Available online at www.giornaleitalianoendodonzia.it

Winner of The Best Poster SIE Award 36th SIE National Congress 2019

ORIGINAL ARTICLE/**ARTICOLO ORIGINALE**

Root canal morphology of lower lateral incisors: a CBCT in vivo study

Morfologia del sistema endodontico negli incisivi inferiori: uno studio in vivo attraverso la tomografia computerizzata cone beam

KEYWORDS
CBCT, Lower Incisor, Endodontic Anatomy

PAROLE CHIAVE
CBCT, incisivi inferiori, morfologia endodontica

Abstract

Aim: *The aim of this study was to analyze the root canal configuration in mandibular central and lateral incisors in vivo using cone-beam computed tomography (CBCT) imaging in a European population.*
Methodology: *A total of 500 mandibular lateral incisors from 250 patients were examined using CBCT imaging, previously taken for diagnosis and treatment. The number of roots, root canal system configuration, presence of apical confluences, distance between confluences and radiographic root end, symmetry between left and right elements were recorded and statistically analyzed.*
Results: *All the examinated teeth presented only one root.*
Conclusions: *The percentage of Vertucci type II configuration was higher than expected, being more frequent than type III. Other configurations were present but rare.*

Obiettivo: *lo scopo del presente studio è analizzare la morfologia endodontica degli incisivi laterali inferiori utilizzando la tomografia computerizzata cone beam (CBCT).*
Metodologia: *sono stati presi in esame 500 incisivi inferiori provenienti dalle scansioni CBCT di 250 pazienti, precedentemente effettuate per motivazioni diagnostiche e di trattamento. Sono stati esaminati i seguenti parametri: numero di radici, configurazione del sistema endodontico, presenza di confluenze apicali, distanza tra le confluenze e apice radiografico, simmetria tra gli elementi sinistro e destro nello stesso individuo; i risultati così ottenuti sono stati analizzati statisticamente.*
Risultati: *tutti gli elementi dentari esaminati presentavano una sola radice, mentre la configurazione dei canali radicolari risultava variabile.*
Conclusioni: *la percentuale di riscontro di configurazioni endodontiche complesse è risultata maggiore del previsto, presentandosi più frequentemente come tipo II di Vertucci; sono inoltre presenti altre configurazioni complesse, quali tipo III e tipo VII di Vertucci.*

Linda Quero[1*]
Giovanni Schianchi[1]
Federico Valenti Obino[1]
Massimo Galli[1]
Luca Testarelli[1]
Gianluca Gambarini[1]

[1]*La Sapienza University of Rome, Italiy*

Received 2019, December 28

Accepted, 2020, February 26

Introduction

The study of the anatomy is very important in endodontics, since most of the errors that occur during an endodontic treatment are related to failure to respect the canal anatomy (1); the existence of an untreated canal may be a reason to fail (2, 3). The study of endodontic anatomy can be divided into ex vivo methods, performed on extracted teeth, and in vivo methods, performed on patients (4).
Multiple methods having been used (6), including canal staining and clearing techniques (5, 6), dentin troughing under magnification (7), scanning electron microscope (8, 9), micro-computed tomography (micro CT) (10, 11), magnetic resonance (12), ultrasonics (13), serial cross-sectioning

Corresponding author
Linda Quero | Department of Oral and Maxillo-Facial Sciences, Sapienza University of Rome | Italy
Tel. 0039 3279193209 | lindaquero94@gmail.com

Peer review under responsibility of Società Italiana di Endodonzia
10.32067/GIE.2020.34.01.14

(14, 15), radiographic examination (16, 17) and CBCT (cone beam computer tomography) (18-22).
In research studies CBCT is usually associated with a larger number of samples, because it does not need extractions; moreover it defines precisely the position of the tooth and allow studies about symmetry.
In clinical practice the use of CBCT overcomes the limitations of conventional radiography, allowing visualization in 3D and reducing the superimposition of the surrounding structures (23-43).
Tooth configurations are usually classified according to Vertucci and the great majority of studies used this classification; more recently Ahmed and Dummer (44) proposed a new classification. It is a more accurate method, based on in vitro microCT (45) evaluations of extracted teeth. Therefore it requires higher resolution of images which is not always achievable by in vivo CBCT to avoid unnecessary high radiation doses to the patient.

