Periodontal Probing Versus Radiographs for the Diagnosis of Furcation Involvement

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The management of molars with furcation involvement (FI) represents one of the major challenges in clinical periodontology.[1,2] Treatment of periodontally diseased molars with no FI or FI Class I[1] may be managed by root debridement alone,[3] whereas advanced FI (Class II or III[1]) requires invasive, in some cases resective, techniques.[4-6] FI Class II[1] of mandibular molars as well as of buccal furcations in maxillary molars may be successfully treated by regenerative procedures.[7] Therefore, accurate presurgical diagnosis of FI is fundamental for decision making and assessing the prognosis of diseased molars. Previous investigations of the validity of various assessment techniques of FI were performed in vitro[8] or prospectively.[9-13] Prospective studies have some advantages because the data might be more reproducible, e.g., standardized radiographs with a receptor holder, strict parallel-right-angle x-ray technique, or examination by one well-instructed examiner. However, this does not reflect real treatment conditions. The present study, therefore, is designed as a retrospective investigation over a long observation period with dentists of different experience to determine the validity of assessing FI by clinical furcation probing (FP) as well as conventional radiographs in comparison to the true situation during open flap surgery (OFS). In addition, the influence of parameters such as diagnostic

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experience of the examiner or type of radiograph was investigated.

MATERIALS AND METHODS

Study Population

This is a part of a longitudinal retrospective clinical cohort study based on demographic, radiographic, and clinical data. From 1982 to 1998, a total of 2,564 patients were treated for moderate-to-advanced periodontitis in the Department of Periodontology, Christian-Albrechts-University of Kiel, Germany. Three hundred ten patients, who received maintenance therapy for ≥10 years with ≥1 visit/year after non-surgical/surgical active periodontal therapy (APT), presenting bone loss of ≥50% at ≥2 teeth, annual pocket probing depth (PD) documentation, and complete conventional radiography documentation at baseline (T0), at the end of the APT (T1), and at the last documented visit of maintenance therapy (T2), qualified for participation in the study.[14] Two hundred thirty-eight patients had at least one first or second molar treated with OFS during APT (in total 939 molars). FI evaluated during OFS was documented in the charts. Twenty-three patients with 105 molars were excluded due to the period of time of >1.5 years between the radiographic documentation and FP of the dental furcation or the date of the OFS. The data of 215 patients (91 males and 124 females, aged 23 to 67 years; mean age: 44.92 ± 9.35 years) with 834 molars finally were analyzed in the present study. Over the time span, 16 different dentists treated the observed patients with OFS in the area of the first or second molar (see *Acknowledgments*). All of them specialized in periodontology and worked at a department of the Christian-Albrechts-University of Kiel during the observation time of 16 years.

All patients gave their informed written consent for the statistical analysis of their data documented during periodontal therapy. The Ethical Committee of the Christian-Albrechts-University of Kiel approved the protocol of the study (AZ 442/10).

FP and Radiographic Assessment of Dental Furcation

The degrees of the documented FP of the FI measured at T0 were entered into a database by one author (CS) for each molar and were categorized as follows (Hamp et al.[1]): Class 0 = no horizontal loss of periodontal tissue support (in addition to the original scoring scale); Class I = ≤3 mm of horizontal loss of periodontal tissue support; Class II = >3 mm of horizontal loss of periodontal tissue support, no through-and-through furcation; and Class III = through-and-through furcation (requiring seeing the tip of the Nabers probe at the contralateral furcation opening).

The reproducibility of the data entry was verified by a second investigator (AP) and eventually corrected. Since 1982, the FI (buccal in maxillary and mandibular molars, lingual in mandibular molars, mesio/disto-palatal in maxillary molars) in every patient new to the department was examined using a manual Nabers probe† marked in 3-mm steps. For the present study, only the highest degree of FI for each molar was recorded.

