대한구강악안면방사선학회지 2004; 34 : 185-90

Diagnostic accuracy of artificially induced vertical root fractures: a comparison of direct digital periapical images with conventional periapical images

Ji-Un Lee, Ki-Jeong Kwon, Kwang-Joon Koh

Department of Oral and Maxillofacial Radiology, School of Dentistry, and Institute of Oral Bio Science, Chonbuk National University

ABSTRACT

Purpose : To compare the diagnostic accuracy for the detection of root fractures in CMOS-based digital periapical images with conventional film-based periapical images.

Materials and Methods : Sixty extracted single-root human teeth with closed apices were prepared endodontically and divided into two groups; artificially induced vertical root fracture group and control group. All radiographs were obtained using the paralleling technique. The radiographs were examined by 4 observers three times within a 4 week interval. Receiver operating characteristic (ROC) analysis was carried out using data obtained from four observers. Intra- and inter-examiner agreements were computed using kappa analysis.

Results : The area under the ROC curve (Az) was used as an indicator of the diagnostic accuracy of the imaging system. Az values were as follows: direct-digital images; 0.93, film-based images; 0.92, and inverted digital images; 0.91. There was no significant difference between imaging modalities ($P < 0.05$). The kappa value of inter-observer agreement was 0.42 (range: 0.28-0.60) and intra-observer agreement was 0.57 (range: 0.44-0.75).

Conclusion : There is no statistical difference in diagnostic accuracy for the detection of vertical root fractures between digital periapical images and conventional periapical images. The results indicate that the CMOS sensor is a good image detector for the evaluation of vertical root fractures. (***Korean J Oral Maxillofac Radiol 2004; 34 : 185-90***)

KEY WORDS : Diagnostic Accuracy; Tooth Fractures; Radiography, Dental, Digital

Root fractures are usually horizontal, vertical, and oblique, depending on the direction of the fracture line to the long axis of the tooth. Generally root fractures comprise between 0.5% and 7% of injuries affecting the permanent dentition.[1]

A true vertical root fracture is a longitudinal fracture confined to the root that usually initiates on the internal canal wall and extends outward to the root surface.[2]

A vertical fracture of an endodontically treated tooth was first reported because of a periodontal abscess and vertical bone loss.[1] Various reasons for vertical root fractures were reported; volumetric expansion of endodontic pins or posts due to corrosion,[3] excessive pressure during placement of endodontic posts,[4] wedging action of inlays, and excessive pressure during lateral condensation of the gutta-percha during obturation of the canal.[5] Chin-Jyh suggested that a fatigue root fracture can result from excessive, repetitive, and heavy masticatory stress applied to a tooth.[6]

Received October 7, 2004; accepted November 4, 2004
Correspondence to : Prof. Kwang-Joon Koh
Department of Oral and Maxillofacial Radiology, School of Dentistry, 634-18, Keum-Am Dong, Duk-Jin Gu, Jeon-Ju, Chonbuk, 561-712, Korea
Tel) 82-63-250-2063, Fax) 82-63-250-2081, E-mail) radkoh@chonbuk.ac.kr

A root fracture poses considerable threat to the life of a tooth and it often necessitates extraction, therefore it is clinically important to diagnose a root fracture correctly, however, it is often difficult.

In general, a root fracture can be visualized radiographically when the X-ray beam passes through the fracture line, therefore two or three radiographs taken at various angles may be needed.[8-10] Some authors reported that the detection of a root fracture was achieved when the X-ray beam was within 4°.[9] However, a root fracture can be detected radiographically when there is considerable separation of two root fragments. Osseous defects or lesions along the length of roots are typical radiographic findings associated with a vertical root fracture, as well as a halo appearance.[10]

Digital radiography has been developed continuously for dental clinics. Many studies have been performed for the evaluation of diagnostic accuracy of digital systems compared to that of dental films.[11-17]

The purpose of this study was to compare the diagnostic accuracy for the detection of vertical root fractures in CMOS-based digital periapical images with conventional film-based

periapical images.

