The Saudi Dental Journal (2023) **35**, 780–784

King Saud University

The Saudi Dental Journal

www.ksu.edu.sa
www.sciencedirect.com

REVIEW ARTICLE

The importance of cone-beam computed tomography in endodontic therapy: A review

Shaul Hameed Kolarkodi

Department of Maxillofacial Surgery and Diagnostic Sciences, College of Dentistry, Qassim University, Saudia Arabia

Received 9 April 2023; revised 19 June 2023; accepted 2 July 2023
Available online 7 July 2023

KEYWORDS

CBCT;
Root morphology;
Endodontic treatment;
Review

Abstract Introduction: Cone-beam computed tomography (CBCT) is a valuable tool in endodontics, particularly for assessing root morphology. Aim: To understand the importance of root morphology in endodontic treatment. Methodology: A comprehensive search of various databases was performed, and 804 studies were identified. After evaluating the studies using the inclusion criteria and eliminating duplicates, 12 articles were included in this review. Results: CBCT assessment demonstrated a high prevalence of single canals in maxillary incisors, varying root configurations in maxillary first premolars, and diverse anatomical distributions in mandibular molars, such as C-shaped canals, more commonly observed in women. Conclusion: The findings from this review concluded that CBCT is a valuable tool for the diagnosis and treatment of root canal anomalies in endodontics.

Contents

1. Introduction . . . 781
2. Materials and methods . . . 782
3. Results . . . 782
   3.1. Maxillary anterior teeth . . . 782
   3.2. Maxillary premolars . . . 782
   3.3. Maxillary molars . . . 782
   3.4. Mandibular anterior teeth . . . 783
   3.5. Mandibular premolars . . . 783
   3.6. Mandibular Molars . . . 783
4. Discussion . . . 783
5. Conclusion . . . 783
   Declaration of Competing Interest . . . 783
   Appendix A. Supplementary material . . . 783
   References . . . 783

E-mail address: S.Kodi@qu.edu.sa

https://doi.org/10.1016/j.sdentj.2023.07.005
1013-9052

1. Introduction

The pulp of a tooth is structurally complex. The dental pulp comprises a sophisticated arrangement of hard tissues, intricate root canals, and a network of nerves and blood vessels (Jazayeri et al., 2020). Precise visualization of these internal components is essential for successful root canal treatment. This requires a comprehensive understanding of tooth anatomy (McDonald, 1992). To examine the dental pulp, dental professionals use various aids, including traditional diagnostic techniques and modern imaging methods such as cone-beam computed tomography (CBCT) (Rios et al., 2017). CBCT offers a cost-effective and non-invasive approach for capturing tooth anatomy details (Marotti et al., 2013).

The two-dimensional (2D) representation of three-dimensional (3D) objects in intraoral radiography hampers the interpretation of root morphology, which in turn, affects treatment and endodontic healing (Parks and Williamson, 2002). Studies conducted by Bauman et al. (2011) and Davis et al. (1972) found that when using 2D periapical radiographs to evaluate the healing of a periapical lesion, only 47% agreement was achieved among six examiners. Moreover, there was only 19%–80% agreement between two evaluations of the same films. A limited understanding of 2D imaging increases the risk of errors and can lead to an underestimation of the endodontic problem compared with 3D imaging (Reda et al., 2022).

In dentistry, CBCT is the preferred three-dimensional imaging method. CBCT uses a rotating arm and a cone-shaped ionizing radiation source to capture images via an X-ray source and detector (Durack et al., 2012). CBCT offers rapid and precise 3D imaging by capturing multiple cross-sectional images. Currently, CBCT is being utilized as an adjunctive aid together with traditional 2D methods for specific dental applications (Schulze et al., 2011).

Radiation exposure in maxillofacial imaging is quantified in sieverts (Sv), millisieverts (mSv), or microsieverts (μSv). The effective dose (E) is determined by considering tissue sensitivity and adjusting for the imaging field extent compared to natural radiation sources (Alamri et al., 2012). A recent comprehensive analysis revealed the advantages of using wide-field of view (FOV) CBCT for implant-prosthetic studies and impacted wisdom tooth surgeries. The study showed that there is a significant overlap between a wider FOV and reduced radiation dosage (Zanza et al., 2022).The 3D visualization of CBCT is superior to that of traditional scans, providing interrelational

