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Root canal working length determination using Cone-Beam Computed Tomography

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SUMMARY

Introduction Cone-Beam Computed Tomography (CBCT) represents unique supporting diagnostic tool in all areas of dentistry as well as endodontics. One of the uses in endodontics is determining working length of the root canals-odontometry.

The aim of this paper was to test the efficacy of CBCT application in determining working length of root canals.

Methods Forty-three extracted human teeth were placed in three wax models shaped as a horseshoe. Preoperatively, CBCT model scanning (voxel size: 0.2 mm) was performed. Access cavities were prepared and working length determined by introducing expanders #08 into the root canal until the *apical foramen*. The length was measured using a micrometer odontometer. The CBCT working length was simply measured by following the line between the apical foramen and the selected reference point. Two experienced operators performed all measurements, independently. The *t*-test was used to compare the obtained values.

Results CBCT measurements showed small deviation from manual measurements. The mean value of the absolute difference between CBCT measurements and manual measurements was 0.39 mm (0.25-0.74 mm). The results of the *t* test (t = 0.311; p = 0.757) showed that there was no statistically significant difference between the odontometry performed by the endodontic instrument and odontometry performed using CBCT.

Conclusion The CBCT measurement is reliable method for determining working length of root canals. In 94.29% of examined teeth, discrepancies less than 1 mm were found, which was not of clinical significance.

Keywords: computer tomography; root canal treatment; precision; working length

INTRODUCTION

Working length determination before chemomechnical instrumentation is one of the most important stages of endodontic treatment. In order to determine working length, the most commonly used are two basic techniques, radiographic and electro-odontometric techniques. The drawback of x-ray technique is that it provides a two-dimensional image of a three-dimensional object, requires multiple exposures to radiation, it can show superimposition of anatomical structures and requires extended time for developing the film. Additionally, this procedure may be difficult in large periapical lesions and apical resorptions [1–4].

Currently, the most often used method to determine working length is electro-odontometric method as it is simple, fast, does not involve radiation, and has great precision [4]. Problems can arise due to the presence of residual pulp tissue and fluid within the canal (exudate, blood, irrigants, salivation), canal obliteration, calcification, presence of metal crowns, amalgam filler residues, incomplete root growth or too wide apex of large periapical lesions. The use of this technique is contraindicated in persons with pacemaker [5–10].

CBCT (Cone beam computed tomography) is technological achievement of digital radiology and today is widely used in dentistry [11, 12, 13]. From the aspect of endodontics, it is important in determining the anatomy of the root canal system, root fractures, periapical lesions and internal and external root resorptions [14, 15, 16]. CBCT is a very precise model that provides a 3D space image, facilitating visualization of anatomical structures that form a proper geometric image with clearer details, greater depth and better image contrast than the conventional 2D radiogram [17]. Unlike conventional CT, it is much smaller and cheaper, allows faster scanning

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(30 seconds), has high resolution, lower radiation dose, gives a millimeter accurate analysis, provides greater benefit for a patient who can sit or stand and is more comfortable than classic CT diagnostics [18].

Better understanding of third dimension of the root canal also helps to increase accuracy of working length measurement. Therefore, measurements of root canals on existing CBCT images are potentially new method for determining the working length before starting endodontic treatment. By exploiting all information available in the vision field, clinicians can apply existing CBCT data to further interventions in the same area, such as root canal treatments.

The aim of this study was to determine the efficacy of the CBCT method in measuring the working length of the root canals.

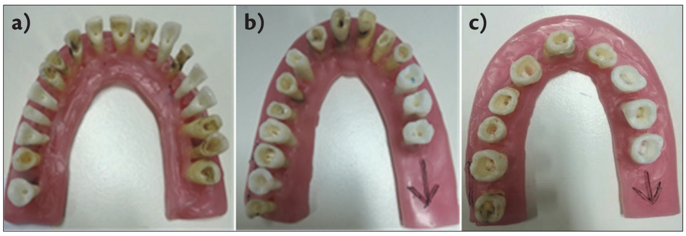

Figure 1. Positioning of extracted teeth in wax:
a) teeth of the intercanine region, b) premolars, c) molars
Slika 1. Pozicioniranje ekstrahovanih zuba u voštanim pločicama:
a) zubi frontalne regije, b) premolari, c) molari