For the investigation, 215 radiographs were evaluated, divided into panoramic radiographs (OPGs) (143) and intraoral radiographs (I-Os) (77). For some patients, both types of radiographs for the diagnosis of the periodontal condition of different molars were used. The evaluated OPGs were taken non-digitally and scanned both jaws to show a two-dimensional view of a half-circle from ear to ear. The analog I-Os were all taken with a receptor holder with fixed arm for accurate positioning of the film parallel to the tooth to show the alveolar crest without deformation. All radiographs of T0 were scanned to make them accessible to digital analysis. This was done by using a scanner‡ with a resolution of 600 × 1,200 dots per inch. Radiographic analysis was performed under standardized viewing conditions in a darkened room by one less experienced examiner (LE) (JW) and one experienced examiner (EE) (CG) using an image processing program.§ The EE had already worked for 12 years in conservative and periodontal dentistry, whereas the LE was a postgraduate dental student with 2 years of clinical practice. LE was calibrated by EE before the beginning of the radiographic evaluation. The degree of suspected FI according to Hamp et al.[1] was entered in a database.‖ In cases of no evaluable FI, e.g., inadequate radiograph with low contrast or overlapping of bone and different roots, the FI was coded as "f" for failed. All examiners were masked during the data entry with respect to the source of the radiographic (CS and AP) and the clinical (JFW and CG) data.

Data Analyses

Data were organized in a database file for all participants. After pseudonymization, all data were exported into a separate data set for statistical analysis. The grade of agreement was analyzed using weighted κ coefficient (κ_w).[15-17] The κ_w as a statistical measure of agreement was determined to indicate the agreement between OFS results and FP or radiography, respectively, with the evaluation of FI during OFS as the gold standard. Proportions were calculated using the McNemar χ^2 test. The statistical analysis of the measurements was performed with statistical software.¶

† ZA3, Deppeler, Rolle, Switzerland.
‡ Epson Expression 1600, Epson, Meerbusch, Germany.
§ ImageJ, National Institutes of Health, Bethesda, MD.
‖ FileMaker Pro, v.11, FileMaker, Santa Clara, CA.

Table 1.

Agreement of FI Diagnosed by Clinical Probing With a Nabers Probe (FP) Compared with the Situation Observed During OFS

FP Region	Confirmed by OFS (%)	Overestimated Compared with OFS (%)	Underestimated Compared with OFS (%)
Total	56.2	14.8	29.0
Maxilla	53.8	16.3	29.9
Mandible	59.3	12.9	27.9

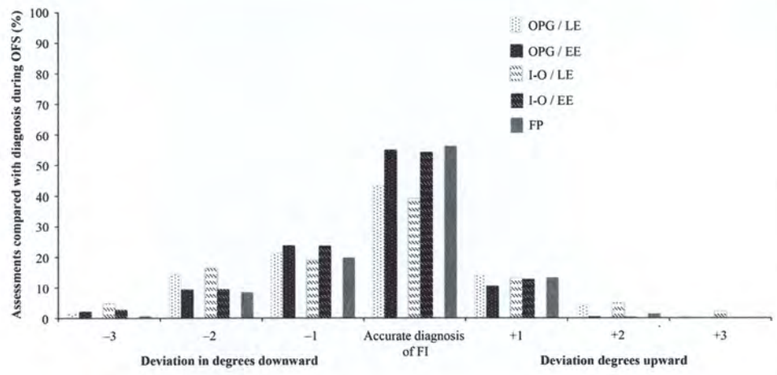

Figure 1.
Under- and overestimation of FI diagnosed by radiographs (OPG and I-O) and FP compared with diagnosis during OFS: confirmation, overestimation (deviation in degrees upward), and underestimation (deviation in degrees downward).

RESULTS

FP Versus Assessment During OFS

Of the 834 investigated molars, during OFS 113 (13.5%) demonstrated FI Class III, 201 (24.1%) were FI Class II, 255 (30.6%) were FI Class I, and 265 (31.8%) were Class 0.

The FI Class (0 to III) measured by FP was confirmed in 56.2% during OFS. The FI was overestimated in 14.8% and underestimated in 29.0% (Table 1, Fig. 1). The degree of agreement between FP and OFS was slightly better for the mandible (59.2%, κ_w = 0.629) compared with the maxilla (53.8%, κ_w = 0.550).