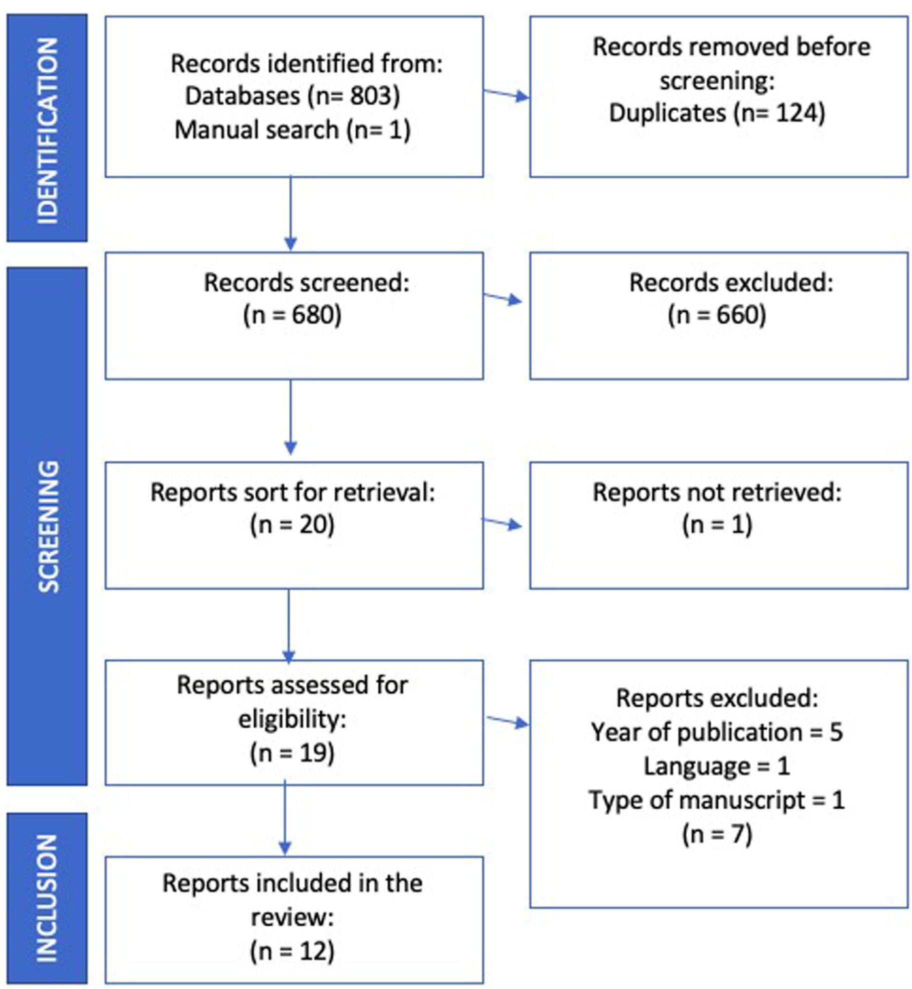

Fig. 1 Identification of studies via databases and registers.

images in three planes and allowing data reorientation for accurate spatial representation in endodontics (Tootell et al., 2014). CBCT has a lower spatial resolution than that of digital- and film-based intraoral radiography (Shokri et al., 2015). Moreover, CBCT illuminates the entire FOV but may struggle to detect minimal attenuation changes. Furthermore, CBCT is prone to artifacts, similar to other imaging modalities (Pauwels et al., 2015).

Accurate identification of all root canals is crucial in endodontic treatment. A previous study reported a prevalence of 69%–93% for a second mesiobuccal (MB2) canal in the maxillary first molars (Scarfe et al., 2009). Detecting variations in structural density in the buccolingual plane can be challenging. With traditional radiographic techniques, only up to 55% of MB2 canals are identified (Ramamurthy et al., 2006). Examination results using different 2D film techniques have revealed that MB2 canals are rarely detected in more than 50% of cases (Ordinola-Zapata et al., 2017). In a study by Matherne et al. (2008), intraoral radiographs failed to identify root canals in 40% of extracted teeth, while CBCT assessments revealed an average of 3.58 root canals in the maxillary molars, 1.21 in mandibular premolars, and 1.5 in mandibular incisors. In a study by Baratto et al. (2009), CBCT detected the presence of a fourth root canal in 92.85% of the mesiobuccal roots of extracted maxillary first molars, while clinical assessment had an overall detection rate of 53.26% and a higher MB2 detection rate of 95.63%. Lascala et al. (2004) suggested that a CBCT resolution of 0.12 mm or less is optimal for increasing the detection rate of root canals.

