

COMPARISON OF TOOTH LENGTH MEASURED WITH CONVENTIONAL PERIAPICAL VERSUS CONE-BEAM COMPUTED TOMOGRAPHY

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ABSTRACT

OBJECTIVES

To compare tooth length measurements obtained using intraoral periapical radiographs (IOPA) and CBCT in extracted single-rooted premolars.

METHODOLOGY

This cross-sectional comparative study was conducted at the Operative Dentistry Department, Riphah International Dental Hospital, Islamabad. Forty extracted single-rooted premolars from Pakistani patients aged 12-50 years were included. Teeth with incomplete root development, structural defects, metallic restorations, or severe attrition were excluded. After extraction, teeth were cleaned, disinfected, and mounted in a dry human mandible with modelling wax to simulate soft tissue. Tooth lengths were measured using IOPA with the paralleling technique and CBCT in the sagittal plane. Measurements were compared using paired t-tests, with stratification by age and gender.

RESULTS

The mean tooth length measured on IOPA was 19.78 mm (SD 1.44), while CBCT measurements were shorter at 18.18 mm (SD 1.37) ($p < 0.001$). This difference was consistent across all age and gender groups. Females had CBCT lengths of 17.98 mm versus 19.64 mm on IOPA, and males had 18.44 mm versus 19.96 mm. Participants aged 13–30 years had CBCT lengths of 17.91 mm versus 19.94 mm on IOPA, and those aged 31–50 years had 18.37 mm versus 19.66 mm.

CONCLUSION

CBCT consistently produced shorter tooth length measurements than IOPA, suggesting that periapical radiographs may overestimate tooth length. Its three-dimensional imaging allows precise localisation of the root apex, making it a reliable modality for endodontic measurement and treatment planning.

KEYWORDS: Tooth Length, Cone Beam Computed Tomography, Intraoral Periapical Radiograph, Endodontic Measurement, Root Apex Localization

INTRODUCTION

Accurate determination of tooth length plays a central role in the success of root canal treatment. One of the most common causes of endodontic failure is inaccurate working length estimation, which can result in underfilling or overfilling.^{1,2} Both conditions may leave behind infection or cause damage to the periapical tissues, ultimately compromising the healing process and long-term prognosis of the treated tooth.³ Establishing the correct working length is essential during both the preparation and obturation phases of root canal therapy.^{4,5} Effective cleaning and shaping must reach the full extent of the root canal system to remove necrotic tissue and bacteria. Similarly, obturation should completely seal the canal to prevent reinfection. An error in length determination at any stage can reduce the effectiveness of treatment and increase the risk of future complications.⁶ Over the

years, several techniques have been developed to estimate root canal length, ranging from traditional methods like tactile feedback and paper point use to more advanced tools such as electronic apex locators and radiographic imaging.⁷ Of these modalities, conventional periapical radiographs have traditionally been the diagnostic modality of choice due to their high levels of availability, cost-efficiency, and operational simplicity.⁸ However, due to the two-dimensional nature of the images produced, such radiographs may negatively impact the accuracy of measurements due to image distortions and overlay of other anatomical structures. Cone-beam computed tomography (CBCT) is a newer technological development that offers volumetric images and is potentially able to increase the accuracy of length measurements, especially those of anatomically complex or multi-rooted dentition.⁹ A previous study conducted in India reported that mean tooth length was 21.2±1.7mm with CBCT and

22.3±1.8mm with periapical radiograph.¹⁰ Though CBCT has shown promising results due to its lack of magnification error, questions remain regarding its routine use, particularly given the higher cost and radiation dose compared to traditional methods. So there is a need to compare conventional periapical radiographs and CBCT in determining tooth length. This will help guide the efficacy of periapical radiographs in determining tooth length. The objective of the current investigation was to compare tooth length measured with conventional periapical radiographs versus cone beam computed tomography.

