Coll. Antropol. **42** (2018) 1: 39–44
Original scientific paper

Standard Intraoral Radiography vs. Cone Beam Computed Tomography for Root Canal Systems Detection in Historical Dental Material

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ABSTRACT

The study of root canal systems of historical teeth is relatively new in anthropological research, and has not been extensively documented in the anthropological literature. The authors of the present study examined the visibility of root canal systems in 231 human teeth belonging to 11 individuals of both sexes from the 18th and 19th centuries in an archaeological site at Radom (Poland). Teeth were divided precisely into one-, two-, and three-rooted specimens, and each root was analyzed separately. Three methods were used: Cone Beam Computed Tomography (CBCT), Standard Intraoral Radiography in Paralleling Technique (PT), and Same Lingual Opposite Buccal (SLOB) technique with constant exposure conditions. It was found that CBCT could be used successfully, even treated as a "gold standard", as it provides the highest visibility rate of all teeth types. In maxilla one-root teeth, the root canal was more visible with PT (77%) than with SLOB (54%) technique. In upper premolars, both buccal and palatal canals were more visible with SLOB (75% and 85%, respectively), and the differences were statistically significant. In three-rooted teeth, the most visible canals were distobuccal, with both SLOB (80%) and PT (70%) methods. Less frequently detected were canals in mesiobuccal roots using both radiographic methods (PT 20% and SLOB 32%). The palatal canals were poorly detectable. In mandibular one-root teeth, a higher visibility rate was achieved with PT (93%) than SLOB (80%) technique. In distal roots of mandibular molars, the canals were more visible with PT (59%) method. Morphology of mesial roots was better detected with SLOB (74%) technique. The study demonstrates the potential of using single-root teeth when the rest of the tooth roots are fragmented.

Key words: *Cone Beam Computed Tomography, Standard Intraoral Radiography, root canal system, Radom*

Introduction

The heterogeneous anatomy and complexity of root canals have been studied in detail for many years in endodontic research[1,2]. This is connected with the fact that the internal anatomy of root canals may vary[3-5]. Based on the number and morphology of root canals in each type of tooth, different authors have proposed numerous classification systems[6-8]. Meanwhile, as shown by some studies, some trials of the internal and external morphology of deciduous and permanent teeth could characterize and differentiate ethnic groups around the world[9,10]. These dental morphological traits have been studied by anthropologists to describe and assess biological relationships within and among recent and present-day human populations[11,12]. It means that studying the structures of root canal systems can be important in bioarchaeological research. However, the number of studies that evaluate the root canal systems in historical material is still insufficient. There are only a few studies concerning root canal systems in historical populations[11,13,14] and prehistoric groups[15,16]. In that research, microcomputed tomography (microCT) and Cone Beam Computed Tomography (CBCT) have been used to a greater extent as they are more accurate than digital X-rays for the in-depth research of root canal morphology. As the study sample sizes were relatively small, in those cases it was justifiable to use three-dimensional methods. However, using three-dimensional methods on a large scale in population studies may prove to be an overly expensive and time-consuming challenge. Therefore, very

Received for publication February 22, 2018

often in endodontics studies, the conventional radiography is used as »preliminary research«[17]. That means that conventional intraoral radiography remains important and is still frequently used in endodontics. Therefore, if one wants to carry out research on the variability of root canals in bioarchaeological materials, the use of conventional radiography is worth taking into account. This »traditional method« does not require any special devices (such as microCT or CBCT) and can be applied in bioarchaeological laboratories.

In this study, the capacity of Standard Intraoral Radiography Paralleling Technique (PT) and the Standard Intraoral Radiography Same Lingual Opposite Buccal (SLOB) technique for assessing internal morphology of the teeth from bioarchaeological populations is evaluated and compared to the results obtained with Cone Beam Computed Tomography (CBCT).

