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Evaluation of the morphology of anterior permanent mandibular teeth in a population of adolescents from Kraków aged 18–20 years on the basis of pantomography and volumetric tomography (CBCT) — a comparative analysis

Krzysztof Gębczyński[1], Hiba Qais Abdulhameed Alobaide[2], Bartosz Wolski[2], Magdalena Krupińska-Nanys[3], Zofia Korkosz[1], Aneta Wieczorek[4], Joanna Zarzecka[1]

[1] Department of Conservative Dentistry with Endodontics, Institute of Stomatology, Faculty of Medicine, Jagiellonian University Medical College, Kraków, Poland
[2] Student Scientific Society at the Department of Conservative Dentistry with Endodontics, Institute of Dentistry, Faculty of Medicine, Jagiellonian University Medical College, Kraków, Poland
[3] Private Dental Office, Kraków, Poland
[4] Depratment of Prosthodontics and Orthodontics, Institute of Dentistry, Faculty of Medicine, Jagiellonian University Medical College, Kraków, Poland

Corresponding author: Krzysztof Gębczyński, D.D.S.
Department of Conservative Dentistry with Endodontics, Institute of Stomatology,
Faculty of Medicine, Jagiellonian University Medical College
ul. Montelupich 4, 31-155 Kraków, Poland
Phone: +48 604952885; E-mail: krzysztof.gebczynski@uj.edu.pl

Abstract: The use of cone beam computed tomography (CBCT) in endodontic diagnostics and treatment is gaining importance due to its ability to provide three-dimensional imaging of tooth structures and their surroundings. CBCT allows a precise assessment of the anatomy of the endodontic space, which is crucial in planning and performing effective root canal treatment. Traditional two-dimensional imaging techniques often prove insufficient in diagnosing the complex morphology of dental canals, increasing the risk of leaving areas untreated and potential treatment failure.

The aim of the study was to assess the ability to analyses the morphology of anterior mandibular teeth in adolescents aged 18–20 from Kraków using two diagnostic methods: panoramic radiographs (OPG) and cone beam computed tomography (CBCT). The study compared the effectiveness of both methods in identifying key anatomical and morphological parameters of teeth.

The analysis covered radiographs of 306 permanent teeth (102 central incisors, 102 lateral incisors, 102 canines) in 51 patients. The analyzed parameters included the number of roots, the number of root canals, the length of teeth and canals, the presence of apical delta, lateral canals, denticles, and the classification of dental cavity morphology according to Vertucci. The results were compared statistically using McNamara and Wilcoxon tests.

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- Central incisors: CBCT showed more pronounced differences in the number of canals and the presence of additional structures (e.g., apical delta in 50% of cases), when compared to OPG (4%).
- Lateral incisors: CBCT showed incisors with two canals in 37% of the cases, while OPG identified none. CBCT also presented the apical delta more precisely (43% vs. 6% in OPG).
- Canines: CBCT identified two channels in 19% and apical delta in 60% of the cases, while OPG identified two channels in 2% and 20% of the cases, respectively.

CBCT proved to be a more precise diagnostic method when compared to OPG, especially in assessing the number of canals, and the presence of apical delta and lateral canals. The results suggest that CBCT provides important information in the diagnostics of the complex endodontic morphology, which is crucial for planning and success of root canal treatment.

Keywords: dental morphology, CBCT, OPG, dental diagnostics, endodontic morphology.

Introduction

The use of cone beam computed tomography (CBCT) for three-dimensional radiographic evaluation of teeth and surrounding structures is becoming increasingly important in the diagnostics and treatment of complex endodontic problems. The popularity of CBCT in endodontic applications is growing worldwide, as proven by statements from specialist societies such as the European Society of Endodontology [1, 2] and the American Association of Endodontists/American Academy of Oral & Maxillofacial Radiology. At the same time, these societies very clearly state indications for its use.

Three-dimensional imaging of tooth anatomy is essential for the accurate diagnosis and successful root canal treatment [1–3]. Given the complexity of the structure of the endodontic space and the variety of spatial configurations of its components, two-dimensional imaging is insufficient to fully visualise its extent. In light of the primary aim of root canal treatment, which is to achieve control over the microbiota of the endodontic space, leaving part of it untreated increases the risk of failure in the shorter or longer term.

Scientists have been struggling long with the challenge of effectively eliminating microorganisms from infected tissues. They emphasis the importance of properly performing each step of root canal treatment: isolating the treatment area with a dental dam, preparing the correct coronal access, followed by proper chemo-mechanical preparation and tight filling of the root canal and the tooth crown. These activities help to avoid reinfection from the oral cavity, prevent leaving necrotic tissues in the dental pulp chamber and canals, and provide optimal access to them, facilitating mechanical and chemical preparation of the surface of the root canal system. The chemo-mechanical preparation, which follows the natural curvature of the canal, and is cone-shaped, facilitates tight final filling of the endodontic space. These activities lead to the reduction in microorganisms in this area. When this state is achieved, conditions for the proper functioning of periapical tissues can be established.

When these steps are performed without full knowledge of the structure of the endodontic space, some areas can be untreated by chemo-mechanical preparation. These areas can cause failure in the future, as they are filled with dead or dead infected tissue. Remaining fragments of old, infected root canal filling can have a similar impact on the treatment success.

Three-dimensional methods for imaging anatomical structures had a tremendous impact on the development of science and of treatment methods. However, when interpreting the radiological image, we should bear in mind the specific characteristics of the diagnosed area. Interpretation of radiographic images, including tooth CBCT, has also seen an increase in the success rate for endodontic treatment, including so-called difficult cases.

In assessing the difficulty of root canal treatment, it is also important to consider the variability of the extent of the endodontic space throughout the patient's lifetime. These changes result from the function of odontoblasts and the deposition of secondary and tertiary dentine. This leads to a reduction in the lumen of the chamber and root canals, as well as of finer structures within the endodontic space, which in practice can mean problems with interpreting radiographic images.

It is also important to consider certain structural patterns that are genetically determined and attributed to the population living in specific areas.

For these reasons, the aim of our study was to:

- study the structure of the endodontic space of mandibular incisors and canines by analyzing orthopantomographic (OPG) images in 18-year-olds. The analysis was designed to assess basic anatomical parameters, such as the number of roots, the number of canals, and the possible presence of accessory structures such as denticles, using traditional two-dimensional imaging techniques.
- examine the same components of the endodontic space of mandibular incisors and canines by analyzing cone beam computed tomography (CBCT) images in the same subjects.
- compare diagnostic performance in terms of recognition of selected anatomical structures.