METHODOLOGY

This cross-sectional comparative study was conducted at Operative Dentistry, Riphah Islamic International Dental Hospital, Islamabad, from October 28, 2025, to March 15, 2026, (Ref No. IIDC/IRC/2025/007/001, Dated: 01-07-2025) using a non-probability, consecutive sampling technique. The sample size was calculated in OpenEpi and was 80 (40 per group) extracted single-rooted premolar teeth, calculated at 80% power and a 95% confidence interval, using a mean tooth length of 21.2±1.7 mm with CBCT and 22.3±1.8 mm with periapical radiograph, based on a previous study.¹⁰ Since the same set of teeth was assessed using two different methods, the final sample size will be 40. The study included Pakistani nationals of both genders aged 12-50 years. Only teeth with complete root development and those that were structurally intact without any root damage were included in the study. Teeth containing metallic restorations were excluded. In addition, teeth with incomplete root apex formation, evident signs of root resorption, or marked occlusal surface wear due to attrition were also excluded from the study. Patients fulfilling the inclusion criteria who were referred from the Orthodontics Department to the Oral Surgery Department for extraction were selected. Written informed consent was obtained from all participants after a detailed explanation of the study. The age and gender of the participants were recorded. This study involved extracted single-rooted premolar teeth collected from patients undergoing orthodontic treatment. Only teeth with complete root development and no structural defects were included. After extraction, the teeth were thoroughly cleaned using ultrasonic scalers to remove any remaining soft tissue, calculus, or bone fragments. The cleaned specimens were then stored in 5% sodium hypochlorite solution in accordance with CDC disinfection guidelines. Below are the operational definitions used in the study. The length of the tooth was measured as the straight distance between the coronal reference point, which

was the tip of the cusp, and the apical end of the root canal. The measurement was recorded in millimetres. The traditional periapical radiograph (IOPA) refers to the periapical imaging assessment of tooth length using images produced with the paralleling technique. Tooth length was measured from the cusp tip to the apex of the root. Cone beam computed tomography (CBCT) was defined as a three-dimensional imaging method that provides volumetric images of the maxillofacial region using a cone-shaped X-ray beam. In this study, tooth length was measured on the sagittal plane using the digital ruler tool available in the CBCT software. The coronal reference point was the most occlusal point of the cusp tip, while the most distal point of the root was used as the apical reference point and served as the endpoint of the tooth-length measurement. The extracted teeth were placed in a dry human mandible in the alveolar sockets in order to simulate clinical situations, which involved ten specimens at a time. A buccal and lingual bilateral 15-mm-thick layer of modelling wax was applied and used to approximate the density of soft tissue. A wooden platform was made to hold the mandible to provide stability and impose a uniform orientation when taking imaging shots. Radiographic assessment was done using standardised imaging guidelines. The radiographs of every tooth were taken separately in the paralleling technique. Exposure was done using a Kodak Insight film, through a Satelac unit using a 0.40-second exposure time. The film was mounted perpendicular to the length of the tooth, and the X-ray beam was set perpendicularly to the film and the specimen. A film holder of XCP was fixed using modelling wax to maintain the same positioning. The radiographs that were obtained were scanned and reviewed by dental imaging software to measure the dimensions of the teeth, crowns and roots. Acquisition of the prepared mandible was done using cone-beam computed tomography (CBCT) at an accelerating voltage of 90 kV, a voxel size of 0.2 mm and a field of view of 5 x 8 cm to ensure that it was in the right position. Afterwards, individual teeth were pointed out in the multiplanar reformatted images, and linear measures were taken in the sagittal plane using the special software. To assess interobserver reliability, two observers independently measured the tooth length on all IOPA and CBCT images using the predefined coronal and apical reference points. The observers were trained and calibrated using the same measurement protocol before the formal assessment. The observers were blinded to each other's measurements and to the results obtained from the alternative imaging modality. Each observer recorded measurements independently in millimetres. Pearson's correlation coefficient was used to assess the correlation between measurements obtained by the two observers. The interobserver

correlation was high ($r = 0.91$), indicating strong consistency between the observers. The statistical tests were done in R 4.3.1. Continuous variables were tested for normality using the Shapiro-Wilk test. In cases like age and length of teeth, which were obtained using both intra-oral periapical radiography (IOPA) and CBCT, the arithmetic mean and standard deviation were calculated. Categorical variables, especially gender, were summarised in terms of counts and percentages. Paired-samples t -test was used in comparisons of tooth length in the two imaging modalities. Paired-samples t -test was also used to conduct subgroup analysis by gender and age in order to examine the possible modification effects. The p -value of less than 0.05 was taken to be statistically significant (two-sided).

