THE JOURNAL OF PROSTHETIC DENTISTRY

RESEARCH AND EDUCATION

Influence of radiographic acquisition methods and visualization software programs on the detection of misfits at the implant-abutment interface: An ex vivo study

Amanda Pasolini Siqueira, DDS,[a] Vanessa Pacheco de Oliveira Mota, DDS,[b] and Sergio Lins de-Azevedo-Vaz, PhD[c]

ABSTRACT

Statement of problem. Misfits at the implant-prosthesis interface may compromise implant-supported prostheses. Periapical radiographs are frequently used to detect misfit and can be obtained by using digital or film-based systems; however, which radiographic acquisition method and visualization software program provides the greatest accuracy is unclear.

Purpose. The purpose of this ex vivo study was to evaluate the influence of 3 radiographic acquisition methods (complementary metal oxide semiconductor [CMOS] sensor, phosphor plates, and radiographic films) and 2 visualization software programs (proprietary and third-party) on the detection of misfits at the implant-prosthesis interface.

Material and methods. Thirty-two dental implants were placed in dry human mandibles. Misfits were simulated by inserting a 50-μm polyester strip at the implant-prosthesis interface; prosthetic crowns installed directly over the implant platforms were considered as controls. Standard parallel periapical radiographs were obtained by using a CMOS sensor, a phosphor plate, and radiographic films. Five dentists assessed the digital radiographs for the presence or absence of misfits at the implant-prosthesis interface by using the proprietary software program and a third-party software program; film-based radiographs were evaluated on a light box. The area under the receiver operating characteristic curves (Az values) were compared (α=.05); sensitivity, specificity, accuracy, positive predictive value, and negative predictive values were also estimated.

Results. All diagnostic and Az values were higher for the phosphor plate than for the CMOS sensor and the film-based methods (P<.05), regardless of the viewing software program used (proprietary or third-party) (P>.05).

Conclusions. The use of phosphor plates positively influenced the diagnostic accuracy for the detection of misfits at the implant-prosthesis interface, irrespective of the viewing software program used. (J Prosthet Dent 2022;127:107.e1-e7)

Perfectly fitting implant-supported restorations are the goal because misfits at the implant-prosthesis interface may compromise the long-term success of dental implants.[1] Peri-implantitis may be initiated if misfits are present because of the accumulation of oral biofilm and microbiological colonization.[2] Moreover, mechanical failures such as screw loosening and micromovement may lead to bone loss or even fracture of the implant components.[3] Therefore, an explorer and, especially, standard parallel periapical radiographs are fundamental tools for detecting misfits at the interface during routine clinical examination.[4-9]

Periapical radiographs may be acquired by using radiographic films or digital direct or semidirect systems. Direct systems work with a solid sensor connected to a computer by a universal serial bus (USB) cable, which transmits the electronic and digital signals.[10,11] Solid

Supported by LUCCAR (grant MCT/FINEP/CT-NFRA-PROINFRA 01/2006) by providing the scanning electron microscope; the Brazilian National Council for Scientific and Technological Development provided APS a scholarship; Research and Innovation Support Foundation of Espírito Santo (FAPES) provided VPOM a scholarship and the digital radiographic systems (grant 007/2014).

[a]Doctor of Dental Surgery, Department of Clinical Dentistry, Federal University of Espírito Santo (UFES), Vitória, Espírito Santo, Brazil.
[b]Graduate student, Dental Sciences Graduate Program, Federal University of Espírito Santo (UFES), Vitória, Espírito Santo, Brazil.
[c]Professor, Dental Sciences Graduate Program, Federal University of Espírito Santo (UFES), Vitória, Espírito Santo, Brazil.

Clinical Implications

The use of phosphor plates to radiographically assess the fitting of a prosthesis over dental implants results in higher diagnostic accuracy than CMOS sensors or film-based radiographies. Whether the viewing software program is a proprietary or a third-party does not seem to influence the task.

sensors are used to work with charge-coupled devices (CCD); however, complementary metal oxide semiconductors (CMOS) are currently more often used. CCD and CMOS sensors differ in the way the system reads the pixels. Furthermore, semidirect systems use phosphor-storage plates (PSPs) to temporarily store the signal received from the X-rays, which is then transmitted to a computer with the aid of a specific scanner.[10,11] PSPs do not require cables, and their size and thickness are similar to those of radiographic films.[11] The diagnostic accuracy of digital systems and film-based radiographs has been compared for several diagnostic-specific tasks, with different results.[12-21] However, the authors are aware of only 2 studies that addressed diagnostic accuracy for the detection of misfits at the implant-prosthesis interface, with conflicting results regarding comparisons between CCD systems and film-based radiographs.[8,9]