Study method

The study used panoramic (OPG) and computed tomography (CBCT) images of 51 patients aged 18 to 20 years. A total of 306 permanent mandibular teeth were examined, including 102 central incisors, 102 lateral incisors and 102 canines. The images were taken using the same X-ray machine and by the same operator. CBCT images were analyzed using Xelis Dental CDViewer software, while OPG images saved in the JPEG format were analyzed using Corel Draw 9. To ensure that acquired images were accurate and clear, radiographic measurements were performed in a darkened room, and image brightness and sharpness were optimized as needed. The study analyzed such factors as the number of roots (i), the number of canals (ii), canal length (iii), tooth length (iv), the number of root canals at the coronal third (v), the number of canals at the medial third (vi), the number of canals at the apical third (vii), canal shape at the coronal third (viii), canal shape at the medial third (ix), canal shape at the apical third (x), presence of apical delta (xi), presence of lateral canals (xii), presence of root canal treatment (xiii), correctness of root canal treatment (xiv), presence of denticles (xv), and classification of dental cavity morphology according to Vertucci (xvi). The CBCT examination was analyzed in 3 planes.

Microsoft Office Excel was used to create the database. Qualitative characteristics were analyzed with McNamara's test, and Wilcoxon paired t-test was used for quantitative characteristics. Statistical calculations were performed using STATISTICA.

Study results

Central incisors

In pantomographic images, all teeth had a single root. Only in one (0.98%) case, a tooth with two canals was noted. The mean canal length was 15.98 mm (minimum = 10.20; maximum = 27.10; Me = 15.75; s = 3.47). The mean tooth length was 21.83 mm (minimum = 14.60; maximum = 34.40; Me = 21.30; s = 4.28). The presence of apical delta was noted in only 3.92% (n = 4) of the cases, and lateral canals were found only in 9.80% (n = 10) of teeth. No denticles were noted in any of the teeth examined. Only one case of type III and as many as 99.02% (n = 101) cases of type I morphology according to Vertucci were diagnosed.

In the CBCT analysis, the great majority of teeth were single-rooted (99%), with two roots found in only 1% of them. One canal was seen in 78.43% (n = 80) and two canals were found in 21.57% (n = 22) of the cases. The mean canal length was 16.70 mm (minimum = 12.80; maximum = 21.50; Me = 16.70; s = 1.45). The mean tooth length was 20.72 mm (minimum = 18.40; maximum = 25.30; Me = 20.70; s = 1.21). Apical delta was present in half of the cases (n = 51). Lateral canals were noted in 34.31% (n = 35) of the incisors, while denticles were noted in only 3.92% (n = 4) of them. The cross-section analysis is provided in Table 1. As in previous cases, five different types of root canal systems according to Vertucci were noted in the CBCT images, because dental canal morphology could be analyzed in three dimensions. Type I represented 78.43% (n = 80) of the cases, type III was found in 9.80% (n = 10) of the cases, 7.84% (n = 8) of the cases were type V, and type IV and VI each represented 1.96% (n = 2) of the cases.

Table 1. Percentage analysis of the number of canals on the CBCT cross-section.

Analyzed parameter	Options	Central incisors	Lateral incisors	Canines
number of canals at the coronal third	One	98%	99%	99%
	Two	2%	1%	1%
number of canals at the medial third	One	87%	77.5%	91%
	Two	13%	22.5%	9%
number of canals at the apical third	One	87%	81%	88%
	Two	13%	19%	12%

The obtained data were used in statistical analyses of the factors showing interdependencies. Thus, a significant statistical dependence of the obtained results on the method was found when determining the number of canals. Both methods confirmed the presence of one canal in 78.43% of the cases and of two canals in only 0.98% of the teeth. As many as 20.59% were those teeth in which two canals were visible in CBCT (Fig. 1) ($p < 0.001$). Also, the dependence of the accuracy of reading canal and tooth lengths on the method is statistically significant. The canal length read in the CBCT (x = 16.70; minimum = 12.80; maximum = 21.50; Me = 16.70; s = 1.45) was shorter than in OPG (x = 15.98; minimum = 10.20; maximum = 27.10; Me = 15.75; s = 3.47) ($p = 0.034$) (Fig. 2). The situation was similar for reading the tooth length in the CBCT (x = 20.72, minimum = 18.40; maximum = 25.30; Me = 20.70; s = 1.21), which was shorter than in OPG (x = 21.83; minimum = 14.60; maximum = 34.40; Me = 21.30; s = 4.28) ($p = 0.028$) (Fig. 3). The presence

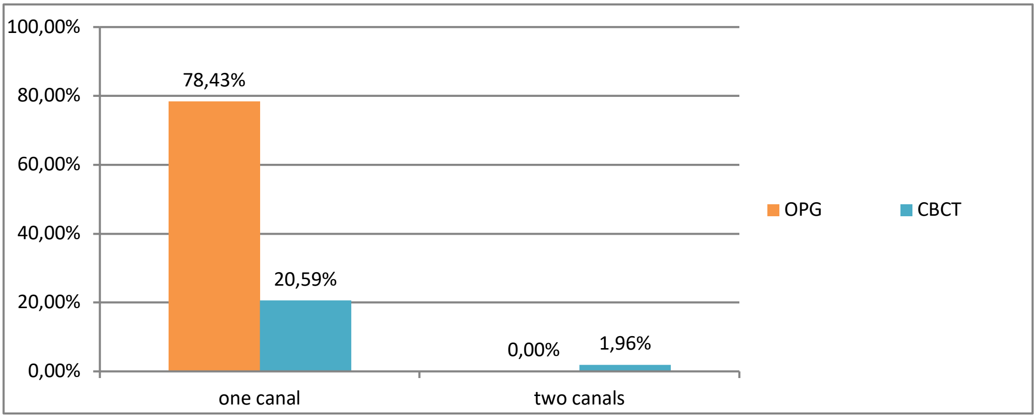

Fig. 1. Consistency of the assessment of a number of central incisor canals on the basis of CBCT and OPG, McNamara's test (p <0.001).

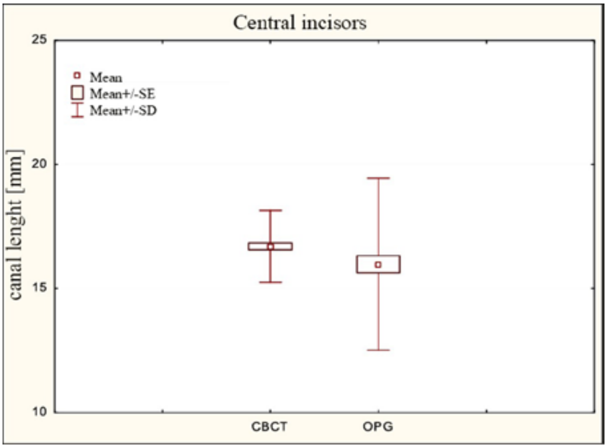

Fig. 2. Mean lengths of central incisor canals in CBCT and OPG, paired Wilcoxon test (p = 0.034).

