Vertical angulation mandibular first premolar tolerance in periapical projection radiography

O E Heryanto, B Nehemia and H B Iskandar*

Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Universitas Indonesia, Jakarta 10430, Indonesia

*E-mail: hanna.bachtiar@gmail.com

Abstract. One evaluation criterion of a radiograph is vertical distortion, which is relatively more common in periapical radiographs of the mandibular premolar region. This study determined the vertical angle changes that can be tolerated in periapical radiographs of mandibular premolars. The lengths of 30 already extracted mandibular first premolars were measured clinically and radiographically. Periapical radiography projections were obtained with vertical angles set at 0°, +10°, +15°, +20°, −10°, −15°, and −20°. Then, tooth length and the difference in cusp height were measured by two observers twice at different times. There was no significant difference in tooth length at vertical angulations of 0°, +10°, +15°, +20°, −10°, and −15° (P > 0.05). On the other hand, a significant difference was noted in the buccal-lingual cusp difference (P < 0.05). In standard periapical radiography, a 10° change from the normal vertical angulation could be tolerated still to measure the vertical dimension or tooth length of the mandibular first premolar tooth.

1. Introduction

Based on the results of Indonesian Household Survey in 2004 conducted by the Indonesian Ministry of Health, dental and oral disease affects 90% of the population in Indonesia [1], indicating that Indonesians have a high level of dental and oral care needs. More than 80% of dental cases require radiographic examination for the management of dental and oral diseases [2]. However, radiographic examination has limitations, such as distortion. In 2011, at the Faculty of Dentistry Universitas Indonesia, the radiographic accuracy measured from vertical distortion occurring on the periapical intraoral radiograph, especially the anterior region, reached 47.9% only, while that in the posterior region reached 46.15% only [3,4].

In dentistry, radiology is performed for further examination of the condition of bone and teeth, number of teeth, and bone density, among other uses. Dental radiography techniques are divided into two types based on the location of the film: intraoral (film placed in the mouth) and extraoral (film placed outside the mouth). Most intraoral radiography techniques were periapical, especially in endodontic cases, to determine the presence of dental abnormalities, such as secondary caries and periodontal tissue conditions [5]. Accurate vertical dimensions are required for the precise management of remaining bone tissue in periodontitis cases or determining the working length in endodontic cases [6]. Any accurate radiographic result should meet the optimal quality criteria, such as the objectives of the examination; with the desired object covered and located in the middle of the radiograph; good detail, sharpness, and the optimal contrast; good vertical and horizontal angles; and minimal distortion [5,6].

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Generally, the distortion of conventional radiographs can occur vertically or horizontally in the form of elongation, shortening, or resizing [6]. If the buccal and lingual cusps are not in a plot and affect the vertical measurement dimensions required for inspection purposes, the radiograph should be repeated. In general, radiograph distortion is influenced by the position of the X-ray source, the object, and location of the radiographic film [7]. If the vertical angle is too large, the tooth image on the radiograph will be shortened, whereas if it is too small, the image will be elongated [5,8]. For anterior teeth, on the shortened object, the cingulum is more radiopaque, and the width increases, while in elongation, the radiopaque region of the cingulum will be widened and blend into the thinner part of the crown, making it less radiopaque than normal. For posterior teeth, vertical distortion can be seen by determining whether the buccal or lingual/palatal cusp is in the plot; that is, determining the height difference of the buccal and lingual or palatal cusps anatomically ranging from approximately 0.3 to 2 mm. In addition, the presence or absence of vertical distortion of the posterior tooth can be predicted by looking at the interdental alveolar crest position rather than the actual or proper state. Positioning an ideal radiographic film in the mouth, either with parallel or bisection techniques, is not always possible, so radiographic techniques sometimes must be modified [9,10].

In 2000, Gegl and Fontanella studied the maximal vertical angle that can be tolerated in maxillary incisors [11]. To our knowledge, no study has been done on the posterior tooth, especially the premolar teeth, whose position in the jaw arch lies between the anterior and posterior regions. In periapical radiography, the radiographic preparation of the premolar tooth must necessarily include the distal tooth canines, two premolar teeth, first molar, and part of the second molar teeth [12,13]. The region is located in the corner of the jaw arch, making it relatively difficult to position the film in the mouth [5].