2. Materials and methods

A comprehensive search was performed using the following databases: MEDLINE/PubMed, Scopus, and Google Scholar. Articles that focused on the anatomy of the maxillary and mandibular teeth and the number of roots and canals present in these teeth were considered. Keywords such as "maxillary teeth," "mandibular teeth," "number of roots," "number of canals," "root canal morphology," "extra roots," "dental anomalies," "abnormal root morphology," and "CBCT" were used in the search. The searches yielded 804 studies. After eliminating duplicates using Mendeley software, 124 studies were screened for eligibility based on their abstracts.

Studies analyzed in the review included anatomical studies and clinical case reports published in peer-reviewed journals that evaluated root and/or root canal morphology. Studies published before 2018 or in languages other than English were excluded, resulting in a total of 660 studies. After exclusion, 19 studies met the inclusion criteria, 12 of which were included in the final review. One study could not be retrieved and was therefore excluded (Fig. 1).

We conducted a comprehensive review of peer-reviewed journal articles that focused on root and/or root canal morphology. The information recorded from each article included the year of publication, authors, number of specimens or patients, patient demographics, and the methodology used. This study analyzed the root morphology, including root fusion, number of roots and root canals per tooth, number of root canal orifices, and type of root canal configuration. The data were categorized according to Vertucci's classification, with other canal configurations being referred to as "others." This study also examined sex differences, bilateral symmetry/asymmetry, apical region morphology, the presence of accessory canals, intercanal communications, and isthmuses. The data were organized using an Excel spreadsheet, and the weighted averages were reviewed for morphological features.

3. Results

The Vertucci classification system categorizes root canal morphology into eight types, which provides valuable information for dental professionals regarding the complexity of root canal systems and assists in treatment planning.

Root morphology of different tooth types:

3.1. Maxillary anterior teeth

A study by Lizzi et al. (2021) found that 99.9% of the maxillary incisors had a single canal, which corresponds to a Vertucci Type I configuration. Only one tooth in the sample had two canals that merged in the middle third, which is a Vertucci Type II configuration (Baratto et al., 2009). Amardeep et al. (2014) studied maxillary canines and found that the most common canal configuration was Type I (81.6%), with other configurations, such as Type III, Type II, Type V, Type XIX, and Type IV, present in smaller proportions. In most maxillary canines, the apical foramen was located laterally (70.4%), and 12% of the canines had accessory canals (Lascala et al., 2004).

3.2. Maxillary premolars

Al-Zubaidi et al. (2021) conducted a study on 500 maxillary first premolars and found that 39.8% (199 teeth) had a single root, 58.6% (293 teeth) had two roots, and only 1.6% (8 teeth) had three roots. The study also found that 83.2% (416 teeth) of the maxillary second premolars had one root, 15.8% (79 teeth) had two roots, and only 1.0% (5 teeth) had three roots. Importantly, there were significant differences in the number of roots between the two groups ($p > 0.05$). Regarding the canal configuration of maxillary first premolars, the most common was Type IV (57.8%), followed by Type II (32.8%). The most prevalent configuration was Type I (60.4%), followed by Type II (16.4%) in maxillary second premolars (Lizzi et al., 2021).

3.3. Maxillary molars

A study by Alrahabi and Zafar (2015) found that the majority (94%) of maxillary first molars had three distinct roots, with 6% having four roots. In Type I, the palatal and distobuccal roots generally have one root canal (100%). Additionally, the mesiobuccal root had either one canal (29.4% with a Type I configuration) or two canals (70.6% with Type II, III, or IV) (Amardeep et al., 2014). Another study by Ghoncheh et al. (2019) found that only 1.1% of the first molars and 11.3% of the second molars had a single root. The occurrence of four separate roots was rare, detected in only 0.5% of first molars. The majority of first molars (54%) and second molars (86%) had three roots with one canal each, with the mesiobuccal root of the first molars most commonly exhibiting anatomical variations, whereas second molars showed greater variations in their root canal systems (Al-Zubaidi et al., 2021).

3.4. Mandibular anterior teeth

Kamtane and Ghodke (2016) found that all specimens had one root, while 36% had a second canal. In this study, Vertucci Type I was the most observed (Alrahabi and Zafar, 2015). In a study by Zhengyan et al. (2015), a small proportion of the lateral incisors (0.3%) and canines (0.8%) had double roots. The prevalence of multiple root canals was higher in the central incisors (3.8%), followed by the lateral incisors (10.6%), and canines (4.2%). The study also revealed a statistically significant difference in the frequency of multiple canals between men and women. The highest incidence of multiple canals was observed in the central incisors in individuals aged 21–30 years (5.0%), lateral incisors in those aged 41–50 years (14.7%), and canines in those aged 41–50 years (8.1%) (Ghoncheh et al., 2019).