Material and methods

The dental material came from the Radom Cemetery and was dated from the 18th and 19th centuries. According to historical information, we know that the first urban municipal cemetery was founded at the stronghold in 1791 but, due to the lack of space, a new cemetery was established in 1811 at another location, meaning that the municipal cemetery at the stronghold was abandoned and forgotten[18,19]. This means that all examined human remains were buried within a 20-year timeframe (Figure1). The Radom Cemetery collection is curated at the Department of Human Ecology at Cardinal Stefan Wyszynski University (Warsaw, Poland).

A total of 11 individuals of both sexes with 231 teeth were examined (Table 1). The dental material was divided precisely into the teeth with one (maxillary: incisors, canines, and second premolars – total: 55; mandibular: incisors, canines, and premolars – total: 41), two (maxillary first premolars – total: 21; mandibular: molars – total: 54), and three roots (maxillary molars – total: 60).

Fig. 1. Location map of the study area.

Table 1.
Number of teeth used in the study.

	Maxilla															
FDI	11	12	13	14	15	16	17	18	21	22	23	24	25	26	27	28
No teeth	7	6	7	11	9	8	11	11	6	6	3	10	11	13	6	11
	Mandible															
FDI	41	42	43	44	45	46	47	48	31	32	33	34	35	36	37	38
No teeth	2	3	7	4	6	11	11	7	2	5	4	3	5	10	11	4

The sex of individuals was not taken into account. The study used only permanent teeth with completely developed roots. We chose only well-preserved dental materials (e.g., without any traces of post-mortem damage). The presence of fused or accessory roots, root fractures, or cracks was ruled out by further tests. We examined both the teeth embedded in the alveolar bone and those outside of the alveolar bone. Then, the radiographic analysis was performed separately for each root, and all visible canals were marked.

Our studies have been narrowed to three methods: Cone Beam Computed Tomography (CBCT) – treated as a "gold standard", Standard Intraoral Radiography Paralleling Technique (PT), and the Standard Intraoral Radiography Same Lingual Opposite Buccal (SLOB) technique. Using Standard Intraoral Radiography, pictures were taken by the intraoral X-ray unit GENDEX 765 DC with constant exposure conditions inflicted for each picture: anode voltage 65kV, radiation intensity 7mA, and an exposure time of 0.1sec. Detection of root canal systems was performed by PT (Long Cone Technique) and SLOB technique (taken at a 25° angle) in oblique mesial and distal projection, using the Rinn kit holder and photosimulable phosphor plate (PSP) receptor in both techniques. To confirm the presence of root canal systems, the prepared samples were placed onto the bite plane of a Ray-Scan Symphony V CBCT unit, also with constant following settings for each picture: anode voltage 90kV, radiation intensity 10mA, and an exposure time of 20sec. Images were examined with the Xelis-Dental CD Viewer. The presence of root canal systems was diagnosed in three projections: coronal, sagittal, and axial scans (Figure 2). Applied selected methods are non-invasive and do not damage the historical material. All experimental procedures in this research were performed in the X-ray lab of the University Dental Clinic in Kracow.

In order to verify the reliability of the PT and SLOB techniques, the proportions of positive results obtained by both methods were calculated. In the second step, the differences between the proportions of results and standard error for different proportions were calculated. The McNemar's test was also used to assess the significance of the differences in observation between the two methods. To compare the results, observations of 30 teeth (10 one-root-

ed teeth, 10 two-rooted teeth, and 10 three-rooted teeth) were carried out by two independent researchers (AP, JZ). Reliability observations between the two investigators were assessed with the Spearman's rank correlation coefficient. Differences with $p \leq 0.05$ were considered statistically significant. Statistical analyses were performed using the R Project for Statistical Computing[20].

Results

Two investigators read the radiographs independently. Full compatibility was not attained between the observers for 15 root canals,. However, these differences did not influence the high observation compliance ($p < 0.0001$, $r_s = 0.976$).