RESULTS

All of our continuous variables were normally distributed, so parametric tests were run. (Table 1). The mean age of participants was 33.2 years (SD 10.15). The mean tooth length was 19.78 mm (SD 1.44) on intraoral periapical radiographs and 18.18 mm (SD 1.37) on cone beam computed tomography. Females accounted for 57.5% (23/40) and males 42.5% (17/40). Participants aged 31–50 years comprised 57.5%, while 42.5% were aged 13–30 years. (Table 2) Tooth length measured on cone beam computed tomography (mean 18.18 mm, SD 1.37) was significantly shorter than that measured on intraoral periapical radiographs (mean 19.78 mm, SD 1.44) ($p < 0.001$). (Table 3) Tooth length measured on cone beam computed tomography (CBCT) was significantly shorter than on intraoral periapical radiographs (IOPA) across all gender and age groups. For females, the mean CBCT length was 17.98 mm versus 19.64 mm on IOPA ($p < 0.001$), and for males, 18.44 mm versus 19.96 mm ($p < 0.001$) (Student's t -test). By age group, participants aged 13–30 years had mean lengths of 17.91 mm (CBCT) versus 19.94 mm (IOPA, $p < 0.001$), and those aged 31–50 years had 18.37 mm versus 19.66 mm ($p = 0.01$) (Student's t -test). (Tables 4 & 5)

Table 1: Normality Distribution of Continuous Data

Variable	W-Statistic	p-value
Age in years of the participants	0.956	0.121
Tooth length (intraoral periapical radiograph)	0.975	0.511
Tooth length (cone beam computed tomography)	0.970	0.349

* Shapiro-Wilk test

Table 2: Descriptive Statistics of Demographics and Tooth Length on Periapical Radiograph and CBCT

Variable	N=40*
Age, years	33.2 (10.15)
Tooth length (intraoral periapical radiograph)	19.78 (1.44)
Tooth length (cone beam computed tomography)	18.18 (1.37)
Gender	
Female	23 (57.5%)
Male	17 (42.5%)
Age group (years)	
13–30	17 (42.5%)
31–50	23 (57.5%)

Table 3: Comparison of Tooth Length Measured by Cone Beam Computed Tomography and Intraoral Periapical Radiography

Variable	Statistic	Cone beam computed tomography (CBCT)	Intraoral periapical radiography (IOPA)	Mean difference (95% CI)	p-value
Tooth length	Mean (SD)	18.18 (1.37)	19.78 (1.44)	-1.60 (-2.05 to -1.15)	<0.001

* Paired t -test

Table 4: Comparison of Tooth Length Measured by Cone Beam Computed Tomography and Intraoral Periapical Radiography According to Gender

Gender	Parameter	CBCT	IOPA	Mean difference (95% CI)	p-value
Female	Tooth length, Mean (SD)	17.98 (1.45)	19.64 (1.72)	-1.66 (-2.35 to -0.93)	<0.001
Male	Tooth length, Mean (SD)	18.44 (1.25)	19.96 (0.98)	-1.52 (-2.11 to -0.93)	<0.001

* Paired t -test

Table 5: Comparison of Tooth Length Measured by Cone Beam Computed Tomography and Intraoral Periapical Radiography According to Gender

Age group (years)	Variable	Cone beam Computed Tomography (CBCT)	Intraoral Periapical Radiography (IOPA)	p-value
13–30	Tooth length, Mean (SD)	17.91 (0.67)	19.94 (1.58)	<0.001
31–50	Tooth length, Mean (SD)	18.37 (1.70)	19.66 (1.36)	0.01

* Student's t -test

DISCUSSION

The current study aimed to compare tooth length measurements, obtained using conventional intra-oral periapical radiographs (IOPA) and cone beam computed tomography (CBCT) in extracted single-rooted premolar samples. The findings also revealed

that CBCT-related measurements were always shorter in comparison with those of IOPA in all the participants of the study, regardless of age and sex. Such a difference implies that there is no concordance between the two imaging methods and that IOPA has a systematic overestimation of the actual length of the teeth anatomy. The observed difference was statistically significant and was observed in younger (13-30 years) and older (31-50 years) cohorts, male and female subjects, which supports the presence of an effect associated with the imaging modality per se (and not demographic characteristics). The differences that have been observed can be attributed to the inherent technical and geometrical peculiarities of these two imaging modalities. The cone-beam computed tomography (CBCT) provides real three-dimensional volumetric images, which allow us to view the root apex directly, in various orthogonal views: sagittal, coronal and axial.¹¹ The three-dimensional representation minimises the superimposition of the adjacent structure and also allows a more accurate localisation of the apical terminus.¹² In comparison, traditional periapical radiographs form two-dimensional shadows of naturally three-dimensional anatomy; these projections are prone to magnification, foreshortening, and distortion, which are contingent on X-ray beam angulation and/or positioning. The apical region can be covered by superimposed structures, including adjacent teeth or alveolar bone, which frequently causes the apparent increase in the length of the tooth on radiographs.¹³ In addition, slight changes in X-ray beam orientation or film location can be of great concern on intra-oral periapical (IOPA) images. However, CBCT measurements are relatively immune to these errors as they are volumetrically reconstructed and the position of the linear measurement tools is more than simple to use with specialised software. Such considerations are probably the underlying factor in the shorter tooth lengths always reported with CBCT in the current study. Our findings support the findings of previous *in vitro* studies. Sherrard et al.¹⁴ observed that tooth and root lengths measured using CBCT were similar to those measured using digital callipers and that periapical radiography significantly overestimated tooth length in particular premolars and incisors. Similarly, Kumar et al.¹⁵ also found that CBCT provided very high reliability and accuracy in the measurements of both root and crown length, but the intraoral periapical radiographs were prone to very high deviations, which could be mainly due to projection errors. Combined, these studies highlight the fact that the three-dimensional imaging that CBCT allows enables a more accurate assessment of the dental anatomy, thus reducing the tendency at overestimation that is inherent to two-dimensional radiographic methods.

