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Comparison between Scanora® Panoramic Radiography and Bitewing Radiography in the Assessment of Marginal Bone Tissue

Deimante Ivanauskaite, Christina Lindh, Klara Rangne, Madeleine Rohlin

SUMMARY

Objectives: To compare panoramic radiographs made with the Scanora® dental program and bitewing radiographs in the assessment of marginal bone tissue.

Materials and Methods: Panoramic and posterior bitewing radiographs were made for 96 consecutive patients. Six observers assessed marginal bone level, and five observers identified the presence or absence of vertical bone defects and furcation involvements. Observer agreement was calculated.

Results: Assessments of the marginal bone level with the two methods were identical for 57% of the sites. If a difference of one score was allowed, assessments for 95% of the sites were in agreement. Vertical bone defects and furcation involvement were detected with an agreement of 93%. Ranges of kappa indexes for intra-observer agreement on assessments of the marginal bone level were 0.37-0.46 in panoramic radiography and 0.31-0.55 in bitewing radiography. Ranges for agreement on detection of vertical bone defects were 0.52-0.63 and 0.47-0.56 and on detection of furcation involvements 0.64-0.79 and 0.66-0.77, respectively. The kappa index for inter-observer agreement on marginal bone level was 0.28 for panoramic and 0.29 for bitewing radiography. Corresponding figures for detection of vertical bone defects were 0.38 and 0.35 and for detection of furcation involvement 0.56 and 0.67.

Conclusions: For those sites or teeth that are possible to assess, the diagnostic information available with Scanora® panoramic radiography is comparable to that with bitewing radiography for marginal bone tissue. Therefore, Scanora® dental panoramic radiography is a valuable diagnostic alternative in the primary examination of the periodontal status.

Key words: radiography dental, bitewing; radiography dental, panoramic; alveolar bone loss, furcation defects; observer variation.

INTRODUCTION

Clinical and radiographic examinations play an integral role in the diagnostics of periodontal disorders as well as in the choice of treatment and in follow-up examinations [1, 2]. Bitewing and periapical radiography are both useful tools for this purpose [3, 4, 5, 6]. In addition to intra-oral radiography, panoramic radiography has been used as an adjunct to the examination of marginal bone tissue [7, 8, 9]. Panoramic radiography compares favourably with intra-oral radiography in the assessment of marginal bone level [10, 11, 12]. Very few radiographic studies [13, 14] have elucidated the diagnostic yield on alveolar vertical bone defects and furcation involvements.

In the 1990s, the Scanora® multimodal system was developed for radiographic examinations of the dental and maxillofacial region. The dental panoramic program of Scanora® is restricted mainly to the alveolar processes, which are imaged with a magnification of 1.7. The image quality of the Scanora® program has been found to be significantly higher than that of other panoramic programs in assessments of the crestal bone [15]. The ability of Scanora® dental panoramic radiography to depict the condition of marginal bone tissue has, however, not been evaluated. In light of the above, the aim of this study was to evaluate the agreement between Scanora® dental panoramic radiography and posterior bitewing radiography in the assessment of marginal bone level and in the detection of vertical bone defects and furcation involvements. Furthermore, in assessments of a diagnostic method, observer performance is of utmost importance. Until now, studies on assessments of marginal bone tissue with panoramic radiography have involved only a few observers who assessed comparatively few sites. Several observers were therefore asked to participate in this study.

