CLINICAL ORAL IMPLANTS RESEARCH

Sergio Lins de Azevedo Vaz
Frederico Sampaio Neves
Evandro Portela Figueirêdo
Francisco Haiter-Neto
Paulo Sérgio Flores Campos

Accuracy of enhancement filters in measuring *in vitro* peri-implant bone level

Authors' affiliations:
Sergio Lins de Azevedo Vaz, Frederico Sampaio Neves, Francisco Haiter-Neto, Department of Oral Diagnosis, Division of Oral Radiology, Piracicaba Dental School, University of Campinas, Piracicaba, São Paulo, Brazil
Evandro Portela Figueirêdo, Department of Oral Diagnosis, Division of Oral and Maxillofacial Surgery, Piracicaba Dental School, University of Campinas, Piracicaba, São Paulo, Brazil
Paulo Sérgio Flores Campos, Department of Oral Radiology, Division of Oral Radiology, School of Dentistry, Federal University of Bahia, Salvador, Bahia, Brazil

Corresponding author:
Sergio Lins de Azevedo Vaz
Department of Oral Diagnosis
Piracicaba Dental School
University of Campinas
UNICAMP, 901, Limeira Avenue
PO Box 52, 13414-903
Piracicaba, SP, Brazil
Tel.: +55 19 2106 5327
Fax: +55 19 2106 5327
e-mail: sergiolinsv@gmail.com

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Abstract

Objectives: To identify the accuracy of enhancement filters of an intraoral phosphor-plate system for measuring the simulated peri-implant bone level.

Materials and methods: A total of 20 titanium implants (Titamax®) were placed into six fragments of bovine ribs and defects simulating bone loss were created. Periapical radiographs were taken with a phosphor-plate system (Vista Scan®) according to the paralleling standard technique, and nine enhancement filters were applied: fine, caries 1, caries 2, perio, endo, noise reduction, invert, emboss, and sculpture. The Friedman test compared the radiographic measurements of the defects to those obtained on the bovine ribs with a digital caliper. Intra- and interobserver agreement was calculated with the intra-class correlation coefficient (ICC).

Results: The ICC values showed excellent intra- and interobserver agreement. The caries1, caries2, endo, and perio filters resulted on measurements statistically different from both the original images and the measurements of the digital caliper ($P < 0.05$). The other filters did not show statistically significant differences from the original images nor from the measurements of the digital caliper.

Conclusion: In addition to the original images, the fine and emboss filters resulted on the most precise measures. The caries1, caries2, endo, and perio filters were the less accurate for measuring the peri-implant bone level.

In implant therapy, bone loss is one of the criteria used to establish the success, survival or failure of the treatment (Misch et al. 2008). Thus, proper determination of the distance from the alveolar bone level to the implant neck is required by means of periapical radiography. It allows a satisfactory evaluation of the peri-implant bone level, especially when the paralleling standard technique is applied (Schulze & d'Hoedt 2001).

The literature has shown that digital radiography may improve the diagnostic accuracy of the peri-implant bone status, since it detects minimal changes (Salvi & Lang 2004). In addition, the use of digital images has spread into implant dentistry to monitor peri-implant bone healing.

Digital radiographs can be improved by the application of task-specific filters. There is little data about the influence of enhancement filters on the radiographic evaluation of the peri-implant bone level (Berglundh et al. 2003). In contrast, the usefulness of these tools to the accuracy on the diagnosis of caries lesions (Møystad et al. 1996; Shrout et al. 1996; Haiter-Neto et al. 2009), root fractures (Wenzel et al. 2009; Kamburoğlu et al. 2010), and periodontal diagnosis (Vandenberghe et al. 2011) has been demonstrated.

Therefore, this investigation aimed to identify the accuracy of enhancement filters for measuring the simulated peri-implant bone level in periapical radiographs. The variables and factors in study were the measures of the peri-implant bone level and the enhancement filters, respectively.

Materials and methods

The design of this study received full approval from the local Ethical Research Committee of Piracicaba Dental School (University of Campinas). An oral surgeon placed twenty 3.75 × 11 mm titanium implants (Titamax®; Neodent, Curitiba, PR, Brazil) into six fragments of bovine ribs. The bovine ribs were used to simulate the radiographic aspect of the alveolar bone, based on a previous methodology (Razavi et al. 2010). After this, the oral surgeon created defects simulating bone loss with a cylindrical bone burr (KG, Sorensen, Brazil) on the left and right sides of each implant (Fig. 1), totaling a sample of 40 sites of evaluation.