Nevertheless, clinical and *in vivo* studies have recorded slightly different results in a number of cases. As an example, Bhullar et al.¹⁶ and de Moraes et al.¹⁷ found that cone-beam computed tomography (CBCT) values were more likely to be highly precise, but the differences to those of periapical radiographs were often not statistically significant. The heterogeneity of this kind may be explained by several factors such as the occurrence of periapical lesions, the anatomic variability of people, and discrepancies in measuring methodology. Periapical pathology may blur the apex of roots on intraoral periapical (IOPA) images, therefore changing the apparent root length. On the other hand, CBCT allows visualisation of the apex and surrounding bone structures and the surrounding bone structure with precision. In addition, the voxel size, software tools used in measurement, and calibration of observers can alter results, particularly in the clinical setting where patient movement and soft tissue interference can produce small errors. All of these considerations, in turn, suggest that, though the general trend is toward greater accuracy of CBCT, the extent of its superiority over IOPA might vary depending on certain clinical and methodological factors. Unlike the available literature on the study of obturation and working length, such as that of Cheng et al., the study established that CBCT could detect discrepancies in radiographically adequate obturations, with about 30 per cent of the cases that were acceptable on IOPA having an unacceptable length on CBCT.¹⁸ This fact highlights the clinical importance of CBCT in endodontics, where accuracy in determining the measurements of teeth and roots is crucial in cleaning of the canal, shaping and obturation. This information is expanded to extracted premolars by the current study, which proves that CBCT values are closer to the actual anatomical lengths and, thus, reduce the potential errors related to the procedure when implementing endodontic and restorative treatment.

LIMITATIONS

This study has several limitations. The relatively small sample size (n=40) and inclusion of only extracted single-rooted premolars may limit the generalizability of the findings to other tooth types and clinical situations. The *in vitro* design and use of a dry human mandible with modelling wax could not fully replicate clinical conditions such as patient movement and soft-tissue variation. In addition, no independent gold-standard method, such as direct measurement with a digital calliper, was used to determine the actual anatomical tooth length. CBCT measurements were also obtained only in the sagittal plane, which may have introduced measurement variability. Therefore, larger

in vivo studies involving different tooth types and direct reference measurements are recommended.

CONCLUSIONS

Measurement of the tooth length by means of cone-beam computed tomography (CBCT) always reported shorter lengths in comparison with those of periapical radiography in all age and sex groups, indicating that intra-oral periapical radiographs (IOPA) could be overestimating the tooth length. The CBCT volumetric imaging allows more accurate localisation of the root apex, and thus, it makes it a more reliable modality for accurate endodontic measurements and treatment plans.

CONFLICT OF INTEREST: None

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AUTHORS CONTRIBUTION

Ijaz Ul Haq - Concept & Design; Data Acquisition; Drafting Manuscript; Supervision; Final Approval

Alia Ahmad - Concept & Design; Data Acquisition; Drafting Manuscript; Final Approval

Perkha Ali - Concept & Design; Data Acquisition; Data Analysis/Interpretation; Drafting Manuscript; Final Approval

Arooba Nazami - Concept & Design; Data Acquisition; Drafting Manuscript; Final Approval

Toqir Ahmad - Concept & Design; Data Acquisition; Drafting Manuscript; Critical Revision; Final Approval

The authors accept responsibility for all aspects of the work and will ensure that any concerns regarding the accuracy or integrity of any part are properly investigated and resolved.



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