Materials and Methods

1. Tooth preparation

Sixty extracted single-root human teeth with closed apices were used in this experiment. Age, gender, and the reason for extraction were not considered as inclusion criteria.

Extracted teeth were cleansed and conventional access opening was performed with a round shaped carbide bur. The root canal was prepared with file numbers 15 to 40 and the coronal portion was enlarged with a #2 to #4 gates-glidden bur. Debris was removed from the root canal by irrigation. Each tooth in the experimental group was mounted in a putty block. A vertical root fracture was induced as described by Monagham, et al.(3). A conical 60°-beveled tip wedge was used to induce vertical/oblique radicular fractures. The wedge was driven into the tooth apically until there was a sharp 'cracking'sound in 28 teeth (Fig. 1), while the rest were left intact. Each tooth was then carefully removed from the putty block and remounted in a wax block to simulate the soft tissues.

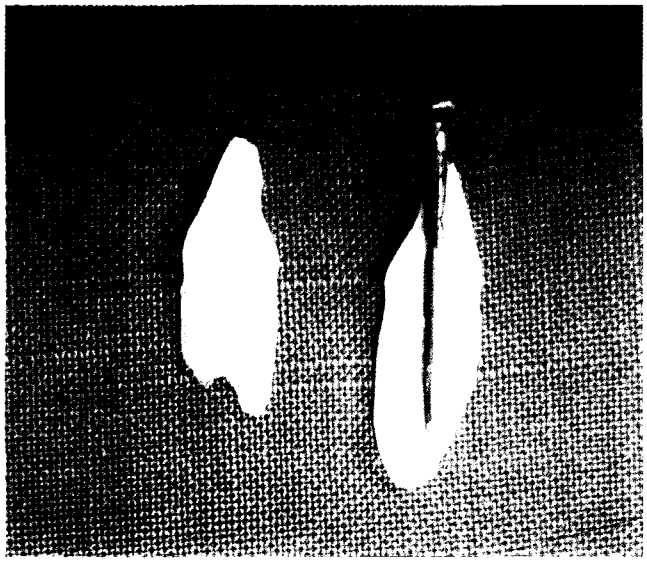

Fig. 1. A conical 60°-beveled tip wedge was used to induce vertical/oblique radicular fractures. The wedge was driven into the tooth apical third.

2. Radiographic procedure

Radiographs of each tooth were obtained in the buccolingual view using the paralleling technique. The projection angle to the receptor and tooth were kept constant for both conventional and digital radiographs.

All radiographic exposures were made with Heliodent MD dental X-ray unit (Sirona, Bensheim, Germany) at 60 kVp and 7 mA. The exposure time was 0.05s for digital radiographs and 0.1s for film-based radiographs. The focus-object distance was 20 cm and the object-film distance was 0.5 cm. Conventional film images were obtained from F-speed No. 2 periapical films (Insight, Eastman Kodak Co., Rochester, NY, USA) and processed automatically (Level 356, Flat Co., Japan) for 4.5 min at 26°C with Readymatic® (Eastman Kodak Co., Rochester, NY, USA), as recommended by the manufacturer. Direct digital radiographs were acquired using a #2 CMOS (complementary metal oxide semiconductor) sensor (Shick CDR; Shick Technologies, Long island, NY, USA).

