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A comparative study of three periapical radiographic techniques for endodontic working length estimation

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Abstract

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Aim To compare the diagnostic quality of endodontic working length estimation films produced using film holders with those taken using the bisecting angle technique and to assess the level of acceptance of film holders by operator and patient.

Methodology Five post-graduate and 20 final year undergraduate students attending a UK Dental School produced working length radiographs using either the paralleling or the bisecting angle technique. The paralleling group used one of two film holders, the Endoray II or the XCP Endodontic Instrument, on alternate patients. An assessment of the ease of use of the device and the patients' views on the comfort of the examination were recorded. Each radiograph was examined simultaneously by two assessors, scored for film faults and diagnostic acceptability. Statistical data was derived using the Mann–Whitney *U* test and Cohen's kappa.

Results The rates of unacceptable radiographs for the XCP Endodontic Instrument, Endoray II and the bisecting angle techniques were 12.2%, 21.4% and 48.6%, respectively. The combined percentage of unacceptable paralleling technique films (16.7%) was highly significantly different ($P < 0.001$) when compared with the bisecting angle technique (48.6%). The paralleling technique produced a significant reduction in incorrect vertical angulation ($P < 0.001$), cone cutting ($P < 0.001$) and incorrect film placement ($P < 0.001$). Film holders were rated either excellent or good in 90% of examinations by operators and 47.5% of patients reported no discomfort.

Conclusions These results support the use of the film holders for endodontic working length estimation.

Keywords: dental, dental pulp cavity, radiography.

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Introduction

The data derived from the Annual Report and Digest of Statistics of the Dental Practice Board (Dental Practice Board 2005) for the period 2004–2005, show that 907 148 adult root filling treatments were carried out within England and Wales. A large number of these treatments will have relied upon one or more intraoral radiographs to allow root canal treatment to be undertaken.

Whilst the literature reveals that the paralleling technique in endodontic radiography is superior to the bisecting angle technique (Forsberg 1987, Gound *et al.* 1994), its routine use in endodontic practice ranges from 26.3% (Chandler & Koshy 2002) to 41.7% of dentists (Saunders *et al.* 1999). Moreover, the routine use of film holders ranges from 21.6% (Saunders *et al.* 1999) to 26% (Chandler & Koshy 2002). The

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increasing use of film holders has been shown to have a relationship to those clinicians who routinely use rubber dam (Chandler & Koshy 2002), those practitioners who are specialists in endodontics (Chandler & Koshy 2002) and also has a significant relationship to younger practitioners (Saunders *et al.* 1999).

There are a limited number of studies (Forsberg 1987, Gound *et al.* 1994) in which the use of the paralleling technique has been compared with the bisecting angle technique when determining the technical accuracy of endodontic working length films.

The aims of the study were

(1) to assess the quality of endodontic working length radiographs taken within a UK Dental Hospital;

(2) to assess the efficacy of two types of endodontic film holder and to compare these with films taken using the bisecting angle technique;

(3) to assess the practitioners' acceptance of the film holder and to determine the patients' assessment of the comfort of these devices.

Materials and methods

Five post-graduate students and 20 final year undergraduate dental students, within a UK Dental Hospital, participated in this study. The undergraduate cohort had prior clinical experience of using the paralleling technique. By contrast, the post-graduate students had never practically encountered the paralleling technique in either their undergraduate training or post-graduate clinical practice. This group, therefore, received instruction in its use before the commencement of the study. Each participant was asked to alternate between two proprietary endodontic film holders on successive patients to ensure that they obtained an even clinical exposure to both devices. The film holders used were the Endoray II (Rinn Dentsply, Weybridge, UK) and a recently introduced endodontic working length film holder, the XCP Endodontic Instrument (Rinn Dentsply). If the participant was unable to use the paralleling technique, for whatever reason, then the bisecting angle technique was adopted.