Digital radiographs obtained with digital systems can be either visualized with the same software program used for imaging acquisition (proprietary software program) or in an imaging viewer (third-party software program). Given the increase in the use of digital systems, more specific software programs have been developed.[22] The software program has been reported to influence the diagnostic accuracy for detecting carious lesions,[23,24] whereas others have reported no influence.[25] However, the authors are unaware of a study that has reported the influence of using different viewing software programs for the detection of misfits at the implant-prosthesis interface and the use of semidirect systems instead of direct CMOS systems or film-based radiographs. This knowledge would guide for clinicians when choosing the imaging tools that will be used in the routine clinical examination of implant-supported prostheses. Therefore, this study assessed the influence of 3 radiographic acquisition methods (CMOS sensor, PSP, and radiographic films) and 2 viewing software programs (proprietary and third-party) on the detection of misfits at the implant-prosthesis interface. The null hypotheses were that the radiographic acquisition method and the viewing software program would not influence the detection of misfits at the implant-prosthesis interface.

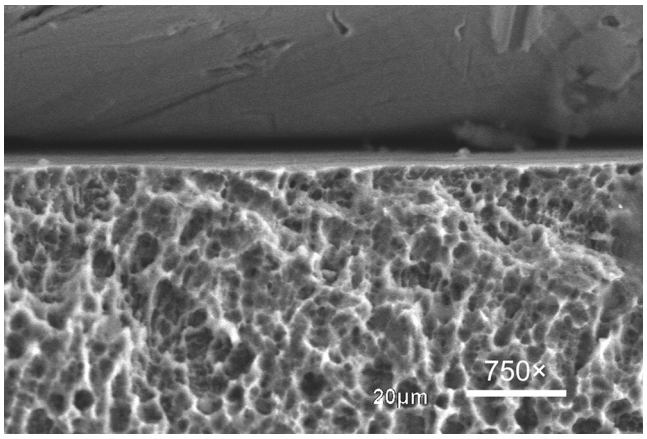


Figure 1. Reference standard obtained by scanning electron microscopy (original magnification ×750).

MATERIAL AND METHODS

After approval of the study protocol by the local ethics research committee, 4 dental implants were placed in 8 human dry mandibles, totaling 32 implants. As each implant was imaged under control and misfit conditions, the sample size consisted of 64 radiographs for each experimental group. The sample size was estimated for receiver operating characteristic curve (Az values) comparisons considering an alpha error of 5%, beta of 20%, Az values of 0.7, and a control and misfit implant ratio of 1 (MedCalc software program; MedCalc).

Four acrylic resin (VIPI FLASH; VIPI) single crowns were made by using titanium abutments (UCLA CoCr antirotational; Neodent). The crowns were screwed to the implants with 32 Ncm before radiographic exposure. One polyester strip (Fita matriz de poliéster; TDV Dental) was interposed between the implant and crown to simulate a 50-µm misfit. The crowns were directly screwed to the implants without polyester strips for the control, and a reference standard was determined by using a scanning electron microscope (JSM-6610LV; Jeol) to ensure the absence of manufacturing misfits in excess of 10 µm (Fig. 1).

Standard parallel periapical radiographs of each implant at both the misfit and control conditions were obtained by using CMOS (Snapshot; Instrumentarium Imaging) and PSP (VistaScan Mini Easy; Dürr Dental) systems and radiographic films (Dentus E-speed; Agfa HealthCare). The specimens were positioned on an acrylic resin device to keep the implants parallel to the radiographic receptors during exposures. A 20-mm-thick acrylic resin block was positioned in the path of the X-rays to simulate soft-tissue attenuation according to a previous study.[8] The X-ray tube (Timex C; Gnatus) operated at 70 kVp and 7 mA, with exposure times of 0.2, 0.32, and 0.56 seconds for the PSP, CMOS, and radiographic films, respectively. The exposure time settings