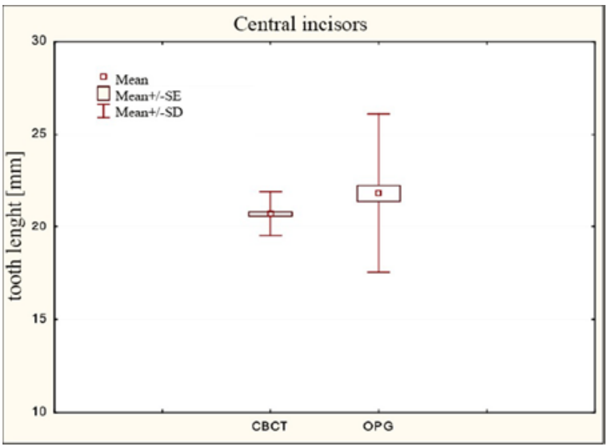

Fig. 3. Mean central incisor lengths in CBCT and OPG, paired Wilcoxon test (p = 0.028).

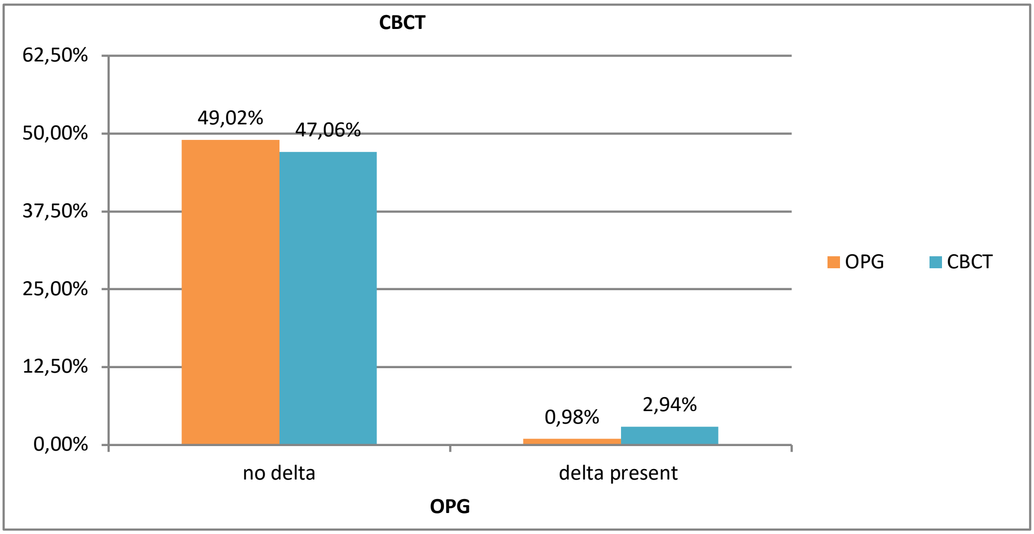

Fig. 4. Consistency of the presence of apical delta in central incisors on the basis of CBCT and OPG, McNamara's test (p <0.001).

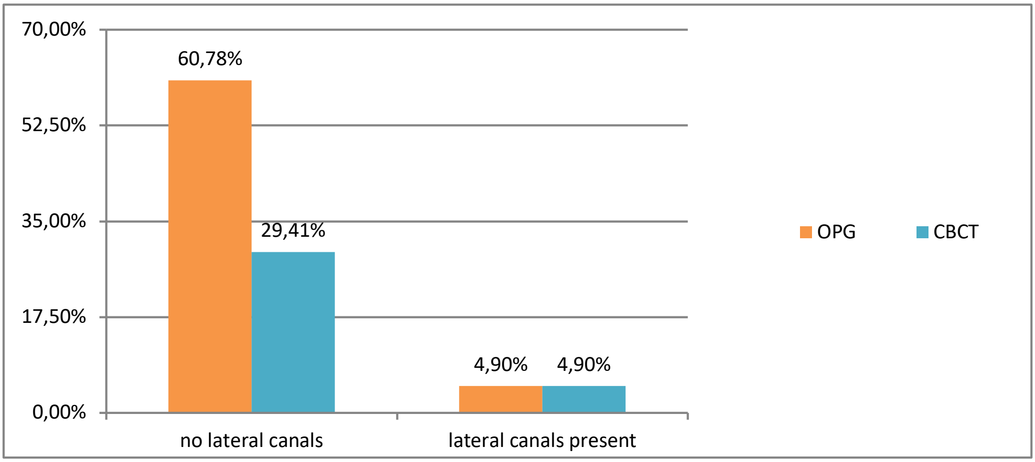

Fig. 5. Consistency of the presence of lateral canals in central incisors on the basis of CBCT and OPG, McNamara's test (p <0.001).

of apical delta was confirmed in both scans simultaneously in only 2.94% of the cases, and its absence in 49.02% of the cases. OPG was more accurate than CBCT in only 0.98% of the cases, while CBCT showed the apical region in more detail in as many as 47.06% (n = 48) of the cases (p <0.001) (Fig. 4). The choice of diagnostic method is also important in determining the presence of lateral canals. A positive result in both methods was obtained in only 4.90% (n = 5) of the cases, while the absence of lateral canals was noted in 60.78% (n = 62) of the cases. CBCT was clearly more accurate, because in as many as 29.41% (n = 30) of the cases lateral canals were detected only with this method (p <0.001) (Fig. 5).

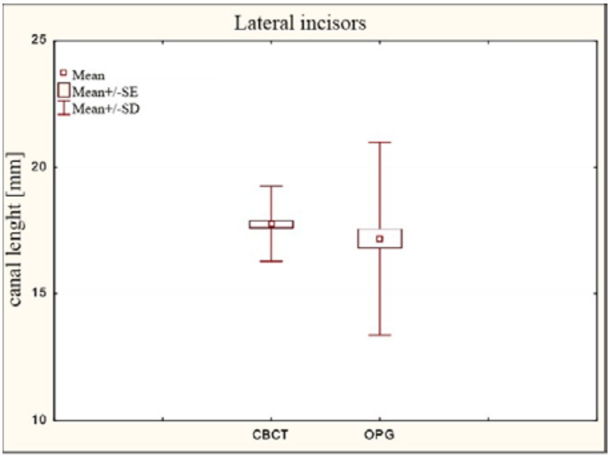

Fig. 6. Mean lengths of lateral incisor canals in CBCT and OPG, paired Wilcoxon test. The analysis showed no significant differences (p >0.05).