[1]*Institute of Odontology, Faculty of Medicine, Vilnius University, Vilnius, Lithuania*
[2]*Department of Oral Radiology, Faculty of Odontology, Malmo University, Malmo, Sweden*

Deimante Ivanauskaite[1] *- D.D.S., M.D.S., assist. prof.*
Christina Lindh[2] *- D.D.S., Odont. Dr., assoc. prof. in Oral Radiology*
Klara Rangne[2] *- D.D.S., specialist trainee in Oral Radiology*
Madeleine Rohlin[2] *- Odont. Dr., professor in Oral Radiology*

Address correspondence to Deimante Ivananauskaite, Institute of Odontology, Vilnius University, Zalgirio 115, LT-08217 Vilnius, Lithuania
E-mail: deimantei@one.lt, deimantei@hotmail.com

MATERIALS AND METHODS

Patients

Ninty-six consecutive patients referred to the Department of Oral Radiology, Faculty of Odontology,

Patient group	Upper jaw																	
	17		16		15		14		13	23		24		25		26		27
	d	m	d	m	d	m	d	m	d	d	m	d	m	d	m	d	m	d
1	15	15	14															
2				13	14	14												
3							11	11	15									
4										16	13	13						
5													15	15	12			
6																15	12	12
Patient group	Lower jaw																	
	47		46		45		44		43	33		34		35		36		37
	d	m	d	m	d	m	d	m	d	d	m	d	m	d	m	d	m	d
1																13	14	14
2													15	15	12			
3										16	14	14						
4							16	16	16									
5				10	14	14												
6	15	15	11															

Fig. 1. Patient groups and site selection for the assessment of marginal bone level by score. Shadowed areas represent site selection for each patient group and figures within the shadowed areas represent the number of available sites for assessment (m=mesial, d=distal)

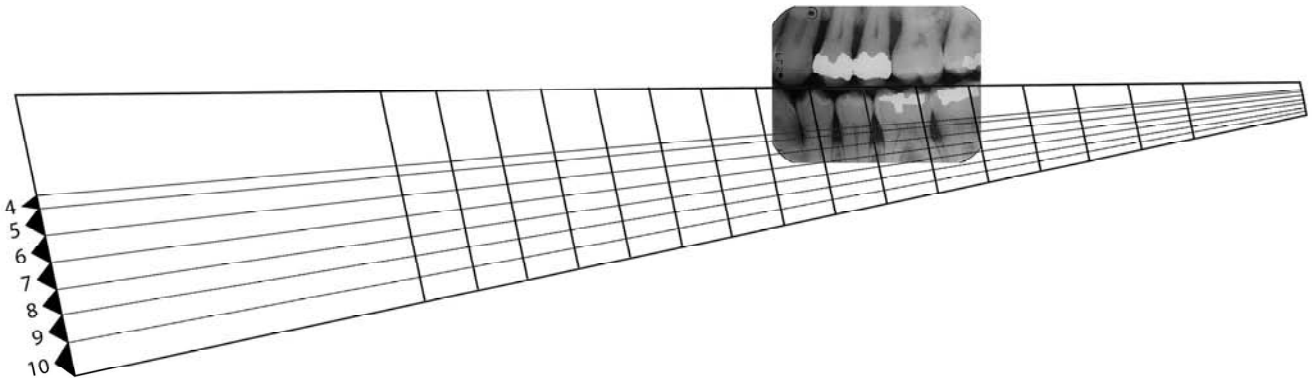

Fig. 2. The ruler designed for assessment of marginal bone levels in bitewing radiography by Håkansson *et al.* (1981), on a bitewing radiograph

Malmö, Sweden, for radiographic examination of teeth and surrounding bone tissue were examined. The age and sex distribution of the examined patients is shown in Table 1. Forty-four of the patients were male, mean age 49 years (range 21-78 years), and 52 were female, mean age 48 years (range 20-85 years). The Ethics Committee of Lund University, Lund, Sweden, approved the study.

Radiographic techniques

Panoramic radiography was performed with the Scanora® (Soredex, Helsinki, Finland) multimodal radiography system and the screen/film combination Lanex medium/T-mat G (Eastman Kodak Co., Rochester, N.Y., USA). The Scanora® dental panoramic program 003 was used; the voltage settings were 66 or 70 kV at 10, 13, 16 or 20 mA, and the exposure time was 15, 19, or 23 s. The vertical angulation of the tube was a constant – 5°. The films were processed in an automatic processor (Curix HT-33OU, AGFA, Belgium) with a developing time of 2 min.