No exposure to X-rays was undertaken for the purpose of this study unless it was part of the treatment plan. Participants used size 0 film with its long axis vertically positioned with each of the film holders in the anterior (incisor and canine) region of the jaws. Size 2 film was used with its long axis horizontally positioned with the film holders in the posterior (premolar and molar) regions. Size 2 film was always used when the bisecting angle technique was adopted. After each exposure, the acceptability of the technique to both the operator and the patient was recorded.

Each radiograph was examined simultaneously by two assessors (DK and VER) using standardized viewing conditions. These comprised a standard X-ray viewer with masking, 2× magnification with all films viewed in a darkened room. The scoring of faults and the assessment was by consensus of the observers. The radiographs were assessed for total technical faults using a classification (Table 1) previously developed by Rushton & Horner (1994). The assessors then made a decision whether the radiograph was 'excellent', 'diagnostically acceptable' or 'unacceptable' for diagnostic purposes (National Radiological Protection Board 2001) according to national guidelines (Table 2). In those films deemed 'unacceptable', the faults specifically causing failure (significant faults) were noted. No assessment was made of film density and contrast as the use of a daily regime of sensitometric and densitometric analysis within the Dental Hospital ensured consistently high quality processing.

The resulting data was analysed using the SPSS PC + system (SPSS for Windows 2001). Mann–Whitney *U* tests were used to compare the frequencies of total faults, significant faults and unacceptable radiographs for each of the three techniques. Ninety-five per cent confidence levels were set as the threshold for statistical significance. Repeatability of the observations was determined by re-examining a random sample of 22 radiographs taken from all three techniques. The kappa statistic (Cohen 1960) was used to test the reproducibility of the decisions regarding the presence of film faults and overall diagnostic acceptability.

Results

Twenty-five students volunteered to participate in the study. Of these, five were post-graduate students and 20 were undergraduate students. A total of 103 working length radiographs were taken for the purpose of this study. Five radiographs had to be excluded from the study because they were taken using a film holder without the projecting arm and the aiming ring. The remaining 97 radiographs consisted of 60 radiographs which were taken using the paralleling technique, of which 28 films were taken using the Endoray II and 32 with the XCP Endodontic Instrument. The remaining 37 films were taken using the bisecting angle technique. Of these films, the post-graduate students performed 26 exposures, representing 43% of their cases. Conversely, the undergraduate group used the

Table 1 Classification of technical film faults

Film fault	Classification of the film fault
1. Presence of tooth apex (or apices),or area of diagnostic interest	A fault was recorded when the apex was absent from the image or when less than 3 mm of periapical bone was present on the image. A fault recorded in this category rendered the film diagnostically unacceptable
2. 'Obscured' root apex (or apices), or area of diagnostic interest	A fault was recorded if the apex (or area of interest) was present on the film but 'obscured', for example due to (3), (5) or (7) (see below). Where the root apex was rendered uninterpretable the film was considered to be diagnostically unacceptable
3. Vertical angulation of the X-ray beam	This was assessed by examining the image for evidence of foreshortening or elongation. This was aided by an assessment of the clinician's preset working length value and knowledge of the reference point used. Faults were categorized subjectively as 'mild' or 'severe'. All films with a 'severe' degree of foreshortening or elongation present were rejected for clinical use
4. Horizontal angulation of the X-ray beam	This was assessed by examining the radiograph for overlapping images of adjacent teeth. This measurement was undertaken for crowns and roots separately. Where overlap extended to half of the horizontal dimension of the root or crown of the tooth being examined, then the film was considered unacceptable. If, however, there was clear evidence of gross dental crowding, overlap of teeth was not scored as a fault
5. Distortion due to bending	This was recognized by a 'stretching out' of the image in a localized area of the radiograph. Films were rejected if the assessors agreed that the extent of the distortion would make the radiograph unreliable for clinical use
6. Cone-cut	The presence of a cone cut was scored as a fault. Where the cone cut obscured any part of the tooth (or teeth) for which the radiograph was exposed, the radiograph was categorized as unacceptable
7. Superimposition of anatomy over the 'area of interest'	The anatomical structure producing the superimposition was noted. If the superimposition obscured (see 2, above) the apex (or apices) or area of interest the radiograph was rejected
8. Absence of the crown of the tooth from the image	Any loss of image of the crown was recorded as a fault. The complete absence of the crown caused the film to be rejected. If the tooth had been decoronated, then an assessment was made as to what proportion of the crown would have been lost had it been present
9. Film positioning	An 'ideal' position of the film was defined as one in which the tooth under examination was centrally positioned along the horizontal axis of the film and where the incisal edges or cusp tips were entirely seen, as must the rubber stop or other chosen identifier on the diagnostic file. If incorrect positioning had led to a loss of any of the above structures from the radiograph or if the tooth apex (or apices) was lost, then the error was recorded as a significant fault
10. Other faults	These faults included movement, film in reverse orientation, and superimposed artefacts (i.e. superimposition of areas of interest by the embossed dot of the film)