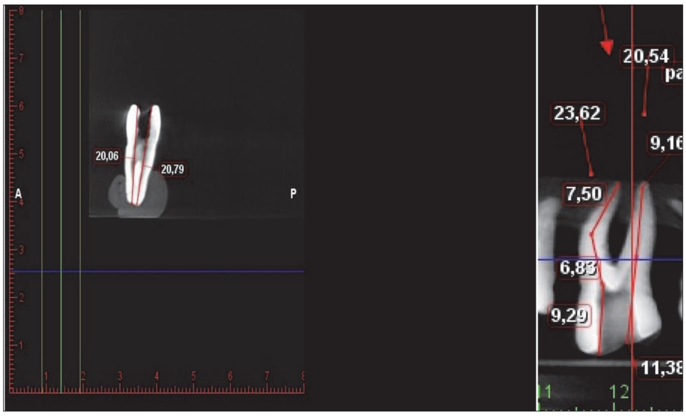

Figure 2. Connecting the apical foramen and reference point with one straight line and multiple segmented lines on a CBCT cross-section
Slika 2. Povezivanje foramena apikale i referentne tačke jednom pravom linijom u jednom CBCT preseku i sa više segmentiranih linija u jednom CBCT preseku

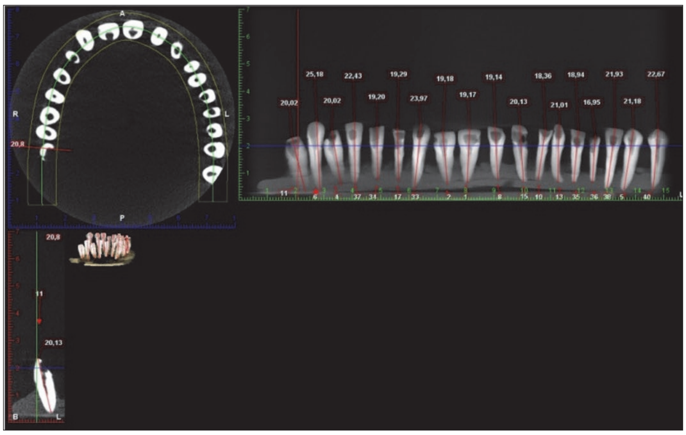

Figure 3. Teeth of the intercanine sector (n = 18)
Slika 3. Zubi interkaninog sektora (n = 18)

MATERIAL AND METHODS

The research was conducted at the Faculty of Medicine, University of Banja Luka, at the Division of Dental Diseases and Endodontics and the Division of Oral Surgery in 2018. The study was carried out on 43 teeth, extracted for various reasons, divided into the three experimental groups: teeth of the intercanine sector (n = 18), teeth of the postcanine sector – premolars (n = 15) and the teeth of the postcanine sector – molars (10).

All teeth were photographed, numbered and stored in alcohol until the beginning of the research. The teeth were cleaned, and access cavity was prepared. The coronal third of all canals was prepared using Gates Glidden drills (1-4) and pulp extirpator was used to remove the remaining pulp tissue.

The working length of the root canals was determined using K file number 08, in a way that it was pulled back 1 mm inside the canal (to the position of physiological narrowing) after it appeared at the apex. The working length was also measured using a micrometric odontometer for each tooth. The extracted teeth with determined working length were then fixed in wax (Figure 1).

CBCT images were obtained with Planmeca ProMax 3D Mid (Planmeca, Helsinki, Finland) and analyzed using the Romexis software 4 by two engineers of medical radiology. The operating principle of this software is based on quantitative analysis of the root canal that requires segmentation of endodontic space. Segmentation of the CBCT image separates endodontic space from surrounding tissue, dentin and root cement. Selecting the appropriate segmentation technique is important because it affects the morphometric parameters. By analyzing the CBCT cross-section, the position of the anatomical foramen was determined first to represent one reference point. Line measurements were performed from first to the second reference point, identified arbitrary – incisal edge, the top of the cusp, or the plateau. Linear measurements were parallel to vertical tooth axis, whereby it was necessary to choose axial section that allowed straight line to be drawn from the anatomical foramen to the top of the cusp or incisal edge of teeth (Figure 2). For segmented canals, segmented linear measurements that made up a particular angle were used (Figure 3). CBCT segments were reformatted so that the root canal of each analyzed tooth was placed in vertical position to visualize incisal edge, pulp chamber, apical foramen, and if possible, the entire length of the canal in one cross-section. This procedure was repeated for all teeth to obtain bucco-oral and mesio-distal dimensions. The length of the root canal was determined as the distance between the most incisal edge of the tooth in projected central pulp space and apical foramen. The measuring line was placed in the center