3. Radiographic evaluation

The radiographs were numbered in a random order and examined by 4 observers with no prior knowledge about the fractured teeth. The observers were composed of four radi-

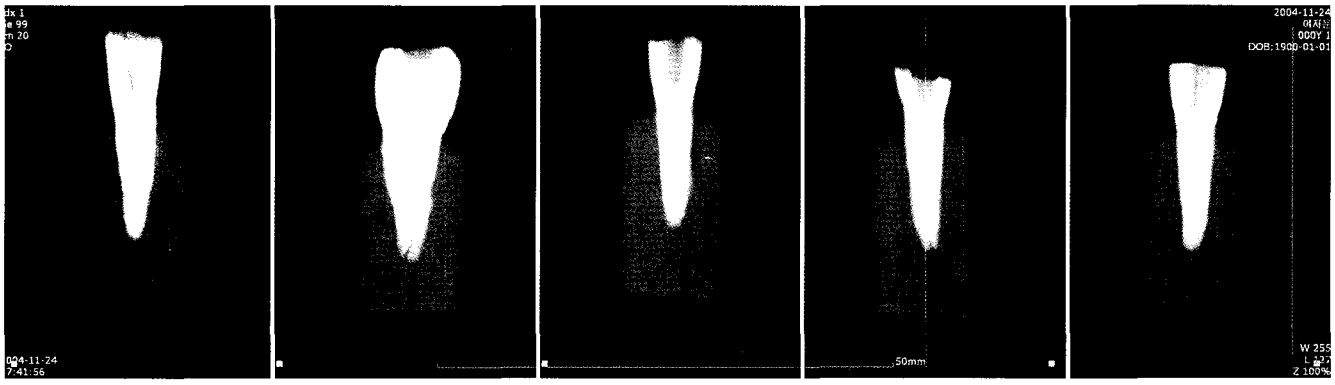

Fig. 2. Radiographs show the images of a fractured tooth using the digital system.

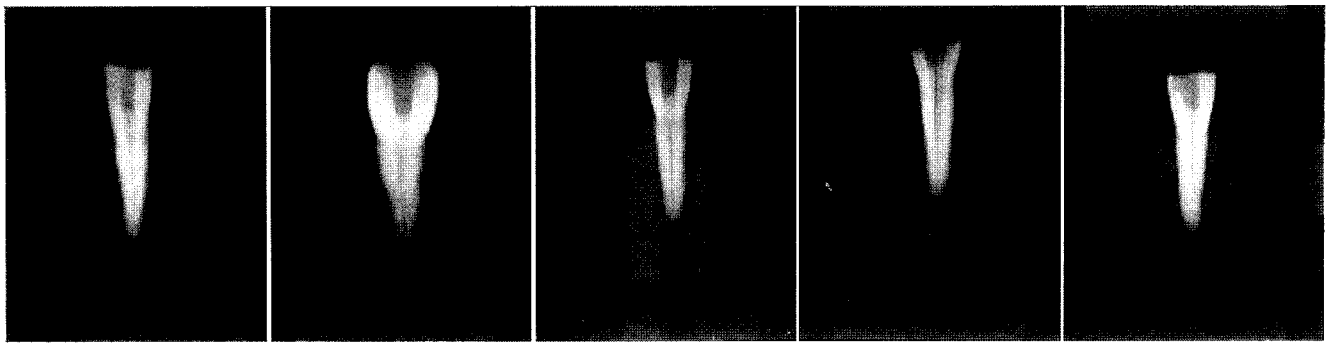

Fig. 3. Radiographs show the images of a fractured tooth using the film-based conventional system.

Fig. 4. Radiographs show the images of a fractured tooth using the digital system and inverted image.

ologists; two radiologists had 3 years experience and the other radiologists had 7 and 10 years experience in a dental clinic respectively. For the evaluation of the conventional images, a view box was used. Each observer was required to express subjective confidence of the presence or absence of a fracture on a 5-point rating scale : 1) fracture definitely not present; 2) fracture probably not present; 3) uncertain if fracture is present or not; 4) fracture probably present; 5) fracture definitely present.

The viewing process was repeated 3 times within a 4 week interval.

4. Statistical analysis

ROC analysis was carried out using the data obtained from all four observers. Az values were computed for each observer and imaging modalities.

ANOVA was done for testing variability based on imaging modalities, and calculated kappa value to compare the radiographic images. The score on the confidence-rating scale was dichotomized for this purpose.