In maxilla one-root teeth, a high visibility rate resulted from PT (77%) and was clearly lower with SLOB technique (54%), with the difference between these observations being statistically significant (Table 2). Both the buccal and palatal canals in the upper premolars were more visible with SLOB (75% and 85%, respectively), and the differences were statistically significant. The canals of three-root teeth were seen separately on each root: mesiobuccal, distobuccal, and palatal. The most visible canals were the distobuccal ones, with both SLOB (80%) and PT (70%) methods. The difference between these methods was not, however, statistically significant. The canals in mesiobuccal roots were clearly less frequently diagnosed with both radiographic methods. Among the maxillary molars, the worst observation was recorded for palatal roots. Only 20% of canals were detected by SLOB, and no canals were detected by PT (Table 2).

In lower one-root teeth, a better diagnosis appeared from PT (93%) than from SLOB (80%) technique, with the difference between these observations not being statistically significant (Table 2). Roots of mandibular molars were studied separately. The morphology of the mesial root was better detected with SLOB technique (74%), and the difference was statistically significant. The reverse observation results were obtained in the evaluation of the distal roots. PT, at a 59% visibility rate, was consistent with the observations made by CBCT, while SLOB was only consistent with the CBCT technique at a rate of 38%. The observations made with these methods were statistically significant.

Discussion

The internal morphology of historical teeth has received little attention in anthropological studies. The analysis of the root canals may be a useful tool, not only in the evaluation of abnormalities, but also in the study of population variability[15,21]. Research focused on the comparison of root canal systems between different ethnic groups could produce comparable information to molecular analysis. Studies in this respect confirm the importance of root canal systems in analyzing the origins of populations[22,23]. This means that the evaluation of the internal morphology of teeth may be important for future anthropological and bio-archaeological studies.

The best and the most commonly used method of visualization of root canals in endodontic research is the CBCT technique[24,25]. This method was also used in our studies and treated as a "gold standard". It was found that the particularly preferred configuration for evaluation of the root canal was proved in the axial slice, when the plane is perpendicular to the long axis of the tooth roots (Figure 2). Similar observations were reported by other authors analyzing contemporary materials[26,27]. It means that CBCT can be considered reliable for further analysis and can be applicable to historical material with high efficiency. Unfortunately, using CTBC is severely limited in bioarchaeological studies. This is due to the cost and time of the analyses, which is not without significance in the case of population studies.

Unfortunately, the results of both radiographic methods (PT and SLOB) in any cases did not fully comply with the CBCT technique, due to the fact that radiography is

Table 2.
Frequency of visible root canals in two methods of visualization. Types of roots: M – mesial, D – distal, BUC – buccal, PAL – palatal, MB – mesiobuccal, DB – distobuccal.

Type of root			the proportion of positive results		difference	p*	CI (95%)	
			PT	SLOB			Lower bound	Upper bound
Maxilla	One rooted	-	42/55 (77%)	30/55 (54%)	23%	0.0133	0.07	0.38
	Two rooted	BUC	8/21 (39%)	16/21 (75%)	36%	0.0003	0.18	0.55
		PAL	9/21 (41%)	18/21 (85%)	44%	<0.0001	0.23	0.64
	Three rooted	MB	12/60 (20%)	19/60 (32%)	11%	0.0455	0.07	0.38
		DB	48/60 (80%)	42/60 (70%)	10%	0.2386	0.03	0.23
		PAL	0/60 -	12/60 (20%)	-	-	-	-
Mandible	One rooted	-	38/41 (93%)	33/41 (80%)	13%	0.0734	0.01	0.22
	Two rooted	M	14/54 (26%)	40/54 (74%)	48%	<0.0001	0.29	0.68
		D	32/54 (59%)	20/54 (38%)	22%	0.0014	0.09	0.35

