ORIGINAL RESEARCH

A Novel 20° X-ray Angle Shifter for Superimposed Canal Separation

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Abstract

Aim and objective: The purpose of this study was to evaluate the efficacy and frequency of a 20° angle Shifter in separating superimposed canals on multirooted tooth radiographs.

Materials and methods: Radiographs from patients with 38, 44, and 39 of two-canal maxillary premolars, three- and four-canal mandibular molars, respectively, were taken at a horizontal 20° mesial and distal shift using the Shifter. The radiographs were evaluated by two examiners using the PowerPoint program. The percentage of distinctly separated canals in both shifted radiographs was analyzed using the Chi-square test ($p = 0.05$). The strength of agreement between each examiner (intra and inter) was evaluated using kappa statistics ($p < 0.05$).

Results: The percentage of acceptable radiographs using the mesial and distal shift for both examiners was similar for maxillary premolars. However, the distal and mesial shift was superior compared with the mesial and distal shift in separating the root canals in three- and four-canal mandibular molars, respectively. The strength of agreement between examiners evaluated using kappa statistics ($p < 0.05$) was substantial-almost perfect.

Conclusion: The Shifter efficiently separates superimposed canals. The advantage of the Shifter is the precise radiograph angle taken and at the same position during the multiple steps requiring radiographs in endodontic treatment.

Clinical significance: The same position of the tooth on the multiple-step radiographs in endodontics is the benefit of this novel shifter.

Keywords: 20° angle, Canal separation, Radiograph.

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Introduction

Radiographic evaluation is important in most root canal treatment steps, beginning from measuring the working length to determining the accurate root canal length for cleaning and shaping the canals through the final root canal filling. An accurate working length prevents pushing the instruments, debris or necrotic tissues, or irrigant into the apical tissue as well as determining the end position of the root canal filling material, which affects the long-term success rate of root canal treatment.[1,2] Currently, endodontists typically use an electronic apex locator (EAL) for measuring the root canal length to determine the working length.[3] However, in some cases, a radiograph is still used for working length determination before continuing root canal treatment. The disadvantage of using a periapical radiograph is that the three-dimensional tooth is represented on a two-dimensional film. The depth of the buccolingual aspect of the tooth cannot be shown on a radiograph, especially for mandibular molars and maxillary premolars that have superimposed roots.

Gulabivala et al.[4] revealed that 61% of first mandibular molars have three canals and 31% have four canals. Moreover, 58 and 17% of secondary mandibular molars have three canals and four canals, respectively. Approximately 70% of maxillary first premolars have two canals; 29% have one canal, and only 1% have three canals. In maxillary second premolars, the incidence of one canal is 82% and of two canals is 18%.[5] Thus, there is a high chance that a periapical radiograph of these teeth would have superimposed canals that are not sufficiently diagnostic for use in endodontic treatment.

To generate a high-quality radiograph with separated root canals, shifting the X-ray tube on the horizontal plane in the mesial or distal direction is usually used based on the buccal object rule,[6] which refers to when the position of the X-ray tube is moved mesially to the tooth. The radiograph was taken in this manner then shows the separated root canals in which the lingual canal is always closer than the buccal canal. Due to this phenomenon, the buccal object rule can be also interpreted as SLOB or the same lingual opposite buccal.

Radiographs taken where the X-ray is perpendicular to the film are less effective in separating superimposed root canals compared with those taken using a 20° horizontal mesial or distal

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shift.[7] Several studies have confirmed that radiographs were taken using a 20°[8] or a 40° horizontal shift[9] produced separated root canals. Another study of 120 patients with four-canal mandibular molars found that a 20° mesial shift was more likely to generate radiographs with distinct root canal separation compared with a distal shift.[10]

Despite these findings, shifting the X-ray tube by approximately 15–20° horizontally in daily practice by endodontists may not acceptably separate superimposed root canals due to the lack of equipment to indicate the exact angle. Thus, it is necessary to retake the radiograph to achieve an acceptable quality film. This takes extra time, and most importantly the patient is exposed to more radiation. Therefore, the distinct canal separation equipment is needed in the process of radiography.