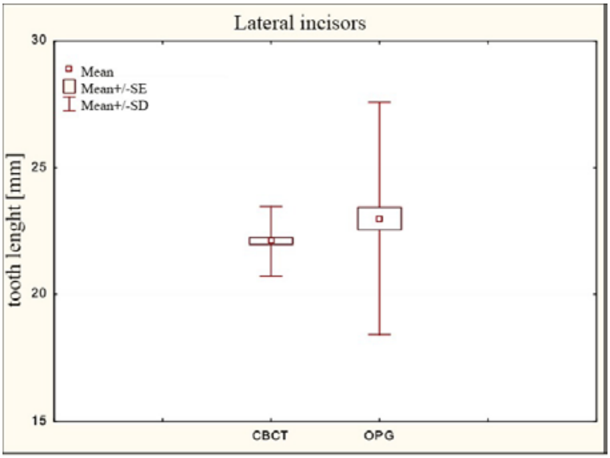

Fig. 7. Mean lengths of lateral incisors in CBCT and OPG, paired Wilcoxon test. The analysis showed no significant differences (p >0.05).

Lateral incisors

All of the teeth examined in the pantomographic (OPG) radiographs were single-rooted and single-canal. The mean tooth length was 23.00 mm (minimum = 15.60; maximum = 35.50; Me = 22.10; s = 4.58), while the mean canal length was 17.18 mm (minimum = 11.10; maximum = 28.50; Me = 16.70; s = 3.82) (Figs. 6, 7). Apical delta was found in 6 (5.88%) of the cases. Lateral canals were observed in only 14 (13.73%) teeth. Only one denticle was shown during the analysis of the pantomograph. As only one canal was visible, and the three-dimensional analysis of the root canal system was not possible, all cases were classified as type I morphology according to Vertucci.

The analysis of the volumetric tomography results indicated more pronounced anatomical and morphological diversification than OPG. CBCT showed two cases of teeth with two roots (2%) and as many as 38 teeth with two canals, which represented 37.45% of all cases. The mean tooth

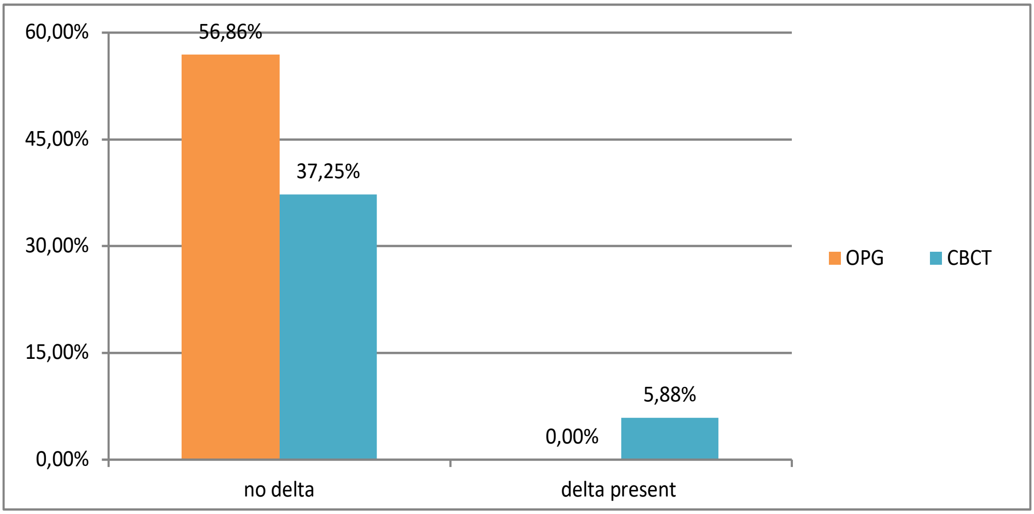

Fig. 8. Consistency of the presence of apical delta in lateral incisors on the basis of CBCT and OPG, McNamara's test (p <0.001).

length was 22.09 mm (minimum = 19.00; maximum = 26.60; Me = 22.00; s = 1.38), while the mean canal length was 17.77 mm (minimum = 13.40; maximum = 22.50; Me = 17.70; s = 1.50) (Figs. 7, 8). The apical delta was present in 44 (43.14%) cases, while lateral canals were visible in 33 (32.35%) teeth. Denticles were found in 4 (3.92%) cases. The analysis of the number and shape of canals on cross-sections is shown in Table 1. Taking into account the three-dimensional imaging in CBCT and the possibility of learning the morphology of the canals along their entire length, as many as five different types of morphology according to Vertucci were observed among the studied teeth. The largest number, i.e. 63.73% (n = 65) of the cases were classified as type I, type III was found in 18.63% (n = 19) of the cases, 15.69% (n = 15) of the cases were type V, and type IV and VI each represented 0.98% (n = 1) of the cases.

A statistical analysis of the collected data was performed, revealing that the choice of radiological method (OPG vs. CBCT) was of no statistical significance for several aspects, including measuring tooth and canal lengths, assessing the number of roots and canals, and evaluating the presence of dentine.

However, the chosen method was of statistical significance for assessing the presence of apical delta and lateral canals. In 56.68% of the cases, none of the methods detected apical delta. It should be noted that 37.25% of the cases showed the presence of apical delta in CBCT, but not in OPG images. Only in 5.88% of the cases did both methods unanimously indicate the presence of apical delta, and this difference was statistically significant (p <0.001) (Fig. 8).

Concerning the presence of lateral canals, their absence was consistently showed in 61.76% of the cases in both methods. In 7.84% of the cases, both methods indicated the presence of lateral canals. In 5.88% of the cases, the panoramic image was more accurate, while in 24.51% of the cases, CBCT provided more accurate results, and this discrepancy was statistically significant (p = 0.001) (Fig. 9).