Intra- and inter-examiner agreements were computed using kappa analysis. The data from the first reading were used for computation of inter-observer agreement while data from the first, second and third sessions were used to calculate intra-observer agreements.

Table 1. Mean areas under the ROC curve (Az) based on imaging modalities

Imaging modality	Area (Az)	SD
Direct digital images	0.93	0.02
Film-based images	0.92	0.02
Inverted digital images	0.91	0.02

SD: standard deviation

Result

Data were pooled together based on each imaging modality (Fig. 5). Table 1 shows the mean Az values recorded for all observers. Fig. 6 shows the ROC curve based on the first reading from imaging modalities by four observers. Az values were calculated in all imaging modalities varied between observers (Table 2).

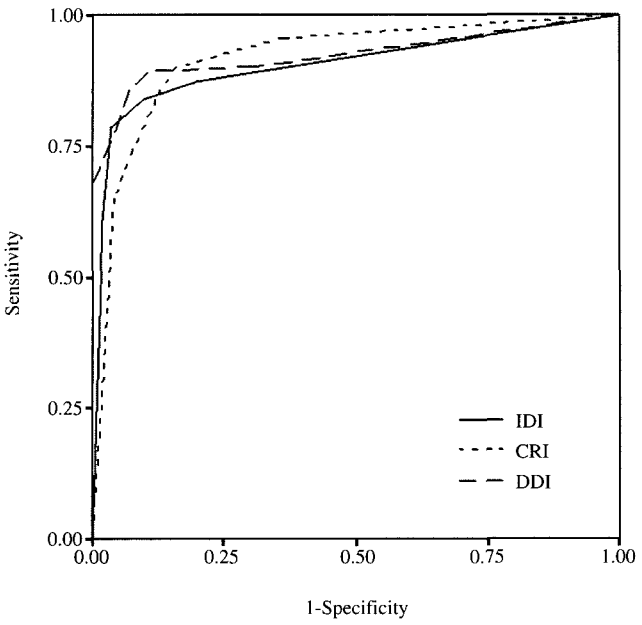

Fig. 5. ROC curves obtained from imaging modalities. DDI: direct digital images, CRI: conventional radiographic images, IDI: inverted digital images.

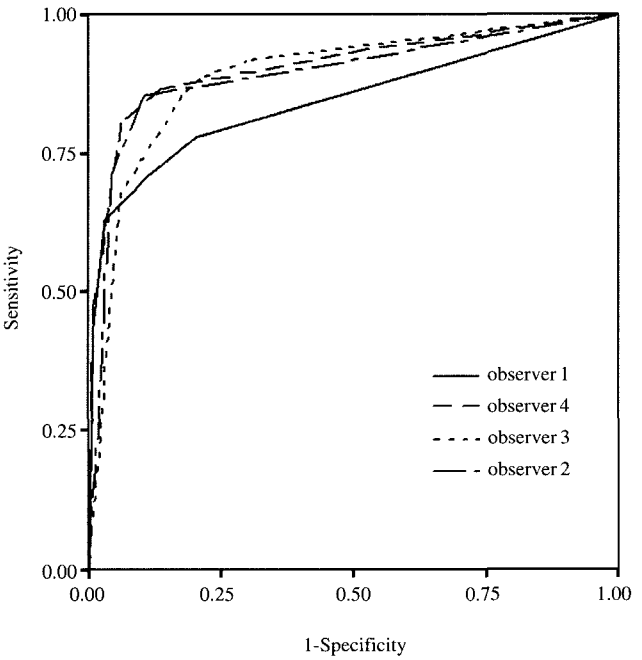

Fig. 6. ROC curves obtained from four observers.

No statistical significance between image modalities ($P < 0.05$) was found. There was substantial agreement between the digital periapical images and the actual images ($\kappa = 0.703$), between the conventional and the actual images ($\kappa = 0.683$), and between the inverted images and the actual images ($\kappa = 0.681$).

