

Assessment of conventional and digital radiographic methods in the diagnosis of marginal fit of the implant-abutment interface

Avaliação dos métodos radiográficos convencional e digital no diagnóstico da adaptação marginal da interface pilar-implante

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ABSTRACT

To evaluate digital and conventional radiographs in the assessment of the implant/abutment interface with different marginal openings. Custom-made abutments were manufactured. Polyester matrix strips with 50 µm thickness were used as spacers to simulate different marginal openings. Abutments were evaluated radiographically in 3 different positions, with 5 different marginal opening situations: marginal fit (0µm- without spacers), 50 µm (1 spacer), 100 µm (2 spacers), 150 µm (3 spacers), and 200µm (4 spacers). A total of 150 radiographic images were made: 75 with the conventional system, and 75 with the digital system. For each image, 2 sites were evaluated (mesial and distal). A decision matrix was used to calculate sensitivity, specificity, accuracy, positive and negative predictive values, with 95% confidence intervals (CI). Overall sensitivity of both conventional and digital radiographs was 95% (CI= 86.3% to 98.29%). Specificity of the conventional radiographs was 100% (CI= 79.61% to 100%). Similarly, digital images showed high specificity of 93.33% (CI= 70.18% to 98.81%). Overall diagnostic accuracy was 96% (CI=88.89% to 98.63%) for conventional, and 94.7% (CI= 87.07% to 97.91%) for digital images. Positive and negative predictive values were, respectively, 100% (CI= 93.69% to 100%) and 83.33% (CI = 60.78% to 94.16%) for conventional images; and 98.28% (CI= 90.86% to 99.7%) and 82.35% (CI= 58.97% to 93.81%) for digital systems, respectively. Marginal openings without spacers determined microscopically ranged from 0 µm to 1.06 µm (average 0.39 µm). Marginal openings of 50 µm could be detected radiographically on both digital images and films. Conventional and digital radiographs are efficient diagnostic tools in the assessment of marginal fit, even with marginal openings as small as 50 µm.

Keywords: Dental implants; Abutment; Marginal fit; Digital radiography

RESUMO

Para avaliar os métodos radiográficos convencional e digital na interface pilar-implante com diferentes aberturas marginais. Foram fabricados pilares personalizados. Matriz de poliéster com espessura de 50µm foram usadas como espaçadores para simular diferentes aberturas marginais. Os pilares foram avaliados radiograficamente em três diferentes posições, com 5 diferentes situações de abertura marginal: adaptação marginal (0 µm – sem espaços), 50 µm (1 espaçador), 100 µm (2 espaçadores), 150 µm (3 espaçadores), 200 µm (4 espaçadores). Um total de 150 imagens radiográficas foram feitas: 75 com o sistema convencional, e 75 com o sistema digital. Para cada imagem, 2 locais foram avaliados (mesial e distal). A matriz de decisão foi usada para calcular sensibilidade, especificidade, acurácia, valores preditivos negativo e positivo, com intervalo de confiança (IC) de 95%. A sensibilidade de ambas as radiografias digital e convencional foi 96% (IC = 86,3% a 98,29%). A especificidade da radiografia convencional foi de 100% (IC = 79,61% a 100%). Da mesma forma imagens digitais mostraram alta especificidade de 93,33% (IC = 70,18% a 98,81%). A precisão geral do diagnóstico foi de 96% (IC = 88,89% a 98,63%) para o método convencional e 94,7% (IC = 87,07% a 97,91%) para imagens digitais. Valores preditivos positivos e negativos foram, respectivamente, 100% (IC = 93,69% a 100%) e 83,33% (IC = 60,78% a 94,16%) para o método convencional e 98,28% (IC = 90,86% a 99,7%) e 82,355 (IC = 58,97% a 93,81%) para o sistema digital, respectivamente. Abertura marginal sem espaçadores determinou microscopicamente uma abertura que variou de 0 µm a 1,06 µm (média de 0,39 µm). Abertura marginal com 50 µm pôde ser detectada radiograficamente em ambas as imagens. Radiografias convencionais e digitais são eficientes ferramentas de diagnóstico em avaliar adaptação marginal, mesmo em aberturas marginais pequenas como 50 µm.

Palavras-chave: Implante dental; Pilar; Adaptação marginal; Radiografia digital.

