Tolerance of vertical angle alteration on lower molar periapical radiographs in the laboratory

A S Primazetyarini, H Suryonegoro* and S I Syahraini

Department of Radiology, Faculty of Dentistry, Universitas Indonesia, Jakarta 10430, Indonesia

*E-mail: herusuryonegoro@yahoo.com

Abstract. Tolerance of vertical angle alteration is an important aspect to minimize vertical distortion on lower molars radiographs. To analyze the tolerance of vertical angle alteration on periapical radiograph of lower molars, measurement of clinical tooth length was performed for 30 lower molars, which were then planted in models. Radiographic examination using periapical radiography was performed seven times for each tooth with vertical angles 0°, +5°, +10°, −5°, −10°, and −15°. Tooth length and buccal and lingual cusp height differences on radiograph were measured. The result showed that a positive vertical angle alteration of 15° during periapical radiographs of lower molars to view tooth length is tolerated.

1. Introduction
The first molars, which erupt when a child is between 6 and 7 years old, are the first permanent teeth to erupt [1]. The early eruption of the first molars makes these teeth the first and longest exposed to oral conditions [2]. The time of eruption of first molars is fairly rapid, and this happens when there are still many primary teeth in the oral cavity. First molars are often mistakenly thought to be primary teeth.

Many children and parents are less attentive to the hygiene of first molars because they believe that the first molars will be replaced by permanent teeth [3]. As a result, first molars are very susceptible to caries [3], and the prevalence of caries of the first molars increases with age. The prevalence of caries of the first molars in 6–8-year-old children is 25.8%, that for 9–11-year-old children is 54%, and that for 12–13-year-old children is as high as 72%.

It is important to note that if a carious tooth is not immediately treated, the carious lesions will become more widespread and deeper and cariogenic bacteria may invade the dentin and pulp. The invasion of bacteria into the pulp results in irreversible pulpitis, if not treated immediately. In these advanced cases, the required treatment is a root canal [4]. Approximately 36% of dental cases requiring root canal treatment are those with irreversible pulpitis, whereas 30.80% are those with pulp necrosis and 27.20% are those with apical periodontitis. A total of 59.18% of dental cases treated by root canal are caused by caries and 29.97% of cases are due to errors in previous root canal treatment. The lower first molars are the first and most commonly treated with root canal, with the lower right molar treated first 9.12% of the time and the lower left molar treated first 7.07% of the time [5].

The goal of root canal treatment is to prevent or eliminate dental pathosis that originates in the pulp, so the tooth can be retained for as long as possible in the mouth [6]. The success rate of root canal treatment is generally high at 85%–92% [7, 8]; however, in root canal treatment for the first
molars, the success rate is still quite low at 18.52% [9]. This is due to the varied and complex morphology of molar teeth and incorrect working length of root canal resulting in root canal failure due to apical perforation and overfilling, with post-treatment incidence of pain [10, 11].

The working length of root canal is one of the determinations in root canal treatment that is key to the success of the treatment. According to the American Association of Endodontists Glossary of Endodontic Terms, the working length of the root canal is defined as the distance from the reference point of the crown to the point of preparation and obturation of the root canal that must be terminated. The point at which root canal preparations should be terminated within the apical range is the cementodentinal junction, commonly thought to be at the apical constriction. The apical constriction is the smallest area in the root canal system. Although the apical constriction is a well-described anatomical feature, the determination of the working length to this point is still required [12]. If the exact working length of the root canal is known, it can ensure precise pulp expenditure and filling without underfilling or overfilling [13]. The working length in root canal treatment can be determined based on the average length of the tooth, tactile sensation, patient response, radiographs, and an electronic apex locator [12].

Determining the recommended working length for root canal treatment is achieved using the electronic and radiographic methods; however, it is most commonly determined using the radiographic method. Although the electronic method provides more accurate results, the working length is generally determined radiographically [7]. The radiographic method uses a periapical radiograph with parallel or bisection techniques. In practice, radiographic length assignment has several limitations such as distortion, elongation and shortening, variations in interpretation, and lack of three-dimensional aspect. Even if a parallel technique is used in the radiographic method, distortion is still found 5% of the time [13].

In Ingle’s method of determining the working length of the root canal radiographically, it is necessary to reduce the length of the preoperative radiograph by at least 1 mm safety allowance because of the possibility of distortion and magnification of the image [14]. If there is lengthening or shortening of the radiographic image because of vertical distortion, it is very likely to cause an error in determining the working length of the root canal. This will certainly affect the success of the treatment [15].