Table 2. Mean areas under the ROC curve (Az) based on four observers

Observer	Area (Az)	SD
1	0.85	0.02
2	0.89	0.02
3	0.89	0.02
4	0.91	0.01

Table 3. Sensitivity and specificity according to the imaging modalities

Observer	Imaging modality	Sensitivity	Specificity
1	DDI	0.64	0.96
	CRI	0.68	0.98
	IDI	0.57	0.98
2	DDI	0.85	0.88
	CRI	0.89	0.89
	IDI	0.80	0.91
3	DDI	0.90	0.78
	CRI	0.88	0.83
	IDI	0.81	0.86
4	DDI	0.83	0.89
	CRI	0.81	0.95
	IDI	0.80	0.93

Table 4. Sensitivity and specificity according to the imaging modalities

Imaging modality	Sensitivity	Specificity
Direct digital images	0.81	0.88
Film-based images	0.82	0.91
Inverted digital images	0.74	0.92

Inter-observer agreement by kappa analysis was 0.42 and intra-observer agreement was 0.57.

Sensitivities and specificities were computed using dichotomized data for all imaging modalities (Table 3 and 4). Film-based conventional periapical images displayed slightly higher sensitivity and specificity values in all imaging modalities. Inverted images displayed lower sensitivity than other images, however it showed higher specificity than other images.

Discussion

Vertical root fractures tend to have an iatrogenic cause, whereas horizontal root fracture is typically of traumatic origin and easy to diagnose.[18] Vertical root fractures occur in vital teeth with an intact pulp as a result of conservative restoration or in endodontically treated teeth as a result of excessive pressure used during endodontic treatment or during the

placement of a post. Differential radiographic diagnosis between vertical root fracture and other etiologies (eg. periapical lesions, periodontal diseases) is important[19] because it directly affect treatment planning and prognosis.

The diagnosis of vertical root fractures can present problems. While the clinical presentation of a vertical root fracture can be variable, radiographic signs are, at times, quite specific. These signs can vary considerably from case to case, depending on the angle of the X-ray beam in relation to the plane of fracture, the time after fracture and the degree of separation of the fragments.[20]

Occasionally an isolated pocket on one aspect of a suspected tooth is reliably diagnostic for a root fracture.[21] A radiographic image of a tooth with vertical root fracture shows diffuse widening of the periodontal ligament space,[22] separation of root fragments, fracture lines along the root or root filling, space beside a root filling, or a post, double images, extrusion of cement or root filling material into the fracture site or apically,[20] and vertical alveolar bone loss,[21] etc. The widening of the root canal and the discontinuity of the root density can lead to the correct diagnosis of a root fracture.[6]

Any radiographic system has limitation for the detection of root fractures. Fracture may be missed if the X-ray beam does not pass through the fracture line. Detection can be achieved when the X-ray beam is within 4°.[3] Furthermore, mesiodistally oriented root fractures are not visualized directly on a typically exposed radiograph unless dislocation of the two components has led to a step phenomenon along the border of the root. Therefore another radiographs are required.

There were many reports that compare digital radiographs and film-based conventional radiographs and reports on basic image quality, image acquisition and diagnostic quality etc.[23] In the paper that compared diagnostic capability, the diagnostic accuracy of the CCD-based system was equivalent to that of conventional intra-oral radiography for the detection of caries.[13,15,16] and the enhancement of storage phosphor images improved detection of approximal caries in vitro study compared with unenhanced images and Ektaspeed film.[24,25] However digital image magnification had a significant influence on observer performance for the detection of approximal caries, with an upper limit beyond which diagnostic accuracy may be reduced.[26]

Yokota et al.[17] found that there was no difference between conventional and CCD-based digital radiography for the detection of periapical lesions, and many authors studied about the diagnostic accuracy of the CCD-based system on periodontal lesions.[11,14,27]

However, until now, few reports existed for the comparison of vertical root fracture detection using digital and conventional periapical images.