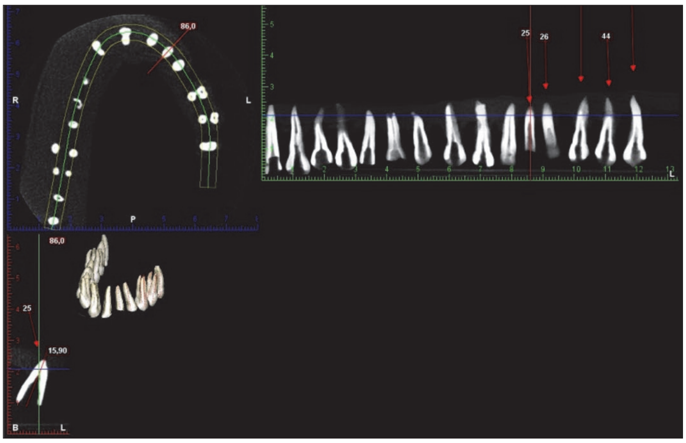

Figure 4. Teeth of the postcanine sector – premolars (n = 15)
Slika 4. Zubi postkaninog sektora – premolari (n = 15)

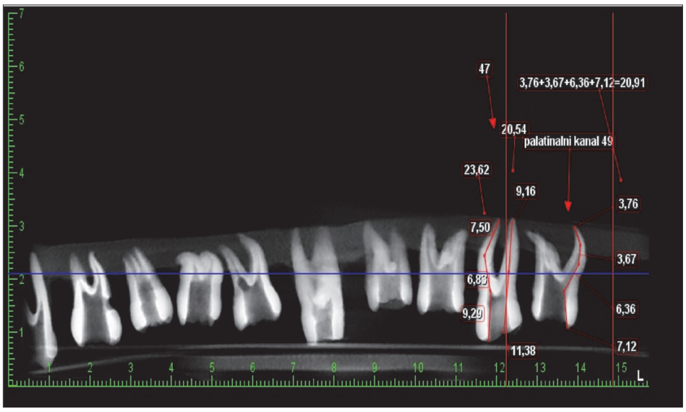

Figure 5. Teeth of the postcanine sector – molars (n = 10)
Slika 5. Zubi postkaninog sektora – molari (n = 10)

of pulpal space and following any visible deviation of the canal path at the given CBCT cross-section (Figure 2-5).

RESULTS

The obtained results are shown in Tables 1 and 2. The *t* test results (t = 0.311; p = 0.757) showed no statistically significant difference between odontometry with an endodontic instrument and odontometry using a 3D image. Both methods indicated high precision in measurements regardless of experimental group of teeth, anthropomorphic root measurements, degree of curves of the root canal, except in the group of distal canals of lower molars (p < 0.645).

In the 3D method, more coherent deviation was observed in relation to deviations in odontometry with an endodontic instrument regardless of the morphology of teeth. Table 2 presents the results of ANOVA and Tukey HSD post hoc tests. There was no statistically significant difference in values between the groups of teeth and the two methods. Minimal deviation between the two methods was found in the group of premolars - lingual roots, and the greatest deviation between the methods was found in the group of lower molars – ML canals, but without statistically significant difference.

DISCUSSION

CBCT (Cone beam computed tomography) is certainly one of the most important discoveries in radiology and provides wide possibilities for use in all dental areas. The main advantage is lower radiation level compared to conventional CT. The American Association of Endodontists has issued a document (Position statement), which presents strict indications for the use of CBCT in dentistry. The document contains 11 specific recommendations with indications for use in endodontics (preoperative, intraoperative and postoperative) [19].

Our research showed high correlation of CBCT measurements in relation to other methods, where for only two teeth the deviation was greater than 2 mm and for only three teeth it was greater than 1 mm. The biggest difference in measurements was observed in lower molars and it was 3.29 mm for mesiolingual and 2.67 mm for distal canal (Table 2). Greater deviations than 2 mm were observed for two more teeth while other deviations ranged from 0.04 mm to 2 mm. These findings are in correlation with research of Connert et al. where in 99% of cases the deviation was from 0.31 mm to 0.52 mm [20].

Liang et al. also compared manual techniques and CBCT in measuring the canal length. They showed that the difference in results between the methods was 0.46 mm and deviation was greater than 1 mm only in nine of 198 (4.5%) measurements [21]. CBCT measurements of the working length have often been compared with standard measurements of apex locators. The smallest deviations were found between measurements done in the mesodistal direction of CBCT sections. Unlike CBCT scanning, it was difficult for apex locators to identify the main foramen of the root canal system. Gomide de Morais et al. pointed out that in 96% of cases, the position of the apical foramen measured with an apex locator can be accurately identified with the deviation of 2 mm from the value measured by CBCT [22].