Posterior bitewing radiographs were taken with a Heliodent 70 (Siemens, Erlangen, Germany) The X-ray unit operated at 70 kV, 7 mA. A Kwik-bite (Hawe-Neos Dental, Gentilino, Switzerland) film-holder was used for the horizontal posterior bitewing radiographs and a Take-All (Wijkström, Menton, France) film-holder or paper tabs for the vertical posterior bitewing radiographs. The focus–skin distance was 20 cm, and a rectangular collimator (30 x 40 mm^2) was used. The vertical angulation of the tube was kept constant at +10°. Ektaspeed Plus films (Eastman Kodak Co., Rochester, N.Y., USA) at exposure times of 0.32-0.64 s were used. The films were processed in an X-ray film automatic processor (XR 24 Nova, Dürr Dental, Bietigheim, Germany) with a developing time of 6 min.

The overall image quality of all radiographs was assessed by one of the authors, and images of poor quality in terms of film placement, projection, centring, density, contrast, or sharpness were retaken before the radiographic examination of each patient was considered completed.

Observers and observations

Six observers with varying experience in oral radiology (mean: 13 years; range 1-30 years) were asked to assess marginal bone level. Five of them also assessed the presence or absence of vertical bone defects and furcation involvements. Each observer read the radiographs independently. Bitewing radiographs and panoramic ra-

Table 1. Age and sex distribution of the patients.

	Number of patients Age-Groups						
Sex	**20–29**	**30–39**	**40-49**	**50-59**	**60-69**	**70-79**	**80-89**
Male	4	7	12	13	2	6	0
Female	7	8	15	12	3	3	4

Table 2. The distribution of marginal bone level scores of assessed sites. The figures represent the assessments by one observer in panoramic radiographs.

Upper jaw						
Score	13/23	14/24	15/25	16/26	17/27	**Total**
4	1	1		2		**4**
5	7	12	24	24	26	**93**
6	8	6	17	18	19	**68**
7	1	3	6	7		**17**
8	1				1	**2**
9						
10						
Total	**18**	**22**	**47**	**51**	**46**	**184**
Lower jaw						
Score	33/43	34/44	35/45	36/46	37/47	**Total**
4	3	3	4	3	1	**14**
5	18	34	33	31	40	**156**
6	9	15	13	9	14	**60**
7	1	4	1	1	1	**8**
8			1		1	**2**
9			1			**1**
10						
Total	**31**	**56**	**53**	**44**	**57**	**241**

diographs were assessed at an interval of 1 week. Prior to assessment, the observers had a joint discussion, and the assessment criteria were specified in writing. Thus, during the observations, written instructions were available. A second observation was made after 4 weeks by three of the observers.

Teeth/Sites for assessment

Sites for assessment of the marginal bone level. The radiographs of the 96 patients were randomly divided into six groups (each group = 16 patients). The sites to be assessed were selected from the distal site of the canine to the distal site of the second molar. The same six sites of the patients within the same group were assessed. Figure 1 presents the selection of sites. For example, for the 16 patients in group 1, the sites from 17 distal to 16 distal and from 37 distal to 36 distal were assessed. Since not all of the patients had a full dentition, only 499 sites (245 in the upper jaw and 254 in the lower jaw) of the possisble 576 sites (96 patients x 6 sites) were available for assessment of marginal bone level. The number of available sites is presented in the shadowed areas in Figure 1. Each observer evaluated the image quality of each site. When image quality was unacceptable, the marginal bone level of that site could not be assessed. Table 2 presents the distribution of marginal bone level scores of the sites assessed by one of the observers in panoramic radiography. Most of the sites were scored as either 5 or 6, which corresponds to a bone loss of one third or less of the root length.