Based on the vertical distortion that is relatively more common in the manufacture of periapical radiographs, especially in the lower jaw premolars located relatively on the angle of the jaw, a study was needed to determine the amount of distortion in the vertical angle changes that can be tolerated still. The vertical angle reference used in the world literature was $-10^\circ$ for mandibular premolar teeth in bisection techniques, but the vertical angle used in Indonesia was $-15^\circ$ [5,6]. Due to patient anatomy and limitations of radiographic techniques, vertical distortion cannot be avoided; however, it is necessary to find the tolerance so that it does not affect the measurements or their prediction in the vertical dimension. In general, vertical distortion of the posterior teeth can be seen from the difference in the buccal cusp and the lingual heights on the radiograph. We attempted to determine how large a maximum vertical angle change can still be tolerated so that the radiograph can still be interpreted well. In addition, we determined the precision of the prediction method of vertical distortion by measuring the difference in buccal and lingual cusp heights to determine whether the distortion can be tolerated still.

2. Methods

Samples of 30 mandibular first premolar teeth were extracted in good condition (no attrition, good apical foramen conditions, and no caries). Two different observers used a digital caliper to measure the sample length twice. Then, these measurements were tested for intra- and interobserver reliability using the Dahlberg formula, which is used to determine the error value of the Technical Error of Measurement (TEM) technique [14,15]. Then, the root of the tooth was coated with wax for approximately 1 mm.

After that, the premolar teeth were implanted in a $1.5 \times 1.5 \times 3$ cm cast and a periapical radiograph was obtained with vertical angles of $0^\circ$, $+10^\circ$, $+15^\circ$, $+20^\circ$, $-10^\circ$, $-15^\circ$, and $-20^\circ$ with an 8 cm distance between the film and X-ray tube. Exposure time was 0.13 second, using an Ezsensor digital sensor. Tooth length and the difference in the buccal and lingual cusp heights on the resulting radiographs were measured (using EasyDent Viewer digital software) by enlarging the radiograph, marking the tip of the buccal cusp and the root tip by a red line, and then drawing a line from the tip of this tooth mark. These measurements were performed by two different observers each twice at different times, and were calibrated and adjusted to the size of the pixels in the EasyDent Viewer software. The measured data were recorded on the data form. Then, after obtaining the inter- and intraobserver TEM values, the data with the lowest TEM value were obtained and analyzed for normality and significance with a statistical program.
3. Results
Tables 1 and 2 show the average teeth length and difference in the buccal and lingual cusp heights obtained from the software.

**Table 1. Average tooth length**

| Tooth Length | Amount | Mean ± Standard Deviation (mm) |
|--------------|--------|--------------------------------|
| Angle $-20^\circ$ | 30 | $23.43 \pm 1.79$ |
| Angle $-15^\circ$ | 30 | $23.06 \pm 1.65$ |
| Angle $-10^\circ$ | 30 | $22.81 \pm 1.58$ |
| Angle $0^\circ$ | 30 | $22.26 \pm 1.45$ |
| Angle $+10^\circ$ | 30 | $21.95 \pm 1.60$ |
| Angle $+15^\circ$ | 30 | $21.78 \pm 1.59$ |
| Angle $+20^\circ$ | 30 | $21.64 \pm 1.63$ |

**Table 2. Average difference in cusp tooth height**

| Difference of Cusp Tooth Height | Amount | Mean ± Standard Deviation (mm) |
|--------------------------------|--------|--------------------------------|
| Angle $-20^\circ$ | 30 | $2.46 \pm 0.60$ |
| Angle $-15^\circ$ | 30 | $2.04 \pm 0.55$ |
| Angle $-10^\circ$ | 30 | $1.66 \pm 0.53$ |
| Angle $0^\circ$ | 30 | $1.17 \pm 0.42$ |
| Angle $+10^\circ$ | 30 | $0.66 \pm 0.37$ |
| Angle $+15^\circ$ | 30 | $0.48 \pm 0.34$ |
| Angle $+20^\circ$ | 30 | $0.25 \pm 0.25$ |

Tooth length was directly proportional to the difference in cusp height; the more positive the vertical angle, the greater the difference in cusp height decrease and the greater its superimposition (Fig. 1).