El Ayouti et al. reported correlation of values measured with an apex locator and CBCT in 85% of cases. Since the use of apex locator as a control can show certain limitations related to identification of the main apex foramen in the case of obliteration or metal crown restorations, in our study we used manual technique due to its reliability and the ability to control the absolute reference value of the working length for the comparison. The advantage of the new approach to measuring lengths by CBCT lies in the fact that it is entirely based on software whereas already existing CBCT data can be evaluated without the physical presence of a patient [2, 6].

The reliability of working length measurement by CBCT has been confirmed by numerous researchers (Janner et al. 2011, Liang et al. 2013, Connert et al. 2014) and deviations in working length measurements are the result of different sizes of voxels in CBCT which affect the sharpness of images and interpretation of results [18, 20, 21].

The study done by Costa et al., found high correlation between CBCT measurements of different voxel sizes of

Table 1. Measuring values of the manual and CBCT methods of all experimental groups
Tabela 1. Vrednosti merenja manuelne i CBCT metode svih eksperimentalnih grupa

Canal type Tip kanala	ODONTOMETRY ODONTOMETRIJA	Mean values [mm] Srednja vrednost [mm]	N	Standard deviation [mm] Standardna devijacija [mm]	P
Incisors, canines and one-root premolars Sekutići, očnjaci i jednokoreni premolari	Manual method Manuelna metoda	19.875	24	2.232	0.962
	CBCT 3D image CBCT 3D snimak	19.844	24	2.297	
	Total Ukupno	19.859	48	2.241	
Premolars – B canals Premolari – B kanali	Manual method Manuelna metoda	20.778	9	2.279	0.971
	CBCT 3D image CBCT 3D snimak	20.816	9	2.054	
	Total Ukupno	20.797	18	2.105	
Premolars – P canals Premolari – P kanali	Manual method Manuelna metoda	19.000	9	2.828	0.942
	CBCT 3D image CBCT 3D snimak	18.902	9	2.784	
	Total Ukupno	18.951	18	2.723	
Upper molars – MB canals Gornji molari –BM kanali	Manual method Manuelna metoda	17.500	4	3.873	0.983
	CBCT 3D image CBCT 3D snimak	17.443	4	3.453	
	Total Ukupno	17.471	8	3.397	
Upper molars – DB canals Gornji molari –BD kanali	Manual method Manuelna metoda	18.667	3	4.726	0.997
	CBCT 3D image CBCT 3D snimak	18.683	3	4.368	
	Total Ukupno	18.675	6	4.070	
Upper molars – P canals Gornji molari – P kanali	Manual method Manuelna metoda	17.333	3	3.512	0.951
	CBCT 3D image CBCT 3D snimak	17.513	3	3.186	
	Total Ukupno	17.423	6	3.001	
Lower molars – MB canals Donji molari – BM kanali	Manual method Manuelna metoda	18.857	7	3.338	0.833
	CBCT 3D image CBCT 3D snimak	18.474	7	3.308	
	Total Ukupno	18.666	14	3.199	
Lower molars – ML canals Donji molari – LM kanali	Manual method Manuelna metoda	19.200	5	3.493	0.787
	CBCT 3D image CBCT 3D snimak	18.572	5	3.603	
	Total Ukupno	18.886	10	3.362	
Lower molars – D canals Donji molari – D kanali	Manual method Manuelna metoda	18.000	7	3.367	0.645
	CBCT 3D image CBCT 3D snimak	17.167	6	2.902	
	Total Ukupno	17.615	13	3.060	
Total Ukupno	Manual method Manuelna metoda	19.254	71	2.892	0.757
	CBCT 3D image CBCT 3D snimak	19.104	70	2.841	
	Total Ukupno	19.179	141	2.858	

B – buccal; P – palatinal; MB – mesiobuccal; DB – distobuccal; ML – mesiolingual; D – distal canals;
B – bukalni; P – palatinalni; BM – bukomezijalni; BD – bukodistalni; LM – lingvomezijalni; D –distalni kanali

Table 2. Deviation between methods
Tabela 2. Odstupanje između metoda

Canal type Tip kanala	Mean values [mm] Srednja vrednost [mm]	N	Standard deviation [mm] Standardna devijacija [mm]
Incisors, canines and one-root premolars Sekutici, očnjaci i jednokoreni premolari	0.250	24	0.332
Premolars – B canals Premolari – B kanali	0.340	9	0.336
Premolars – P canals Premolari – P kanali	0.142	9	0.184
Upper molars – MB canals Gornji molari – BM kanali	0.303	4	0.267
Upper molars – DB canals Gornji molari – BD kanali	0.283	3	0.104
Upper molars – P canals Gornji molari – P kanali	0.240	3	0.304
Lower molars – MB canals Donji molari – BM kanali	0.729	7	1.146
Lower molars – ML canals Donji molari – LM kanali	0.924	5	1.335
Lower molars – D canals Donji molari – D kanali	0.740	6	0.961
Total Ukupno	0.390	70	0.636