The best correlation of FP and OFS was found in the mandible for the first left molar (κ_w = 0.690) and in the maxilla for the second right molar (κ_w = 0.637). Of all furcations diagnosed as Class III during OFS, 68.1% were not detected correctly by FP (Table 2) (maxilla 66.2% and mandible 71.4%).

The mean agreement between FP and OFS for all investigators was κ_w = 0.588. The number of treated molars per single examiner did not influence the agreement (Pearson correlation: P = 0.313).

Radiographic Diagnosis Versus Assessment During OFS

Overall, 524 dental furcations were analyzed by OPG and 310 by I-O. The LE was not able to evaluate the FI in 30 cases (3.6% of 834 molars) and set these as FI Class "f" (EE: no cases). Furthermore, LE did not find any FI Class II by OPG or I-O. Missing an FI Class III by radiographs was more likely in the maxilla compared with the mandible (EE: 59.2% versus 35.7%; LE: 52.9% versus 14.3%).

The agreement of OFS and radiographs was κ_w = 0.542 (OPG κ_w = 0.555 and I-O κ_w = 0.521) for both examiners. A slightly better agreement was found for the mandible, with 52.3% (κ_w = 0.619) versus 44.5% (κ_w = 0.477) in the maxilla. The best correlation of OPG and OFS was found at the first left molar in the mandible (EE κ_w = 0.876; LE κ_w = 0.629) (Table 3).

The assessment of FI by OPG versus I-O achieved a close agreement with OFS (for EE, 55.0% versus 54.2%; for LE, 39.7% versus 43.3%) (Table 4). This finding was in accord with FI Class III (EE, 48.5% versus 51.1%; LE, 69.7% versus 56.1%).

Influence of Examiner Experience and Tooth Anatomy

Overall the accuracy of the FI assessment by radiography seemed to depend on the examiner's experience (EE κ_w = 0.618 versus LE κ_w = 0.426). For further details, see Table 4 and Figure 1. Of all FI Class III assessed during OFS, 43.2% (EE 50.4% and LE 38.5%) were not detected in any type of radiography (Table 5).

DISCUSSION

Advanced FI in molars results in a less favorable outcome of periodontal therapy and an increased risk for tooth loss.[2,18] Therefore, an accurate diagnosis

¶ SPSS, v.20, IBM, Chicago, IL.

Table 2.

Evaluation of FI for Specific Classes During OFS Related to the Previous Clinical Diagnosis (FP)

	FI Diagnosed During OFS (%)			
FI Diagnosed by FP (%)	FI 0 (n = 265)	FI I (n = 255)	FI II (n = 201)	FI III (n = 113)
FI 0 (n = 303)	**74.3**	29.0	12.9	5.3
FI I (n = 305)	21.5	**54.1**	32.2	39.8
FI II (n = 177)	4.2	16.5	**48.8**	23.0
FI III (n = 49)	0	0.4	6.0	**31.9**

Bold type results represent the proportion of agreement between radiographic examination and OFS for each degree of FI. Total number of furcations = 834.
All agreements were significant according to McNemar x2 test by $P<0.001$.

of the degree of FI is required for adequate decision making and considerably influences treatment for a periodontal patient. This retrospective study evaluates whether clinical, radiographic, or a combined assessment of FI is most reliable to assess the degree of FI. The advantage of this study design, aside from the large number of participants, is that the examinations were performed under the conditions of daily clinical practice by periodontists unaware of their participation in a study. Study-related effects, such as a bias of the examiners, e.g., during clinical probing, could therefore be excluded. The electronic database was set up more than 30 years ago with the aim to later analyze the clinical outcomes and, therefore, a lot of effort was made to optimize the quality and validity of the clinical evaluations over time. However, the accuracy and reproducibility of the diagnostic method could not be controlled as would be done in a prospective study.

A limitation of this analysis was that only the most severe FI of each molar was considered. Therefore, the FIs of tri- or bifurcation have to be matched for the highest degree of FI. Hence, on the tooth level, it is possible to discuss the results, e.g., for prognosis or therapeutic implications, but the results are not suited to be discussed on a site level (each furcation entrance).