Exposure to X-rays cannot be avoided in making radiographs. Although the dose of radiation required for the production of periapical radiographs is very small, the dentist should still minimize the radiation exposure received by the patient based on the principles of As Low as Reasonably Achievable [16, 17]. If there is a vertical distortion on the radiograph, the radiograph should be repeated; however, this may expose the patient to unnecessary radiation [18]. Vertical distortions have tolerable limits so repetition of radiographic examinations can be avoided. To date, the vertical distortion indicator on the mandibular tooth is the height difference between buccal and lingual cusps. [19]. Buccal and lingual cusps can be plotted, and vertical distortion can be tolerated if the height difference of cusp ranges from 1 to 2 mm [20]. Until the current study, there have been no studies on the effectiveness of these indicators for determining the vertical distortion of radiographs on the lower molars. In the production of periapical intraoral radiographs with bisection techniques, the arrangement of vertical angulation or vertical angle must still be noted [21].

The main purpose of this research is to analyze whether the vertical angle can still be tolerated during the production of radiographs with a periapical projection of the lower molar. If so, the clinicians can be more attentive to vertical angle tolerance and accuracy in the determination of working length when using the radiographic method to provide the best clinical outcomes for root canal treatment of the lower molars.

2. Methods

This research used 30 lower molars, consisting of 15 lower first molars and 15 lower second molars. Equipment included Belmont Phot-X II EX10G0062 series X-ray and cone-beam device, digital X-
rays sensor, EzDent software (Vatech), and Microsoft Windows XP-based laptops for radiographic proofing.

Before planting in the model, measurements were taken on the 30 lower molars from the mesiolingual cusp peak to the mesial root using a digital caliper. Each tooth was planted to the cervical level in the model with the position of the tooth perpendicular to the axis of the tooth. Next, after setting up Windows XP on the laptop that was connected with EzDent’s digital X-ray sensor, the embedded gear position in the model was set so that the buccal section was facing toward the cone and the lingual section was facing toward the X-ray sensor. The side models close to the lingual part of the tooth were affixed parallel to the X-ray sensor using isolation, with both perpendicular to the horizontal plane. The vertical angle of the cone was set to 0°, and then the position of the cone was arranged so that the X-rays could spread throughout the entire tooth, from the crown to the root. The digital X-ray sensor recommended that the distance from the center of the cone to the X-ray sensor should be at least 8 cm in length. The exposure time for X-rays was set to 0.13 s, and radiographic examination was performed. The same step was repeated with vertical angles of +5°, +10°, +15°, −5°, −10°, and −15° by changing the vertical angle of the cone.

After radiographs of the 30 teeth were taken seven times for each tooth, the measurement for the length on the radiograph of each tooth from the mesiolingual cusp to the mesial root and the difference in mesiolingual and mesiobuccal cusps using the EzDent software was completed. The data on the clinical work length and work length were entered in the statistical software to be processed and analyzed. The clinical dental and radiographic length data as well as the high-differential data of the buccal cusps were analyzed using the Shapiro–Wilk normality test. For tooth length data, if the data were normally distributed, the dental clinical length and length of the dental radiograph at +5°, +10°, +15°, −5°, −10°, and −15° were tested using paired t-test to identify the average difference. However, if the data was not abnormally distributed, the clinical tooth length and radiographic length were tested using the Wilcoxon test.

If data were normally distributed, the radiographic length and the high difference data of the buccal cusp were tested using paired t-test. The comparison was between the high difference data of the buccal cusp at the vertical angle of 0° and the high difference data of the buccal cusp at the vertical angles of +5°, +10°, +15°, −5°, −10°, and −15°.

3. Results

Descriptive data and the mean of clinical tooth length, radiographic, and difference in buccal and lingual cusp height can be seen in Table 1.

Table 1. Clinical–radiographic tooth length and difference in buccal and lingual cusp height

| Vertical Angle (°) | N  | Radiographic Tooth Length (mm) | Difference in Radiographic Buccal and Lingual Height (mm) |
|-------------------|----|-----------------------------|----------------------------------------------------------|
|                   |    | Mean | Standard Deviation | Mean | Standard Deviation |
| -15               | 30 | 19.81 | 1.84              | -0.39 | 0.24             |
| -10               | 30 | 19.88 | 1.80              | -0.13 | 0.20             |
| -5                | 30 | 19.97 | 1.77              | 0.07  | 0.14             |
| 0 (Clinical)      | 30 | 19.92 | 1.79              | 0.27  | 0.14             |
| +5                | 30 | 20.26 | 1.82              | 0.39  | 0.19             |
| +10               | 30 | 20.47 | 1.83              | 0.59  | 0.28             |
| +15               | 30 | 20.74 | 1.86              | 0.86  | 0.35             |
The results of the paired t-test between clinical length and radiographic length data with vertical angles +5°, +10°, and +15° showed that the values were significant at 0.000 (p < 0.05) and there was a difference in the mean between the two groups. Meanwhile, the results of the paired t-test between the clinical length and the tooth length data of the radiograph, with a vertical angle of −5°, showed a significant value of 0.486 (p > 0.05), indicating that there was no significant difference between the mean of the two groups (Table 2).