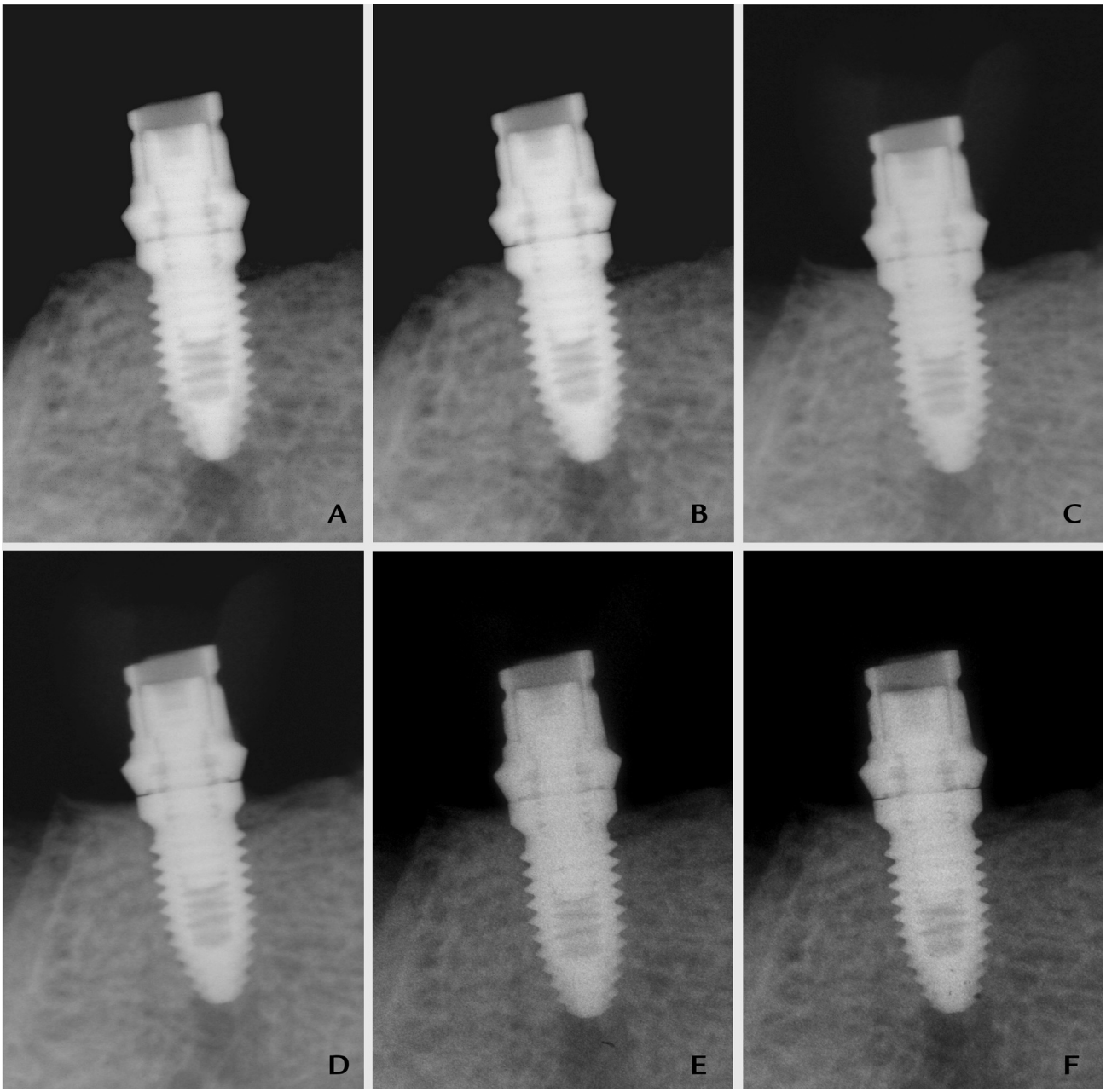


Figure 2. Cropped radiographs obtained for study. A, CMOS without misfit. B, CMOS with misfit. C, PSP without misfit. D, PSP with misfit. E, Film-based without misfit. F, Film-based with misfit. CMOS, complementary metal oxide semiconductor sensor; PSP, phosphor storage plates.

had been previously determined in pilot tests. Digital radiographs were acquired in the proprietary software program (PSP: Viewbox Studio, Dürr Dental; CMOS: Cliniview, Instrumentarium Imaging), while radiographic films were manually processed according to the time and temperature method table provided by the manufacturer (Dentus E-speed; Agfa HealthCare), mounted into transparent plastic cards for evaluation. Figure 2 shows examples of radiographs acquired for the study.

Two oral radiologists, 2 prosthetic dentists, and 1 general practitioner participated in the study as observers and assessed the radiographs. Before the evaluation, they were trained under the same environmental conditions used for the evaluation sessions. The radiographs of control and misfit conditions presented to the observers during training sessions were not used in the study. These sessions aimed to solve any doubts about the methodology used for image evaluations and took place in a silent dimly lit room.