B – buccal; P – palatinal; MB – mesiobuccal; DB – distobuccal;
ML – mesiolingual; D – distal canals;
B – bukalni; P – palatinalni; BM – bukomezijalni; BD – bukodistalni;
LM – lingvomezijalni; D – distalni kanali

$0.2\ mm^3$, $0.3\ mm^3$ and $0.4\ mm^3$ and manual method. Although all CBCT images showed reliable values, the smallest voxel size of $0.2\ mm^3$ and the CBCT image with the highest resolution showed the highest correlation with manual measurement [23]. These findings are similar to obtained results of the current study with reported deviation of 0.3 mm, since we used the size of voxel of $0.2\ mm^3$ and high resolution of the obtained CBCT images (Table 2). At present, general protocol for the use of CBCT in relation to specific diagnostic tasks in dentistry has not been defined yet, although $0.4\ mm^3$ scanning of CBCT appears to be less reliable than the voxel size of 0.3 and $0.2\ mm^3$ [24].

Some authors indicate that measurement values with CBCT - 3D measurements are more reliable than radiovisionography-RVG and CBCT - 2D measurements. The difference is seen in the positioning of the reference points, which are buccal or lingual, and impossibility of designing the root canal with multiple curves in one level [25, 26, 27].

Manual method of measuring working length of root canals in our study showed the actual length because it was performed directly under eye control. CBCT measurements (for voxel sizes from $0.2\ mm^3$) showed deviations from absolute working length in the group of one-root teeth of 0.2 mm, in the group of two-root premolars for buccal canal of 0.3 mm and lingual of 0.1 mm, while in the group of molars the greatest deviation was observed for the mesiolingual canal of lower molars, and the least for the lingual canal of the upper molars. However, for definitive conclusion on the reliability of such measurements, it is necessary to perform testing with larger group of teeth than in our study, but also more detailed analysis of the morphology of the canals. The deviations in the CBCT measurements can be explained by the fact that they are obtained through different sagittal cross-sections, which may affect re-measurement of the working length.

CONCLUSION

Measurement is more reliable if performed on both mesiodistal and buccooral cross-sections, and the calculated mean value represents working length. The lack of this method is in the fact that the reference points are determined according to the curved canal path, which can also affect the results of the re-measurement.

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Primena CBCT-a u određivanju radne dužine kanala korena zuba

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KRATAK SADRŽAJ

Uvod CBCT predstavlja danas nezamenjivo pomoćno dijagnostičko sredstvo u svim oblastima stomatologije pa i u endodonciji. Jedna od namena u endodonciji je merenje radne dužine kanala korena zuba – odontometrije.
Cilj ovog rada je bio da se proveri efikasnost primene CBCT-a u određivanju radne dužine kanala korena zuba.
Metode Četrdeset i tri ekstrahovana ljudska zuba postavljena su u tri voštana modela oblika potkovice. Preoperativno, izvršeno je CBCT skeniranje modela (veličina voksela: 0,2 mm). Pripremljeni su pristupni kaviteti i radna dužina je određena uvođenjem proširivača #08 u korenski kanal dok se vrh ne uoči na foramenu apikale. Dužina je merena pomoću mikrometarskog odontometra. CBCT radna dužina je jednostavno izmerena prateći liniju između apikalnog foramena i izabrane referentne tačke. Merenja realne i CBCT dužine su sprovedena od strane dva iskusna operatera nezavisno jedno od drugog. T-test je korišćen za poređenje dobijenih vrednosti.
Rezultati CBCT merenja su imala mala odstupanja od manuelnih merenja. Srednja vrednost apsolutne razlike između CBCT merenja i manuelnog merenja iznosila je 0,39 mm (0,25–0,74 mm). Rezultati t-testa ($t = 0,311$; $p = 0,757$) pokazali su da nije postojala statistički značajna razlika između odontometrije realizovane uvođenjem endodontskog instrumenta i odontometrije pomoću kompjuterizovane tomografije.
Zaključak CBCT merenje je pouzdan metod za određivanje radne dužine kanala korena zuba. Kod 94,29% ispitanih zuba pronađena su odstupanja manja od 1 mm, što nije imalo klinički značaj.
Ključne reči: kompjuterska tomografija; tretman kanala korena zuba; preciznost; radna dužina

UVOD

Određivanje radne dužine kanala korena zuba predstavlja jednu od najvažnijih faza endodontske procedure. Za određivanje radne dužine preparacije danas se najčešće koriste dve osnovne tehnike – rendgenografska i elektroodontometrijska tehnika. Problemi rendgenografske tehnike su u tome što daje dvodimenzionalnu sliku trodimenzionalnog objekta, što zahteva višestruko izlaganje pacijenta zračenju, što su moguće superpozicije anatomskih struktura i što se često mora dugo čekati da se film razvije. Takođe, ovaj postupak može biti otežan kod velikih periapikalnih lezija i apikalnih resorpcija [1–4].