Materials and Methods

Sample selection
A total of 500 mandibular lateral incisors selected from the CBCT examinations of 250 patients (130 males and 120 females) with an age ranging between 18 and 79 years were examined.
Images were obtained from CBCT examinations as part of diagnosis and treatment planning of patients who required large field of view for reasons including facial trauma or maxillary sinusitis, preoperative assessment for multiple implants, orthodontic treatment because of impacted teeth and for endodontic reasons. Ethical Committee was used for all the individual participants included in the study: the research was approved by the Ethics Committee of Sapienza, University of Rome (ref. 582/17).
The samples were selected according to the following criteria:

- available CBCT images of lower incisors with complete root formation;
- absence of root canal treatment;
- high-quality images of CBCT.

Teeth with immature apices and root resorption were excluded.

Image acquisition
The CBCT images had been taken using the GXDP-500 system (Gendex Dental, Biberach, Germany), operating at 90 kVp and 7 mA, with an exposure time of 23 s and a voxel size of 0.2 mm^3, with a field of view of 13, 9, 13 cm, with an estimated dose of about 50 mSv, allowing measurements to an accuracy of 0.2 mm.

Image evaluation
Through the use of Horos™ software (The Horos Project, 64-bit medical image viewer, GNU Lesser General Public Licence, version 3.0) three-dimensional reconstructions were analyzed to evaluate the parameters of interest.
The images were reworked according to the axial, sagittal, and coronal planes.
CBCT images were viewed on reconstructions according to the axial plane, scrolling the cursor in the coronal-apical direction before, and then in the apical-coronal, to get a detailed view of the root canal system of examined teeth. This action was repeated three times, and when the images in the axial plane were not clear, the teeth were also inspected in three-dimensional.
The following parameters were evaluated:

- number of roots;
- root canal system configuration (using as a reference Vertucci classification);
- presence of apical confluences;
- distance between confluences and radiographic root end;
- symmetry between left and right elements in the same individual.

The classification of the canal morphology was done according to the Vertucci's criteria:

- Type I: single canal from the pulp chamber to the apex;
- Type II: two different canals emerge from the pulp chamber but converge to the apex;
- Type III: a canal emerges from the pulp chamber, divides into two within the root and emerges into one at the apex;
- Type VII: one canal in the pulp chamber that divides and rejoins within the root, and redivides into two canals at the apex.