*McNemar's test

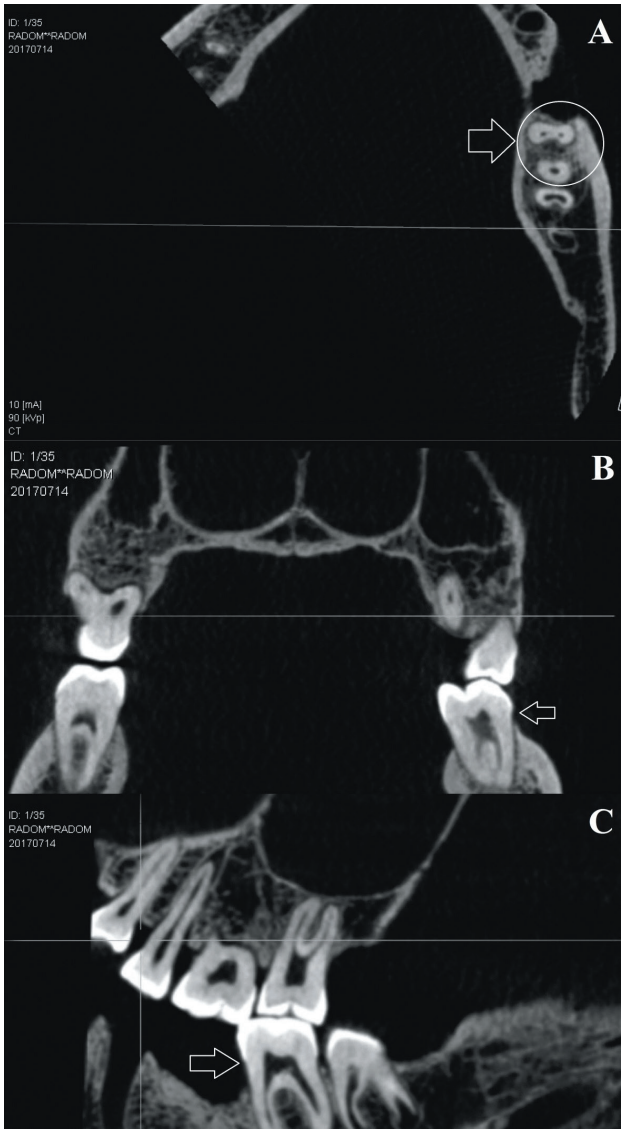

Fig. 2. Images of cbct with marked root canals in the first permanent lower molar: a – axial scan (two canals in the mesial root and one canal in the distal root), b – coronal scan (two canals in the mesial root), c – sagittal scan (mesial and distal root).

limited to two-dimensional images, shadows cast by structures, and in effect their distortion. Despite their not entirely identical nature, we could not completely remove the standard X-ray procedures from root canal systems analysis. Particularly, the radiographic methods were used for the first classification of canal configurations within a single root according to the pattern of division of the main root canal[28]. Moreover, standard radiographic methods are still used by many authors[29,30].

The greatest compatibility for the correct detection of root canal systems has been reported for one-root teeth. Maxillary central and lateral incisors, both canines and 40% of maxillary second premolars, almost always have one canal, while over 40% of mandibular central and lateral incisors, and 58% maxillary second premolars and part of maxillary first premolars have two canals, but only just over 1% have two separate foramina[3,5,31]. In these teeth, PT method supplies higher visibility than SLOB method. It is compatible with other observations made in endodontics patients[24,27]. Thus, when studying one-root teeth in historical populations, it is better to use the PT then SLOB technique. This is an important result because the long cone technique seems to be easier to use, especially in the case of historical material, which cannot always be set correctly for imaging.

Different results were observed among the two-root teeth. For upper first premolars and lower molars, SLOB was a better method for diagnosing root canal systems in the buccal, palatal, and mesial roots respectively, while the better radiographic method for distal roots in lower molars was PT. This can be explained by the fact that lower molars generally have two roots and three canals: two canals in the mesial root and one large oval canal distally, whereas maxillary first premolars typically have two roots with a single canal[3,5,32]. Therefore, the detection of canals in the mesial, palatal, and buccal roots is more easily achieved with SLOB, when the central X-ray is inclined at an angle of about 20/25° in the horizontal plane, while the distal roots, which contain one canal, are better diagnosed by PT, when the central X-ray is parallel to the long axis of the teeth (Figure 3).