In a review on radiographic parameters, Brägger[19] stated that in case the cemento-enamel junction and the root apices are difficult to identify, the radiographic assessment of furcation areas will be less reliable due to the complex anatomy and the overlay of the different anatomic structures. According to the study design of the current investigation, the authors used only conventional radiographs under the conditions of daily practice without any standardization devices and digitized them. Despite the extensive innovations in imaging methods in recent years, the traditional method of obtaining an image has basically remained the same.[19] There seems to be no evidence that digital methods are more precise than analog ones with respect to the detection of FI. Neither one should be superior at depicting periodontal structures.[19,20] However, according to Brägger,[19] the methodological error of each radiographic parameter, which influences the amount of bone change in the furcation area, cannot be solved.

Another presurgical furcation examination is the clinical probing. Whether its reliability is different or equalizes to radiographic measures is still unclear. It seems indisputable that the force during clinical probing of the furcation,[21] the size and design of the probe,[22] and the experience and the training of the examiner[23] influence the clinical assessment of the FI.[24,25] This could be an explanation for the differences in the interrater reliability for the correlation between FP and OFS in the present study, despite the same degree of treatment experience. The structure of the probe does not seem to influence the pocket PD severely. Eickholz and Kim[10] found a high correlation between replicate measurements for different kinds of probes (κ_w = 0.50 to 0.89), whereas curved probes custom-made for FP, like the one used in the current study, were the most appropriate ones. In contrast, special pressure-calibrated probes seem to be unsuitable for a proper assessment of the FI.[10,26,27] Nevertheless, in a prospective study with 100 molars, a good-to-excellent agreement of replicate measurements of furcation degrees with a Nabers probe for one operator (κ_w = 0.706 to 0.944) without significant differences between furcation degree as assessed presurgically and intrasurgically was possible.[9] The overall correlation of all 16 operators with κ_w = 0.588 is lower compared with the results of Eickholz and Staehle[9] but still showed a moderate correlation according to Landis and Koch.[17] In a similar investigation with six involved dentists after diagnosis of 1,180 clinical furcations, Zappa et al.[13] found an agreement of κ = 0.373, but used Cohen κ as statistical method, which is not comparable with the present results determined by the weighted κ. Cohen κ is appropriate for binomial variables or categorical variables that are not ordinal. The classification of FI according to Hamp et al.[1] is categorical and ordinal. Therefore, the appropriate test for agreement is the κ_w. Nevertheless, the value of κ_w depends on the specific choice of weights and is usually higher than the unweighted κ,

Table 3.

Agreement (κ_w) of FI Diagnosis Separately for Different Tooth Types by Radiography (I-O and OPG) Performed by EE and LE and Diagnosis During OFS

	Maxilla				Mandible			
	Right		Left		Right		Left	
Agreement	First Molar (n = 119)	Second Molar (n = 127)	First Molar (n = 111)	Second Molar (n = 104)	First Molar (n = 98)	Second Molar (n = 103)	First Molar (n = 79)	Second Molar (n = 93)
Between FI diagnosed during OFS and radiographically diagnosed FI by EE								
I-O	0.675	0.758	0.433	0.664	0.413	0.562	0.713	0.512
OPG	0.356	0.531	0.521	0.599	0.610	0.720	0.876	0.765
I-O + OPG	0.473	0.615	0.485	0.621	0.549	0.671	0.809	0.646
Between FI diagnosed during OFS and radiographically diagnosed FI by LE								
I-O	0.308	0.336	0.350	0.346	0.477	0.573	0.425	0.588
OPG	0.344	0.282	0.305	0.142	0.484	0.530	0.629	0.584
I-O + OPG	0.330	0.302	0.327	0.212	0.483	0.549	0.549	0.587
Between FI diagnosed during OFS and radiographically diagnosed FI by LE and EE								
I-O	0.530	0.536	0.386	0.475	0.404	0.544	0.518	0.605
OPG	0.378	0.485	0.474	0.412	0.571	0.645	0.767	0.679
I-O + OPG	0.439	0.504	0.439	0.434	0.521	0.614	0.667	0.648
Between FP performed by 16 dentists and OFS								
FP	0.637	0.534	0.439	0.554	0.550	0.646	0.690	0.610
FI diagnosed during OFS and the combination of radiographic and FP diagnosed FI								
FP + OPG + I-O	0.621	0.723	0.522	0.697	0.577	0.661	0.633	0.494

because deviations of adjacent categories are more common than differences across multiple categories.[28] This might explain the lower agreement values due to unweighted κ statistics used from Zappa et al.[13]