3.5. Mandibular premolars

In the study by Alenezi et al. (2021), most mandibular first premolars had one root (73.9%), 24.9% had two roots, and only 1.2% had three or four roots. In contrast, the majority of mandibular second premolars had one root (79.2%), and 20.8% had two roots. The most common root canal configuration was Vertucci Type II (18.7%), followed by Type VI (14.3%). The majority of teeth were straight (74.8%), while 21% had distal root angulation. Non-Vertucci-classified canal configurations were found in 21.4% of teeth, and second premolars showed higher variability than the first premolars ($P < 0.05$) (Kamtane and Ghodke, 2016).

Suomalainen et al. (2010) found that among 914 mandibular first premolars, 85.6% had one root on the left side, 69.6% had one canal, 14.4% had two roots, and 30.4% had two canals. Among the mandibular second premolars, 94.3% on the left side had one root, 77.9% had one canal, 5.7% had two roots, and 22.1% had two canals (Zhengyan et al., 2015).

3.6. Mandibular Molars

In a study by Alenzi et al. (2021), the most common root and root canal morphologies were $^2MM\ M^2\ D^1$ (29.65%), $^2MM\ M^{2\text{-}1}\ D^1$ (22.3%), and $^2MM\ M^1\ D^1$ (13.4%) (where M represents mesial and D represents distal). A total of 32 different anatomical distributions were identified, with C-shaped canals found in 7% of molars and more commonly observed in women. Alenezi et al. (2020) found that 12.5% of permanent maxillary first molars had an additional third root, while only 0.5% had four roots. De Seta et al. (2016) showed that the most common canal configurations in the mesial root of both molars were Types V and III, with Type I being the most common configuration in the distal root.

Root curvature in cross-sectional images was observed in 25% of the distal canals in the mandibular first molars. The prevalence of C-shaped canals was 10% or less. Another study by Al-Zubaidi et al. (2022) found that 94.1% of teeth had two roots and 4.3% had C-shaped root canal systems. Of these, 25.3% had two canal openings, 72.0% had three, and 0.3% and 2.0% had four and five canal openings, respectively. Type IV was most common in the mesial root, accounting for 57.7% of the samples, whereas Type I was most common in the distal root, occurring 282 times (96.60%). The most common root canal morphology was two canals in the mesial root and one canal in the distal root (variant 3), with a prevalence of 69.4%. The overall prevalence of C-shaped root canals was 4.3% (Alkhader et al., 2022).

4. Discussion

Root morphology is a critical determinant of root canal treatment success. Various studies have been conducted to better understand this aspect of endodontics. CBCT has gained popularity in dentistry as a diagnostic aid as it provides a more detailed and accurate representation of the dental root and pulp system. CBCT facilitates more accurate measurements compared to traditional two-dimensional radiographs. For example, Gambarini et al. (2017) reported that CBCT provided precise measurements of the root and canal dimensions, which are useful for precise treatment planning. The authors believed that CBCT is a valuable diagnostic tool in endodontics. Kim (2015) also concluded that CBCT is useful for detecting complex root morphologies, such as multiple roots, root fusion, and accessory canals, which are often missed on traditional radiographs. The authors emphasized the importance of CBCT in endodontic practice. These findings are consistent with the results of this review.

Additionally, Parrone et al. (2017) examined sex differences in root canal configurations and found that men had a higher frequency of bifurcated roots in maxillary incisors than women had. The authors believe that CBCT can be useful in evaluating sex differences in root morphology and that this information can be valuable in endodontic treatment planning.

5. Conclusion

CBCT is crucial in endodontics. Because of its ability to provide detailed information about root morphology, it contributes significantly to optimal diagnosis and treatment planning. CBCT is superior in evaluating root features, detecting complex morphologies, and assessing sex differences, thus making it a valuable tool for the diagnosis and treatment of root canal anomalies.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sdentj.2023.07.005.

References

Alamri, H.M., Sadrameli, M., Alshalhoob, M.A., Alshehri, M.A., 2012. Applications of CBCT in dental practice: a review of the literature. Gen. Dent. 60 (5), 390–400.