Teeth or sites for detection of vertical bone defects and furcation involvements. All available sites from the distal site of the canine to the distal site of second molar or teeth in all patients were assessed for vertical bone defects and furcation involvements. A total of 1435 approximal sites in the upper jaw and 1446 sites in the lower jaw from the canine distal to the second molar distal were available for assessment of vertical bone defects. For detection of furcation involvement, 580 molars (299 in the upper jaw and 281 in the lower jaw) and 164 maxillary first premolars were available.

Assessment of marginal bone tissue in the radiographs

Marginal bone level. When the radiograph of the site was considered readable, marginal bone level was assessed with a ruler designed for bitewing radiographs (Figure 2) as described by Håkansson *et al*. [4]. A vertical line of the ruler was placed along the longitudinal axis of the tooth to be assessed. The reference points were the tip or incisal edge of the crown, the cemento-enamel junction (CEJ), and the alveolar bone crest (AC). The alveolar bone crest was defined as the most coronal level where the periodontal ligament space was considered to retain its normal width [3]. The last reference point was read as a score on the ruler. When the CEJ was not clearly visible or missing because the crown had been restored, the mirror image of the CEJ was used. If two levels of alveolar bone crest were detected, the more apical one was scored. The unit for assessment was CEJ–AC per site expressed by scores 4-10, where score 4 indicated a normal level of marginal bone tissue and scores 5-10 indicated equidistant levels of marginal bone tissue. The higher the score, the more apical the marginal bone level (Figure 2).

Vertical bone defects and furcation involvements. When the radiograph of the site or tooth was considered readable, the presence or absence of a vertical bone defect and of a furcation was determined. A vertical bone defect was considered present when two levels of marginal bone were detected or an alveolar bone pocket was visible as an angular radiolucency adjacent to the root surface. A furcation involvement was defined as an clear radiolucency between the roots.

Analysis

Agreement between the techniques in the assessment of marginal bone level was expressed as the percentage of sites whose panoramic and bitewing scores were identical. Agreement between the techniques was also calculated for the percentage of sites whose scores differed by one unit at the most. Agreement between the techniques in the detection of vertical bone defects and furcation involvement was expressed as the percentage of either being recorded or not being recorded at the same site or tooth. Sensitivities, that is, sites or teeth with positive test results compared with all sites or teeth with a vertical bone defect or furcation involvment or both, were calculated for both panoramic and bitewing radiography. The results of the sensitivity assessments were used as

Table 4. Detection of vertical bone defects. Agreement and disagreement between panoramic (Scanora® dental program) and bitewing radiography by site. Values are expressed as the percentage of the sites (n) that were assessed in both techniques by five observers altogether.

Tooth site	n	Agreement		Disagreement	
		No defect	Defect	Defect visible only in panoramic	Defect visible only in bitewing
Upper jaw		(%)	(%)	(%)	(%)
13/23d	352	94	0.2	5	1
14/24m	262	81	6	3	10
14/24d	426	92	1	4	3
15/25m	392	84	6	5	5
15/25d	581	89	2	5	4
16/26m	573	83	3	8	6
16/26d	684	82	5	11	2
17/27m	679	80	6	10	4
17/27d	665	86	3	7	4
Mean		85	4	7	4
Lower jaw					
33/43d	832	96	1	2	1
34/44m	800	94	2	2	2
34/44d	830	95	2	1	2
35/45m	778	89	2	7	2
35/45d	783	93	1	3	3
36/46m	584	87	3	7	3
36/46d	637	90	1	6	3
37747m	754	83	6	7	4
37/47d	726	85	5	7	3
Mean		91	3	4	2

Table 3. Assessment of marginal bone level. Agreement and disagreement between panoramic (Scanora® dental program) and bitewing radiography by tooth site. Values are expressed as a percentage of the number of sites that were assessed in both techniques by the six observers altogether (n).