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INTRODUCTION

Osseointegration principles have been associated with high long-term success rates in the treatment of edentulous and partially

edentulous patients.¹⁻³ However, sporadic failures may occur and therefore mechanisms of failure must be recognized and understood. Microbial colonization and penetration of bacterial products between

implant and abutment represents a risk for soft tissue inflammation and loss of supporting bone.^{4,5} The interface between those components is commonly located 2–4 mm subgingivally, and the effect of possible plaque formation and inflammation must not be ignored. According to Byrne et al,⁶ peri-implantitis is a major risk for late stage implant failure. Misfit of implant components may also result in mechanical fractures of the implant screw, abutment or prosthesis, as well as inappropriate distribution of forces to the supporting bone, and ultimately loss of osseointegration.⁷⁻¹⁰

There is no definitive method for assessing the implant/abutment interface, thus, the need for a proven effective diagnostic method remains. Some techniques have been mentioned in the literature involving the use of dental explorers, elastomers, and tactile evaluation.^{7,8} Those techniques present diagnostic subjectivity and may be questionable since the detection of marginal discrepancies relies on many factors, including: observer's visual acuity, manual ability, and personal experience, as well as variability of the material used, e.g. the diameter of the dental explorer's tip.¹¹

Information on the radiographic diagnosis of implant/abutment marginal fit through conventional and/or digital methods is not well documented. Protocols for implant-supported prosthetic rehabilitation have indicated the use of intraoral radiographs, but no consistent evidence-based decisions have been presented.^{2,6,12}

Digital radiographic systems present advantages compared to conventional techniques, including radiation dose reduction, elimination of chemical processing of films, and shorter time of acquisition.^{12,13} The purpose of this study was to evaluate the sensitivity, specificity, accuracy, positive and negative predictive values of digital and conventional imaging in the estimation of implant–abutment interface marginal fit with different marginal openings. It is hypothesised that both digital and conventional images are adequate tools in the assessment of implant/abutment marginal fit.

MATERIAL AND METHODS

Five custom-made titanium abutments (Procera Alltitan, Nobel Biocare, Göteborg, Sweden) were manufactured. Each abutment was connected to the implant

(Brånemark System Mk III, RP 4.0×13 mm, Nobel Biocare AB, Göteborg, Sweden), and the abutment screw tightened with 10 Ncm torque with an electronic torque controller (Osseoset, Nobel Biocare AB). Polyester matrix strips (K-Dent; Quimidrol, SC, Brazil) were used as spacers between the implant and the abutment to simulate different marginal opening situations. Each implant/abutment was then fixed to a metal hexagonal base (Fig. 1). The design of the metal base allowed the implant/abutment device to be placed at different positions over a positioning platform for the radiographic exams and microscopic evaluation.

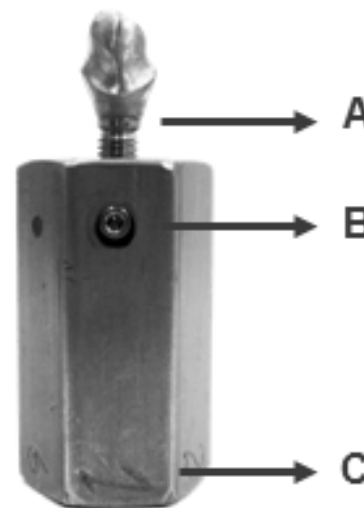


Figure 1. Positioning platform and hexagonal metal base with the implant and abutment in place. (A) Implant/abutment interface; (B) screw for fixing the implant to the metal base; (C) number indicating the position of the hexagon for radiographs and microscopic evaluation.

The devices were evaluated using conventional and digital radiographs, in 3 different positions, with 5 different marginal openings: without spacer (fit - 0 μm), with 1 spacer (50 μm), 2 spacers (100 μm), 3 spacers (150 μm), and 4 spacers (200 μm). After the torque was applied, excessive spacer material was cut off using a scalpel blade without deforming the polyester strips.

Parallelism principles were used to acquire the radiographs, with a focal distance of 40 cm. The implant/abutment devices were placed over a flat surface parallel to the horizontal plane, and perpendicular to the x-ray tube. A Spectrum

70X Eletronic (Dabi Atlante, São Paulo-Brazil) X-ray unit, 70 KVp, 8mA, was used for the intraoral radiographic study. Phosphor plate sensors (Digora, Soredex, Finland) were used for digital radiographs, with exposure of 0.08 seconds. For conventional radiographs, standard periapical films (Insight, Eastman Kodak Co, Rochester, NY) were exposed for 0.2 seconds and automatically processed (Periomat; Dürr Dental, Bietigheim-Bissingen, Germany). The optimal exposure time was established previously in a pilot study.