On the tooth level, the agreement of clinical probing to OFS was nearly similar for all molars, while the highest degree of agreement was found for mandibular molars (κ_w = 0.629). Clinical probing showed a high specificity of 0.74 and a moderate sensitivity of 0.57 in the current study. Therefore, probing seems to be a reliable diagnostic tool for all cases of mild periodontitis with FI Class 0 to I,[1] because such cases could be managed by non-surgical mechanical debridement with >90% survival rate over 5 years.[3] Whereas the combination of no and initial FI (FI Class I) is equally detected by FP or radiographs (FP 90% and OPG/I-O 97% correct correlation to OFS), advanced FI Class III is more easily diagnosed by radiographs (OPG/I-O 57% versus FP 32% correct correlation to OFS). The comparison of clinical and intrasurgical FP is limited, as clinical FP assesses horizontal tissue attachment, whereas intrasurgical probing assesses bone level. Thus, intrasurgical measurements tend to overestimate clinical measurements. On the other hand, the examiners of the current investigation interpreted the FI Class III according to Hamp et al.[1] during clinical FP as through-and through furcation, which requires visibility of the tip of the Nabers probe at the contralateral furcation opening. This definition corresponds to Class IV according to Glickman.[29] He described FI Class IV as a "super grade III lesion" according to Hamp et al.[1] Therefore, Glickman[29] defined two

Table 4.

Proportions of Agreement of FI Diagnosed by Radiography (I-O and OPG) Compared with the Real Situation During OFS: Confirmation, Overestimation, and Underestimation by EE and LE

	EE				LE			
Diagnosis	Confirmed by OFS (%)	Overestimated Compared with OFS (%)	Underestimated Compared with OFS (%)	κ_w	Confirmed by OFS (%)	Overestimated Compared with OFS (%)	Underestimated Compared with OFS (%)	κ_w
I-O (n = 310)								
Full mouth	54.2	15.8	30.0	0.622	39.7	12.5	38.9	0.440
Maxilla	54.6	16.6	28.8	0.648	40.5	15.8	43.7	0.357
Mandible	53.7	15.0	31.3	0.570	46.4	28.6	25.0	0.534
OPG (n = 524)								
Full mouth	55.0	12.8	32.3	0.616	43.3	21.8	34.9	0.416
Maxilla	48.3	12.8	38.9	0.525	36.8	15.4	47.7	0.282
Mandible	63.7	12.8	23.5	0.738	43.4	29.0	27.6	0.560

different degrees of through-and-through lesion, one as having sustained enough bone loss to make it completely probable, whereas he defined Class IV as a through-and-through lesion with no soft tissue occluding the entrances, therefore allowing the diagnosis by visual inspection alone. However, according to Glickman,[29] in a Class III FI, the bone also is no longer attached to the furcation of the tooth, essentially resulting in a continuous tunnel, but morphologic factors such as long root trunks, root concavities, bifurcation ridges, small furcation entrances, or soft tissue may still occlude the FI, inhibiting the ability to probe in its entirety.[30] Measurements from different sides equaling or exceeding the width of the tooth, nevertheless, only allow one to assume the presence of a Class III FI,[1] resulting in some degree of uncertainty. The established Hamp classification[1] has already been modified by other authors[31] in terms of a subclassification. The additional FI Class "II to III" according to Walter et al.[31] allows for a discrimination of horizontal loss of periodontal tissue >6 mm without detectable through-and-through breakdown. Hereby, the uncertainties in clinically assessing the FI are illustrated, and it also becomes clear that the choice of the method used to classify FI sets the way in which the uncertainty is directed. Diagnosing the FI Class III as a through-and-through furcation as it was done in the present study leads more likely to an underestimation of the FI compared with the intrasurgically evaluated FI, which is the accepted gold standard. On the other hand, the possibility of clinically overestimating FI is diminished compared with other definitions. This corresponds to the results of the present study, showing FI Class III less often in clinical compared with intrasurgical assessment. However, as the presented results are analyzed retrospectively, the most important issue is that the system of classification had not been changed over time. This is the precondition for interpreting the results. Whether an underestimation or an overestimation of the clinical examination of FI is better for clinical decision making may depend on the subsequent therapeutic concept.