The Shifter, a novel instrument (an innovation from Rangsit University, pending patent No. 1801001126), can be used with the EndoRay II and XCP Rinn (Dentsply Rinn, PA, USA), which are regularly used in endodontic treatment. The Shifter can be used for setting a 20° horizontal mesial or distal angulation of the X-ray tube to generate radiographs with separated superimposed root canals. However, the use of the Shifter in producing radiographs with separated root canals has not been clinically investigated.

Therefore, the objective of this study was to evaluate the efficacy and frequency of generating radiographs with separated superimposed root canals in multirooted teeth in endodontic procedures when using the 20° Shifter for mesial and distal angling the X-ray tube.

Materials and Methods

Participant Selection

The study involved three groups of 121 patients (sample size calculated using nQuary Advisor program using 80% power) with 38 maxillary premolars with two canals, 44 mandibular molars with three canals, and 39 mandibular molars with four canals that had been clinically determined to require endodontic treatment by dental students at the comprehensive dental clinic, College of Dental Medicine, Rangsit University, Thailand. Mandibular molars with a C-shaped root canal were excluded. The study protocol was approved by the Ethics Committee of the Research Institute, Rangsit University (RSEC 42/2560).

Endodontic Treatment Procedure

A dental student prepared an access opening on each tooth under the close supervision of an endodontist. A radiograph was taken using the EndoRay II and the Shifter, using the 20° mesial and distal shift angulation as indicated on the Shifter in one of the following steps: working length determination after using an EAL, master cone fitting, or root canal filling.

Radiographic Procedures

The rubber dam frame was removed from the tooth, and a film was inserted into the film holder, and the aiming arm was connected to the EndoRay II body along with the aiming ring positioned at the end of the attachment rod. This assembly was placed over the tooth such that its position was parallel to the buccal surface of the tooth and the patient was requested to slightly occlude on the assembly and the vertical angulation was adjusted. The X-ray tube was positioned in the center position of the aiming ring.

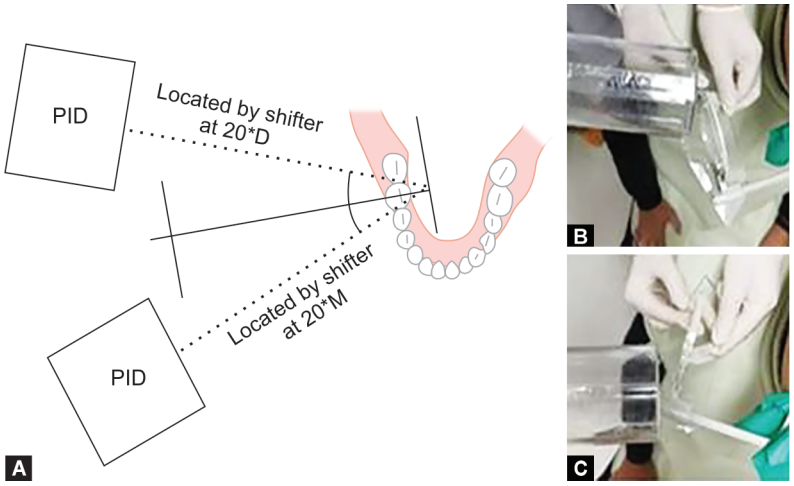
The mesial and distal radiographs were taken by fitting the Shifter slot on the aiming ring. The housing arm of the X-ray tube was moved horizontally in the mesial direction until the center of the ring was parallel to the 20° mesial shift indicating line on the Shifter. The X-ray tube was not moved upward or downward, only the horizontal angle was changed from 0° to +20°. The mesial shift radiographs were then taken. The distal shift radiographs were taken using the same Shifter as mentioned above; however, the other side of the indicating line was parallel to the X-ray tube (Fig. 1). The procedure was performed by the radiologist.