**Table 2.** Results of the paired t-test between the clinical length and the radiographic tooth length

| Radiographic Tooth Length | Clinical Tooth Length (0°) | Mean Difference ± SD | Confidence Level 95% | p       |
|---------------------------|----------------------------|----------------------|----------------------|---------|
| +5°                       | 0.33 ± 0.25                | 0.24-0.42            | < 0.001*             |
| +10°                      | 0.54 ± 0.30                | 0.43-0.66            | < 0.001*             |
| +15°                      | 0.81 ± 0.39                | 0.66-0.96            | < 0.001*             |
| -5°                       | 0.08 ± 0.32                | 0.07-0.16            | < 0.486**            |

*p<0.05; **p>0.05

The results of the Wilcoxon test between the clinical tooth length and the radiographic tooth length using positive vertical angles of +5°, +10°, and +15° showed significance at p > 0.05, indicating that there were no significant differences between the mean of the two groups. Wilcoxon test showed a high difference between the data of buccal and lingual cusps at angles of 0° and +5°, +10°, +15°, −5°, −10°, and −15° and obtained the same significance value of 0.000 (p < 0.05), which meant there was a significant difference between the mean of each group.

4. Discussion

When angles are more positive (+5°, +10°, or +15°), the measured radiographic length of teeth from the lingual cusp peak to the root of the molar can be longer. Conversely, if the vertical angle is more negative (−5°, −10°, or −15°), the radiographic length of teeth will be shortened. This agrees with the theory of vertical distortion in the technique of periapical bisection, which states that the greater vertical angle of the teeth will be shortened, and if the vertical angle that is used is not sufficient, the teeth will appear elongated [21]. The vertical angle that is used in molar bisection techniques ranges from −5° to 0° [22]. The part of the lower molars that is below the occlusion line makes the vertical angle range negative. If the negative vertical angle is too large, the lower molars will appear shortened, and if the positive vertical angle is not sufficient, the teeth will appear elongated [21].

The paired t-test between the clinical length of teeth and the radiographic length uses a vertical angle of −5°, which shows no significant difference between the mean of the two groups. The mean difference between the clinical tooth length and the radiographic tooth length with the vertical angle of −5° matches the theory of angles. The theory states that the vertical angle used in the lower molar molecular bisection technique is −5° [22]. However, if the average difference between the clinical tooth length and the radiographic tooth length using a positive vertical angle of +5°, +10°, and +15° is compared with the average difference between the clinical tooth length and the radiographic tooth length using a vertical angle setting of −5°, −10°, and −15°, the average difference between the clinical tooth length and the radiographic tooth length using positive vertical angles are more meaningful than that between the clinical tooth length and the radiographic tooth length using negative vertical angle settings. This may be caused by a different vertical angle area.

In a negative vertical angular setting that is matched to the lower molars below the occlusal line, the average difference between the clinical tooth length will not be significant. In a positive vertical angle setting, the average difference in the clinical tooth length is more significant when compared with the negative vertical angle setting because the angle does not match with the location of the tooth below the occlusal line [21].
In Ingle’s method of determining the working length of root canal treatment with radiographs, there is a safety allowance of 1 mm for possible distortion and magnification [14]. In the current study, the vertical distortion tolerance limit of dental length is <1 mm. After analyzing the comparative results between the average clinical length and the average radiographic length of the tooth, best vertical angle alteration tolerance is +15° because the difference in average clinical tooth length and the length of the tooth at a vertical angle of +15° had reached −0.81. The radiographic tooth length at a vertical angle of +15° had increased by 0.81 from the average clinical length with a deviation of ±0.39. It is estimated that if the vertical angle is changed to +20°, the radiographic tooth length will increase significantly to ≥1 mm. The negative vertical angle alteration tolerance cannot be established because for up to −15° angle, the average difference between the clinical tooth length and the radiographic tooth length has not shown any significant difference.

In this study, high-differential measurements of buccal and lingual cusps were not clinically performed. As a result, it is not known if the high difference data of the buccal and lingual cusps at an angle of 0° are the same with the difference in clinical height of buccal and lingual cusps. Furthermore, there is still no research about the average difference in high buccal cusps of the lower molars in Indonesians who can be used as reference for this research. Therefore, the high differences in buccal cusps cannot be used as references for determining the tolerance of vertical angle alteration to visualize the length of the teeth. Tolerance for changing of vertical angles in molars will bring attention to the vertical angle arrangement of the periapical bisection technique so that vertical distortion can be minimized.

If an error is made adjusting the vertical angle but the angle is still tolerable, the operator does not need to repeat the radiographic examination, thereby minimizing unnecessary X-ray exposure. When determining the working length of the root canal by the radiographic method, the tolerance of vertical angle alteration can allow the clinician to obtain a working length with minimal vertical distortion, avoiding errors in determining the working length.

5. Conclusions
The tolerance of +15° vertical angle alteration for the lower molar is best to visualize the length of the tooth. However, the tolerance of negative vertical angle alteration in the tooth cannot be ascertained because up to −15°, the average difference in the clinical tooth length and the average radiographic tooth length are not significantly different.

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