For FI Class III of all diseased molars in the maxilla and mandible, with nearly 57% versus 32% by FP, the agreement of FI Class III diagnosed by FP compared with OFS is particularly true. For mandibular molars, Topoll et al.[32] concluded that an additional examination of a conventional radiograph (I-O) can be advantageous regardless of the severity of FI. This seems obvious, since especially I-O may give information about interradicular bone density, and this may be correlated to the severity of FI. Nevertheless, the present results correspond to other publications demonstrating an improved precision of assessing conventional radiographs as the FI increased.[33] The horizontal depth of the furcation lesion was the main influencing factor for the observers' diagnostic performance.[33] Thus, in cases with advanced periodontitis and suspected FI, a conventional radiographic image is essential in addition to FP for evaluation and planning of further periodontal treatments such as OFS, tunneling, or root resection. Surgical therapy is the treatment of choice for molars with advanced FI after initial non-surgical therapy,[18,34,35] and limitations of FP might lead to intraoperative alteration of a surgical treatment plan. In the mandible, FI Class III was not detected in 68.1% of the cases. If guided tissue regeneration were planned according to an underestimated FI, the probability for success of such cost-intensive treatment would have

Table 5.

Proportions of Relationship Between Radiographic Diagnosis (OPG and I-O) of FI Separately for Different Degrees Evaluated by EE and LE and the Situation During OFS

FI diagnosed on radiographs (OPG and I-O) (%)	FI During OFS (%)			
	FI 0 (n = 265)	FI I (n = 255)	FI II (n = 201)	FI III (n = 113)
By EE (n = 834)				
FI 0 (n = 360)	**77.7**	36.9	24.4	9.7
FI I (n = 259)	21.9	**48.6**	30.8	13.3
FI II (n = 136)	0.4	13.3	**34.8**	27.4
FI III (n = 79)	0	1.2	10.0	**49.6**
FI f (n = 0)	0	0	0	0
By LE (n = 804)				
FI 0 (n = 429)	**76.4**	56.5	36.0	10.7
FI I (n = 170)	14.1	**23.5**	23.5	23.2
FI II (n = 0)	0	0	**0**	0
FI III (n = 205)	5.3	17.6	38.5	**61.6**
FI f (n = 30)	4.2	2.4	2.0	4.5

Bold type results represent the proportions of agreement between radiographic examination and OFS for each degree of FI. f = no evaluable FI on radiographs.
All agreements were significant according to McNemar x2 test by $P<0.001$.

decreased significantly, if the real FI was Class III.[7,36] Ross and Thompson[12] found a more reliable assessment of FI in maxillary molars by radiography than by clinical examination, which was opposite for the mandible. The findings for the maxilla corresponded to the present results. The reason for this disparity, regardless of the already mentioned reliability of clinical probing, may be a difference in the density of alveolar bone of the maxilla and mandible. Therefore, the present authors agree with the conclusion of Ross and Thompson[12] to use both methods of examination, radiographic and clinical, to detect the presence of FI. With a receiver operating characteristic curve, Gürgan et al.[33] evaluated radiographic assessment of artificial bony defects with the corresponding buccal FI Class I and II in the mandible with a high correlation within the 12 observers (68% and 86%) and without significant difference between mandibular first and second molars, similar to the present investigations (Table 3). Their analysis revealed that furcation lesion depth was the major factor influencing the observers' diagnostic performance.[33] That is contradictory to the results of the present investigation (FI Class I: 61% and FI Class II: 48% for EE), which may be due to the standardized radiographs and artificial defects.