Digital radiographs were assessed on a 22-inch liquid crystal display (LCD) monitor (LE2201w; Hewlett-Packard). PSP and CMOS radiographs were evaluated

Table 1. Weighted kappa values for intraobserver and interobserver reproducibility

Experimental Group	Observer 1	Observer 2	Observer 3	Observer 4	Observer 5
CMOS-1					
Observer 1	0.49	-	-	-	-
Observer 2	0.83	0.80	-	-	-
Observer 3	1.00	0.83	0.45	-	-
Observer 4	0.67	0.49	0.67	1.00	-
Observer 5	0.83	1.00	0.83	0.62	1.00
CMOS-2					
Observer 1	0.58	-	-	-	-
Observer 2	0.35	1.00	-	-	-
Observer 3	0.71	0.35	0.80	-	-
Observer 4	0.75	0.46	0.58	0.80	-
Observer 5	0.69	0.59	0.65	0.80	1.00
PSP-1					
Observer 1	1.00	-	-	-	-
Observer 2	1.00	0.83	-	-	-
Observer 3	0.68	0.68	0.54	-	-
Observer 4	1.00	1.00	0.68	0.83	-
Observer 5	0.68	0.68	1.00	0.68	0.69
PSP-2					
Observer 1	0.83	-	-	-	-
Observer 2	0.50	0.43	-	-	-
Observer 3	0.66	0.41	0.39	-	-
Observer 4	0.90	0.58	0.57	0.83	-
Observer 5	0.77	0.63	0.57	0.80	0.69
Film-based					
Observer 1	0.69	-	-	-	-
Observer 2	0.84	0.84	-	-	-
Observer 3	0.43	0.55	0.55	-	-
Observer 4	1.00	0.84	0.43	0.84	-
Observer 5	1.00	0.84	0.43	1.00	0.69

CMOS, complementary metal oxide semiconductor sensor; CMOS-1, radiographs acquired with CMOS and assessed by using proprietary software program; CMOS-2, radiographs acquired with CMOS and assessed by using third-party software program; PSP, phosphor storage plates; PSP-1, radiographs acquired with PSP and assessed by using proprietary software program; PSP-2, radiographs acquired with PSP and assessed by using third-party software program.

in the proprietary software program (Viewbox Studio and CLINIVIEW), constituting the experimental groups PSP-1 and CMOS-1, respectively. These images were also assessed in the same third-party software program (Windows imaging viewer; Microsoft Corp), constituting the experimental groups PSP-2 and CMOS-2. Film-based radiographs (group film-based) were assessed by using a light box (Negatoscópio Ultra Slim Panorâmico; Biotron), magnifying glasses (Lupa de mão; DFV), and a black mask to exclude excess light. The observers were not aware of the reference standard and used a Likert scale to assess the presence or absence of misfits as follows: 1, misfit definitely absent; 2, misfit probably absent; 3, unsure; 4, misfit probably present; 5, misfit definitely present. The radiographs were randomly arranged by using a spreadsheet (Microsoft Excel; Microsoft Corp) before being presented to the observers.

Table 2. Diagnostic and Az values for detection of misfits at implant-prosthesis interface as function of radiographic acquisition method and viewing software program

Value	CMOS-1	CMOS-2	PSP-1	PSP-2	Film-Based
Sensitivity	76.3	68.1	86,9	74.4	76.3
Specificity	75.6	90.0	90.6	93.8	85.0
Accuracy	75.9	79.1	88,8	84.1	80.6
PPV	75.8	87.2	90.3	92.2	83.6
NVP	66.1	73.8	87,3	78.5	78.2
Az	0.82 A	0.84 A	0.91 B	0.90 B	0.83 A
SD	0.02	0.02	0.01	0.01	0.02
CI (95%)	0.77-0.86	0.80-0.88	0.88-0.94	0.86-0.93	0.79-0.88

Az, area under receiver operating characteristics curve; CI, confidence interval; CMOS, complementary metal oxide semiconductor sensor; CMOS-1, radiographs acquired with CMOS and assessed by using proprietary software program; CMOS-2, radiographs acquired with CMOS and assessed by using third-party software program; PSP, phosphor storage plates; PSP-1, radiographs acquired with PSP and assessed by using proprietary software program; PSP-2, radiographs acquired with PSP and assessed by using third-party software program; SD, standard deviation. Different uppercase letters indicate statistically significant differences ($P<.05$).

