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Evaluation of the relationship between crown size and root canal morphology of mandibular incisors by cone beam computed tomography (CBCT)

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Abstract

Background: The main reason for the failure of endodontic therapy is the incomplete knowledge about the anatomical variation of root canals. One of the most important factors that leads to the failure of root canal treatment, is missed and untreated major root canals.

Objective: with respect to the complexity of mandibular incisors treatment and high prevalence of the second canal, and the possibility of the relationship between the crown size and the extra canal in these teeth, the aim of this study was to determine the relationship between crown size and root canal morphology in mandibular incisors with CBCT.

Methods: In this cross-sectional study, mandibular permanent incisors were randomly collected in Qazvin City, Iran, and were mounted in eight ternary groups on a plastic slot, using putty molding material. After preparation of Scot view, the samples were scanned by CBCT NewTom 5G. Afterward, the mesiodistal and buccolingual dimensions were measured by the software's measurement tool with a precision within tenths of a millimeter. In the next stage, a multi-planar option and 400% magnification tool of the software were utilized to study axial and cross sectional views of each tooth to determine canal type. Data were analyzed employing one-sample Kolmogorov-Smirnov, Levene, independent- samples t-test and Roc curve by SPSS version 20.

Results: The majority of mandibular incisors have a single canal (63.9% of them had type I canal system). In addition, 36.1% of the roots had two canals, among which, type III was the most common. The mean of maximum mesiodistal and buccolingual diameters in type III was significantly bigger than that in type I ($p<0.05$), but the means of crown size in the two canal types were not significantly different.

Conclusion: Despite increase in mesiodistal and buccolingual dimension in two canal mandibular incisors with type III canal system, their crown sizes (M-D/F-L index) were not significantly different, in comparison to single canal incisors.

Keywords: Crown Size, Cone Beam Computed Tomography, Mandibular Incisor, Root Canal Morphology

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1. Introduction

One fundamental prerequisite in achieving successful endodontic treatment is comprehensive knowledge about typical root canal shape and its varieties (1). Missed root canals are the reason for endodontic retreatment in 42% of the cases. Therefore, having comprehensive knowledge of a tooth's anatomy and paying meticulous attention to detail to minimize the failure and need for subsequent endodontic retreatment are critical (2). The mandibular incisors have the most difficult root canal treatment because of their small dimension and the high prevalence of presenting two canals (3). Root canal treatment procedure of these teeth is harder than that of molars, and is as tricky as that of mandibular two-canal premolars (4). In different anatomical studies, the prevalence of 11-68% was noted for second canal in mandibular incisors (5-10). This difference is due to the disparity in the study design (in vivo/ex vivo), canal identification techniques (direct observation with dental operating microscope, cross sections and direct observation, conventional and digital radiographic examinations, tooth staining and clearing, and micro-CT and CBCT scans, etc.) and/or racial diversity (10). There is a relationship between the crown size and the prevalence of bifid canals in these teeth. Nagas et al., in a morphometric study investigated the relationship between buccolingual dimension and root canal morphology in a total of 100 extracted mandibular incisors. Through measuring the buccolingual dimensions at the level of cementoenamel junction (CEJ), using a digital caliper, and then by grounding off the crown to expose root canal orifices, viewing under dental operating microscope, with magnification of 6.4x, and also taking digital radiography in buccolingual direction, they concluded that both the number and type of root canal were significantly affected by buccolingual dimension of the tooth. In addition, they found out that when the buccolingual dimension increases, the prevalence of two canals increases as well (7). Warren, for the first time, introduced the relationship between crown size (M-D/F-L index) and the prevalence of bifid canals. The smaller index in mandibular incisor tooth mostly indicates a double canal (11). An ideal method for identifying root canal morphology should be precise, simple, and non-destructive, and at the top, it should be useable in in vivo for diagnosis and evaluation prior to treatment. Unfortunately, the canal staining and tooth clearing method (gold standard) cannot be used in in vivo (12). Cone beam computed tomography technique (CBCT) is more accurate than digital radiography in recognizing the root canal system. In addition, in vivo is used for diagnosis and evaluation prior to treatment, and at the top, in terms of precision, it is comparable with the staining and clearing technique (8). This technology provides us with information about extra canals, apical deltas, canal type, and in general, a 3 dimensional image of root canal anatomy. Moreover, CBCT as our third eye, can be effective prior, during, and after endodontic treatment (13). Therefore, with respect to the complexities of mandibular incisors treatment, high prevalence of canal morphological varieties, the existence of extra canal in these teeth, and probable relationship between them and crown size, it is clear that CBCT is highly potential in examination and diagnosis of these cases. In this regard, we intend to use CBCT to determine the relationship between the crown size and root canal morphology in mandibular incisor teeth.

