Original Article

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Dentistry Section

Predictability of Proximal Enamel Thickness Assessment using Intraoral Periapical Radiographs: A Cross-sectional Study

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ABSTRACT

Introduction: Measurements of tooth crown dimensions and enamel thickness are useful guides for interproximal stripping procedures aimed at creating space. In borderline non extraction orthodontic treatment cases, interproximal stripping is performed to gain space. Intraoral periapical radiographs and bitewing radiographs are commonly used to determine Proximal Enamel Thickness (PET).

Aim: To determine the predictability of using IOPA-based PET measurements for assessing real/anatomic PET.

Materials and Methods: This was a single-centre, cross-sectional study conducted at Saveetha Dental College and Hospital, Chennai, Tamil Nadu, India, between March 2022 and April 2022. Digital Intraoral Periapical Radiographs (IOPAs) of 40 premolar teeth with intact crown structures were obtained using the paralleling technique. The PET of both the mesial and distal sides of the same teeth was measured using Carestream Imaging software. Subsequently, the extracted teeth were sectioned and examined under a Stereomicroscope (SM), and PET measurements of the mesial and distal surfaces were obtained along the heights of contour using ImageJ analysis software. Pearson's correlation, along with linear and polynomial regression analyses, was performed using International Business Machines (IBM) Statistical Package for Social Sciences (SPSS) software.

Results: A low but significant positive correlation between the PET of the sectioned teeth and the PET measured from IOPAs was observed ($p=0.002$, $R=0.55$). A significant difference in PET between the two methods for both sides was noted ($p<0.05$). The mean distal enamel thickness was significantly greater than the mean mesial enamel thickness for both the IOPA and SM methods ($p<0.05$). A polynomial regression equation, $Y=2.084-1.234X+0.318X^3$, was established to predict PET of the sectioned teeth (Y) based on PET measured from IOPAs (X).

Conclusion: The present study establishes a correlation between the true PET of teeth measured using cut-sections and PET measured from IOPAs, which are readily available in clinical practice. A correlation coefficient was determined, and PET can be predicted using IOPAs, although not with absolute accuracy. Distal PET was found to be higher than mesial PET, with no significant difference in enamel thickness between the two sides.

Keywords: Dental digital radiography, Dental enamel, Dental radiography, Microscopy, Tooth preparation

INTRODUCTION

The surfaces of the teeth facing towards adjoining teeth in the same dental arch are called proximal or proximate surfaces. The proximal surface may be either mesial or distal [1]. A systematic review reported that the distal PET was higher than the mesial by an average of 0.10 mm (ranging from 0.09 to 0.12 mm) [2]. Symmetry of the proximal thickness is observed in both right and left contralateral teeth [3]. The enamel thickness of permanent teeth does not significantly differ between genders, and males have wider teeth [4]. Interproximal attrition is a dynamic physiological process that presents as occlusal facets of various sizes and shapes in modern populations. Proximal attrition facets are typically located on the upper half of the crown's proximal aspect [5]. In each tooth, the mesial facet is positioned more lingually, while the distal facet is positioned more buccally due to the progressive increase in lingual inclination towards the posterior [6]. In primitive civilisations, proximal attrition problems like tooth crowding, impacted molars, and rotations were not common [7].

Assessing PET is important before carrying out procedures such as Interproximal Reduction (IPR), which is commonly used by orthodontists to create space. Interproximal reduction involves stripping of the proximal enamel, and various authors have suggested limiting enamel stripping to not more than 50% of the total enamel thickness. Since enamel tissue is non regenerative and can be susceptible to dental caries after IPR, it is crucial to assess PET conservatively [8]. Ignoring PET could result in dental tissue involvement and adverse effects [9].

Previous studies have utilised various methods to determine PET. In-vitro methods include sectioning the teeth and measuring using vernier callipers, profilometers, and stereoscopic microscopes [5, 10-12]. Clinically, intraoral periapical radiographs and bitewing radiographs are most commonly used [13-16]. Other techniques include orthopantomography, Computed Tomography (CT), micro-CT, and cone beam computed tomography [17-19]. Although there are several radiographic methods available, no previous literature has evaluated their accuracy with tooth cut-sections.