![Figure 1. Tooth length and cusp difference.](image-url)
The more negative the vertical angle, the greater the teeth length increase and the difference in the buccal and lingual cusp height of the first premolar.

Statistical tests were performed to determine the normality of the distribution of data. In the normality test, teeth length showed a normal distribution ($P > 0.05$), so that parametric and independent $t$-tests could be done to determine a significant difference between angles [16]. The angles compared were between $0^\circ$ and $+10^\circ$, $0^\circ$ and $-10^\circ$, $0^\circ$ and $+15^\circ$, $0^\circ$ and $-15^\circ$, $0^\circ$ and $+20^\circ$, and $0^\circ$ and $-20^\circ$. However, in the normality test of difference in cusp height, there was one abnormal result for a difference in cusp $+20^\circ$ ($P < 0.05$). Therefore, a nonparametric Mann-Whitney $U$ test was used between angles $0^\circ$ and $+20^\circ$. For cusp data at other angles, an independent $t$-test was used, with $P > 0.05$ indicating statistical significance for normal distributions.

4. Discussion

In this study, when compared to the clinical tooth length, tooth length at a $10^\circ$ angle showed a difference of 0.55 mm at a negative angle and 0.31 mm at a positive angle. Statistically, this difference was not significant ($P > 0.05$), so that the vertical angle of $10^\circ$ is still tolerable. Tooth length at a $15^\circ$ angle only changed by 0.8 and 0.48 mm, respectively (not statistically significant, $P > 0.05$), so a vertical angle of $15^\circ$ positive and negative can be tolerated still. Tooth length at a $20^\circ$ angle changed by 1.17 and 0.62 mm, respectively. Statistically, this was not significant; therefore, it was tolerable. However, the difference at the $-20^\circ$ angle was significant, so that the $-20^\circ$ angle cannot be tolerated. At the negative angle, the tooth length increases caused vertical distortion in the form of elongation, compared to the shortening that occurred at a positive angle.

The differences in cusp tooth heights at negative and positive angles were 1.66 and 0.66 mm, respectively, at an angle of $10^\circ$, 2.04 and 0.48 mm, respectively, at a $15^\circ$ angle, and 2.46 and 0.25 mm, respectively, at a $20^\circ$ angle. Statistically, the difference in clinical angle with all comparable angles was ($P < 0.05$); therefore, for all the vertical angle changes, the change in cusp difference could not be tolerated. The cusp difference in this case could not tolerate the vertical angle change at $+10^\circ$, $+15^\circ$, $+20^\circ$, $-10^\circ$, $-15^\circ$, and $-20^\circ$. This result is not in accordance with the theory expressed by Langlais [17] on the difference in the cusp buccal and lingual posterior teeth of $1\sim2$ mm to determine the minimal vertical distortion. This is likely due to the variation of cusp differences and the fact that, to our knowledge, no studies have shown the average cusp difference especially in the mandibular first premolar teeth.

Figure 1 is an image of the average yield obtained in Tables 1 and 2. The tooth length and cusp difference are directly proportional; that is, the longer the tooth length, the greater the difference in cusp tooth height, and, conversely, the smaller tooth length, the smaller the differences in cusp tooth height as well.

From our results, we concluded that a vertical angle change of $10^\circ$ can be tolerated still. These results were similar to those of Gegler and Fontanella [9] showing that the error in vertical angle could be tolerated in the upper incisors. In their study, dental inclinations were altered at the vertical angle of $+10^\circ$ and $-10^\circ$ with X-ray source position parallel to the radiographic film. The $10^\circ$ angle seen from the difference in tooth length can be tolerated still. In this study, X-ray tubes were altered with radiographic films positioned parallel to a tooth axis. Likewise in this study, in the posterior tooth, especially the mandibular first premolar, the same results were found at a $10^\circ$ vertical angle, such that there was no significant tooth length change of less than 1 mm [8].