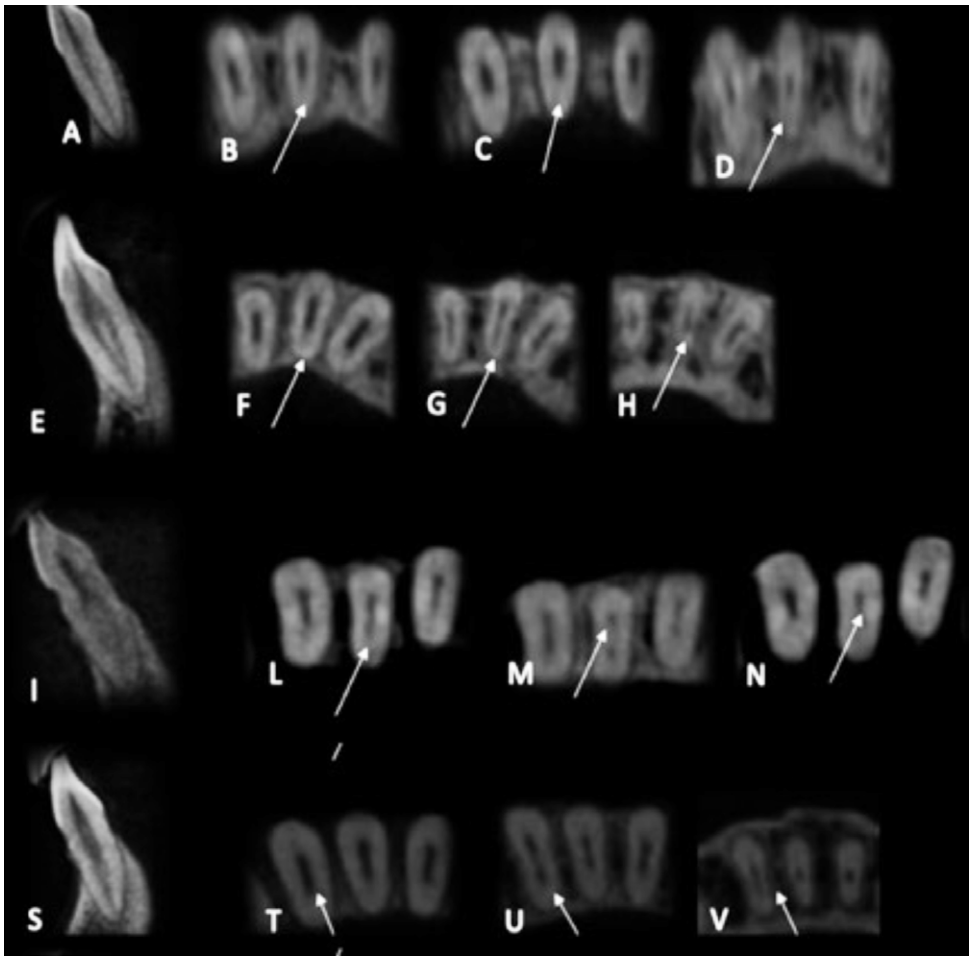

Figure 1
Sagittal plane of CBCT scanning Type I **(A)**, Type II **(E)**, Type III **(I)**, Type VII **(S)**. Axial plane of CBCT scanning in the coronal, middle, and apical thirds of the root displayed variations in canal morphology: **(B-D)** Type I, **(F-H)** Type II, **(L-N)** Type III, **(T-V)** Type VII.

Statistical Analysis
The results were analysed statistically using SPSS 20.0 (SPSS, Inc., Chicago, IL, USA) with the significance set at P<0.05. One-way ANOVA was used for the association between the variables along with the post hoc tests, Tukey's HSD and Games–Howell. The t-test was used to compare the means of canal length and distance from confluence to apical foramen.

Results

Number of roots and canal system configuration according to Vertucci:
- all examinated teeth presented only one root,
- for mandibular lateral incisors type I Vertucci configuration was present in 53% of cases, type II Vertucci configuration in 30% of cases, type III Vertucci configuration in 15% of cases, type VII Vertucci configuration in 2% of cases.

Apical confluences were present in all the incisors with a type II, type III and type VII Vertucci configuration; overall were present in 47% of examined cases.
The average distance between confluences and radiographic root end was 3,102 mm in type II Vertucci configuration and 3,234 mm in type III Vertucci configuration, and 2,802 mm in type VII Vertucci configuration.
Symmetry of root canal morphology between left and right in the same individual was found in 86% of cases.

Table 1

Prevalence of the Number of Root Canals in Mandibular Lateral Incisors

Tooth	1 canal (%)	2 canals (%)	Total
Mandibular lateral incisors	265 (53,0)	235 (47,0)	500

Table 2

Distribution of Root Canal Types according to Vertucci Classification in Mandibular Lateral Incisors

Tooth	Type I	Type II	Type III	Type VII	Total
Mandibular lateral incisors, n (%)	265 (53,0)	150 (30,0)	75 (15,0)	10 (2,0)	500 (100)

Discussion

Our results showed a high prevalence of type II configuration in mandibular lateral incisors. More precisely type II configuration was found in 30% of the teeth examined. This result was in agreement with the study by Benjamin and Dawson (23). On the contrary, the majority of studies (24-33, 40) performed on the mandibular lateral incisors, showed a significantly lower prevalence, ranging from 1% to 26,9%.

Type I Vertucci configuration was present in 53% of mandibular lateral incisors, lower when compared to the majority studies (23-28, 36-42), in accordance with Kartal et al (31), and superior to Sert et al (29). The total range was from 89,4% to 36,8%.

Type III Vertucci configuration was found 15% in mandibular lateral incisors. These findings were different from the majorities of previous researches (23-33), which showed an average percentage ranging from 0% to 27%.

Type VII Vertucci configuration was found in 2% of mandibular lateral incisors; interestingly, only the research by Han et al (32) ever showed this configuration (0,08% in mandibular lateral incisors).

The mean distance between confluences in type II mandibular lateral incisors was 3,102 mm (ranging from 1,442 mm to 6,432 mm). Similarly, in type III configuration in mandibular lateral incisors was 3,234 mm (ranging from 1,429 mm to 6,231 mm). These results were in accordance with a previous study (43) performed on confluences in molars, and significantly lower than the research of Han et al (32), performed on mandibular incisors, who reported that distribution was concentrated in the 6-12 mm range. The mean distance in type VII was 2,802 mm (ranging from 2,648 mm to 3,014 mm) in lateral incisors. Concerning with the symmetry between right and left in the same individual, we found the percentage of 86% in mandibular lateral incisors; our results were similar with the research by Kayaoglu et al (41) and lower than other studies performed on molars (43).

Conclusions

Some of the findings from the present study can be clinically relevant. The percentage of mandibular incisors presenting a complex anatomy (two canals with different config-

urations) is higher than previously reported. Type VII Vertucci configuration was clearly found before only in a single study.
No study previously reported the localization of confluences in lower incisors. They are mostly found in the apical third, 3-4 mm shorter than radiographic root end.
The controlateral teeth usually showed a high percentage of similar anatomy: simmetry between right and left in the same individual was found in 86% of cases.
These results highlighted the need for accurate preoperative radiographic exams to identify canal configuration: multiple radiographs with different angles or CBCT.