2. Material and Methods

The plan was carried out after being approved by the scientific committee, and observing moral codes adopted by the National Ethics Committee in Medical Sciences Research. This cross-sectional study was conducted on 202 extracted mandibular incisor teeth that were obtained from general dentists in Qazvin City, Iran. The selected teeth had complete roots and healthy external morphologies. The excluded teeth were: those with very narrow, blocked canals or other defects such as internal and external root resorption, as well as the endodontically treated teeth. Also, those with multiple decays encompassing much of the crown and root structure so that measuring the maximum MD and FL diameter of the crown was deemed impossible, were excluded. After immersing the teeth in 5.25% sodium hypochlorite for 15 min, the tissue tags, calculus, and bone spurs were removed by scaling and polishing the root surface. In order to homogenize and stabilize the samples' position, the teeth were placed inside the putty on the plastic tool. The desired model was in a circular form with eight slots for the samples. In each slot, three teeth were place inside the putty material. After preparation of Scot view, the scan was carried out by CBCT system (NewTom 5G, Verona, Italy). The specifications of the scan include a rotating gantry and a flat panel sensor in which the patient lies on the table (FOV=18×16cm, KVP=110, tube current=0.56. mA, mAS=2.69, exposure time=4.8, focal spot=0.3mm, and voxel=75 micro m). The obtained volumetric data was observed by endodontist and maxillofacial radiologist, using NNT Viewer. The observation was done using SONY monitor (VGN-FW490JAB) in a semi dark room. The following features were analyzed by 2 examiners (one endodontist and one maxillofacial radiologist): number of root canal, root canal configuration (vertucci classification), mesiodistal and buccolingual dimensions. Inter-rater agreement was measured between the endodontist evaluator and radiologist. Intra-rater agreement was measured by having the endodontist and radiologist evaluate one half of the CBCT images at each of 2 separate sessions. At first, mesiodistal and buccolingual dimensions of the tooth were measured, at the maximum point of diameter, by the software's measurement tool with a precision of tenths of a millimeter. In the next stage, multi-planar option and 400% magnification tool of the software were utilized to study axial and cross sectional views of each tooth with the purpose of determining root canal type. In addition, the root was examined from 0.1 mm of dimension using rooling button. The positions of pulp chamber floor and canal orifice were measured based on the law of centrality (first law) of Krasner and Rankow: the pulp-chamber floor is always in the center of the tooth at the level of the CEJ (14). Changing grayscale and sharpness characteristics allowed better resolution and contrast. In order to answer the research questions and hypotheses testing, check for normal distribution of data, examine the equality of variances, compare the mean of maximum mesiodistal diameter (M-D) variables, the maximum buccolingual diameter (B-L) and the crown size, one-sample K-S (Kolmogorov-Smirnov), Levene, and independent-samples t-tests were used in turn. Moreover, ROC Curve and the area under the curve were applied to evaluate the diagnostic value of the root canal type based on the mentioned variables. In this study, the type one error was set at 0.05, so the p-values below it, were considered statistically significant. We used IBM© SPSS© Statistics version 2o (IBM© Corp., Armonk, NY, USA) for data analysis.

3. Results

Of the total 209 teeth studied in this research, in 7 (3.3%) cases it was not possible to diagnose the root canal type due to canal calcification. From the remaining 202 teeth, there were two type II, one type IV, two type V, 129 (63.9%) type I, and 68 (33.7%) type III canal configurations. Of the teeth with two canals, Type III was the most common root canal system followed by Type II and Type V with 1%, and then Type IV. With respect to the small number of types II, IV, and V samples, only the results from comparison between type I and type III canals would be provided in the following. On this basis, 63.9% and 36.1% of teeth had, in turn, one and two canals. According to the results of one-sample (K-S) Kolmogorov-Smirnov test, distribution of the variables of maximum mesiodistal diameter (M-D), maximum buccolingual diameter (B-L), and crown size (M-D/B-L index), in the two canal types were normal with the minimum value of 0.56. Therefore, parametric tests were used for drawing comparisons. Additionally, variance equality of dependent variables in the two canal types was performed using Levene's test, and the minimum possibility value of 0.142 for equality of variances was accepted. Independent-samples t-test showed that there is a significant different between the mean of M-D in Type I and Type III canals ($p<0.05$). As seen in Table 1, the mean of M-D in Type III group is 4.85+0.62 mm bigger than that in type I with a mean of B-L of 4.55±0.69 mm, with respect to the mean of B-L, similar findings were obtained. In other words, the mean of B-L in type III is significantly bigger than that in type I ($p<0.05$). However, the average crown size (M-D/B-L index) was equal to 0.80±0.10 in type III and 0.78±0.12 in type I that according to independent T test, no significant difference was seen between the two types ($p=0.227$). According to ROC curve (Figure 1), the areas under the curve for M-D, B-L, and crown size (M-D/B-L index) variables were measured and their values were, in turn, equal to 0.624, 0.617, and 0.559. As the closeness of this index to 1, reflects higher effectiveness of the variable for detection, so maximum mesiodistal diameter (M-D), with a little difference to other two variables, is a better index for canal type detection based on the crown size criteria.