Radiograph Processing

Two radiographs of each tooth were taken with horizontal angulations of +20° (M), or –20° (D) with a PSIX Phosphor Plate Standard Imaging Plate Size 2 (SOPRO, La Ciotat, France). The images were exposed using a digital apparatus (GENDEX expert DC, Chicago, IL, USA) set at 65 kVp, 7 mA, 0.32 seconds, and 0.4 seconds scan time for the mandibular molars and maxillary premolars. The radiographs were obtained using a PSPIX[2] sopro Imaging plate scanner (SOPRO, La Ciotat, France).

Radiographic Image Evaluation

The radiographs from each patient were retrieved and arranged using the PowerPoint program. Each set of radiographs were



Figs 1A to C: Diagram showing the Shifter as the guide for a mesial and distal shift (A) and experimental set-up at a 20° angulation on tooth 46 from the distal shift (B) and the mesial shift (C) (pending patent no. 1801001126)

shown at the same magnification. The images were evaluated by two calibrated endodontists, each with >10 years of experience. The endodontists evaluated the separation of the superimposed root canals on the radiographs obtained during the working length determination, master cone fitting, or root canal filling. The mesial and distal angulation views were not labeled. The radiographs were evaluated twice (the second time was 1 week after the first evaluation) as either: 0 = not acceptable (no separation of all superimposed root canals, i.e., another shifted radiograph was needed) or 1 = acceptable (distinct separation of all superimposed root canals).

Data Analysis

The percentage of distinctly separated root canals in the −20°, and +20° shifted radiographs were determined by each examiner. The strength of agreement between the radiograph evaluations of each examiner (intra- and interexaminer) was evaluated using kappa statistics. Significant differences between the percentages of radiographs demonstrating separated root canals based on the angle taken as determined by each examiner were analyzed using the Chi-square test. Significance was set at $p < 0.05$.

Results

The 121 endodontically-treated teeth used in this study consisted of 38 maxillary premolars with two-canal orifices, 44 mandibular molars with three-canal orifices, and 39 mandibular molars with four-canal orifices.

Premolars

The evaluations by the first and second examiner revealed that the percentage of distinctly separated root canals (acceptable) on the M shift radiographs was 76.3 and 76.3% and on the D shift radiographs was 68.4 and 71%, respectively (Fig. 2). The intra- and interagreement values of both examiners determined by kappa analysis were 0.839–1. These results indicated almost perfect agreement.[11] The statistical analysis of both examiners' findings revealed that the M shift and D shift results in a similar percentage of radiographs with an acceptable separation of superimposed canals ($p = 0.489$ and 0.611, respectively).

Molars with Three Canals

The first and second examiner determined that the percentage of distinctly separated root canals (acceptable) on the M shift and D shift radiographs was 59% and 59% and 68.1% and 70.4%, respectively (Fig. 3). The intra- and interagreement values of both examiners determined by kappa analysis were 0.891–1. These results also indicated almost perfect agreement.[11] The Chi-square analysis of the examiners' results indicated that the D shift resulted in a significantly greater percentage of radiographs demonstrating distinct separation compared with the M shift ($p = 0.002$ and 0.008, respectively).

Molars with Four Canals

The first and second examiners' evaluation indicated that the percentage of distinctly separated root canals (acceptable) on the M shift and D shift radiographs was 71.7 and 69.2% and 51.2 and 53.8%, respectively (Fig. 4). Kappa analysis demonstrated that the intra- and interagreement values of both examiners were 0.690–1. These results demonstrated substantial-almost perfect agreement.[11] The statistical analysis of the examiners' analysis showed that the M shift resulted in a significantly greater percentage of radiographs demonstrating distinct separation compared with the D shift ($p = 0.001$ and 0.010, respectively).

Discussion

A major factor in successful root canal treatment in multirooted teeth is the cleaning and completely obturating every canal from the coronal portion to the apical constriction. Thus, obtaining radiographs that clearly demonstrate the anatomy of each canal is an important step in evaluating the results of each step during treatment to ensure the success of the root canal treatment. It has previously been reported that taking radiographs using a mesial shift or distal shift helps in separating superimposed root canals.[7] A 20° shift from the perpendicular is widely accepted to be used to separate superimposed canals.[6,7,10] In the present study, the Shifter was used to fix the X-ray tube angle at a 20° mesial and distal shift.