Youssenfzade et al.[28] suggested that CT is superior to dental radiograph for the detection of vertical root fractures. Nair et al.[29] reported that the diagnostic accuracy of TACT is higher than that of conventional radiographs for the detection of vertical root fractures. More specifically, the diagnostic accuracy of TACT for vertical root fracture detection improved after 3 iterative restorations.[30]

Kositbowornchai et al.[12] reported that CCD-based digital radiographs are similar to film-based radiograph for the detection of artificially fractured roots. But there were few reports that compared CMOS-based digital radiographs with conventional radiographs.

Recently digital image enhancement was introduced to improve visibility and to increase diagnostic accuracy. Furkart et al. found that magnification using a monitor display of the digital image may improve the detection of the lesion.[11] However, other authors reported that the use of magnification for the diagnosis of root fracture did not improve diagnostic accuracy.[31]

This study compared CMOS sensor based-direct digital and conventional film-based radiograph for the detection of vertical root fractures. Moreover this study included the inverted images for the detection of root fractures.

We expected that detection using inverted images would be higher than film-based and direct-digital radiographs. Actually the inverted images were easier to use for the detection of root fractures than other images, but there was no statistical difference. However, it showed a higher specificity values in all images.

These results indicate that there is no statistical difference in diagnostic accuracy for both radiographic and CMOS-based digital images for the detection of vertical root fractures. The results seemed to be similar with respect to diagnostic accuracy when comparing CCD-based digital radiographs and film-based radiographs. Although the in vitro nature of this experiment is a limitation,[12] these results indicate that the CMOS sensor is a good image detector for the evaluation of vertical root fractures.

References

1. Andreasen JO. Etiology and pathogenesis of traumatic dental injuries. A clinical study of 11,298 cases. Scant J Dent Res 1970; 78 : 329-42.
2. Meister FJ, Lommel TJ, Davies EE. A periodontal abscess associated with vertical root fracture-case report, J Wis State Dent Soc 1976; 53