Thirty days after imaging evaluation, the observers reassessed 20% of the radiographs for intraobserver reproducibility calculation. Intraobserver and interobserver reproducibility values were estimated by using the Kappa test and interpreted as follows[26]: poor (<0.00), slight (0.00-0.20), fair (0.21-0.40), moderate (0.41-0.60), substantial (0.61-0.80), and almost perfect reproducibility (0.81-1.00).

Data were tabulated in a spreadsheet (Microsoft Excel; Microsoft Corp), and Az values were estimated and compared by using a receiver operating characteristic (ROC) curve comparison ($\alpha=.05$). Descriptive analyses were also performed to estimate the values for sensitivity, which represent the chance to identify a misfit when it is present; specificity, which relates to the chance of identifying misfit absence when it is absent; accuracy, a value that represents the proportion of correct and incorrect answers; positive and negative predictive values (PPV and NPV), which show the probability of true-positive and true negative results, respectively. Statistical analyses were performed with the aid of a software program (Epidat 3.1; Conselleria de Sanidade de Xunta de Galicia Health and Pan American Health Organization).

RESULTS

The intraobserver reproducibility ranged from fair to almost perfect for PSP-2, whereas it ranged from moderate to almost perfect for the other groups. The interobserver reproducibility ranged from moderate to almost perfect for CMOS-1, PSP-2, and film-based radiographs; from fair to substantial for CMOS-2; and from substantial to almost perfect for PSP-1 (Table 1).

PSP-1 and PSP-2 had the highest diagnostic values in the study. Sensitivity (86.1), accuracy (88.8), and NPV

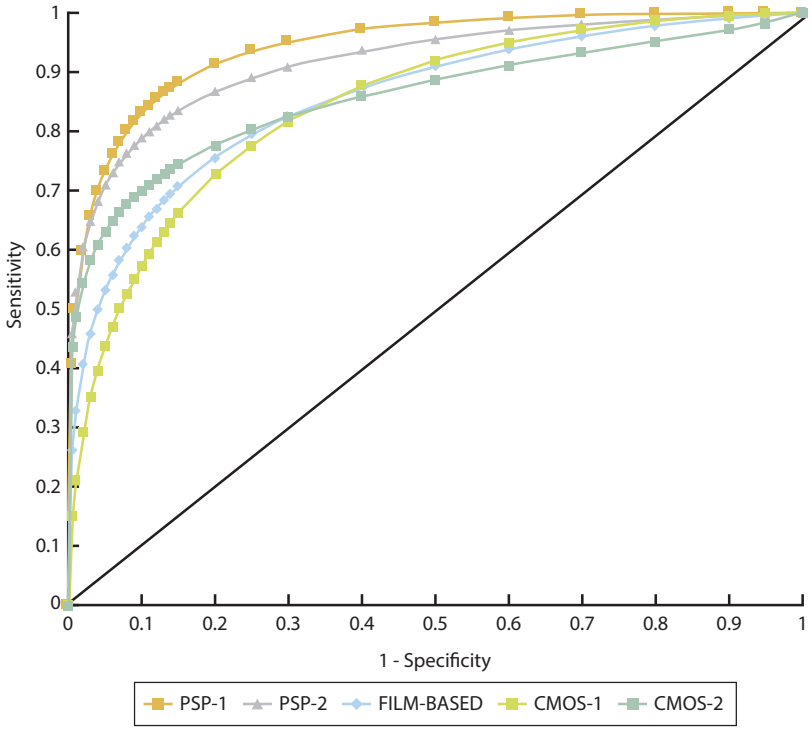


Figure 3. ROC curves generated for study. CMOS, complementary metal oxide semiconductor sensor; CMOS-1, radiographs acquired with CMOS and assessed by using proprietary software program; CMOS-2, radiographs acquired with CMOS and assessed by using third-party software program; PSP, phosphor storage plates; PSP-1, radiographs acquired with PSP and assessed by using proprietary software program; PSP-2, radiographs acquired with PSP and assessed by using third-party software program. ROC, receiver operating characteristic.

(87.3) were the highest for PSP-1, indicating better identification of misfits, a higher proportion of correct answers, and high true-negative rates for this group. PSP-2 had the highest specificity (93.2) and PPV (92.2), which showed a higher frequency of misfit absence identification and true-positive results (Table 2).

The Az values found for PSP-1 and PSP-2 were statistically higher than those for the other groups ($P<.05$). Figure 3 illustrates the ROC curves generated in the study.