Danas se ovaj postupak najčešće realizuje elektroodontometrijskom metodom zbog prednosti ove jednostavnosti izvođenja, mogućnosti ponavljanja postupka usled izostanka zračenja, te veće preciznosti utvrđivanja granice preparacije [4]. Problemi mogu nastati usled prisustva zaostataka pulpnog tkiva i tečnosti unutar kanala (eksudat, krv, irigansi, pljuvačka), obliteracije kanala, kalcifikacije, prisustva metalnih krunica, ostataka amalgamskog ispuna, nedovršenog rasta korena ili preširokog apeksa velikih periapikalnih lezija. Upotreba ove tehnike je kontraindikovana kod osoba sa ugrađenim pejsmejkerom [5–10].

CBCT (*Cone beam computed tomography*) jeste tehnološko dostignuće digitalne radiologije i danas se široko upotrebljava u stomatologiji [11, 12, 13]. Sa aspekta endodoncije značajan je u određivanju anatomije kanalnog sistema, preloma korena, periapikalnih lezija i unutrašnjih i spoljašnjih resorpcija korena [14, 15, 16].

CBCT predstavlja modalitet koji je vrlo precizan i koji daje sliku 3D prostorne veze, čime se olakšava vizualizacija anatomskih struktura, koje formiraju pravilnu geometrijsku sliku sa jasnije izraženim detaljima, većom dubinom i boljim kontrastom slike u odnosu na konvencionalni 2D radiogram [17]. Za razliku od klasičnog CT-a, mnogo je manji i jeftiniji, omogućava brže skeniranje (30 sekundi), ima visoku rezoluciju, manju dozu radijacije, daje milimetarski tačnu analizu, obezbeđuje veću ugodnost za pacijenta u odnosu na klasičnu CT dijagnostiku [18].

Bolje razumevanje treće dimenzije korena zuba takođe može pomoći da se poveća tačnost merenja radne dužine, a rezultati merenja korenskih kanala na postojećim CBCT snimcima su potencijalna nova metoda za određivanje dužine korenskog kanala pre početka endodontskog tretmana. Iskorišćavanjem svih vizuelnih informacija dostupnih u vidnom polju kliničari mogu primeniti već postojeće CBCT podatke na dalje intervencije u istom području, kao što su tretmani korenskog kanala.

Cilj ovog istraživanja je bio da se proveri efikasnost CBCT metode u određivanju radne dužine kanala korena zuba.

MATERIJAL I METODE

Istraživanje je sprovedeno na Medicinskom fakultetu Univerziteta u Banjoj Luci, na Katedri za bolesti zuba i endodonciju i Katedri za oralnu hirurgiju u 2018. godini. Ispitivanje je sprovedeno na 43 iz različitih razloga ekstrahovana zuba, podeljena u tri eksperimentalne grupe: zubi interkaninog sektora ($n = 18$), zubi postkaninog sektora – premolari ($n = 15$) i zubi postkaninog sektora – molari ($n = 10$).

Svi zubi su fotografisani, numerisani i čuvani u alkoholu do početka istraživanja. Sa zuba su uklonjene meke i čvrste naslage, posle čega se pristupilo formiranju pristupnih kaviteta na svim zubima. Koronarna trećina svih zuba je obrađena svrdlima Gates Glidden (1-4), a preostalo pulpno tkivo uklonjeno pulpekstirpatorom.

Radna dužina kanala korena zuba je prvo određena pomoću endodontskog instrumenta i proširivača broj 08, tako što je instrument povučen 1 mm koronarnije (na poziciju fiziološkog suženja) od vrha korena. Radna dužina je izmerena pomoću mikrometarskog odontometra za svaki zub. Ekstrahovani zubi kojima je određena radna dužina su potom fiksirani u vosku (Slika 1).