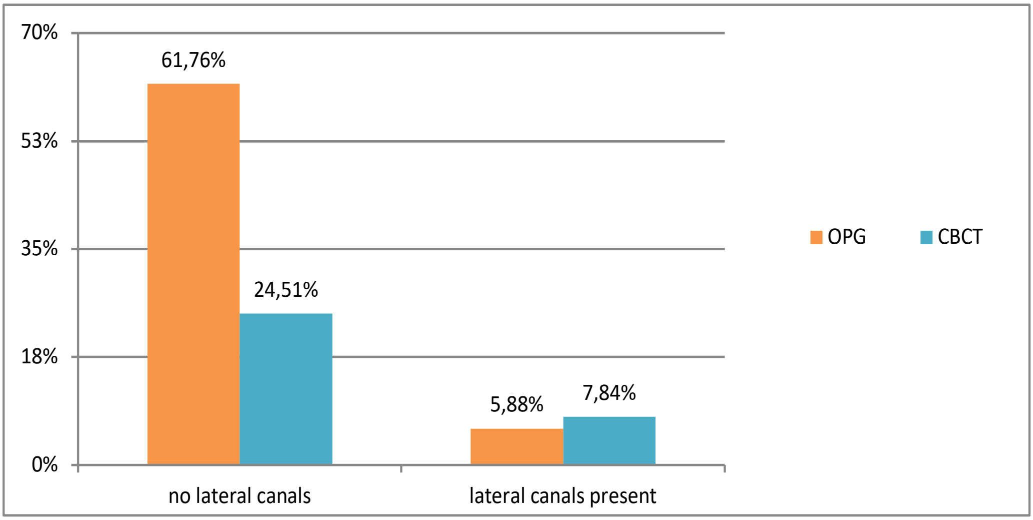

Fig. 9. Consistency of the presence of lateral canals in lateral incisors on the basis of CBCT and OPG, McNamara's test (p = 0.001).

Canines

In the analysis of the panoramic radiographs (OPG), 98.04% of the observed teeth were identified as single-rooted teeth, and two roots were found in only two cases. Similarly, when determining the number of canals, 98.04% were single-canal teeth, while two canals were found in only 1.96% of the cases. The mean canal length was 20.46 mm (minimum = 12.90; maximum = 31.40; Me = 20.04; s = 4.17). The mean tooth length was 26.91 mm (minimum = 18.60; maximum = 40.60; Me = 26.45; s = 5.00). Due to the two-dimensional nature of the panoramic examination, it was not possible to assess the number and shape of root canals in the cross-section. Apical delta was observed in 20% of the cases, and lateral canals were visible in only 17.65% of all teeth. No dentine was found. As a result, an accurate analysis of the spatial arrangement and the number of root canals was difficult, and canal morphology according to Vertucci corresponded primarily to type one (98.04% of the cases), with only 1.96% of the cases representing type two.

The CBCT analysis showed that 92% of the teeth examined had a single root, while 8% of them had two roots. When the teeth were classified as with one or two canals, one and two canals were found in 81% and 19% of the cases, respectively. The mean canal length was 19.42 mm (minimum = 14.7; maximum = 24.9; Me = 19.65; s = 2.04). The mean tooth length was 24.39 mm (minimum = 19.8; maximum = 29.8; Me = 24.5; s = 1.91).

Using the capabilities of three-dimensional imaging, the study also evaluated the number and shape of canals in the tooth cross-section at three different heights: coronal third, medial third, and apical third (Table 1). Of the analyzed cases, apical delta was observed in 60% of them, while lateral canals were seen in 33% of the cases. There were no cases of previous endodontic treatment, and denticles were observed in only 1% of the cases. When the morphology of the root canal system was evaluated on the basis of Vertucci's classification, type I was the most common (82%), followed by type III (6%), then type IV (1%) and type V (11%).

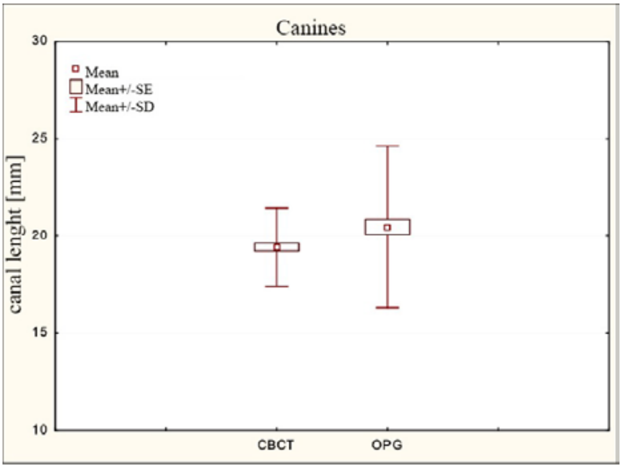

Fig. 10. Mean lengths of canine canals in CBCT and OPG, paired Wilcoxon test ($p = 0.027$).

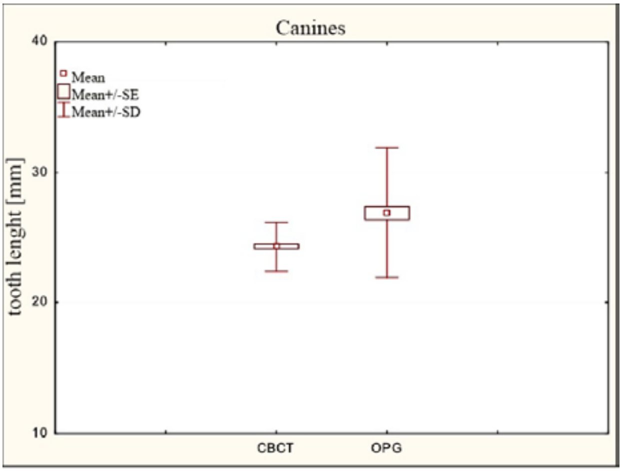

Fig. 11. Mean canine lengths in CBCT and OPG, paired Wilcoxon test ($p = 0.001$).

On the basis of the data obtained in OPG and CBCT scans, a comparative analysis of some factors was performed. The average canal length recorded in CBCT (x = 19.42; Me = 19.65; minimum = 14.70; maximum = 24.90; s = 2.04) was shorter than the one read in the OPG image (x = 20.46; Me = 20.08; minimum = 12.90; maximum = 31.40; s = 4.17). This difference was statistically significant ($p = 0.027$) (Fig. 10). The situation was similar for the tooth length measurements. The measurement in CBCT (x = 24.29; Me = 24.50; minimum = 19.80; maximum = 29.80; s = 1.91) was shorter than the one in OPG (x = 26.91; Me = 26.45; minimum = 18.60; maximum = 40.60; s = 5.00) ($p < 0.001$) (Fig. 11). In 92.16% (n = 94) of the cases, only one root was observed in both scans. In 5.88% (n = 6), there was a discrepancy in the evaluation, in the form of an incorrect determination of the number of roots in the OPG scan. In this case, two roots were visible in CBCT, while only one was visible in the OPG image. Only two cases, representing 1.96% of all cases,