Table 1. Statistical indices of dependent variables in types I and III

Variable	Maximum Mesiodistal Diameter (mm)		Maximum Buccolingual Diameter (mm)		Crown Size	
Canal Type	I	III	I	III	I	III
Mean	4.55	4.85	5.86	6.1	0.78	0.80
95% Confidence Interval for the Mean of Lower Bound	4.43	4.70	5.77	5.96	0.76	0.77
95% Confidence Interval for the Mean of Upper Bound	4.67	5.00	5.96	6.20	0.80	0.82
Median	4.5	4.8	6.00	6.10	0.78	0.81
Standard Deviation	0.69	0.62	0.55	0.5	0.12	0.10
Range (Maximum-Minimum)	3.2 (6.2 - 3)	3.4 (6.8 - 3.4)	3.1 (6.9 - 3.8)	2.7 (7.2 - 4.5)	0.70 (1.22 - 0.52)	0.54 (1.08 - 0.54)

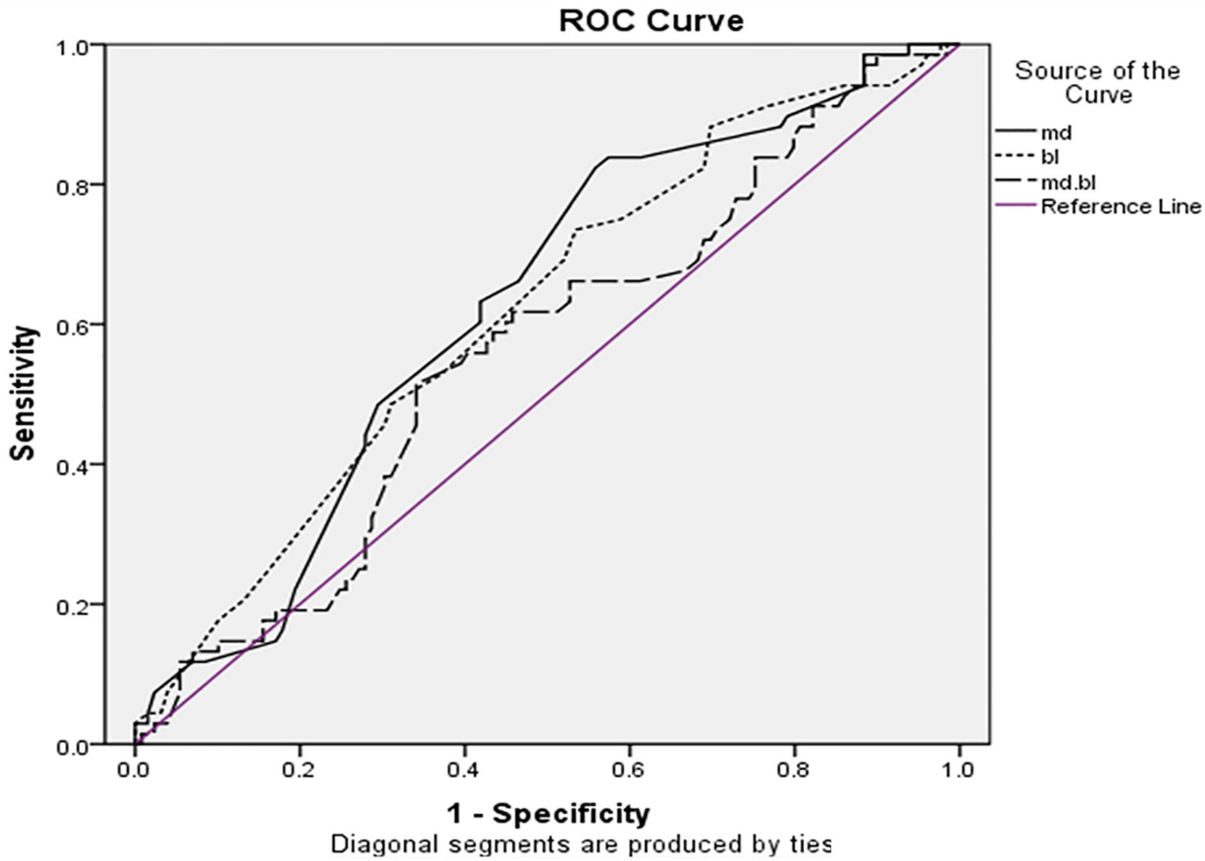

Figure 1: ROC curve of canal type detection based on the three variables namely M-D, B-L, and crown size