Reliable measurements of tooth crown dimensions and enamel thickness would be a useful guide for orthodontists during the stripping procedure [20]. Variations in PET may have clinically significant ramifications in treatment planning in these areas. With non extraction treatment using IPR as a method of creating space, it is vital for orthodontists to have comprehensive clinical information on enamel thickness and IPR. Measuring PET on IOPAs as a chair-side procedure will negate the need for more extensive and invasive procedures for PET measurement. Literature on the correlation between PET measured on IOPAs and actual PET is not available. Thus, the present study was designed to determine the predictability of using IOPA-based PET measurements for assessing real/anatomic PET and to assess the enamel thickness on either of the proximal surfaces of both sides.

MATERIALS AND METHODS

This was a single-centre, cross-sectional study conducted at Saveetha Dental College and Hospital, Chennai, Tamil Nadu, India, between March 2022 and April 2022. Ethical clearance was obtained

from the Institutional Review Board prior to the commencement of the present study, and it was provided with the following number: IHEC/SDC/ORTHO-2105/21/655.

Inclusion criteria: Completely erupted human permanent premolar teeth with intact and undamaged crown structure were included in the study.

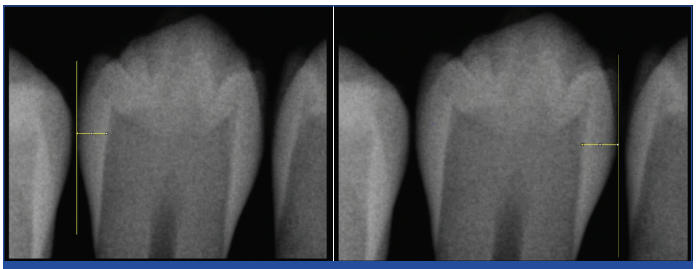
Exclusion criteria: Restored, attrited, decayed teeth, and teeth with developmental anomalies were excluded.

Sample size calculation: The sample size calculation for the present study was performed using G Power software (Heinrich Heine University, Dusseldorf), version 3.0.10. The study conducted by Macha A de C et al., was used as a reference for sample size calculation [11]. The alpha level and power were set at 0.05 and 80%, respectively, resulting in an estimated sample size of 40. The teeth were collected from an adult Indian population aged between 19 and 40 years.

Study Procedure

The in-vivo part of the present study involved taking IOPA radiographs of 20 subjects scheduled for fixed orthodontic treatment who required tooth extraction. In all subjects, either the 1st or 2nd premolars were extracted for orthodontic reasons.

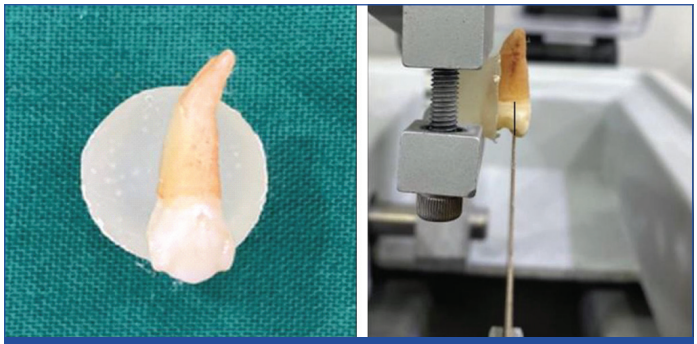
Radiographs: Digital IOPAs were taken using the Carestream Kodak RVG 5000 sensor, based on SuperCMOS Scintillator Optical Fibre technology, with a resolution of 16 LP/mm. All periapical radiographs were taken using the paralleling technique with an RVG sensor positioner [21]. The settings used were 60 kVp, 7 mA, and 0.32 s, with standardised contrast settings [3]. The radiographs were then viewed and measured using Carestream Kodak imaging software (USA). In each digital radiograph, lines were drawn marking the mesial and distal heights of contour. A perpendicular line was then drawn to the dentinoenamel junction. The measurements were made in millimetres using two-dimensional design measurement software [Table/Fig-1,2]. The scale of the radiographs was determined with an electronic dental calliper. The primary investigator performed all measurements to minimise error and maintain consistency. The same investigator repeated the measurements after a week with five samples, and the intraclass correlation coefficient was used to determine the intrarater reliability of tooth measurements.