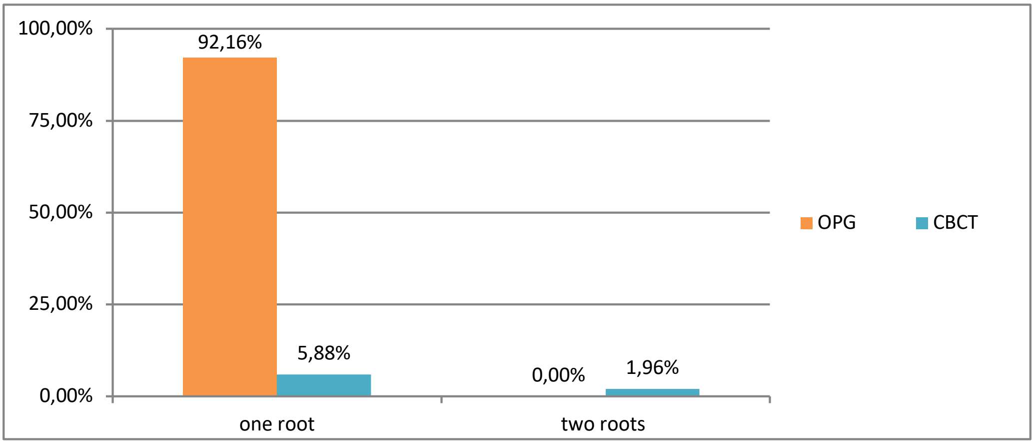

Fig. 12. Consistency of the assessment of a number of canine roots on the basis of CBCT and OPG, McNamara's test (p <0.041).

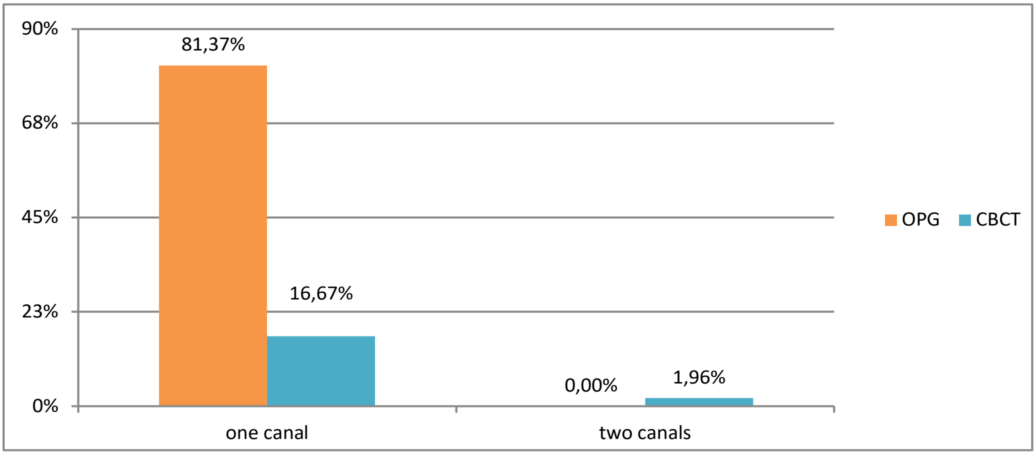

Fig. 13. Consistency of the assessment of a number of canine canals on the basis of CBCT and OPG, McNamara's test (p <0.001).

showed an inverse relationship, i.e. two roots visible in OPG and one in CBCT (p = 0.041). In this case, a statistically significant influence of the method on the accuracy of determining the number of roots was observed (Fig. 12).

When the exact number of canals was determined, the data obtained supported the three-dimensional diagnostic method even further. In 81.37% (n = 83) of the cases, one canal each was noted in both scans, while in as many as 16.67% (n = 17) of the case, two canals were detected in CBCT and only one in OPG. Two cases (1.96%) are different from the other study results, with one canal visible in CBCT, and two in OPG. In this case, the method had a highly statistically significant impact on the scan accuracy (p <0.001) (Fig. 13).

The diagnostic accuracy of CBCT vs. OPG was also confirmed and statistically proven by the presence of apical delta or lateral canals. In as many as 43 (42.16%) cases, the analysis of dental

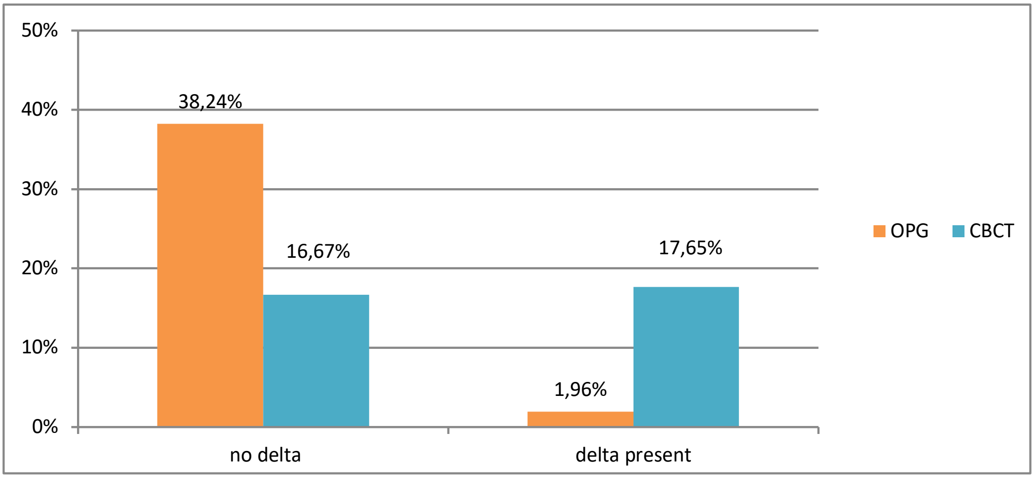

Fig. 14. Consistency of the presence of apical delta in canines on the basis of CBCT and OPG, McNamara's test (p <0.001).