CBCT slike su dobijene sa aparatom Planmeca ProMax 3D Mid (Planmeca, Helsinki, Finska) i analizirani pomoću *Romexis softvera* 4 od strane dva inženjera medicinske radiologije. Princip rada ovog softvera se zasniva na kvantitativnoj analizi korena kanala, koji zahteva segmentaciju endodontskog prostora. Segmentacijom CBCT slike se odvaja endodoncijum od okolnog tkiva dentina i cementa korena zuba. Izbor odgovarajuće tehnike segmentacije je bitan jer utiče na morfometrijske parametre. Analizom CBCT preseka prvo je utvrđena pozicija anatomskog foramena apikale koji predstavlja prvu referentnu tačku. Potom su sprovedena linijska merenja od prve do druge referentne tačke, određene proizvoljno – incizalna ivica, vrh kvržice ili plato. Linijska merenja su paralelna sa aksijalnom osovinom zuba, pri čemu je potrebno bilo izabrati onaj aksijalni presek koji je omogućio povlačenje ravne linije od anatomskog foramena do vrha kvržice ili incizalne ivice zuba (Slika 2). Kod povijenih kanala su korišćena segmentirana linijska merenja koja međusobno čine određeni ugao (Slika 3). CBCT segmenti su reformatirani tako da je korenski kanal svakog analiziranog zuba postavljan u vertikalni položaj da bi se vizualizovali incizalna ivica, pulpna komora, foramen apikale, i ako je moguće, cela dužina kanala u jednom preseku. Ova procedura je ponovljena za sve uključene zube da bi se dobila vestibulooralna i meziodistalna dimenzija odgovarajućeg zuba. Dužina korenskog kanala je utvrđena na CBCT presecima kao rastojanje između najincizalnijih (ili najkuspidalnijih) ivica zuba u projektovanoj srednjoj šupljini pulpe i foramena apikale. Merna linija je postavljena u središte u pulpnoj šupljini i pratila je svako vidljivo odstupanje smera pružanja kanala u datom CBCT preseku (slike 2–5).

REZULTATI

Dobijeni rezultati prikazani su u tabelama 1 i 2. Rezultati t-testa ($t = 0,311$; $p = 0,757$) pokazali su da nije postojala statistički značajna razlika između odontometrije sa endodontskim instrumentom i odontometrije pomoću 3D snimka.

Analiza dobijenih rezultata je pokazala da su bez obzira na eksperimentalnu grupu zuba, antropomorfološke mere korena, stepen zakrivljenosti kanala, obe metode ukazale na visoku preciznost, izuzev u grupi distalnih kanala donjih molara ($p < 0,645$).

Kod 3D metode je uočeno ujednačenije odstupanje u odnosu na odstupanja kod odontometrije sa endodontskim instrumentom bez obzira na morfologiju zuba. Tabela 2 pokazuje rezultate ANOVA i Tukey HSD *post hoc* testova, koji pokazuju da ne postoji statistički značajna razlika u vrednostima između grupa zuba i između dve metode. Minimalno odstupanje između dve metode utvrđeno je kod grupe „premolari – palatinalni kanali", a najveće odstupanje između metoda je bilo kod grupe „donji molari – LM kanali", ali bez statistički značajne razlike.

DISKUSIJA

CBCT je sigurno jedno od najznačajnijih otkrića u radiologiji i pruža široke mogućnosti upotrebe u svim stomatološkim oblastima. Osnovna prednost je manja doza zračenja u odnosu na konvencionalni CT. Američka asocijacija endodonata je donela dokument (*Position statement*), u kome su predstavljene stroge indikacije za upotrebu CBCT-a u stomatologiji. U dokumentu postoji 11 konkretnih preporuka uz indikacije za upotrebu u endodonciji (preoperativne, intraoperativne i postoperativne) [19].

Sprovedeno istraživanje je pokazalo visoku korelaciju CBCT merenja u odnosu na manuelnu metodu gde je kod samo dva zuba odstupanje bilo veće od 2 mm, a na samo tri zuba veće od 1 mm. Maksimalna razlika u merenjima je primećena kod donjeg molara i iznosila je 3,29 mm za lingvomezijalni, a 2,67 mm za distalni (Tabela 2). Veća odstupanja od 2 mm uočena su kod još dva zuba, dok su se ostala odstupanja kretala u granicama od 0,04 mm do 2 mm. Ovakav nalaz je u korelaciji sa merenjima Connerta i saradnika, kod kojih je u 99% slučajeva odstupanje bilo od 0,31 mm do 0,52 mm [20].