The present investigation showed that underestimation of furcation defects by FP was much more common than overestimation. Müller and Eger[21] described that neither the tooth type nor the furcation location seemed to play a significant role in clinical measurement. They critically noted that the identification of the reference for measurements, an initial fluting of the root surface, is expected to considerably contribute to measurement error. If this concavity is in a subgingival location, the examiner relies on tactile sensation alone. Errors in detecting this landmark will certainly result in considerable variation of the measurements[21] and therefore explain the difference in the interrater reliability in the current investigation. Eickholz and Kim[10] showed that straight probes may increase this underestimation and, therefore, recommended curved probes as used in this study. Zappa et al.[13] reported that 7% and 24% of the measurements in Class I and II furcations, respectively, were overestimations compared with OFS. Müller and Eger[21] speculated that such false diagnoses may condemn a molar to premature extraction or at least to unnecessary surgical intervention. The present inverse results with 17% (FI Class I) and 6% (FI Class II) overestimation may relate to a lower risk of overtreatment or premature extraction. However, similar to previous investigations,[13] the present authors found only a moderate agreement ($\kappa_w = 0.588$) and hence suggested that clinical probing of the furcation alone is not sufficient for treatment decisions. Nevertheless, in this investigation the FI Class I with simple treatment options could be distinguished from FI Class II to III with higher treatment effort by FP (Table 2). Further diagnostic tests should be used to complement and improve the clinical furcation diagnosis.

Because conventional radiographs are still commonly used by practitioners, the analog radiographic data evaluated in this study is in step with actual practice. It should be noted that the magnitude of the methodologic error of each radiographic method

limits the amount of real change in disease status that could be detected with a certain level of confidence.[19] Nevertheless, radiographic parameters can be used to come to a periodontal diagnosis; to create a treatment plan; to document tissue stability, remodeling, or breakdown; and perhaps to detect periodontal risk factors.[19]

Whether three-dimensional computed tomography (CT) and other image processing techniques will give an advantage in the identification of subtle changes in tissue density, e.g., in dental furcations, is not yet clear, as at present these techniques primarily remain research tools.[19] Different studies with three-dimensional CT and cone beam CT (CBCT) found a correlation of the FI during FP and CT in 27% to 69% of all sites, whereas 23% to 29% were overestimated and 21% to 44% underestimated, respectively.[31,37,38] These findings are similar to the data from this retrospective study done with two-dimensional radiographs, where an experienced examiner found the right degree of FI on radiographs in 55% (OPG) and 54% (I-O), whereas 13% (OPG) and 16% (I-O) were overestimated and 32% (OPG) and 30% (I-O) were underestimated. The agreement between two-dimensional radiographs and OFS in this study was also similar to the results gained by a CT with a κ_w for the maxilla of 0.572 (EE; corresponding $\kappa = 0.319$) and mandible $\kappa_w = 0.675$ (EE; corresponding $\kappa = 0.426$) by two-dimensional radiographs and $\kappa = 0.27$ to 0.38 and $\kappa = 0.35$ to 0.52 by CT, respectively.[38] The spans of the correlation are caused by different FIs of oral and buccal sides.[38] In another in vivo study, Walter et al.[11] showed a higher correlation for CBCT with 84% ($\kappa_w = 0.926$), and like other investigations demonstrated the excellent performance of CBCT over conventional radiographs in detecting complex furcation defects.[8,39] Despite the advantages of CT and CBCT, there is criticism because of the radiation to which the patient is exposed;[8] however, with CBCT a reduction of radiation exposure can be achieved compared with CT.[40] Based on these results, the more expensive CT and CBCT should be used only in planning complex therapies such as guided tissue regeneration,[41] and the diagnostic advantages must be carefully balanced by the higher radiation exposure.

CONCLUSIONS

For experienced operators, the combination of radiographic imaging of furcations and clinical probing is mostly reliable. It cannot be concluded by the data of this study which degree of clinically examined FI necessitates further radiographic diagnostic techniques such as I-O or OPG. It should be noted that all three methods (FP, I-O, and OPG) investigated in this retrospective study underestimated the FI compared with the surgical measurements. Therefore, the gold standard remains visual control during OFS. In the case that an underestimation will result in unfavorable outcomes, e.g., inappropriate planning of regenerative measures, further and more sophisticated diagnostic tools might be used.

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