: 562-3.
3. Rud J, Andreasen JO. A study of failures after endodontic surgery by radiographic, histologic and stereomicroscopic methods, Int J Oral Surg 1972; 1 : 311-28.
4. Wechsler SM, Vogel RI, Fishelberg G, Shovlin FE. Iatrogenic root fractures; a case report, J Endod 1978; 4 : 251-3.
5. Lommel TJ, Meister FJ, Gerstein H, Davis EE, Tilk MA, Alveolar bone loss associated with vertical root fractures. Oral Surg 1978; 45 : 909-19.
6. Chin-Jyh Y. Fatigue root fracture: a spontaneous root fracture in non-endodontically treated teeth. Br Dent J 1997; 182 : 261-6.
7. Pitts DL, Natkin E. Diagnosis and treatment of vertical root fracture. J Endod 1983; 9 : 338-46.
8. Andreasen JO, Andreasen FM. Essentials of traumatic injuries to the teeth. 2nd ed. Copenhagen: Munksgaard; 2000. p.14-6.
9. Rud J, Omnell KA. Root fractures due to corrosion: diagnostic aspects. Scand J Dent Res 1970; 78 : 397-403.
10. Aviad T, Zvi F, Joseph L, Yehunda G, Israel K, Tel AI. Radiographic features of vertically fractured, endodontically treated maxillary premolars. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1999; 88 : 348-52.
11. Furkart AJ, Dove SB, McDavid WD, Nummikoski P, Matteson S. Direct digital radiography for detection of periodontal bone lesions. Oral Surg Oral Med Oral Pathol 1992; 74 : 652-60.
12. Kositbowornchai S, Nuansakul R, Sikram S, Sinahawattana S, Sangmontri S. Root fracture detection: a comparison of direct digital radiography with conventional radiography. Dentomaxillofac Radiol 2001; 30 : 106-9.
13. Naitoh M, Yussa H, Toyama M, Shiojima M, Nakamura M, Ushida M, et al. Observer agreement in the detection of approximal caries with direct digital intraoral radiography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1998; 85 : 107-12.
14. Pass B, Furkart AJ, Dove SM, McDavid WD, Gregson PH. 6-Bit and 8-Bit digital radiography for detecting simulated periodontal lesions. Oral Surg Oral Med Oral Pathol 1994; 77 : 406-11.
15. Syriopoulos K, Sanderink GCH, Velders XL, van der Stelt PF. Radiographic detection of approximal caries: a comparison of dental films and digital imaging system. Dentomaxillofac Radiol 2000; 29 : 312-8.
16. White SC, YOON DC. Comparative performance of digital and conventional images for detecting proximal surface caries. Dentomaxillofac Radiol 1997; 26 : 32-8.
17. Yokata ET, Miles DA, Newton CW, Brown CE. Interpretation of periapical lesions using RadioVisioGraphy. J Endod 1994; 20: 490-4.
18. Tamse A. Iatrogenic vertical root fractures in endodontically treated teeth. Endod Dent Traumatol 1998; 4 : 190-6.
19. Polson AM. Periodontal destruction associated with vertical root fracture: report of four cases. J Periodontol 1977; 48 : 27-32.
20. Alex JM, Bill K. Diagnosis and management of teeth with vertical root fractures. Aust Dent J 1999; 44 : 75-87.
21. Karayianni KN, Bragger U, Lang NP. Patterns of periodontal destruction associated with incomplete root fractures. Dentomaxillofac Radiol 1997; 26 : 321-6.
22. Meister FJ, Lommel TJ, Gerstein HB. Diagnosis and possible causes of vertical root fractures. Oral Surg 1980; 49 : 243-53.
23. Versteeg CH, Sanderink GCH, van der Stelt PF. Efficacy of digital intra-oral radiography in clinical dentistry. J Dent 1997; 25 : 215-24.
24. Møystad A, Svanaes DB, Risnes S, Larheim TA, Gröndahl HG. Detection of approximal caries with a storage phosphor system. A comparison of enhanced digital images with dental X-ray film. Dentomaxillofac Radiol 1996; 25 : 202-6.
25. Svanaes DB, Møystad A, Risnes S, Larheim TA, Gröndahl HG. Intraoral storage phosphor radiography for approximal caries detection and effect of image magnification: comparison with conventional radiography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1996; 82 : 94-100.
26. Møystad A, Svanaes DB, Larheim TA, Gröndahl HG. Effect of image magnification of digitized bitewing radiographs on approximal caries detection: an in vitro study. Dentomaxillofac Radiol 1995; 24 : 255-9.
27. van der Stelt PF, van der Linden LW, Geraets WG, Alons CL. Digitized pattern recognition in the diagnosis of periodontal bone defects. J Clin Periodontol 1985; 12 : 822-7.
28. Youssenfzadeh S, Gahleitner A, Dorffner R, Bernhart T, Kainberger FM. Dental vertical root fractures: value of CT in detection. Radiology 1999; 210 : 545-9.
29. Nair MK, Nair UP, Gröndahl HG, Webber RL, Wallace JA. Detection of artificially induced vertical radicular fractures using Tuned Aperture Computed Tomography. Eur J Oral Sci 2001; 109 : 375-9.
30. Nair MK, Gröndahl HG, Webber RL, Nair UP, Wallace JA. Effect of iterative restoration on the detection of artificially induced vertical radicular fractures by tuned aperture computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2003; 96 : 118-25.
31. Kositbowornchai S, Nuansakul R, Sikram S, Thinkhamrop B. Root fracture detection on digital images: effect of the zoom function. Dent Traumatol 2003; 19 : 154-9.