bisecting angle technique only on 11 occasions, corresponding to 30.5% of their total radiographic exposures. Within the post-graduate group, the most common reason for adopting the bisecting angle technique was a lack of previous clinical experience using film holders (15 cases), patient intolerance of the device (six cases) and the presence of a shallow palate (five cases). For the undergraduate group, the reasons given for using the bisecting angle technique were patient intolerance (seven cases) and a shallow palate (four cases). The factors involved in patient intolerance of the film holder were limited mouth opening and a severe gag reflex.

Table 3 shows the total number of faults for each technique, their frequency and statistical comparison with the bisecting angle technique. The paralleling technique produced a significant reduction in the number of films exhibiting foreshortening, cone-cutting, superimposition of normal anatomy and incorrect film positioning. There was a significant reduction in the number of technical faults per film ($P < 0.001$) when using endodontic film holders compared with the

Table 2 Subjective quality rating of radiographs (National Radiological Protection Board 2001)

Rating	Quality	Basis
1	Excellent	No errors of patient preparation, exposure positioning, processing or film handling
2	Diagnostically acceptable	Some errors of patient preparation, exposure positioning, processing or film handling, but which do not detract from the diagnostic utility of the radiograph
3	Unacceptable	Errors of patient preparation, exposure positioning, processing or film handling, which render the radiograph diagnostically unacceptable

Table 3 The number and frequency (in parenthesis) of radiographs exhibiting total faults and statistical comparisons of the paralleling technique (using combined data from both types of Endoray® film holder) with the bisecting angle technique

Technical faults	Paralleling technique [number and (percentage)]	Bisecting angle technique [number and (percentage)]	*P*-value
Apex missing	9 (15.0)	14 (37.8)	NS
Incorrect vertical angulation			
Foreshortening	3 (5.0)	18 (48.6)	<0.001
Elongation	15 (25.0)	13 (35.1)	NS
Incorrect horizontal angulation of the root	11 (29.7)	10 (16.7)	NS
Incorrect horizontal angulation of the crown	15 (25.0)	11 (29.7)	NS
Distortion due to bending	3 (5.0)	2 (5.4)	NS
Cone-cut	12 (20.0)	23 (62.2)	<0.001
Cone cut obscuring the area of interest	0 (0)	2 (5.4)	0.07
Superimposition of normal anatomy	2 (3.3)	7 (18.9)	0.011
Crown missing	8 (13.3)	9 (24.3)	NS
Incorrect film positioning	10 (35.7)	23 (62.2)	<0.001

Table 4 The range of subjective quality of films and their frequency (in parenthesis) with statistical comparison of the combined data of both Endoray® film holders (using the paralleling technique) with the bisecting angle technique

Overall film quality	Paralleling technique	Bisecting angle technique	*P*-value
Excellent	22 (36.7)	0 (0)	<0.001*
Diagnostically acceptable	28 (46.7)	19 (51.4)	
Diagnostically unacceptable	10 (16.7)	18 (48.6)	

bisecting angle technique. For the paralleling technique, 50% of films exhibited either no faults or one single fault compared with 2.7% of films taken using the bisecting angle technique.