5. Conclusions

Based on the results using vertical angle changes of $+10^\circ$, $+15^\circ$, $+20^\circ$, $-10^\circ$, $-15^\circ$, and $-20^\circ$, it is concluded that positive and negative vertical angle changes of $10^\circ$ and $15^\circ$ can be tolerated still to estimate the vertical dimensions of periapical intraoral radiographs on mandibular first premolar teeth. Differences between buccal and lingual cusp heights on periapical radiographs with vertical angle changes of $+10^\circ$, $+15^\circ$, $+20^\circ$, $-10^\circ$, $-15^\circ$, and $-20^\circ$ are not tolerable statistically, but the average result of
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cusp difference on vertical angle change of $10^\circ$ is a tolerable range still, according to the theory of quality evaluation guidelines. This study results are less in line with existing theories, which may be due to the smaller number of samples.

6. References

[1] Data statistik kasus penyakit gigi dan mulut. Juni 2012 [cited 2013 Jun 14]. Available from: http://lontar.ui.ac.id/file?file=20313350-T%2031725-Evaluasi%20radiografi%20tanggung%20full%20text.pdf

[2] Kasus kedokteran gigi [cited 2013 Jun 13]. Available from: http://staff.ui.ac.id/internal/131126137/material/PendekatanINTERPRETASI.pdf

[3] Arleny Y S 2011 (Jakarta: Fakultas Kedokteran Gigi Universitas Indonesia) Kesalahan Angle Vertikal Pada Pembuatan Radiograf Periapikal Regio Anterior oleh Mahasiswa Profesi FKG UI.

[4] Dennis A 2011 (Jakarta: Fakultas Kedokteran Gigi Universitas Indonesia) Kesalahan Angle Vertikal Pada Pembuatan Radiograf Periapikal Regio Posterior oleh Mahasiswa Profesi FKG UI.

[5] Pharoah M J and White S C 2009 Oral radiology: Principle & Interpretation 6th ed (St. Louis: Mosby) p 46–109

[6] Whaites E 2003 Essentials of Dental Radiography and Radiology 3rd ed (London: Churchill Livingstone) p 75–100

[7] Carlton R R 2005 Principles of Radiographic Imaging an Quality Control 4th ed (United States: Harles C. Thomas Publisher Spring Field Illinois) p 236–45

[8] Langlais R P 2004 Exercises in Oral Radiology and Interpretation (Saunders: Texas) p 56–65

[9] Haring J I, Howerton L J 2000 Dental Radiography : Principles and Techniques 2nd Edition. (Saunders: Philadelphia) p. 154-63.

[10] Pretty I A and Maupome G 2004 A closer look at diagnosis in clinical dental practice: part 3. effectiveness of radiographic diagnostic procedures J. Can. Dent. Assoc. 70 392

[11] Gegler A and Fontanella V 2008 In vitro evaluation of a method for obtaining periapical radiographs for diagnosis of external apical root resorption Eur. J. Orthod. 30 315–7

[12] Iannuci J M and Howerton L J 2011 Dental Radiograph: Principles and Techniques 4th ed (Missouri: Elsevier) p 168–90

[13] Perini T A, Olieveira G L, Ornellas J S and Oliveira F P 2005 Technical error of measurement in anthropometry Rev. Bras. Med. Esporte 11 86–90

[14] Hogg R V and Tanis E 2009 Probability and Statistical Inference 8th ed (Pearson: London) p 221–3

[15] Ulijaszek S J, Tanley C G and Lourie J A 2005 Anthropometry: The Individual and The Population (Cambridge University Press) p 30–55

[16] Soekidjo N 2005 Metode Penelitian Kesehatan (Rineka Cipta : Jakarta) p 188

[17] Sopyyudin D M 2008 Statistik untuk Kedokteran dan Kesehatan. Edisi 5 (Jakarta: Salemba Medika) p 75–80.