Clinical Relevance

Complex endodontic anatomies can be identify only with preoperative radiographic exam.

Conflict of Interest

The authors declares that there is no conflict of interest.

Acknowledgements

No acknowledgements.

References

1. *Perlea P, Nistor CC, Toma C, Dimitriu B. Endodontic configuration of the lower incisors in a Romanian population: a radiological study. Rom J Morphol Embryol. 2013;54:775-8.*
2. *Vertucci FJ. Root canal morphology and its relationship to endodontic procedures. Endod Top. 2005;10:3-29.*
3. *Saati S, Shokri A, Foroozandeh M, et al.. Root morphology and number of canals in mandibular central and lateral incisors using cone beam computed tomography. Braz Dent J. 2018;29:239-44.*
4. *Gambarini G, Ropini P, Piasecki L, et al. A preliminary assessment of a new dedicated endodontic software for use with CBCT images to evaluate the canal complexity of mandibular molars. Int Endod J 2018;51:259-68.*
5. *Vertucci FJ. Root canal anatomy of the human permanent teeth. Oral Surg Oral Med Oral Pathol.1984;58: 589-99.*
6. *Weng XL, Shi-Bin Yu SB, Zhao SL, et al. Root canal morphology of permanent maxillary teeth in the Han nationality in Chinese Guanzhong area: a new modified root canal staining technique. J Endod 2009;35:651-6.*
7. *Yoshioka T, Kikuchi I, Fukumoto Y, et al. Detection of the second mesiobuccal canal in mesiobuccal roots of maxillary molar teeth ex vivo. Int Endod J 2005;38:124-8.*
8. *Schwarze T, Baethge C, Stecher T, Geurtsen W. Identification of second canals in the mesiobuccal root of maxillary first and second molars using magnifying loupes or an operating microscope. Aust Endod J 2002;28:57-60.*
9. *Gilles J, Reader A. An SEM investigation of the mesiolingual canal in human maxillary first and second molars. Oral Surg Oral Med Oral Pathol 1990;70:638-43.*
10. *Plotino G, Grande NM, Pecci R, et al. Three-dimensional imaging using microcomputed tomography for studying tooth macromorphology. J Am Dent Assoc 2006;137:1555-61.*
11. *Somma F, Leoni D, Plotino G, et al. Root canal morphology of the mesiobuccal root of maxillary first molars: a micro computed tomographic analysis. Int Endod J 2009; 42:165-74.*
12. *Ariji Y, Ariji E, Nakashima M, Iohara K. Magnetic resonance imaging in endodontics: a literature review. Oral Radiol. 2018;34:10-6.*
13. *Alacam T, Tinaz AC, Genç O, Kayaoglu G. Second mesiobuccal canal detection in maxillary first molars using microscopy and ultrasonics. Aust Endod J 2008;34:106-9.*
14. *Kulild JC, Peters DD. Incidence and configuration of canal systems in the mesiobuccal root of maxillary first and second molars. J Endod 1990;16:311-7.*
15. *Alqedairi A, Alfawaz H, Al-Dahman Y, et al. Cone-beam computed tomographic evaluation of root canal morphology of maxillary premolars in a Saudi population. Biomed Res Int. 2018;2018:8170620.*
16. *Thompson SA, al-Omari AO, Dummer PM. Assessing the shape of root canals: an in vitro method using microradiography. Int Endod J 1995;28:61-7.*
17. *Omer OE, Al Shalabi RM, Jennings M, et al. A comparison between clearing and radiographic techniques in the study of the root-canal anatomy of maxillary first and second molars. Int Endod J 2004;37:291-6.*
18. *Scarfe WC, Levin MD, Gane D, Farman AG. Use of cone beam computed tomography in endodontics. Int J Dent 2009.2009:634567.*
19. *Ji Y, Wen S, Liu S, et al. Could cone-beam computed tomography demonstrate the lateral accessory canals? BMC Oral Health. 2017;17:142.*
20. *Monsarrat P, Arcaute B, Peters OA, et al. Interrelationships in the variability of root canal anatomy among the permanent teeth: a full-mouth approach by Cone-Beam CT. PLos One 2016;11:e0165329.*
21. *Lo Giudice R, Nicita F, Puleio F, et al. Accuracy of periapical radiography and CBCT in endodontic evaluation. Int J Dent. 2018;2018:2514243.*
22. *Gurtu A, Aggarwal A, Mohan S, et al. CBCT: a revolutionary diagnostic aid for endodontic dilemmas. Minerva Stomatol. 2014 Sep;63:325-31.*
23. *Benjamin KA, Dowson J. Incidence od two root canals in human mandibular incisor teeth. Oral Surg Oral Med Oral Pathol 1974;38:122-6.*
24. *Madeira MC, Hetem S. Incidence of bifurcations in mandibular*

References

incisors. Oral Surg Oral Med Oral Pathol 1973;36:589-91.