4. Discussion

The root canal morphology of mandibular incisors varies greatly in the reported articles, and the difference in prevalence is affected by factors such as sample size, examination methods, and ethnic diversity (7). In this study, crown size, number and type of root canal, and relationship between crown size, and the type and number of root canal (according to Vertucci's classification) in 202 mandibular incisors were studied, using CBCT. Our results, regarding number and type of root canal, show that mandibular incisors contain a single canal (Type I) in 63.9% of samples and two canals in 36.1% of samples. Boruah and Bhuyan, by using staining and clearing techniques, found that 65.6% of mandibular incisors had a single canal and 36.25% had two canals, which is consistent with the results of the present study (16). Rahimi and Milani, by using standard clearing technique, reported that 36.62% of mandibular incisors had two canals and the probability of these having two separate apical foramina was 0.64% (17). With two periapical radiograph surveys, Didar found that prevalence of a second canal in the mandibular lateral incisor was 38% (18), the results of the Didar study are almost similar to the results of the Sheikh study in which the prevalence of two root canals in the mandibular lateral incisor were 39% (19). These root canal morphologies are almost within the same range of the data of the present study and a slight difference can be justified by the tooth type, sample size and identification technique of the canals (CBCT or radiography). Scarlatescu et al., by using staining method, reported that the prevalence of a single canal and two canals in this group of mandibular incisors were 65.6% and 34.4%, respectively. Their findings were consistent with our study (20). Vertucci found that the presence of two canals in mandibular central and lateral incisors were, in turn, 30% and 25%, which is relatively close to the results of our study (6). Warren et al., in a study on 286 mandibular incisors, using radiography technique, reported that the presence of two canals in central and lateral incisors were, in turn, 43% and 36% (11). On the other hand, according to the present study, among the teeth containing two canals, Type III configuration was the most common (33.7%), followed by Types II and V, and then Type IV. These findings are in full agreement with the study of Boruah and Scarlatescu, as in their studies, Type III was the most common configuration, followed by Type II and Type V (16, 20). Nagas et al., in an investigation on 100 mandibular incisors, using digital radiography technique, noted Type II and Type III canals with the highest rate of prevalence (25% each), followed by Type V and Type IV (7). Al-Qudah, in a study on 450 mandibular incisors in a Jordanian population, revealed that 26.2% of these teeth possess two canals. In this research, Type II was the most common configuration followed by Type III, Type IV, and Type V. Al-Qudah's findings are inconsistent with ours. It seems that as this research shares a similar technique with previous studies, the results may have been affected by an ethnic diversity factor (10). Mauger et al., in an investigation on different levels of canal morphology of 100 mandibular incisors, reported that 98-100% of these teeth have a canal in the 1-3 mm of the apical, and the prevalence of two separate foramina, within this range is relatively 1-2%. These findings are in agreement with our study in that 98.6% of these teeth leave the pulp chamber with one apical foramen (Types I, II, and III), and 1.5% of them leave that with two separate apical foramina (Types V and IV) (21). According to the present study, the mean of maximum mesiodistal and buccolingual diameters of mandibular incisor crown of Type I were 4.55 and 5.86 mm, respectively. In addition, the mean of the mentioned diameters in root canal Type III were 4.85 and 6.08 mm, in turn. As can be seen, the mean of M-D and B-L in incisors possessing canal Type III is significantly higher than Type I ($p<0.01$). However, the average of crown size in incisors possessing canal Type III (0.80) is bigger than in incisors possessing canal Type I (0.78), but the differences between these values were not statistically significant ($p=0.227$). Nagas et al. used a digital caliper to measure buccolingual dimension at the level of cementoenamel junction (CEJ) and stated that when buccolingual dimension increases, the probability of the presence of two canals increases. This is in agreement with our study. It should be noted that in Nagas' study, the minimum buccolingual dimension is 6.4 mm while it is 3.8 mm in our study. It should be noted that Nagas et al. measured these values in the incisors possessing two orifices, and did not gauge the crown mesiodistal dimension (7). According to our findings, despite the fact that the mean of crown size in incisors possessing canal Type III was bigger than that in Type I, this