Alenezi, D.J., Al Nazhan, S.A., Al Maflehi, N., Soman, C., 2020. Root and canal morphology of mandibular premolar teeth in a Kuwaiti subpopulation: a CBCT clinical study. Eur. Endodontic J. 5 (3), 248–256.

Alenzi, S., Khurayzi, T., Alshalan, A., Almuhawas, F., Alsanosi, A., 2021. Systematic review of postcochlear implant electrode migration: what is known? Otol. Neurotol. 42 (2), 208–216.

Alkhader, M., Almansour, Y., Shamsan, H., Banimostafa, L., Qaqish, F., Alnuseir, A., Hawari, N., Alzghoul, S., 2022. CBCT appraisal of anatomical landmarks used in Vazirani-Akinosi nerve block technique. Oral Radiol. 39, 446–450.

Alrahabi, M., Zafar, M.S., 2015. Evaluation of root canal morphology of maxillary molars using cone beam computed tomography. Pakistan J. Medical Sci. 31 (2), 426–430.

Al-Zubaidi, S.M., Almansour, M.I., Al Mansour, N.N., Alshammari, A.S., Alshammari, A.F., Altamimi, Y.S., Madfa, A.A., 2021. Assessment of root morphology and canal configuration of maxillary premolars in a Saudi subpopulation: a cone-beam computed tomographic study. BMC Oral Health 21 (1), 397.

Al-Zubaidi, S.M., Almansour, M.I., Mansour, N.N., Alshammari, A. S., Alshammari, A.F., Altamimi, Y.S., Madfa, A.A., 2022. Root and canal morphology of mandibular premolars in a Saudi subpopulation: a cone-beam computed tomography study. Int. J. Dent. 2022, 4038909.

Amardeep, N.S., Raghu, S., Natanasabapathy, V., 2014. Root canal morphology of permanent maxillary and mandibular canines in Indian population using cone beam computed tomography. Anatomy Res. Int. 2014, 731859.

Baratto Filho, F., Zaitter, S., Haragushiku, G.A., de Campos, E.A., Abuabara, A., Correr, G.M., 2009. Analysis of the internal anatomy of maxillary first molars by using different methods. J. Endod. 35 (3), 337–342.

Bauman, R., Scarfe, W., Clark, S., Morelli, J., Scheetz, J., Farman, A., 2011. Ex vivo detection of mesiobuccal canals in maxillary molars using CBCT at four different isotropic voxel dimensions. Int. Endod. J. 44 (8), 752–758.

Davis, S.R., Brayton, S.M., Goldman, M., 1972. The morphology of the prepared root canal: a study utilizing injectable silicone. Oral Surgery Oral Med. Oral Pathol. 34 (4), 642–648.

De Seta, D., Mancini, P., Russo, F.Y., Torres, R., Mosnier, I., Bensimon, J.L., De Seta, E., Heymann, D., Sterkers, O., Bernardeschi, D., Nguyen, Y., 2016. 3D curved multiplanar cone beam CT reconstruction for intracochlear position assessment of straight electrodes array. A temporal bone and clinical study. Acta Otorhinolaryngologica Italica. 36 (6), 499–505.

Durack, C., Patel, S., 2012. Cone beam computed tomography in endodontics. Braz. Dent. J. 23, 179–191.

Gambarini, G., Miccoli, G., Gaimari, G., Pompei, D., Pilloni, A., Piasecki, L., Al-Sudani, D., Di Nardo, D., Testarelli, L., 2017. Detection of bone defects using CBCT exam in an Italian population. Int. J. Dent.. 2017, 7523848.

Ghoncheh, Z., Panjnoush, M., Kaviani, H., Kharazifard, M.J., Zahirnia, F., 2019. Knowledge and attitude of Iranian dentists towards cone-beam computed tomography. Front. Dent. 16 (5), 379–385.

Jazayeri, H.E., Lee, S.M., Kuhn, L., Fahimipour, F., Tahriri, M., Tayebi, L., 2020. Polymeric scaffolds for dental pulp tissue engineering: a review. Dent. Mater. 36 (2), 47–58.

Kamtane, S., Ghodke, M., 2016. Morphology of mandibular incisors: a study on CBCT. Pol. J. Radiol. 81, 15–16.

Kim, H.C., 2015. Role of C-arm cone-beam CT in chemoembolization for hepatocellular carcinoma. Korean J. Radiol. 16 (1), 114–124.