25. Vertucci FJ. Root canal anatomy of the mandibular anterior teeth. J Am Dent Assoc 1974;89:369-71.
26. Caliskan MK, Pehlivan Y, Sepetcioglu F, et al. Root canal morphology of human permanent teeth in a Turkish population. J Endod 1995;21:200-4.
27. Miyashita M, Kasahara E, Yasuda E, et al. Root canal system of the mandibular incisor. J Endod 1997;23:479-84.
28. Al-Qudah AA, Awawdeh LA. Root canal morphology of mandibular incisors in a Jordanian population. Int Endod J 2006;39:837-7.
29. Sert S, Aslanalp V, Tanalp J. Investigation of the root canal configurations of mandibular permanent teeth in the Turkish population. Int Endod J 2004;37:494-9.
30. Rahimi S, Milani AS, Shahi S, et al. Prevalence of two root canals in human mandibular anterior teeth in an Iranian population. Indian J Dent Res 2013;24:234-6.
31. Kartal N, Yanikoglu FC. Root canal morphology of mandibular incisors. J Endod 1992;18:562-4.
32. Han T, Ma Y, Yang L, Chen X, Zhang X, Wang Y. A study of the root canal morphology of mandibular anterior teeth using CBCT in a Chinese subpopulation. J Endod. 2014;40: 1309-14.
33. Liu J, Luo J, Dou L, et al. CBCT study of root and canal morphology of permanent mandibular incisors in a Chinese population. Acta Odontol Scand 2014;72:26-30.
34. Kamtane S, Ghodke M. Morphology of mandibular incisors: a study on CBCT. Pol J Radiol. 2016 Jan 13;81:15-6.
35. Lin Z, Hu Q, Wang T, et al. Use of CBCT to investigate the root canal morphology of mandibular incisors. Surg Radiol Anat. 2014;36:877-82.
36. Altunsoy M, Ok E, Nur BG, et al. A cone-beam computed tomography study of the root canal morphology of anterior teeth in a Turkish population. Eur J Dent. 2014;8:302-6.
37. Aminsobhani M, Sadegh M, Meraji N, et al. Evaluation of the root and canal morphology of mandibular permanent anterior teeth in an Iranian population by cone-beam computed tomography. J Dent (Tehran). 2013 May;10:358-66.
38. Verma GR, Bhadage C, Bhoosreddy AR, et al. Cone beam computed tomography study of root canal morphology of permanent mandibular incisors in Indian subpopulation. Pol J Radiol. 2017;82:371-75.
39. Haghanifar S, Moudi E, Bijani A, Ghanbarabadi MK. Morphologic assessment of mandibular anterior teeth root canal using CBCT. Acta Med Acad. 2017;46:85-93.
40. Zhengyan Y, Keke L, Fei W, et al. Cone-beam computed tomography study of the root and canal morphology of mandibular permanent anterior teeth in a Chongqing population. Ther Clin Risk Manag. 2015;12:19-25.
41. Kayaoglu G, Peker I, Gumusok M, et al. Root and canal simmetry in the mandibular anterior teeth of patients attending a dental clinic: CBCT study. Braz Oral Res. 2015;29.
42. Zhao Y, Dong YT, Wang XY, et al. Cone-beam computed tomography analysis of root canal configuration of 4 674 mandibular anterior teeth]. Beijing Da Xue Xue Bao Yi Xue Ban. 2014;46:95-9.
43. Gambarini G, Piasecki L, Ropini P, et al. CBCT analysis on root and canal morphology of mandibular first permanent molar among multiracial population in Western European population. Eur J Dent. 2018;12:434-38.
44. Ahmed HMA, Dummer PMH. A new system for classifying tooth, root and canal anomalies. Int Endod J. 2018; 51:389-404.
45. Spagnuolo G, Ametrano G, D'Antò V, et al. Microcomputed tomography analysis of mesiobuccal orifices and major apical foramen in first maxillary molars. Open Dent J. 2012;6:118-25.