL	C	C	NO	571.2
9	MD	A	A	YES	1160.2
	BL	E	E	—	—
10a	MD	F	F	—	—
	BL	F	F	—	—
10b	MD	F	F	—	—
	BL	F	F	—	—
11	MD	C	C	NO	150.2
	BL	C	C	YES	1356.6
12	MD	C	C	NO	714.0
	BL	E	E	—	—
13	MD	E	E	—	—
	BL	E	E	—	—
14	MD	D	D	—	—
	BL	D	D	—	—
15	MD	D	D	—	—
	BL	E	E	—	—

analysis. Dummer<sup>4</sup> observed the presence of an AC in 89% of the canals of his sample. When considering each projection independently, we found an AC on at least one projection in 44.7% of the canals observed. On the other hand, AC was present on both projections in only 21.0% of the canals analysed, when projections from the same tooth were plotted. Obviously, the observation of two projections from the same tridimensional reconstruction of a tooth at the time is a more accurate analysis than that made with only one projection. Clearly, the methods used by Dummer, who observed anatomical sections with a stereomicroscope, are the most imprecise. Since the prevalence of the AC decreases when the accuracy of the analysis increases, it is likely that the prevalence of the AC in a sample depends on the quality of the observation. Therefore, it appears that there is an

indirectly proportional relationship between the precision of the analysis and the identification of the AC.

Older studies also failed to identify complex morphologies of the AC when compared with recent studies performed with micro-TC.<sup>4,6</sup> Thus, it looks reasonable to think that non-tridimensional observations tend to simplify the actual morphology of the AC. Hence we can conclude that older classifications do not represent accurately the tridimensional morphology of the AC and the attempt to classify the apical morphology based on such classifications may not serve meaningful purposes.

Finally, since no canal met the requirement to be considered as presenting a clinically valid AC, we can state that AC can no longer be thought to be a reliable landmark in endodontics.

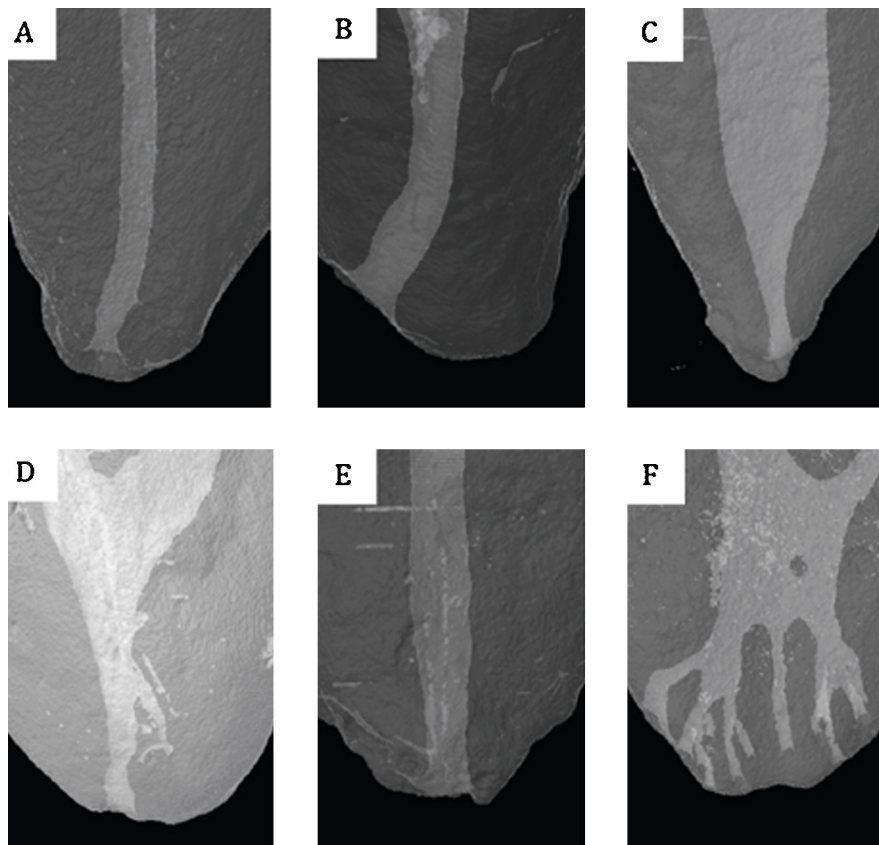


Figure 4 Morphology of the AC; A = single; B = multiple; C = tapered; D = flaring; E = parallel; F = apical delta.

## Conclusions

Based on the results of our observations, we concluded that root canal anatomy as described in the literature is more conceptual than real. The presence of AC appears to be an exception rather than a canon. The AC is a structure that constantly appears to be complex, variable and most of all tridimensional.

## Conflict of interest

The authors declare that there are no conflicts of interest.

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