In the present study, both examiners found that the +20° M and −20° D shifts provided similar separation of superimposed canals ($p > 0.05$) in maxillary premolars with two canals. However,

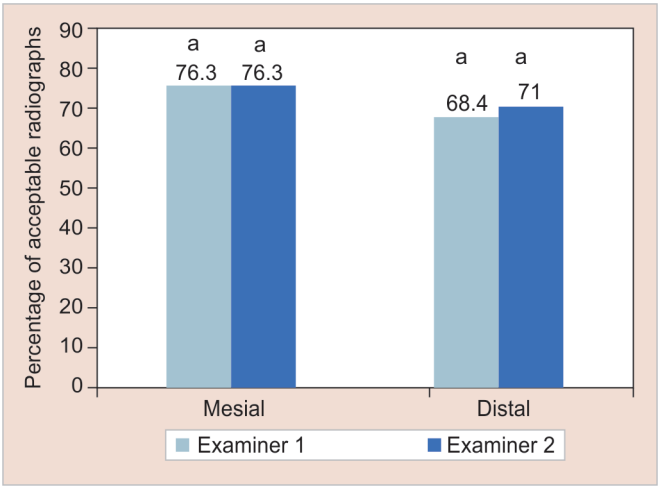


Fig. 2: Graph showing the percentage of acceptable premolar radiographs determined by the two examiners. The same letters indicate no significant difference between bars ($p > 0.05$)

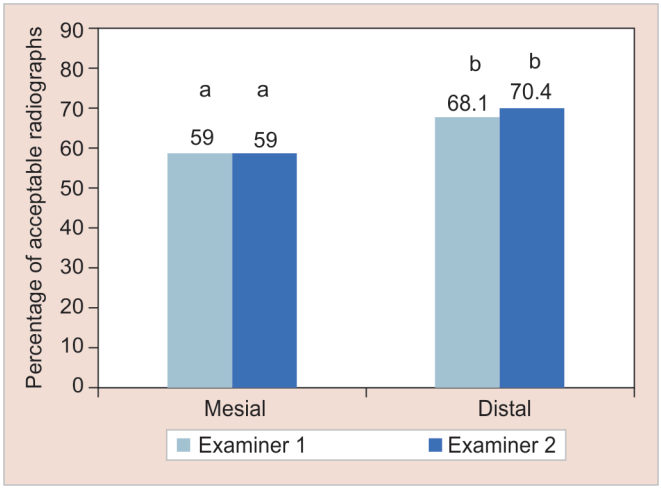


Fig. 3: Graph showing the percentage of acceptable molar (three canals) radiographs determined by the two examiners. The different letters indicate a significant difference between bars ($p < 0.05$)

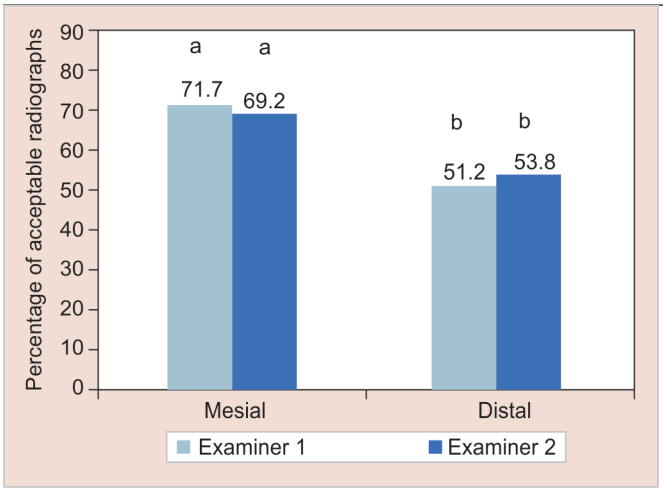


Fig. 4: Graph showing the percentage of acceptable molar (four canals) radiographs determined by the two examiners. The different letters indicate a significant difference between bars ($p < 0.05$)