Tooth site	n	Agreement	Disagreement	
			Less bone loss detected in panoramic	More bone loss detected in panoramic
Upper jaw		(%)	(%)	(%)
13/23d	50	44	14	42
14/24m	24	62	21	17
14/24d	50	60	20	20
15/25m	80	68	16	16
15/25d	118	64	20	16
16/26m	100	52	30	18
16/26d	138	54	11	35
17/27m	133	53	10	37
17/27d	130	54	13	33
Mean		56	16	28
Lower jaw				
33/43d	93	50	35	14
34/44m	131	50	8	41
34/44d	143	66	23	11
35/45m	128	54	17	29
35/45d	140	55	21	24
36/46m	104	63	15	22
36/46d	126	66	18	16
37/47m	159	60	10	30
37/47d	126	55	11	34
Mean		58	17	25

the reference.

Intra-observer agreement was calculated for three observers and expressed as overall agreement in percent and as kappa as described by Cohen [16]. Inter-observer agreement was calculated and expressed as kappa for several observers as described by Fleiss [17] and as kappa for pairs of observers.

RESULTS

Assessment of the radiographs

The marginal bone level. Of 2 994 possible assessments (245 available sites x 6 observers in the upper jaw and 254 x 6 in the lower jaw), a total of 823 sites in the upper jaw and 1 150 sites in the lower jaw were actually assessed in both radiographs by all six observers. Table 3 presents the mean agreement calculated for sites with identical panoramic and bitewing scores: 56% of the sites in the upper jaw and 58% of the sites in the lower jaw. The highest agreement (60%-68%) was found in the premolar region of the upper jaw and in the molar region of the lower jaw (55%-66%). The mean agreement between the two techniques, if a difference of one score was allowed, was 95% of the sites in the upper jaw and 94% in the lower jaw (range for both: 88%-100%). The panoramic score was lower (less bone loss) than the bitewing score in 16% of the sites of the upper jaw and 17% of the sites of the lower jaw. In 28% of the sites in the upper jaw and 25% of the sites in the lower jaw, panoramic scores were higher (greater bone loss) than bitewing scores.

The agreement between the techniques in the assessment of bone level varied between the six observers. Two observers each assessed bone level on both panoramic and bitewing radiographs identically in 65% of the sites whilst a third observer only scored bone level identically in 50% of the sites. The latter had a general tendency to assess bone loss as being lower on a panoramic than on a bitewing radiograph.

Vertical bone defects. Table 4 presents the results of the detection of vertical bone defects. The lowest agreement between techniques (80% of the sites) was

Table 5. Detection of furcation involvements. Agreement and disagreement between panoramic (Scanora® dental program) and bitewing radiography by tooth. Values are expressed as a percentage of the number teeth that were assessed in both techniques by five observers altogether (n).

Tooth	n	Agreement		Disagreement	
		No furcation	Furcation	Furcation visible only in panoramic	Furcation visible only in bitewing
		(%)	(%)	(%)	(%)
17/27	726	89	5	5	1
16/26	751	83	10	4	3
14/24	800	96	1	2	1
36/46	645	75	12	5	1
37/47	759	87	7	4	2
Mean		86	7	4	2

Table 6. Intra-observer agreement in the assessment of marginal bone tissue concerning scoring of marginal bone level, presence of vertical bone defects, and furcation involvement in panoramic (Scanora® dental program) and bitewing radiography. Values expressed as overall agreement (%) and kappa (κ).

Observer	Marginal bone level				Vercical bone defect				Furcation involvement			
	Panoramic		Bitewing		Panoramic		Bitewing		Panoramic		Bitewing	
	(%)	(κ)	(%)	(κ)	(%)	(κ)	(%)	(κ)	(%)	(κ)	(%)	(κ)
1	72	0.46	76	0.55								
2	69	0.45	66	0.43	93	0.57	94	0.62	98	0.79	97	0.72
3	59	0.37	55	0.31	92	0.62	92	0.52	93	0.65	96	0.77
4					99	0.56	99	0.61	97	0.73	97	0.78

Table 7. Inter-observer agreement for assessment of marginal bone tissue in panoramic (Scanora® dental program) and bitewing radiography, expressed as kappa (κ), for several observers.