Lascala, C.A., Panella, J., Marques, M.M., 2004. Analysis of the accuracy of linear measurements obtained by cone beam computed tomography (CBCT-NewTom). Dentomaxillofacial Radiology. 33 (5), 291–294.

Lizzi, E.P., Piorno, R.C., Aranda, C.M., Gualtieri, A.F., Rodríguez, P. A., 2021. Maxillary incisor internal root anatomy evaluated by cone-beam computed tomography in a population of the Autonomous City of Buenos Aires. Argentina. Acta Odontológica Latinoamericana. 34 (2), 188–194.

Marotti, J., Heger, S., Tinschert, J., Tortamano, P., Chuembou, F., Radermacher, K., Wolfart, S., 2013. Recent advances of ultrasound imaging in dentistry–a review of the literature. Oral Surg. Oral Med. Oral Pathol. Oral Radiol. 115 (6), 819–832.

Matherne, R.P., Angelopoulos, C., Kulild, J.C., Tira, D., 2008. Use of cone-beam computed tomography to identify root canal systems in vitro. J. Endod. 34 (1), 87–89.

McDonald, N.J., 1992. The electronic determination of working length. Dent. Clin. N. Am. 36 (2), 293–307.

Ordinola-Zapata, R., Bramante, C.M., Versiani, M.A., Moldauer, B. I., Topham, G., Gutmann, J.L., Nuñez, A., Duarte, M.H., Abella, F., 2017. Comparative accuracy of the Clearing Technique, CBCT and Micro-CT methods in studying the mesial root canal configuration of mandibular first molars. Int. Endod. J. 50 (1), 90–96.

Parks, E.T., Williamson, G.F., 2002. Digital radiography: an overview. J Contemp Dent Pract. 3 (4), 23–39.

Parrone, M.T., Bechara, B., Deahl II, S.T., Ruparel, N.B., Katkar, R., Noujeim, M., 2017. Cone beam computed tomography image optimization to detect root fractures in endodontically treated teeth: an in vitro (phantom) study. Oral Surg. Oral Med. Oral Pathol. Oral Radiol. 123 (5), 613–620.

Pauwels, R., Araki, K., Siewerdsen, J.H., Thongvigitmanee, S.S., 2015. Technical aspects of dental CBCT: state of the art. Dentomaxillofacial Radiol. 44 (1), 20140224.

Ramamurthy, R., Scheetz, J.P., Clark, S.J., Farman, A.G., 2006. Effects of imaging system and exposure on accurate detection of the second mesio-buccal canal in maxillary molar teeth. Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endodontol. 102 (6), 796–802.

Reda, R., Zanza, A., Bhandi, S., Biase, A., Testarelli, L., Miccoli, G., 2022. Surgical-anatomical evaluation of mandibular premolars by CBCT among the Italian population. Dental Medical Problems 59 (2), 209–216.

Rios, H.F., Borgnakke, W.S., Benavides, E., 2017. The use of cone-beam computed tomography in management of patients requiring dental implants: an American Academy of Periodontology best evidence review. J. Periodontol. 88 (10), 946–959.

Scarfe, W.C., Levin, M.D., Gane, D., Farman, A.G., 2009. Use of cone beam computed tomography in endodontics. Int. J. Dent. 2009, 634567.

Shokri, A., Eskandarloo, A., Noruzi-Gangachin, M., Khajeh, S., 2015. Detection of root perforations using conventional and digital intraoral radiography, multidetector computed tomography and cone beam computed tomography. Restorative Dent. Endodontics 40 (1), 58–67.

Suomalainen, A., Venta, I., Mattila, M., Turtola, L., Vehmas, T., Peltola, J.S., 2010. Reliability of CBCT and other radiographic methods in preoperative evaluation of lower third molars. Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endodontol. 109 (2), 276–284.

Tootell, A., Szczepura, K., Hogg, P., 2014. An overview of measuring and modelling dose and risk from ionising radiation for medical exposures. Radiography 20 (4), 323–332.

Zanza, A., Seracchiani, M., Reda, R., Miccoli, G., Testarelli, L., Di Nardo, D., 2022. Metallurgical tests in endodontics: a narrative review. Bioengineering 9 (1), 30.

Zhengyan, Y., Keke, L., Fei, W., Yueheng, L., Zhi, Z., 2015. Cone-beam computed tomography study of the root and canal morphology of mandibular permanent anterior teeth in a Chongqing population. Ther. Clin. Risk Manage. 12, 19–25.