DISCUSSION

Data collected in the study supported partial rejection of the null hypotheses because the radiographic acquisition methods influenced the detection of misfits at the implant-prosthesis interface. Digital radiographs have been widely adopted in dentistry because of their advantages over film-based radiographs, including reduced radiation dose, shorter working time, and long-term financial savings. Furthermore, they can facilitate communication among professionals and allow image enhancement.[13] Similar or better accuracy has been reported for digital radiographs compared with film-based radiographs for many diagnostic-specific tasks,[12-21] including for the fit of implant-supported prostheses, important for their long-term success.[8,9] However, the authors are unaware of studies regarding the use of PSP systems, and in the present study, irrespective of the viewing software program used, PSP radiographs resulted in better diagnostic accuracy than CMOS or film-based, since PSP-1 and PSP-2 showed the highest diagnostic and Az values. However, all the radiographic systems studied provided satisfactory Az values as they were higher than 50%, which would represent the "flip of a coin." Therefore, even though the findings suggest that the use of PSP can positively influence treatment longevity by providing a higher diagnostic accuracy for misfit detection, all systems could be considered acceptable for clinical practice.

When comparing CCD with film-based radiographs in the assessment of prosthetic fitting over implants, published data are still controversial. Sharkey et al[9] reported results similar to those of the present study because the CCD system used had no statistically significant differences from film-based radiographs in the detection of misfits at the implant-prosthesis interface. Cançado Oliveira et al[8] reported that CCD performed better than film-based radiographs processed manually or automatically.

One technical characteristic of radiographic receptors that could justify the superiority of PSP in the present

study is spatial resolution, which is associated with the ability to distinguish fine details in the image. Considering discrete misfits at the implant-prosthesis interface as the 50 μm simulated, the bigger the spatial resolution is, the better they can be visualized in radiographs. However, the receptors in the present study had similar spatial resolution settings: 25.6 lp/mm^{-1} for PSP (as informed by the manufacturer), 26.3 lp/mm^{-1} for CMOS (as informed by the manufacturer), and 20 lp/mm^{-1} for analog films.[27] The spatial resolution for CMOS was slightly better than that for PSP, which would theoretically lead to opposite results than those observed in the present study; that is, CMOS would result in higher diagnostic accuracy than PSP.

The X-ray beam vertical angle plays a crucial role in the detection of misfits at the implant-prosthesis interface, and orthogonal projections have been recommended.[5,6,9,28] Specimen positioning was standardized in the present study by using an acrylic resin device, and implants were positioned parallel to the image receptors. However, the weight exerted by the USB cable of the CMOS sensor may have introduced a slight tilt, contributing to the lower values observed. This clinical disadvantage of solid sensors for intraoral radiography has been reported previously and may increase the number of retakes during radiographic examinations.[10]

Among the studies assessing other diagnostic-specific tasks by using different radiographic systems, Shintaku et al[29] reported no statistical difference for the detection of vertical root fractures between a PSP system and film-based radiographs. Nonetheless, their descriptive results were better for the PSP system, and the authors reported that the physical size of images may have influenced the results. In their study, PSP radiographs were assessed on a 24″ LCD monitor, whereas a light box and a magnifying glass were used for radiographs obtained with size-2 radiographic films. Similarly, the presentation of digital radiographs on a computer screen and of films on a light box may have influenced the results of the present study. Studies have also compared the diagnostic accuracy obtained with medical and nonmedical monitors for other diagnostic tasks. Isidor et al[30] reported higher accuracy in detecting carious lesions when using medical monitors, while Pakkala et al[31] and Hellén-Halme et al[32] reported no significant differences in the accuracy of different types of screens. Future studies may clarify whether using medical or nonmedical monitors influences the detection of misfits at the implant-prosthesis interface.

The software programs used for the 2 digital systems had different manufacturers' recommendations. Nevertheless, the study's methodology aimed to reproduce clinical reality when working with digital and film-based systems. Other limitations related to the clinical reproduction of anatomic aspects such as the tongue, oral mucosa, and floor of the mouth were inherent in this ex vivo study.