[Table/Fig-1]: Mesial PET measured on IOPA.
[Table/Fig-2]: Distal PET measured on IOPA. (Images from left to right)

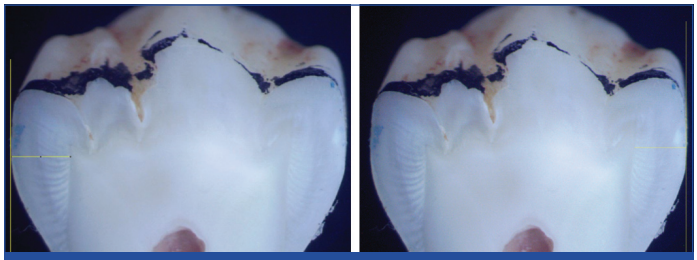
Tooth preparation: After taking intraoral periapical radiographs, the included teeth were extracted with care to avoid damaging the enamel surface. After extraction, the teeth were washed in a saline solution to remove blood residues and then stored in 3% hydrogen peroxide. The specimens (n=40) were numbered, and measurements for the mesial and distal surfaces were performed for each tooth.

A surveyor was used to mark the height of contour on the proximal surfaces of the teeth. A line was drawn along the greatest mesiodistal width on the occlusal surface and extended through the heights on contour on both proximal surfaces. Each tooth was positioned vertically in a 20 mL vial with the demarcated line parallel to the long axis of the vial, using a moulding paste at the bottom of the vial [Table/Fig-3]. Subsequently, each tooth was embedded in transparent epoxy resin. After curing, the block was sectioned using a Leica SP1600 saw microtome (Leica Biosystems, Nussloch, Germany) along the demarcated line to obtain the greatest mesiodistal width of the tooth [Table/Fig-4]. To avoid damaging the specimens, the diamond disc speed was set at 200 rotations per minute [11].



[Table/Fig-3]: Extracted tooth embedded in transparent epoxy resin.
[Table/Fig-4]: Extracted tooth sectioned using Leica SP1600 saw microtome. (Images from left to right)

The sectioned specimens were then viewed under an SM {LB-340 Zoom Stereo Microscope with Light-emitting Diode (LED) Illumination, Labomed Inc, USA} connected to a computer. Digital images were acquired by a coupled camera and imported into the ImageJ analysis software (University of Wisconsin, USA) for taking tooth measurements. The sections were viewed at 70x magnification. Subsequently, the measurements were made using the software ruler [Table/Fig-5,6].



[Table/Fig-5]: Mesial PET measured using Stereomicroscope (SM).
[Table/Fig-6]: Distal PET measured using Stereomicroscope (SM). (Images from left to right)

STATISTICAL ANALYSIS

The statistical analyses were performed using IBM SPSS Software version 23.0. Descriptive statistics were used to determine the mean PET values. Pearson's correlation test, along with linear and polynomial regression analyses, was conducted to investigate the possible correlation between the PET values of the sectioned teeth and those obtained from IOPAs. An independent Student's t-test was performed to test the level of significance between the PET of the mesial and distal surfaces, right and left teeth, and SM and IOPAs.

RESULTS

Of the included teeth, 16 (40%) were from male patients, and 24 (60%) were from female patients. The intrarater reliability, determined using the intraclass coefficient, was highly reliable (ICC- 0.824). The Shapiro-Wilk test showed that the data followed a normal distribution ($p>0.05$).

Descriptive statistics for the mesial and distal PET values obtained from both the SM and IOPA methods has been presented in [Table/Fig-7]. A significant difference in PET was observed between the two methods for both the mesial and distal sides ($p<0.05$). The mean distal enamel thickness was significantly greater than the mean mesial enamel thickness ($p=0.045$, 0.025). However, when comparing the mean mesial and distal PET values between the two sides, no significant differences were found in either the IOPA or SM methods [Table/Fig-8] (Mesial side using IOPA ($p=0.11$), Mesial side using SM ($p=0.67$), distal side using IOPA ($p=0.12$), Distal side using SM ($p=0.98$).