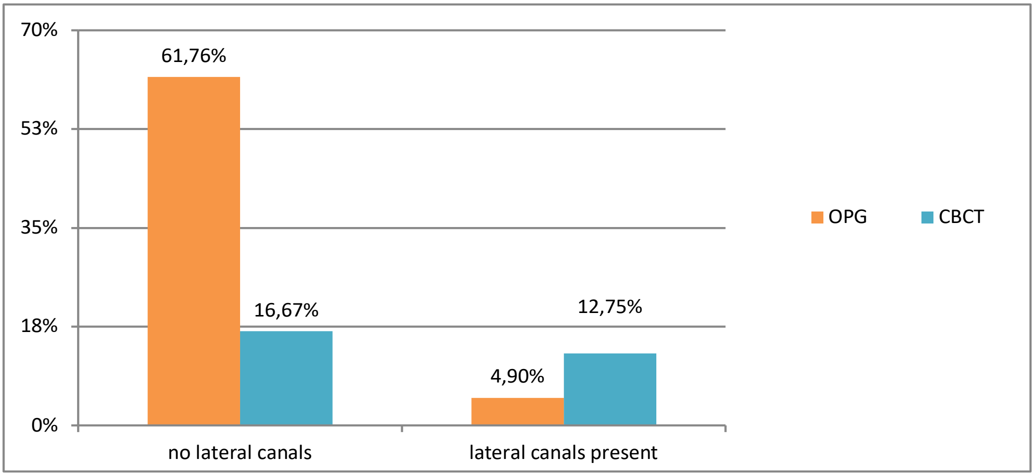

Fig. 15. Consistency of the presence of lateral canals in canines on the basis of CBCT and OPG, McNamara's test (p = 0.003).

cavity morphology by CBCT proved more accurate than in the OPG image and revealed the presence of apical delta. Only in two cases (1.96%) delta was not visible in CBCT, while it could be seen in OPG. In 38.24% (n = 39) of the cases in both scans, no apical delta was confirmed, while 18 (17.65%) cases are those teeth in which delta was observed regardless of the method ($p < 0.001$) (Fig. 14). In 21 (20.59%) cases, lateral canals were discernible in CBCT and not in OPG, and only in five (4.9%) cases this situation was reversed. 13 (12.75%) teeth had confirmed lateral canals in both examinations. In as many as 63 (61.76%) cases, no lateral canals were observed in both CBCT and OPG ($p = 0.003$) (Fig. 15). Only in one case out of 102 teeth a denticle was detected, and that was with CBCT imaging.

Discussion

In the present study, a thorough morphological analysis of anterior mandibular teeth was carried out in a group of adolescents from Kraków aged 18–20 years. The analysis was based on data obtained in OPG and CBCT scans. The results showed that the tooth morphology and anatomy can vary significantly depending on the diagnostic method used, potentially leading to misinterpretations by a clinician.

CBCT and three-dimensional diagnostics proved to provide more extensive and accurate information about anatomy of root canals and their course, the performance that traditional X-ray diagnostics lack. Standard X-ray images enable mainly measurements in the vertical and horizontal dimensions, without the possibility of capturing the third dimension. 3D diagnostic capabilities greatly facilitate accurate identification of the number and course of root canals [2].

One of the scenarios encountered in dental practice is root canal treatment of single-canal teeth. At first glance, this issue may seem straightforward; nevertheless, with numerous studies and the available literature, it is becoming increasingly clear that many teeth that were initially assumed to have only one canal may in fact have two or more canals [1, 4–9]. In such cases, the effectiveness of treatment depends not only on the skill of a doctor and the available equipment, but, more importantly, on an accurate diagnosis and its proper interpretation. Researchers around the world are studying the effectiveness of various commonly used methods in dealing with this challenge.

Today, many methods are available for analyzing the morphology of the root canal system, including taking cross-sections or vertical sections of teeth, creating resin-based cavity models, and using transparent anatomical preparations [8]. Although X-rays remain a crucial and widely used tool, a standard two-dimensional X-ray scan may not always be sufficient. It is important not to lose sight of the fact that traditional X-rays convert a three-dimensional structure of the tooth into a two-dimensional form, limiting three-dimensional diagnosis [10–12].

To address this limitation and assess buccal dimensions, a series of X-ray images can be taken at different beam angles, usually of 10–15 degrees [13–15]. However, even with this approach, the resulting images remain two-dimensional. Complicating factors may include the anatomical structure of the mandible or anomalies in the teeth alignment, which may hinder correct positioning of the film or carrier (CCD), potentially distorting the image. Moreover, multiple exposures may not guarantee satisfactory imaging of anatomical structures or the root canal course [15, 16]. This shift toward CBCT is motivated by the well-known limitations of conventional radiography. The three-dimensional capabilities of CBCT help overcome these limitations, offering a better diagnostic potential [17]. An analysis of the available PubMed database reveals numerous articles discussing the analysis of dental morphology using methods such as CBCT and others [3–5, 8, 12, 15].

Researchers studying and working on this issue in their studies noted varying rates for occurrence of two canals in incisors, ranging from 11% up to even 70% [5–9, 18–20]. For example, Vertucci noted the presence of two canals in about 27.5% of mandibular incisors [18]. The study of Baoruah in the Indian population found that 36.25% of individuals had mandibular incisors with two roots [21]. In Iran, the analysis of data showed that 27.3% of mandibular central incisors and 29.4% of lateral incisors had two canals [22]. These studies often included detailed anatomical examinations using tooth extractions with methyl blue staining.

In contrast, this study was based solely on radiographic analysis of the patients' existing teeth. It revealed that 21.57% of them had two canals when assessed with CBCT, while OPG showed this only in 0.98% of the cases. This emphasizes the fact that CBCT provides a much more accurate representation of the morphology of the root canal system, when compared to a standard panoramic X-ray.

As for canines, most sources usually describe them as single-rooted teeth [22]. However, cases of canines with two roots have been documented, with Pecora et al. noting that 1.7% of canines have two roots, and Aminsobhani *et al.* showed as many as 4.7% of the cases [22, 23]. The data collected revealed that two canine roots were observed in 7.84% of cases in CBCT images, while this was visible in only 1.96% cases in OPG. Interestingly, researchers from Iran reported a higher prevalence of canines with two roots, at the level of 28.2%, while in the population of Kraków adolescents that value was 18.63% for CBCT and 1.96% for OPG [22].

The average incisor length reported in the literature is usually around 21.6 mm, while the canine length ranges from 25.6 mm to 26.7 mm. These values are in close agreement with the results of the conducted study. Specifically, the central incisors were about 20.72 mm long in CBCT, while the lateral incisors were about 22 mm on average. The canines had a mean length of about 24.3 mm.

The prevalence of different types of root canal morphology is an important topic discussed on international forums. Researchers often refer to Vertucci's classification or introduce their own modifications [8]. Table 2 provides data from selected sources for comparison with our results, highlighting differences that may be due to differences in measurement methods, sample size, ethnicity, and geography (Table 3). These factors highlight the need for clinicians to consider potential differences to avoid unexpected complications [8, 22].

The presence of denticles in root canals is a significant challenge in endodontic diagnosis and treatment, affecting the effectiveness of chemo-mechanical canal cleaning. Both this study, as well as the literature, showed a significant impact of patient age, regional differences and the use of CBCT on denticles detection and understanding of their clinical significance.