Walton[12] found that taking a radiograph at a +20° M shift provided better separation of superimposed canals in maxillary premolars. In contrast, Martinez-Lozano et al.[13] demonstrated that a 40° shift results in separated superimposed root canals more often compared with a 20° horizontal shift. For mandibular molars with three root canals, our study revealed more frequent mesiobuccal canal and mesiolingual canal separation on the radiographs using the –20° D shift compared with using the +20° M shift. Walton[12] also showed that a –20° D shift separated superimposed root canals in all mandibular molars.

The current study found that a +20° M shift demonstrated a higher percentage of separated root canals on the radiographs compared with a –20° D shift in mandibular molars with four root canals. These results correspond with those of Haghani et al.[8] and Zhang et al.[10] who also found that +20° in the mesial direction was the most effective X-ray beam angle for identifying four canals in mandibular molars *in vitro* and *in vivo*, respectively. In contrast, Wang et al.[14] demonstrated that a +25° M shift was significantly better compared with a –25° D shift radiograph for obtaining radiographs of four-canal mandibular molars where all canals are visible. A previous study supported that radiographs taken using either a +20° M or a –20° D shift were more likely to have distinct mandibular molar root canal separation.[7] However, this study did not categorize the mandibular molars into two groups of three and four canals as was done in the present study.

As mentioned above and the results from our study indicate that the Shifter has the potential to aid in taking radiographs that demonstrate the complete canal anatomy during root canal treatment procedures. This instrument locates and accurately measures the 20° angles rather than approximating the X-ray tube by eye, which increases the frequency of needing to re-take radiographs. Re-taking radiographs increase patients' radiation exposure, which is a concern. A patient should be exposed to as low as reasonable radiation in every X-ray procedure in dentistry.[15]

A previous study used a 20° shifting jig to determine the X-ray tube angle.[7] The jig fits the peg of the film holder along with the EndoRay's arm and ring. The jig must perfectly fit the peg of the EndoRay or otherwise, it will snap and detach from the EndoRay and then must be re-positioned on the EndoRay. In contrast, the Shifter is used to determine the X-ray tube angle by placing it outside the patient's mouth. Thus, the Shifter is easier to use. The proper vertical angulation from indicating line could be correctly fixed. The 20° horizontal shifted angulation easily be achieved by centering the X-ray tube against the shifter rim which is perpendicular to the mesial or distal indicating line. Another advantage of the Shifter compared with the 20° Shift jig is that the Shifter can be used with both an EndoRay and XCP Rinn, however, the 20° Shift jig can be used only with the EndoRay.

The strength of the present study is that the radiographic image interpretation was performed by examiners having >10 years of experience each in endodontic treatment. The examiners were also calibrated before the study to prevent interobserver differences; thus, the collected data are reliable. The Kappa scores of both examiners indicate the intraobserver agreement levels were almost perfect and the interobserver agreement was at the substantial-almost perfect level.

In some cases, a radiograph taken of a tooth in certain positions does not demonstrate separated root canals when a +20° M and –20° D shift is used. When this occurs, separate root canals can be observed when the horizontal angle was increased to 25°.[14] This may be because the axis of the tooth is inclined; therefore, the 20° shift is not enough to separate the superimposed root canals.

This novel Shifter efficiently separates superimposed root canals and can be easily used in the steps of root canal treatments for determining a precisely shifted radiograph angle. The use of the Shifter can result in radiographs that can be more easily interpreted in multiple steps during endodontic treatment and reduce the number of radiographs that need to be retaken.

Conclusion

Our study confirmed that the percentage of separation of superimposed root canals in maxillary premolars with two canals using a +20° M or –20° D shift was not significantly different. With the mandibular molars with three and four canals, it is suggested that a –20° D and +20° M shift, respectively, is the first choice while taking a radiograph.

Clinical Significance

The advantage of the novel shifter is the same position of the tooth on the radiographs during the process of endodontic treatment.

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