A total of 150 radiographs were made, 75 in the conventional system and 75 in the digital system. Two points of interest, mesial and distal, were evaluated on each image. Two Oral and Maxillofacial radiologists analyzed 15 images per day. Every radiograph complied with the image quality criteria. The images with diverging diagnosis were reviewed and eventual disagreements were resolved by forced consensus.

Films were analyzed on a standard viewbox with use of magnifying lens ($\times 6$), with background light masked around the radiographs, with restricted room lighting. Digital image files were saved in JPG format (Digora system for Windows 2.0, Soredex, Finland) as specific codenames. Digital radiographs were evaluated on the monitor with a background light mask. Zoom, brightness and contrast could be adjusted by the examiners.

A decision matrix was used for statistical analyses, considering the following diagnostic outcomes: true positive (TP, i.e. marginal misfit situation with positive misfit diagnosis); true negative (TN, i.e. marginal fit situation with fit diagnosis); false positive (FP, i.e. marginal fit situation/misfit diagnosis); false negative (FN, i.e. marginal misfit situation/fit diagnosis). Parameters were then calculated with 95% confidence intervals (CI): Sensitivity (TP/TP+FN), specificity (TN/TN+FP), accuracy (TP+TN/TP+TN+FP+FN), positive predictive value (TP/TP+FP), and negative predictive value (TN/TN+FN), with significance level of $p < .05$.

The devices without spacers were additionally evaluated microscopically, using a comparative optical microscope at $\times 60$ magnification (Mitutoyo TM Series 176; Mitutoyo Corp, Tokyo, Japan), in order to confirm perfect adaption between implant and abutment.

RESULTS

Marginal openings of the implant/abutment interfaces without spacers determined microscopically ranged from 0 μm to 1.06 μm (average 0.39 μm).

Overall sensitivity of 95% was found for both conventional and digital radiographic techniques (Confidence Interval = 86.3% - 98.29%). The specificity of the conventional radiographs was 100% (CI= 79.61% - 100%). Similarly, digital images showed high specificity of 93.33% (CI= 70.18% - 98.81%). Overall diagnostic accuracy was 96% (CI=88.89% - 98.63%) for conventional radiographs and 94.7% (CI= 87.07% - 97.91%) for digital images. The positive and negative predictive values were, respectively, 100% (CI= 93.69% - 100%) and 83.33% (CI = 60.78% - 94.16%) for conventional images; and 98.28% (CI= 90.86% - 99.7%) and 82.35% (CI= 58.97% - 93.81%) for digital systems, respectively.

Table 1 shows the positive predictive value (PPV) and negative predictive value (NPV) of conventional and digital radiographs for different marginal openings.

Table 1. Positive predictive value (PPV) and negative predictive value (NPV) of conventional and digital radiographs for different marginal openings

	Modality	PPV (%)	NPV (%)
Overall	Conventional	100	83.33
	Digital	98.28	82.35
Fit - 50 μm	Conventional	100	83.33
	Digital	92.31	82.35
Fit -100 μm	Conventional	100	100
	Digital	93.75	100
Fit -150 μm	Conventional	100	100
	Digital	93.75	100
Fit - 200 μm	Conventional	100	100
	Digital	93.75	100

DISCUSSION

The results confirm that digital and conventional images are efficient tools in the assessment of implant/abutment marginal fit. A passive fit between implant frameworks and underlying structures must be observed, preferably during clinical



testing of the abutment. Marginal misfit detected in earlier stages is favorable to treatment, with possible early replacement of the abutment, or repair of the metal superstructure in cases of multiple implants.

In mechanical terms, misfit of the abutment may transfer a high tension to the implant screw resulting in loosening of the prosthesis or fracture of the screw.⁵⁻⁷ Ultimately, such tension may be transmitted to the underlying bone and result in late failure of the implant. As for biological issues, misfit in the implant/abutment surface may result in microbial colonization resulting in peri-implantitis.⁴

Takahashi, Gunne⁹ evaluated 2 different types of frameworks. The authors demonstrated that the fit of frameworks made with the Procera system was significantly better than that of the frameworks made with cast gold alloy. Therefore, the choice of the Procera system in the present study is justified. The results of the microscopic evaluation showed the marginal fit between 0 μm to 1.06 μm (average 0.39 μm). Such small differences do not represent differences on visual evaluation. According to Bränemark¹, marginal fit with 10 μm or less is considered adequate.