	Marginal bone level	Vertical bone defect	Furcation involvement
Panoramic	0.28	0.35	0.53
Bitewing	0.29	0.38	0.65

found for the mesial site of the second molar in the upper jaw and the highest agreement (96%) for the distal site of the lower cuspid. The majority of the concordance was recordings of no vertical bone defect in either radiograph. Sensitivity was 0.73 for panoramic radiography and 0.53 for bitewing radiography. In 1%-11% of the observations, a vertical bone defect was only detected in the panoramic radiograph. In the molar region in particular, bone defects were moe visible on panoramic than on bitewing radiographs.

Furcation involvements. Table 5 presents the results of the detection of furcation involvement. Agreement between the methods varied between 87% for the lower first molar and 96% for the upper first premolar. The majority of the concordance involved recordings of no furcation involvement. Sensitivity was 0.80 for panoramic radiography and 0.70 for bitewing radiography. In 4% of the teeth, a furcation involvement was only detected in panoramic radiographs.

Observer performance

Intra-observer agreement. Table 6 presents the intra-observer agreement for the assessment of marginal bone level for panoramic and bitewing radiography. The overall agreement in panoramic radiography for observers 1, 2 and 3 was 72%, 69% and 59% and in bitewing radiography 76%, 66% and 55%, respectively. Corresponding kappa values for panoramic radiography were 0.46, 0.45 and 0.37 and for bitewing radiography 0.55, 0.43 and 0.31, respectively. The observer with the highest kappa for bitewing radiography also had the highest kappa for panoramic radiography. Correspondingly, the same observer had the lowest kappa in both techniques.

In the detection of vertical bone defects, the kappa values for observers 2, 3 and 4 were 0.57, 0.62 and 0.56 for panoramic radiography and 0.62, 0.52, and 0.61 for bitewing radiography, respectively. Corresponding values for the detection of furcation involvement were 0.79, 0.65 and 0.73 for panoramic radiography and 0.72, 0.77 and 0.78 for bitewing radiography, respectively. The observers with the lowest and highest kappa values differed between the two techniques in the detection of furcation involvements and vertical bone defects.

Inter-observer agreement. Table 7 presents inter-observer agreement. Inter-observer agreement between a pair of observers on marginal bone level varied widely. Agreement varied between 0.08 and 0.58 in panoramic radiography and between 0.04 and 0.43 in bitewing radiography. One of the observers (Observer 6) had the lowest kappa values for assessing marginal bone level in both techniques.

DISCUSSION

The use of consecutively referred patients allowed us to compile a sample that should have been representative of the general population consuming dental care. The age groups 40-49 and 50-59 years were the ones most strongly represented. Results of cross-sectional studies suggest that the prevalence of bone loss increases in these age-groups. In the age-group 40 years, 5% had alveolar bone loss exceeding one third of the root length around the majority of their teeth whilst the corresponding figure in the age-group 50 years was 21% [18]. Thus, the likelihood of findings that will influence patient management will be higher in individuals of these age-groups than in those of younger age-groups.

The fairly large sample size of 96 patients represented a wide age distribution and a distribution close to equal between the sexes. This is particularly important in the case of panoramic radiography where the patients' anatomy influences image quality. With a sample of 96 patients and a possible 3072 sites in the posterior regions, a selection of sites had to be made to make the assessments manageable. The method of randomly dividing the patients into groups for the assessment of six sites gave us a representative material with an even distribution between jaws (upper and lower), sides (right and left), and regions (molar, premolar, and canine) without having to reduce the number of individuals examined.