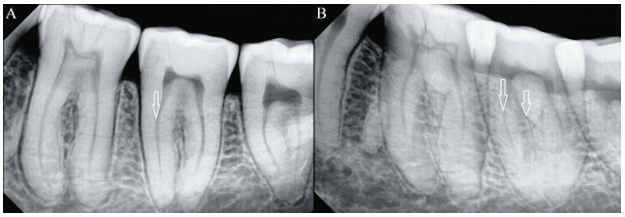

Fig. 3. Picture of lower molars in two radiographic techniques: a – paralleling technique (pt), b – same lingual opposite buccal technique (slob).

The majority of the mesiobuccal roots (upper molars) have multiple root canals[3,25]. This explains why SLOB diagnosed the root system in historical material better than PT. The same X-ray position enabled better observation of the palatal root. Also, a similar observation was made in contemporary clinical practice[33]. However, a greater difference could be expected between the methods, as imaging of the upper teeth is difficult in historical material due to the positioning of the maxilla. Making a good X-ray image of the upper dentition is a difficult task, and PT was more efficient for distobuccal roots[4]. However, among the roots of the upper molars, the worst rate of detection was attained for the palatal roots. These observations indicate that studies of historical material can be carried out on single-root teeth. This is very important because the bioarchaeological material is often damaged and incomplete, and many teeth do not have all of their roots preserved.

Conclusion

Selected visualization methods that are used in endodontic studies have proved to be efficient with historical dry material as well. CBCT is useful for the visualization of root canals in all teeth types. As we have found, standard intraoral radiography is limited in its ability to give reliable results regarding the number and morphology of root canals. However, it can sometimes be an alternative method for the visualization of root canal morphology.

Acknowledgements

The work presented was co-financed by the Ph.D. Candidates Society of the Jagiellonian University and the National Science Centre (Poland) during the years 2013–2017 (Grant No 2013/11/B/HS3/04117).

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STANDARDNA INTRAORALNA RADIOGRAFIJA U ODNOSU NA KONUSNU ZRAČNU RAČUNALNU TOMOGRAFIJU ZA OTKRIVANJE SUSTAVA KORIJENSKIH KANALA U POVIJESNOM ZUBNOM MATERIJALU

S A Ž E T A K

Proučavanje korijenskih kanala povijesnih zuba relativno je novo u antropološkim istraživanjima. Ovo pitanje nije opsežno dokumentirano u antropološkoj literaturi. Autori ove studije otkrili su vidljivost sustava korijenskih kanala u 231 ljudskom zubu koji pripada 11 pojedinaca obaju spolova iz 18. i 19. stoljeća na arheološkom nalazištu u Radomu (Poljska). Zubi su podijeljeni upravo u uzorke jednog, dva i tri korijena. Svaki korijen analiziran je odvojeno. Tri su metode korištene: konvencionalna komutacijska tomografija (CBCT), standardna intraoralna radiografija u paralelnoj tehnici (PT) i tehnika istog jezičnog nasuprotnog buccusa (SLOB) uz stalne uvjete ekspozicije. Utvrđeno je da se CBCT može uspješno koristiti, čak i tretirati kao "zlatni standard", pružajući najvišu vidljivost svih vrsta zuba. U maxilla jednim korijennim zubima korijenski kanal je vidljiviji u PT-u (77%) nego u SLOB (54%) tehnici. U gornjem pretkutnjaku, oba bukalna i palatinalna kanala su vidljivi u SLOB (75% i 85%), a razlike su statistički značajne ($p = 0.0003$ i $p < 0.0001$). U zubima s tri korijena, najvidljiviji kanali su distobuccalni, u obje metode SLOB (80%) i PT (70%). Rijetki su dijagnosticirani kanali u meziobuccal korijenima u oba radiografska metoda (PT 20% i SLOB 32%). Kanali u palatalnom korijenu bili su slabo detektibilni. U zubima mandibularnog jednog korijena postiže se veća brzina vidljivosti s PT (93%) nego SLOB (80%) tehnikom. U distalnim korijenima mandibularnih kutnjaka, kanali su vidljiviji u PT (59%) metodi. Morfologija mezijalnog korijena bila je bolje otkrivena u SLOB tehnici (74%). Studija pokazuje potencijal korištenja jednorukcijskih zuba kada je ostatak korijena zuba fragmentiran.