difference was not statistically significant, so was inconsistent with Warren and Laws (11). They studied 286 mandibular incisor teeth and observed a significant relationship between crown size and the incidence of bifid. It means that when crown size decreases (Peck & Peck index) (22), incidence probability of bifid canal increases. It seems that the difference between these two studies is due to different crown measurement methods; they used a Mitutoyo caliper and we employed CBCT measurement methods. Moreover, differences between used examination methods (radiography versus CBCT) could be another reason. In addition, the role of subjective interpretations and bias should not be ignored. It should be added that in their study, however, the relationship between crown size and bifid canals is noted, it is not obvious whether the bifid canals stand for Type II, Type III, or Vertucci's classification. If the researchers meant canal Type II, it would be obvious that despite the presence of two orifices, buccolingual dimension would increase, so crown size index would decrease; while, in the present study, due to the presence of one orifice in the incisors possessing canal Type III, no relationship was seen between canal number and type, and crown size. In effect, it can be concluded that despite the increase in buccolingual and mesiodistal dimensions of Type III of two canals mandibular incisors, in comparison with single canal incisors, no significant difference in the two groups regarding the crown size (M-D/B-L index) was seen. Therefore, we aimed to see whether there is any relationship between the mean of M-D and the mean of B-L and root canals Type I and Type III. Put differently, to see whether it is possible to determine the canal type from the mean of respective maximum diameters. According to ROC curve, the areas under the curve were 0.625 for maximum mesiodistal diameter, 0.617 for maximum buccolingual diameter, and 0.559 for mean of crown size. As the closeness to 1 means better diagnosis of respective variable, so it was revealed that the mean of M-D, with a little difference from two other variables, is a better measurement for diagnosis of canal type based on crown dimensions. It can be seen that these findings are inconsistent with that of Nagas et al. To them, based on clinical experiences, buccolingual dimension should be considered as a major factor before treatment (7). To explain this paradox, it can be said that these researchers only examined the relationship between buccolingual dimension and root canal morphology in mandibular incisors, and ignored mesiodistal dimension. In the systematic studies carried out on the morphology and shapes of teeth roots, a huge variety of research methodology can be seen. However, this technology has not been used for studying the root canal morphology of mandibular incisors, a multitude of studies conducted on other dental groups implies the effectiveness of this technique. Neelakantan et al., compared different examination methods of canal morphology, including canal staining and clearing, CBCT, PQCT, SCT, and plain and contrast medium-enhanced digital radiography, and stated that CBCT is as precise as the canal staining and tooth clearing method (gold standard) in diagnosis of root canal system (12). Michetti et al., in their attempt to support CBCT as a tool for searching for root canal anatomy, concluded that (M-D/B-L index) the data acquired by CBCT and histology are strongly correlated (23). Matherne et al., in diagnosis process of root canal systems in 72 teeth, concluded that CBCT images lead to detection of more canals than CCD/PSP images (24). Therefore, CBCT is a more advanced diagnostic imaging technique that, in the field of endodontic science, is used for effective evaluation of root canals, and the diagnostic data provided by it would lead to better clinical results. Therefore, it can be a valuable tool in the field of modern endodontic experiments. However, despite the major advantage, it is unfortunately an expensive technology.

5. Conclusions

Due to the high incidence of Type III canals in mandibular incisors and regarding that the canals may join at 2-3 mm to apex, or merge approximately at apical foramina, we can divide Vertucci's Type III canal system into two separate groups, or at least add a subgroup to it. Therefore, it is recommended to perform research on this subject with the purpose of investigating the location of the canal junctions to apical foramina. Similarly, with respect to the lack of study on root canal morphology in mandibular incisors by CBCT, it is recommended to perform related studies with more samples.

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Conflict of Interest:
There is no conflict of interest to be declared.

Authors' contributions:
All authors contributed to this project and article equally. All authors read and approved the final manuscript.

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