Measurement	Mean (mm)	SD (mm)	p-value
Mesial PET SM	1.18	0.12	0.009
Mesial PET IOPA	1.23	0.11	
Distal PET SM	1.20	0.11	0.044
Distal PET IOPA	1.28	0.15	
Mean PET SM	1.19	0.12	0.02
Mean PET IOPA	1.26	0.13	
Mesial PET SM	1.18	0.12	0.045
Distal PET SM	1.20	0.11	
Mesial PET IOPA	1.23	0.11	0.025
Distal PET IOPA	1.28	0.15	

[Table/Fig-7]: Descriptive analysis and t-test for significance of the difference between PET of mesial and distal surfaces derived from SM and IOPA.

Measurement	Groups	Mean (mm)	SD (mm)	p-value
Mesial SM	Right-side	1.17	0.13	0.672
	Left-side	1.19	0.12	
Mesial IOPA	Right-side	1.24	0.05	0.117
	Left-side	1.32	0.14	
Distal SM	Right-side	1.2	0.12	0.982
	Left-side	1.2	0.12	
Distal IOPA	Right-side	1.12	0.10	0.121
	Left-side	1.34	0.13	

[Table/Fig-8]: Descriptive analysis and t-test for significance of the difference between PET of right and left-sides derived from SM and IOPA.

Pearson's correlation test showed a significant positive correlation between the PET values obtained from SM and IOPA (p=0.002, R=0.55). Linear [Table/Fig-9] and polynomial regression analyses [Table/Fig-10] were conducted to estimate the strength of the correlation between the SM values and those obtained from IOPA. The linear regression equation was as follows (R^2=0.114):

Y=0.826+0.288X (F=4.87; p=0.033)

The polynomial regression equation was as follows (R^2=0.171):

$Y=2.084-1.234X+0.318X^3$ (F=3.08; p=0.031)

Here, Y represents the PET of sectioned teeth, and X represents the PET measured on IOPA.

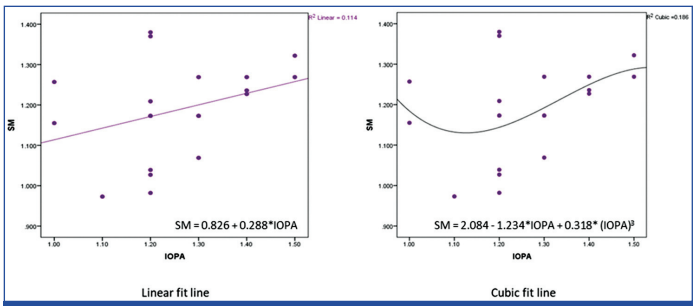
	Coefficients					
	Unstandardised coefficients		Standardised coefficients			
Variables	B	Std. Error	Beta	R^2 (Linear)	t	Sig.
IOPA	0.288	0.130	0.337	0.114	2.208	0.033
SM	0.826	0.165			5.015	0.000

[Table/Fig-9]: Linear regression equation.

	Coefficients					
	Unstandardised coefficients		Standardised coefficients			
Variables	B	Std. Error	Beta	R^2 (Cubic)	t	Sig.
IOPA	-1.234	0.964	-1.444	0.171	-1.279	0.209
$(IOPA)^3$	0.318	0.200	0.413		1.592	0.031
SM	2.084	0.807			2.583	0.014

[Table/Fig-10]: Polynomial regression equation.

There was no linear relationship between the SM and IOPA measures [Table/Fig-11]. Therefore, the linear regression equation is a poor choice, and polynomial regression provides a better model compared to linear regression, as indicated by the R^2 values of these models. R2 represents the coefficient of determination. With the polynomial regression equation, an R^2 of 0.171 suggests that the independent variable (IOPA measure) can predict 17.1% of the variance in the dependent variable (SM measurement). With the linear regression equation, an R^2 of 0.114 suggests that the independent variable (IOPA measure) can predict 11.4% of the variance in the dependent variable (SM measurement). However, the correlation between the two variables is only a low positive correlation (r=0.337 linear; 0.413 cubic).



[Table/Fig-11]: Scatter plot of PET values from IOPA and Stereomicroscope (SM).