Some authors have reported no statistically significant differences among CCD, PSP, and film-based radiographs to determine endodontic working length and internal and external root resorption diagnosis.[12,14,18] Castro et al[15] and Abu El-Ela et al[16] also reported no differences in the detection of proximal caries lesions, although Abu El-Ela et al[16] reported a higher sensitivity for CMOS than PSP when considering incipient lesions. Similar results for the detection of bone lesions were reported when CCD, CMOS, and film-based radiographs were compared.[17]

The influence of different software programs on the diagnostic accuracy for several diagnostic-specific tasks has been reported. Heo et al[33] reported greater accuracy for apical root resorption when using the Emago software program. Güneri et al[24] reported that a software program created by them and the Emago software program were more accurate than Photoshop 8.0 or PaintShop Pro in assessing different diagnostic tasks such as amalgam restorations, carious lesions, and endodontic treatments. In the present study, different software programs used with 2 digital systems did not affect the detection of misfits at the implant-prosthesis interface. Further studies should continue to investigate this issue by adding other radiographic viewing proprietary and third-party software programs. In addition, the factors studied should be investigated by using other radiographic techniques such as bitewing interproximal views.

CONCLUSIONS

Based on the findings of this ex vivo study, the following conclusion was drawn:

1. The PSP radiographic acquisition method positively influenced the diagnostic accuracy for the detection of misfits at the implant-prosthesis interface, irrespective of the viewing software program used.

REFERENCES

1. Hermann JS, Schoolfield JD, Schenk RK, Buser D, Cochran DL. Influence of the size of the microgap on crestal bone changes around titanium implants. A histometric evaluation of unloaded non-submerged implants in the canine mandible. J Periodontol 2001;72:1372-83.
2. Lauritano D, Girardi A, Napoleone C, Riccardo LDE, Carinci F. Implant-abutment leaking: an in-vitro study of the microbiological penetration from external environment to implant-abutment space. Indian J Stomatol 2015;6:5-9.
3. Al-Turki LE, Chai J, Lautenschlager EP, Hutten MC. Changes in prosthetic screw stability because of misfit of implant-supported prostheses. Int J Prosthodont 2002;15:38-42.
4. Konermann AC, Zoellner A, Chang BM, Wright RF. In vitro study of the correlation between the simulated clinical and radiographic examination of microgaps at the implant-abutment interface. Quintessence Int 2010;41:681-7.
5. Cameron SM, Joyce A, Brousseau JS, Parker MH. Radiographic verification of implant abutment seating. J Prosthet Dent 1998;79:298-303.