As diagnostic methods are applied by numerous examiners, it is of utmost importance that evaluations of these methods include multiple observers. Otherwise, it would be difficult to determine whether the findings were a result of the one observer's skill in applying the method(-s) or of the performance of the diagnostic method(-s) under examination. It has been shown that a number of observers larger than six has little consequence on the results when a reasonably large sample is examined [18]. Three observers repeated their observations with one of the methods to make it possible to calculate intra-observer agreement. Agreement between panoramic and bitewing assessments cannot override intra-observer agreement for one technique. We chose to express the agreement between observers as both overall agreement and as a kappa index. Kappa statistics can be interpreted as the chance proportional agreement, but it does not take into account the degree of disagreement. There is no value of kappa that can be regarded universally as indicating good agreement, but it is still the best approach to this type of analysis, and comparisons can be made to other studies within the same field using kappa statistics [20].

In most patients there were two bitewing radiographs of each side (premolar and molar). The sites to be assessed were not marked in the radiographs, which means that the same site may have been assessed in different bitewing radiographs (if present in both the molar and premolar bitewing radiographs). Vertical angulation was kept constant, but for obvious reasons, horizontal angulation was different for premolar and molar bitewing radiographs. This could have an effect on the assessment of the bone level and might have decreased intra-observer as well as inter-observer agreement.

Identical scores of the marginal bone level in panoramic and bitewing radiography were obtained in 56%-58% of the sites. This is comparable to the results of Molander et al.[12] but 10% lower than found in a previous study on panoramic and bitewing radiography Åkesson et al. [13]. The different outcomes might partly be due to the different design of the studies concerning the observers. In the present study, six observers scored all sites whereas in Åkesson's study, each of five observers assessed only one fifth of the material [13]. Various observers arrive at different results, and the same observer sometimes contradicts her or his own results at re-examination. If the analysis had been based on the observer with the highest agreement, the result of the present study would have been that agreement between the techniques was found in 65% of the sites. However, if the observer with the lowest agreement was the only observer in a study, agreement would have been found in only 50% of the sites. The agreement between the techniques was very high (94%-95% of the sites) if a difference of one score was allowed. This is in line with previous studies on the measurement of marginal bone loss [13, 12, 21, 22]. When the scores between the two techniques differed, bone loss was assessed at more sites as more severe in panoramic radiography than in bitewing radiography. This result, which is consistent with those of previous studies [7, 8, 13], should be taken into account when using radiography in epidemiological studies on marginal bone loss.

In the detection of vertical bone defects and furcation involvement, sensitivity and the number of positive findings was higher for panoramic radiography. These results contradict previous results, where more sites with bone defects were detected with bitewing radiography, particularly in the upper jaw, and the number of furcation involvements detected was similar for bitewing and panoramic radiography [13]. Our results could be a reflection of improvements in the panoramic technique.

Observer performance varied both within the same observer and between observers. This further underlines the importance of basing the analysis of diagnostic methods on the interpretations of several observers. One observer had the highest intra-observer agreement and another observer the lowest intra-observer agreement, independent of radiographic technique, when assessing marginal level. That intra-observer agreement was higher than inter-observer agreement has been generally found in studies on observer performance. Inter-observer agreement varied substantially, even though the observers jointly discussed and wrote down assessment criteria in a meeting that was intended to serve as a calibration. The agreement of one observer in particular compared with the agreements of the other observers in assessing bone level was low. For the detection of bone defects and of furcation involvements, intra- and inter-observer agreement was higher than for the assessment of bone level. Since the kappa values for panoramic and bitewing radiography were comparable, it seems safe to conclude that the reproducibilities of observer performance in Scanora® panoramic radiography and in bitewing radiography are similar.

That not only marginal bone level but also the presence of vertical bone defects and furcation involvements were identified strengthens the conclusions of this study. These findings affect the periodontal diagnosis of the tooth and are significant in treatment planning and prognosis. Moreover, when a diagnostic system is implemented, it is necessary to identify not only its technical factors but also other factors, such as observer performance, that influence the outcomes of the actual system.

CONCLUSION

Scanora® panoramic radiography could by considered the radiographic examination of choice for assessment of marginal bone tissue, and it is comparable to bitewing radiography. However, the level of agreement between the techniques is dependent on the observer.

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