DISCUSSION

Accurate determination of the PET of teeth is of immense importance to orthodontists for planning interproximal reduction. The aim of the present study was to establish a correlation coefficient for predicting PET using IOPAs. The PET measured using SM significantly differed from the PET measured using IOPAs. The distal PET was higher than the mesial PET in all teeth, and no difference in PET between the two sides was observed. The results of the study showed a low positive correlation between the PET of the sectioned teeth and the PET measured from the IOPAs.

Previous studies that evaluated PET on both sides of the same teeth found no difference in the measured PET between them [3,10-12]. Most studies comparing the PETs of the mesial and distal sides concluded that the PET on the distal side is thicker than the PET on the mesial side [2,3,10,12,13]. For example, Veillini-Ferreira et al., evaluated enamel thickness in permanent dentition using a profilometer and reported that the distal proximal enamel was 0.1 mm thicker compared to the mesial side. This value increased to 0.2 mm in the mandibular canine and first premolar [3]. Munhoz et al., measured the PET of maxillary first premolars using profilometers and found that the distal enamel was thicker than the mesial enamel [10]. Harris EF et al., observed similar findings using IOPAs, with 0.1mm more enamel on the distal side compared to the mesial side [13]. Macha A de C et al., viewed cut-sections of maxillary premolars under a SM and reported that the distal PET of the upper first premolars was 0.2 mm greater than the mesial side [11]. Stroud JL et al., measured the PET enamel thickness of permanent mandibular posterior dentition and reported that the distal enamel thickness was significantly greater than the mesial enamel thickness [15]. Akli E et al., scanned maxillary canines using microcomputed tomography and measured enamel thickness using MATLAB software. They found that the mesial enamel coverage was thinner than the distal enamel coverage [18]. However, a study by Konstantinidou E et al., found no significant difference between the mesial and distal proximal surfaces. The study used micro-CT to evaluate enamel thickness of mandibular incisors [22]. Another study by Yagci F et al., found that mesial enamel thickness was greater than distal enamel thickness. They also found that mesial enamel thickness was greater on the right side compared to the left side and thicker in females compared to males [20]. The results of the present study are in accordance with most of the studies mentioned above [2,3,10,11,13]. However, Yagci F et al., found mesial enamel thickness to be greater than distal enamel thickness, which contradicts the findings of the present study [20]. This discrepancy may be because Yagci et al., measured enamel thickness at the incisal, middle, and cervical thirds of the crown height, whereas most of the studies, including this one, measured PET at the thickest or maximum height of contour.

Interproximal stripping, when done judiciously does not lead to an increased incidence of enamel caries in patients undergoing orthodontic therapy with fixed bonded appliances [23]. This technique, when executed properly, can help achieve treatment objectives without compromising the integrity of dental and periodontal tissues. The present study involves the accurate measurement of mesial and distal PET of teeth from cut-sections and correlates it with IOPA, which is readily available in dental practices.

A correlation coefficient was established between the PET of the sectioned teeth and that obtained from IOPAs. Similar correlation coefficients and regression formulas were developed between tooth size and orthopantomograms by Yassaei S et al., [24]. Other studies by Staley RN et al., Ballard ML et al., Ballard ML and Wylie WL, Ingervall B et al., and Ingervall B and Lennartsson B, reported correlations and prediction equations between the intraoral periapical radiographic widths of unerupted canines and premolars and the cast widths of the same teeth after eruption [25-27].

Limitation(s)

Only premolar teeth were included in the present study, and the PET measurements may vary in other teeth. Gender or age-related differences in PET were not considered in the present study, which is a limitation.

CONCLUSION(S)

Within the limitations of the study, it can be concluded that PET can be predicted to some extent using IOPAs, as indicated by the established correlation coefficients. However, the prediction may not be very accurate. The distal enamel thickness was found to be greater than the mesial enamel thickness, and no significant difference in enamel thickness between the two sides was observed.

In the future, further research could expand the scope to include all teeth and use a larger sample size to establish a more accurate correlation.

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- Manual Googling: Aug 12, 2023
- iThenticate Software: Sep 02, 2023 (9%)

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