The high sensitivity observed for both conventional and digital radiographs (95%), demonstrates that in dental practice the implant/abutment misfits are likely to be correctly diagnosed radiographically. Therefore, eventual dimensional variations of the abutment can be detected, as well as any interference during the placement of the abutment. The space created by the polyester matrix strips representing 50 μm marginal openings on the implant/abutment interfaces could be detected radiographically, both on digital images and films, showing that those are adequate diagnostic methods for even small marginal misfits. Radiographic images showed an absolute diagnostic sensitivity for misfits over 100 μm , since the abutments of the groups representing 100 μm , 150 μm , and 200 μm misfits had 100% sensitivity for both radiographic methods.

The overall specificity of the conventional radiographs of 100% indicates that, in clinical practice, when the implant/abutment interface is radiographically identified as misfit, there is a possibility of a correct diagnosis in virtually 100% of situations. Similarly, digital images presented high overall

specificity (93.33%).

The overall diagnostic accuracy of 96% and 94.7% for conventional and digital radiographic images, respectively, demonstrates the excellent precision for both radiographic methods. Thus, there is a strong possibility of obtaining a correct diagnosis using both radiographic methods, even for marginal openings of only 50 μm .

The positive predictive value (PPV) refers to the proportion of positive test results (misfit) that are correctly diagnosed. The PPV for conventional radiography was 100% and 98.28% for the digital system (Table I). The negative predictive value (NPV) is the proportion of negative test results (fit) that are correctly diagnosed. The conventional radiography had 83.33% of NPV. When the 100, 150 and 200 μm groups were evaluate, they showed 100% NPV. Those values demonstrate that when the marginal opening is 50 μm , it is 16.67% more likely to be misdiagnosed as fit when compared to other groups. Digital imaging showed similar results, with an overall NPV of 82.35% and 100% for the other groups. Thus, both methods of radiographic imaging displayed similar outcomes.

The results in the present study are in agreement with other studies that have evaluated other restorative materials and caries detection, in which both conventional and digital radiographic imaging present similar diagnostic values.^{12,14-16} However, this in vitro study cannot perfectly reproduce certain intraoral conditions in the laboratory. In addition to adding some image superimposition, the presence of soft and hard tissues may represent difficulty for the proper position of films and phosphor plates during the radiographic acquisition.

Although a few misfit abutments may appear fit in these diagnostic modalities by chance, such probability is quantifiable despite been unavoidable. The best way to estimate this probability is to calculate confidence intervals for sensitivity, specificity and predictive values, allowing for a comparison among other diagnostic tests. This is specially valid when there are no other studies with similar methodology for confrontation of the results, which justifies the statistical analysis employed in this study.

Tyndall¹⁶ evaluated the accuracy of interproximal caries detection comparing enhanced and unenhanced charge-coupled device (CCD) based digital images with films using receiver operating characteristic



(ROC) analysis. Sixty extracted teeth were imaged under identical standardized geometric and exposure conditions. Six observers rated 120 interproximal surfaces for the presence or absence of carious lesions. The ground truth was determined by microscopic analysis of ground sections. They concluded that unenhanced digital images were equivalent to film for the detection of interproximal caries.

Svanaes¹⁵ tested the storage phosphor system Digora for diagnostic accuracy of interproximal caries detection. Digora plates and Ektaspeed films were exposed simultaneously with 50 extracted premolars/molars. Ten observers rated 95 interproximal surfaces for caries. The observations were validated with microscopy. The sensitivity and specificity for film was 0,48% and 0,94%, respectively, and 0.79% accuracy. The digital system had 0.61% and 0.86% for sensitivity and specificity, and 0.72-0.88% accuracy. No significant differences were found between digital images and films.

Paurazas¹⁷ compared E-speed Plus film and digital imaging with a CCD sensor and a complementary metal-oxide semiconductor active pixel sensor (CMOS-APS) in the detection of periapical bone lesions. Periapical lesions were created in the cortical and trabecular bone of 10 dried human mandibles. Seventy radiographic images and 140 digital images were evaluated. No statistically significant differences were found between film, CCD, and CMOS-APS systems, supporting the use of Digital radiography, which requires 50% less radiation than film to obtain the same diagnostic information.