Table 4 illustrates the range of subjective quality of films taken using the paralleling technique compared with those taken using the bisecting angle technique. Within the study, 28 films had significant faults which rendered them diagnostically unacceptable. Of these, 18 (64.3%) films were taken using the bisecting angle technique, four (14.3%) films using the XCP Endodontic Instrument and six (21.4%) films taken with the Endoray II film holder. Table 5 illustrates the number and frequency of radiographs exhibiting significant faults which specifically contributed to diagnostic unacceptability for each technique along with statistical comparison between each technique. Endodontic film holders produced a significant reduction in foreshortening and

Table 5 The number and frequency (in parenthesis) of radiographs produced by the paralleling technique which had 'significant film faults' that specifically contributed to rejection of the radiograph with statistical comparisons with the bisecting angle technique

Technical faults	Paralleling technique (%)	Bisecting angle technique (%)	*P*-value
Apex missing	9 (90.0)	14 (77.8)	NS
Foreshortening	0 (0.0)	9 (50.0)	<0.001
Elongation	4 (40.0)	9 (50.0)	NS
Incorrect horizontal angulation of the root	4 (40.0)	6 (33.3)	NS
Distortion due to bending	2 (20.0)	2 (11.1)	NS
Cone-cut	3 (30.0)	15 (83.3)	0.024
Cone cut obscuring the area of interest	0 (0.0)	2 (11.1)	NS
Superimposition of normal anatomy	1 (10.0)	3 (13.6)	NS
Crown missing	1 (10.0)	4 (22.2)	NS
Incorrect film positioning	4 (40.0)	10 (58.8)	NS

Table 6 Reproducibility of assessment of film faults on a random sample of 22 radiographs using Cohen's kappa

Film fault	Kappa
Overall film quality	0.85
Apex missing	1.00
Horizontal angulation error	0.62
Vertical angulation error	0.72
Cone-cut	1.00
Superimposition of normal anatomy	0.78
Crown missing	0.90
Positioning fault	0.72

cone cutting errors. Table 6 shows the results of a reassessment of film faults of a random sample of 22 radiographs and the kappa (κ) values. The level of agreement for the decision about the diagnostic acceptability and recording of specific film faults was high.

The participants' assessment of the ease of use of the two endodontic film holders found no significant difference ($P = 0.347$). The XCP device was considered either excellent or good by 90.6% of participants, whilst the Endoray II was found to be excellent or good by 88.9%. Patients found both the Endoray II and the XCP Endodontic Instrument comfortable in 48.1% and 46.9% of cases, respectively. Slight discomfort was recorded by 48.1% of patients when using the Endoray II film holder and by 40.6% when using the XCP Endodontic Instrument. A very small proportion of patients found the film holders very uncomfortable with levels of 3.7% and 12.5% for the Endoray II and the XCP Endodontic Instrument, respectively. There was no significant difference between the two devices in this respect.

Discussion

Whilst radiographs are a necessary adjunct in endodontic practice, problems are often encountered. These tend to be related to film placement and stabilization when endodontic instruments, rubber dam and rubber dam clamps are in position (Harbert & Palombo 1983). Chee & Neo (1990) found that the presence of a rubber dam affects the accuracy of the radiographs taken by undergraduate students using the bisecting angle technique. These problems were encountered most commonly amongst maxillary teeth and are considered the result of a rigid palate and its accompanying sloping concavity especially in the molar region (Lim & Teo 1986, Gound *et al.* 1994).

There are a limited number of studies (Van Vorde & Bjorndahl 1969, Forsberg 1987, Gound *et al.* 1994) in which the use of the paralleling technique has been compared with the bisecting angle technique for technical accuracy of endodontic working length films. Each of these studies, however, has confirmed the superiority of the paralleling technique. Only two studies (Forsberg 1987, Gound *et al.* 1994) have made a direct comparison between two techniques within the same investigation. Unfortunately, each of the latter has involved differing research methodology, notably different observer criteria for evaluating film quality, and each has employed different film holders. Consequently, there are obvious limitations on the extent to which these two investigations can be usefully compared with the present study.