6. Darós P, Carneiro VC, Siqueira AP, De-Azevedo-Vaz SL. Diagnostic accuracy of 4 intraoral radiographic techniques for misfit detection at the implant abutment joint. J Prosthet Dent 2018;120:57-64.
7. Regan JE, Mitchell DF. Roentgenographic and dissection measurements of alveolar crest height. J Am Dent Assoc 1963;66:356-9.
8. Cançado Oliveira BF, Valerio CS, Jansen WC, Zenóbio EG, Manzi FR. Accuracy of digital versus conventional periapical radiographs to detect misfit at the implant-abutment interface. Int J Oral Maxillofac Implants 2016;31:1023-9.
9. Sharkey S, Kelly A, Houston F, O'Sullivan M, Quinn F, O'Connell B. A radiographic analysis of implant component misfit. Int J Oral Maxillofac Implants 2011;26:807-15.
10. Wenzel A, Møystad A. Work flow with digital intraoral radiography: a systematic review. Acta Odontol Scand 2010;68:106-14.
11. Parks ET, Williamson GF. Digital radiography: an overview. J Contemp Dent Pract 2002;3:1-13.
12. Kamburoğlu K, Tsesis I, Kfir A, Kaffe I. Diagnosis of artificially induced external root resorption using conventional intraoral film radiography, CCD, and PSP: an ex vivo study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;106:885-91.
13. Mesgarani A, Haghanifar S, Ehsani M, Yaghub SD, Bijani A. Accuracy of conventional and digital radiography in detecting external root resorption. Iran Endod J 2014;9:241-5.
14. Sakhdari S, Khalilak Z, Najafi E, Cheraghi R. Diagnostic accuracy of charge-coupled device sensor and photostimulable phosphor plate receptor in the detection of external root resorption in vitro. J Dent Res Dent Clin Dent Prospects 2015;9:18-22.
15. Castro VM, Katz JO, Hardman PK, Glaros AG, Spencer P. In vitro comparison of conventional film and direct digital imaging in the detection of approximal caries. Dentomaxillofacial Radiol 2007;36:138-42.
16. Abu El-Ela WH, Farid MM, Mostafa MS. Intraoral versus extraoral bitewing radiography in detection of enamel proximal caries: an ex vivo study. Dentomaxillofacial Radiol 2016;45:20150326.
17. Paurazas SB, Geist JR, Pink FE, Hoen MM, Steiman HR. Comparison of diagnostic accuracy of digital imaging by using CCD and CMOS-APS sensors with E-speed film in the detection of periapical bony lesions. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2000;89:356-62.
18. Yaghooti KMM, Ebrahimnejad H. Comparison of the accuracy of conventional and digital radiography in root canal working length determination: an in vitro study. J Dent Res Dent Clin Dent Prospects 2017;11:161-5.
19. Dias da Silva PR, Martins Marques M, Steagall W Jr, Medeiros Mendes F, Lascala CA. Accuracy of direct digital radiography for detecting occlusal caries in primary teeth compared with conventional radiography and visual inspection: an in vitro study. Dentomaxillofacial Radiol 2010;39:362-7.
20. Haiter-Neto F, Dos Anjos Pontual A, Frydenberg M, Wenzel A. A comparison of older and newer versions of intraoral digital radiography systems: diagnosing noncavitated proximal carious lesions. J Am Dent Assoc 2007;138:1353-9.
21. Bardal R, Mobini M, Mirzaee M. In vitro comparison of two photostimulable phosphor plate systems for early detection of occlusal dentin caries with and without a sharpening filter. J Dent Res Dent Clin Dent Prospects 2020;14:223-7.
22. Wenzel A, Møystad A. Experience of Norwegian general dental practitioners with solid state and storage phosphor detectors. DentomaxillofacRadiol 2001;30:203-8.
23. Wenzel A. Digital imaging for dental caries. Dent Clin North Am 2000;44:319-38.
24. Güneri P, Göğüş S, Tuğsel Z, Ozturk A, Gungor C, Boyacioğlu H. Clinical efficacy of a new software developed for dental digital subtraction radiography. DentomaxillofacRadiol 2006;35:417-21.
25. Tsai P, Torabinejad M, Rice D, Azevedo B. Accuracy of cone-beam computed tomography and periapical radiography in detecting small periapical lesions. J Endod 2012;38:965-70.
26. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977;33:159-74.
27. Farman TT, Farman AG. Evaluation of a new F speed dental X-ray film. The effect of processing solutions and a comparison with D and E speed films. Dentomaxillofac Radiol 2000;29:41-5.
28. Papavassiliou H, Kourtis S, Katerelou J, Chronopoulos V. Radiographical evaluation of the gap at the implant-abutment interface. J Esthet Restor Dent 2010;22:235-50.
29. Shintaku WH, Venturin JS, Noujeim M, Dove SB. Comparison between intraoral indirect and conventional film-based imaging for the detection of dental root fractures: an ex vivo study. Dent Traumatol 2013;29:445-9.
30. Isidor S, Faaborg-Andersen M, Hintze H, Kirkevang LL, Frydenberg M, Haiter-Neto F, et al. Effect of monitor display on detection of approximal caries lesions in digital radiographs. Dentomaxillofac Radiol 2009;38:537-41.
31. Pakkala T, Kuusela L, Ekholm M, Wenzel A, Haiter-Neto F, Kortesniemi M. Effect of varying displays and room illuminance on caries diagnostic accuracy in digital dental radiographs. Caries Res 2012;46:568-74.
32. Hellén-Halme K, Nilsson M, Petersson A. Effect of monitors on approximal caries detection in digital radiographs–standard versus precalibrated DICOM part 14 displays: an in vitro study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009;107:716-20.
33. Heo MS, Lee SS, Lee KH, Choi HM, Choi SC, Park TW. Quantitative analysis of apical root resorption by means of digital subtraction radiography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2001;91:369-73.

Corresponding author:
Dr Sergio Lins de-Azevedo-Vaz
Dental Sciences Graduate Program
Federal University of Espírito Santo (UFES)
Av. Marechal Campos 1468
Maruípe, Vitória
ES 29043-900
BRAZIL
Email: sergio.vaz@ufes.br

Acknowledgments
The authors thank Neodent for providing implants.

CRediT authorship contribution statement
Amanda Pasolini Siqueira: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. **Vanessa Pacheco de Oliveira Mota:** Data curation, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. **Sergio Lins de-Azevedo-Vaz:** Conceptualization, Formal analysis, Funding acquisition, Methodology, Project administration, Resources, Supervision, Writing – original draft, Writing – review & editing.

Copyright © 2021 by the Editorial Council for *The Journal of Prosthetic Dentistry*.
https://doi.org/10.1016/j.prosdent.2021.10.016