With age, an increase in the incidence of denticles is seen, related to the processes of dental pulp ageing. This phenomenon results from the deposition of secondary and tertiary dentine in response to stimuli such as micro-injuries, decay or previous dental treatment. The results of the study indicate a low prevalence of denticles in young patients aged 18–20 years (3.92% in CBCT). In contrast, Almohaimede *et al.* (2022) showed a greater complexity of canal morphology, including the presence of denticles, in the age group of 21–40 years [24]. Literature studies confirm that older patients (>40 years) have a higher percentage of denticles, and this can be of a crucial importance for treatment planning.

The analysis of root canal morphology indicates significant regional and ethnic differences in the prevalence of denticles. Mashyakhy *et al.* (2022) showed that in the Saudi population, the prevalence of denticles is lower than in Asian and European populations, highlighting the importance of considering local differences in diagnostics [25, 26]. These observations are consistent with other studies indicating that genetic and environmental variations, as well as differences in lifestyle, can affect the development of mineralization structures in the canals.

Cone beam computed tomography (CBCT) plays a key role in precise imaging of fine structures such as denticles. When compared to traditional imaging techniques such as panoramic radiographs, CBCT enables three-dimensional visualization of root canals, which significantly increases the detection rate for such lesions. Patel *et al.* (2019) and Chan *et al.* (2023) emphasize that CBCT is superior to other methods in terms of the precision of diagnosing complex canal morphology [27, 28]. Despite the higher radiation dose, CBCT is particularly useful in

Table 2. Comparison of OPG and CBCT analyses.

Parameter	Central incisors (OPG)	Central incisors (CBCT)	Lateral incisors (OPG)	Lateral incisors (CBCT)	Canines (OPG)	Canines (CBCT)
Number of roots						
one	100%	99%	100%	98%	98.04%	92%
two	0%	1%	0%	2%	1.96%	8%
Number of canals						
one	99%	78%	100%	63%	98.04%	81%
two	1%	22%	0%	37%	1.96%	19%
Canal length (mm)						
Mean	15.98	16.7	17.18	17.77	20.46	19.42
Minimum	10.20	12.8	11.10	13.4	12.90	14.7
Maximum	27.10	21.5	28.50	22.5	31.40	24.9
Median	15.75	16.7	16.70	17.7	20.04	19.65
Standard deviation	3.47	1.45	3.82	1.50	4.17	2.04
Tooth length (mm)						
Mean	21.83	20.72	23.00	22.09	26.91	24.39
Minimum	14.60	18.4	15.60	19.0	18.60	19.8
Maximum	34.40	25.3	35.50	26.6	40.60	29.8
Median	21.30	20.7	22.10	22.0	26.45	24.5
Standard deviation	4.28	1.21	4.58	1.38	5.00	1.91
Additional observations						
Apical delta	4%	50%	5.88%	43.14%	20%	60%
Lateral canals visible	9.8%	34.31%	13.73%	32.35%	17.65%	33%
Denticle presence	Not found	3.92%	Not found	3.92%	Not found	1%
Canal morphology according to Vertucci						
Type 1	99%	78%	100%	63.73%	98.04%	82%
Type III	1%	9.8%	0%	18.63%	1.96%	6%
Type V	0%	7.84%	0%	15.69%	0%	11%

cases that require precise analysis, such as endodontic re-treatment or diagnosis of structural anomalies.

The presence of denticles in root canals significantly hinders cleaning and disinfection procedures, limiting the effectiveness of mechanical and chemical treatment of the canal system. Denticles can hinder penetration of disinfectants into deeper parts of the canals, increasing the risk of

Table 3. A comparison of results for occurrence of different types of root canal morphology based on Vertucci's classification.
I) Zarzecka and Wieczorek (CBCT)
II) Aminsobhani *et al.*
III) Caliskan *et al.*

		Central incisors			Lateral incisors			Canines		
		I	II	III	I	II	III	I	II	III
Canal configuration according to Vertucci	1	78.43%	72.7%	68.63%	67.73%	70.6%	68.63%	83.33%	71.8%	80.39%
	2	—	11.3%	13.73%	—	7.1%	13.73%	—	10.3%	3.92%
	3	9.80%	4.7%	13.73%	18.63%	3.7%	15.69%	6.86%	2.8%	13.73%
	4	1.96%	7.7%	—	0.98%	15.4%	—	0.98%	12.8%	—
	5	7.84%	3.6%	1.96%	15.69%	3.2%	1.96%	8.82%	2.3%	1.96%
	6	1.96%	—	—	0.98%	—	—	—	—	—
	7	—	—	—	—	—	—	—	—	—
	8	—	—	1.96%	—	—	—	—	—	—

post-treatment complications. The use of CBCT enables better treatment planning and minimizes the risk of failures caused by inadequate canal cleaning.

The advantages of using cone beam computed tomography (CBCT) should be carefully weighed against the higher risk of radiation exposure compared to conventional imaging methods. The effective radiation doses for various CBCT scans, categorized by the field of view (FOV), were measured at the level of 212 μSv for the large FOV, 177 μSv for the medium FOV, and 84 μSv for the small FOV scans. The range for small FOV scans varies from 5 μSv to 146 μSv, but many devices typically provide exposure levels around 30 μSv at default settings. A panoramic radiograph, on the other hand, typically results in radiation doses in the range of 16 μSv to 20 μSv [29].

With this in mind, it should be indicated that the complex morphology and anatomy of anterior teeth requires a very thorough analysis before the procedure performed, in order to ensure the most accurate diagnosis and propose appropriate treatment. A comprehensive understanding of the tooth cavity structures and the root canal system is crucial to minimize complications during and after treatment.

Conclusions

The choice of method for analyzing anatomical spaces significantly affects the measurement results. CBCT proved to be a more precise method when compared to OPG, especially when assessing the number of roots and canals. This method also excels in identifying the presence of apical delta and lateral canals.

In the tooth groups studied, the method of analysis also significantly affected the accuracy of measurement, especially for tooth and canal lengths, as observed for canines and central incisors.

Traditional two-dimensional images are insufficient for three-dimensional analysis of the root canal morphology according to Vertucci's classification. Instead, they may offer only a rough, general diagnosis of selected structures.

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Authors' contribution

Conceptualisation: J.Z., A.W., K.G.; Methodology: K.G., J.Z.; Validation: J.Z.; Formal analysis: K.G.; Research: J.Z., A.W.; Resources: J.Z., A.W.; Data compilation: K.G.; Writing — preparing an original draft: J.Z., A.W., K.G.; Writing — reviewing and editing: J.Z., A.W.; Visualisation: K.G.; Supervision: J.Z.; Project Management: A.W., J.Z.; Acquiring funding: A.W.

Conflict of interest

None declared.

Data availability

The datasets used and/or analyzed in this study are available from the correspondent author upon reasonable request.

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