In this study, the standard adopted for film quality was 'a professionally developed expression of acceptable variations of the norm' (Morris *et al.* 1982). Although the total film faults were recorded numerically for each radiograph, the diagnostic acceptability of the image was determined from whether the faults were of such a degree as to preclude correct radiographic diagnosis. Several methods have been adopted to improve the reliability of judgements which included having terminology, criteria and data recording forms clearly defined. However, although there will always be many film quality criteria that are subjective, the effectiveness of the adoption of these basic principles can be shown in the high levels of inter-observer agreement (Table 6).

As the undergraduate cohort had been routinely using endodontic film holders for almost 2 years before the commencement of the study, it was, therefore, not surprising to find that the undergraduate group resorted to using the bisecting angle technique in a smaller percentage of cases (30.5%) than was the case for the post-graduate group (43%) in which the majority of the participants had no previous 'hands-on' experience of using any type of film holder. Whilst it could be argued that those cases in which the bisecting angle technique was adopted were more clinically challenging, the wide distribution of sites within the oral cavity in which difficulties were encountered tended to contradict this hypothesis. Several reasons were given by participants as to why the film holder could not be positioned correctly in these areas. These ranged from the clinician's lack of previous clinical experience with devices of this type to a lack of tolerance of the device by the patient. It was noticeable that as the project progressed, there were fewer occasions in which the bisecting angle technique was adopted. In addition, the participants were assessing the film holders more favourably towards the end of the project. This

illustrates the fact that a period of time is necessary for practitioners to acquire the necessary knowledge and skills when changing clinical practice. It is well recognized that the film needs to be positioned away from the teeth to ensure not only parallelism between the film and the tooth, but also ensures more comfort for the patient. This small study has shown that the use of endodontic film holders can be affected by both anatomical considerations and patient intolerance. Unfortunately, this study was time limited by the demands of the curriculum which resulted in a small study sample with which to further evaluate these preliminary findings.

Another criticism that could be levelled at this study is that the observers were not 'blinded' to the technique being used, e.g. the film size or the visibility of portions of the film holder on images informed the observers which technique was being used. This problem is essentially insurmountable although the use of two observers in a consensus viewing, rather than a single observer, should have gone some way to combating bias.

Within the UK, the Guidance Notes for Dental Practitioners on the Safe Use of X-ray Equipment (National Radiological Protection Board 2001) set performance targets for the production of good diagnostic quality radiographs using the simple, subjective image quality rating detailed in Table 2. The targets are to be achieved within 3 years of the implementation of a quality assurance programme and are to produce not <70% of excellent films, not >20% of diagnostically acceptable films and not >10% of unacceptable films. Interim targets have also been derived with not <50% of excellent films, not >40% of diagnostically acceptable films and not >10% of unacceptable films (National Radiological Protection Board 2001) and these should be the minimum achievable standard in the short term. Whilst the figures for this study (Table 4) using endodontic film holders fall just outside the interim targets, with 36.7% of films rated as excellent, 46.7% diagnostically acceptable and 16.7% diagnostically unacceptable, they give support to the undoubted benefit of film holders in endodontic practice.

Conclusion

Using film holders gave higher overall film quality for endodontic working length estimation radiographs. There were no significant differences in the efficacy of either film holder but, overall, the paralleling technique was superior to the bisecting angle technique. The paralleling technique was effective in accurately imaging teeth for the purpose of estimating endodontic working length and was able to reduce a significant proportion of the major errors that can cause radiographs to be deemed diagnostically unacceptable for clinical use. Finally, it is important to develop the dental curriculum to ensure that both undergraduate and post-graduate students have the necessary competency when using these devices in clinical practice.

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