Similarly, Wallace¹⁸ evaluated the diagnostic efficacy of Ektaspeed Plus film, CCD, and photostimulable phosphor (PSP)-based digital images for detection of simulated periapical lesions. Lesions were simulated in the periapical areas of 24 human mandibular sections invested in acrylic using burs and imaged using EPF, CCD, and PSP sensors. Percent correct response scores, sensitivity, and specificity values were computed for all variables. Films displayed the highest sensitivity and specificity, followed by PSP and CCD images ($P < .001$). Films outperformed CCD and PSP images when observers could manipulate image characteristics.

The results observed in this study, as well as the findings in the literature for different radiographic tasks, demonstrate

relative equivalence of the conventional and digital radiographic systems. The use of digital radiography in the protocols of implant rehabilitation is suggested, especially during clinical testing of abutment, due to its diagnostic effectiveness and use of lower doses of radiation, elimination of chemical processing of films, and shorter time of acquisition.

CONCLUSIONS

Both conventional and digital radiographic images are efficient diagnostic tools in the assessment of marginal fit of the implant/abutment interface, presenting high sensitivity, specificity, accuracy and predictive values. Marginal openings as small as 50 μm may be detected on radiographs.

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REFERENCES

1. Brånemark PI. Osseointegration and its experimental background. *J Prosthet Dent* 1983; 50:399-410.
2. Sundén S, Gröndahl K, Gröndahl HG. Accuracy and precision in the radiographic diagnosis of clinical instability in Brånemark dental implants. *Clin Oral Implants Res* 1995; 6: 220-6.
3. Khraisat A, Stegaroiu R, Nomura S, Miyakawa O. Fatigue resistance of two implant/abutment joint designs. *J Prosthet Dent* 2002; 88: 604-10.
4. Persson LG, Lekholm U, Leonhardt A, Dahlén G, Lindhe J. Bacterial colonization on internal surfaces of Brånemark system implant components. *Clin Oral Implants Res* 1996; 7:90-5.
5. Kersten S, Tiedemann C. Strength and marginal fit of full and partial porcelain crowns on Branemark implants. *Clin Oral Implants Res* 2000; 11:59-65.
6. Byrne D, Houston F, Cleary R, Claffey N. The fit of cast and premachined implant abutments. *J Prosthet Dent* 1998; 80: 184-92.
7. Kan JY, Rungcharassaeng K, Bohsali K, Goodacre CJ, Lang BR. Clinical methods for evaluating implant framework fit. *J Prosthet Dent* 1999; 81:7-13.
8. Hecker DM, Eckert SE. Cyclical loading of implant-supported prostheses: changes in component fit over time. *J Prosthet Dent* 2003; 89: 346-51.
9. Takahashi T, Gunne J (2003) Fit of implant frameworks: an in vitro comparison between two fabrication techniques. *J Prosthet Dent* 89, 256-60.
10. Misch CE. Dental implant prosthetics. São Paulo: Elsevier Health Sciences, 2004; p. 625.
11. Hayashi M, Wilson NH, Ebisu S, Watts DC. Influence of explorer tip diameter in identifying restoration margin discrepancies. *J Dent* 2005; 33: 669-74.
12. Farman A, Farman T. A status report on digital imaging for dentistry. *Oral Radiol* 2004; 20:9-14.



13. Wenzel A, Gröndahl HG. Direct digital radiography in the dental office. *Int Dent J* 1995; 45: 27-34.

14. Haak R, Wicht MJ, Hellmich M, Noack MJ. Detection of marginal defects of composite restorations with conventional and digital radiographs. *Eur J Oral Sci* 2002; 110:282-6.

15. Svanaes DB, Møystad A, Risnes S, Larheim TA, Gröndahl HG. Intraoral storage phosphor radiography for interproximal caries detection and effect of image magnification: comparison with conventional radiography. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1996; 82: 94-100.

16. Tyndall DA, Ludlow JB, Platin E, Nair M. A comparison of Kodak Ektaspeed Plus film and the Siemens Sidexis digital imaging system for caries detection using receiver operating characteristic

analysis. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1998; 85:113-8.

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. Wallace JA, Nair MK, Colaco MF, Kapa SF. A comparative evaluation of the diagnostic efficacy of film and digital sensors for detection of simulated periapical lesions. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2001; 92:93-7.

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