Another operator performed periapical radiographs of the implants, employing a customized acrylic device for the paralleling standard technique, which also simulates the soft tissues attenuation. A 30.5 × 40.5-mm-size storage phosphor-plate (Vista Scan®; Dürr Dental, Beitigheim-Bissingen, Germany) was positioned parallel to one or two dental implants, with a focus-to-plate distance of 40-cm. The X-ray tube exposure parameters were set on 70 kVp, 7 mA, 0.36 s (Gendex Dental Systems, Lake Zurich, IL, USA).

The radiographic images were acquired using DBSWIN software (Dürr Dental) with a spatial resolution of 1270 dpi. The operator checked the threads on both sides of the implants in the radiographs to ensure an adequate parallelism between implant and phosphor-plate. Nine enhancement filters were applied in all of the radiographs: fine, caries 1, caries 2, perio, endo, noise reduction, invert, emboss, and sculpture (Fig. 2). The enhanced and the original images were exported to the 8-bit uncompressed TIFF (tagged image file format) and imported to the ImageJ software (National Institutes of Health, Bethesda, MD, USA).

After calibration of each image on the ImageJ software, an oral radiologist measured the defects in millimeters, from the neck of the implant to the most apical contact of the bone with the implant (Fig. 3). Two other oral radiologists performed a reproducibility evaluation, employing 40% of the sample, and using the intra-class correlation coefficient (ICC) with a confidence interval of 95%. After 30 days of the first evaluation, the ICC was calculated with 20% of the sample for the intra-observer reproducibility. These tests aimed to certify the reliability of the oral radiologist who evaluated the entire sample.

The operator measured the defects in the bovine ribs using a digital caliper (SC-6 digital caliper; Mitutoyo Corporation, Tokyo, Japan). Each defect was measured in three different times. A mean of these measurements was obtained and compared to the respective radiographic measure. The means had a maximum standard deviation of 0.9-mm.

The data were statistically analyzed on SAS software (Cary, NC, USA). Due to great variance in the measures, the data did not comply with the requirements of ANOVA, so the Friedman nonparametric test was used. The null hypothesis assumed no statistical differences between the measurements performed on the enhanced and the original images with those from the digital caliper, as well as on the enhanced vs. the original images. The significance level adopted was 5%.

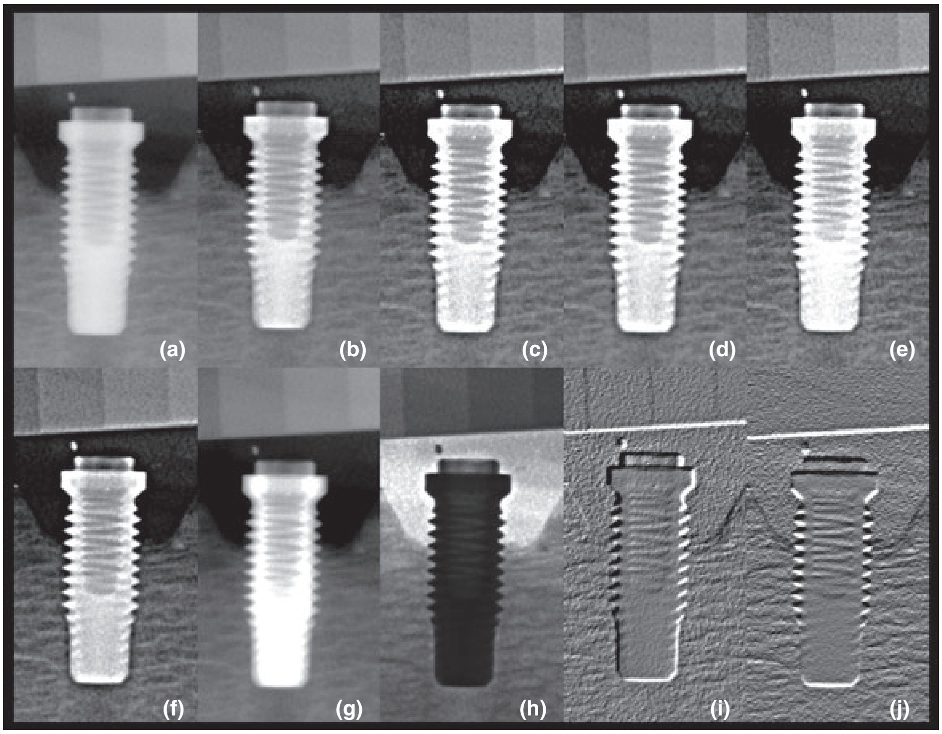

Fig. 2. Filters evaluated: (a) original image, (b) fine, (c) caries1, (d) caries2, (e) endo, (f) perio, (g) noise reduction, (h) invert, (i) emboss, (j) sculpture.