Liang i saradnici su u svojoj studiji takođe koristili manuelnu tehniku merenja dužine kanala korena zuba i poredili sa CBCT-om. Pokazali su da je srednja apsolutna vrednost između metoda iznosila 0,46 mm i da je samo u devet od 198 (4,5%) merenja kanala korena zuba odstupanje bilo veće od 1 mm [21]. CBCT merenja radne dužine kanala korena zuba su često poređena sa standardnim merenjima apeks lokatorima. Najmanja odstupanja nađena su kod merenja koja su obavljena u meziodistalnom smeru CBCT sekcija. Za razliku od CBCT skeniranja, apeks lokatorima je teško identifikovati glavne foramine kanalnog sistema. Gomide de Morais i saradnici ukazuju da se apeks lokatorom može u 96% slučajeva tačno očitati pozicija foramena apikale sa odstupanjima od 2 mm od vrednosti izmerene CBCT-om [22].

El Ayouti i saradnici su pokazali da je korelacija vrednosti izmerene apeks lokatorom sa CBCT-om samo u 85% slučajeva. S obzirom na to da upotreba apeks lokatora kao kontrole može pokazati određena ograničenja vezana za identifikaciju glavnih otvora kod obliteracije ili kod metalnih kruničnih restauracija, u ovoj studiji je korišćena manuelna tehnika zbog pouzdanosti i mogućnosti kontrole apsolutne referentne vrednosti radne dužine za komparaciju. Prednost novog pristupa merenja dužine CBCT-om leži u činjenici da je u potpunosti zasnovan na softveru gde se već postojeći CBCT podaci mogu proceniti i bez fizičkog prisustva pacijenta [2, 6].

Pouzdanost merenja radne dužine CBCT-om potvrdili su brojni istraživači (*Janner et al.* 2011; *Liang et al.* 2013; *Connert et al.* 2014), a odstupanja u merenjima radne dužine rezultat su različitih veličina voksela kod CBCT-a, što utiče na oštrinu slike i tumačenje rezultata [18, 20, 21].

Costa i saradnici su u studiji utvrđivali korelaciju CBCT merenja različitih veličina voksela, 0,2 mm^3, 0,3 mm^3 i 0,4 mm^3, sa manuelnom metodom i uočena je visoka korelacija između manuelnog merenja i CBCT.

Iako su svi CBCT snimci pokazali pouzdane vrednosti, najmanja veličina voksela – 0,2 mm^3 i CBCT snimak najviše rezolucije pokazali su najvišu korelaciju sa manuelnim merenjem [23].

Ovakav nalaz je u korelaciji sa dobijenim merenjima naše studije, s obzirom na to da je i ovde veličina voksela iznosila 0,2 mm^3 i da je uz visoku rezoluciju dobijenih CBCT snimaka dobijeno odstupanje od 0,3 mm (Tabela 2). Još uvek nije definisan opšti protokol primene CBCT-a vezan za specifične dijagnostičke zadatake u stomatologiji iako se čini da je skeniranje od 0,4 mm^3 CBCT nešto manje pouzdano nego veličina voksela od 0,3 i 0,2 mm^3 [24].

Istraživanja nekih autora ukazuju da su vrednosti merenja sa CBCT -3D merenjima bile pouzdanije u odnosu na radioviziografiju – RVG i CBCT -2D merenja. Razliku vide u pozicioniranju referentnih tačaka, koje su locirane bukalno ili lingvalno, ili u nemogućnosti projektovanja kanala korena sa višestrukim zakrivljenjima u jednoj ravni [25, 26, 27].

Manuelna metoda merenja radne dužine kanala korena zuba u ovoj studiji pokazuje stvarnu dužinu jer je direktno pod kontrolom oka. CBCT merenja (pri veličinama voksela od 0,2 mm^3) pokazala su odstupanja od apsolutne radne dužine u grupi jednokorenih zuba – 0,2 mm, u grupi dvokorenih premolara za bukalne kanale – 0,3 mm, a za palatinalne 0,1 mm, dok je u grupi molara najveće odstupanje uočeno kod lingvomezijalnih kanala donjih molara, a najmanje kod palatinalnih kanala gornjih molara. Ipak, za definitivan zaključak o pouzadnosti ovakvih merenja neophodna je provera kod veće grupe zuba nego u ovoj studiji, ali i podrobnija analiza morfologije kanala korenova zuba. Odstupanja u merenjima CBCT-om mogu se objasniti činjenicom da su dobijena kroz različite sagitalne preseke, što može uticati na ponovljivost merenja radne dužine.

ZAKLJUČAK

Merenje je pouzdanije ukoliko se realizuje i na meziodistalnim i na vestibulooralnim presecima, i pri tome izračunava srednja vrednost kao radna dužina. Nedostatak ove metode odontometrijskog merenja je činjenica da se referentne tačke određuju prema zakrivljenoj putanji kanala, što takođe može uticati na rezultate ponovnog merenja.