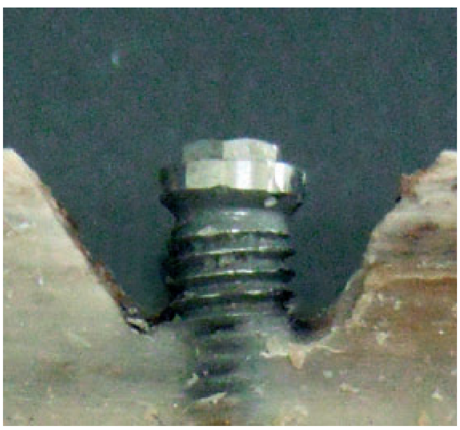

Fig. 1. The implants were placed into bovine ribs and the defects were created on both sides of the implants.

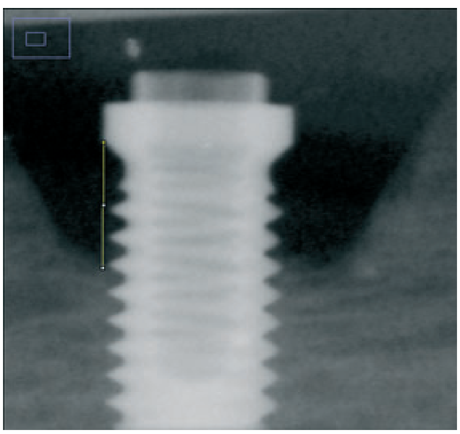

Fig. 3. The measurements were taken from the neck of the implant to the most apical contact of the bone with the implant.

Results

The intra-observer reproducibility was excellent (ICC = 0.93; 95% confidence interval [CI] = 0.89–0.95). The ICC values also showed excellent agreement among all the oral radiologists (Table 1). This validated the evaluation of the entire sample by one oral radiologist.

Table 2 shows the median, minimum, maximum, confidence interval, and *P* values for each group. The Friedman test showed

***Table 1.* Intra-class correlation coefficient (ICC) values for the inter-observer reproducibility**

		95% CI	
	ICC	Lower bound	Upper bound
Observer 1	0.95	0.93	0.96
Observer 2	0.88	0.85	0.9

statistical difference among the protocols tested ($P < 0.001$). A multiple comparisons post hoc test demonstrated that the caries 1, caries 2, endo, and perio filters were statistically different from both the measurements of the digital caliper and the original images ($P < 0.05$), with the most disparate measures. The original images, the fine and emboss filters resulted in the closest values to the measures of the digital caliper ($P > 0.05$). The accuracy of the protocols tested can also be observed on scatterplots (Figs 4 and 5).

Discussion

The radiographic determination of the peri-implant bone level is important to establish the survival of the implant. The neck of the implant is an easy reference point to recognize owing to its shape, and allows higher accuracy in measuring the peri-implant bone level (Berglundh et al. 2003; Salvi & Lang 2004; Fernández-Formoso et al. 2011).

It is known that high-pass filters accentuate the transitions in density levels due to mathematical recomputation of pixels (Wenzel et al. 2009). To evaluate only the influence of the filters applied, no adjustment of brightness and contrast was allowed in this study. Because of this, the grayest pixels of the bone surface were enhanced by the high-pass filters used (i.e. fine, caries1, caries2, endo, perio, and noise reduction), making them more difficult to visualize. Therefore, the caries1, caries2, endo, and perio filters resulted in statistically overestimated measures from those obtained with both the digital caliper and the original images. Nevertheless, because the radiographic evaluation of the peri-implant bone level cannot be more than a precision of 0.5 mm under clinical conditions (Schulze & d'Hoedt 2001) and the differences on the median values were lower than this, they were considered not clinically significant.

Unlike a previous study (Vandenberghe et al. 2011), the filter perio was worse than the original images. Although that investigation involved 12-bit radiographs, which have better image quality. The high-pass filters also failed to improve the measurements of the peri-implant bone level in another study, although there was no statistical difference from the histometric measurements (Borg et al. 2000). Such results reinforce the need to consider how an enhancement filter operates in a specific radiographic evaluation (Mol 2000; Abreu et al. 2001).

The invert filter reverses the grayness of the image so that what is black becomes white and *vice versa*. We did not find improved measurements of the peri-implant bone level with this filter, similarly to another study (Borg et al. 2000).

The emboss and sculpture filters are similar to each other. They result in an image with medium shades of gray and appearance of depth based on the relative densities of the original image, enhancing the borderlines of the structures (Baksi et al. 2010). Regarding the diagnosis of caries lesions using enhanced panoramic digital images, better results were found with the emboss filter (Akarslan et al. 2008) resembling our findings. On the other hand, we did not find statistically significant difference comparing the original images to

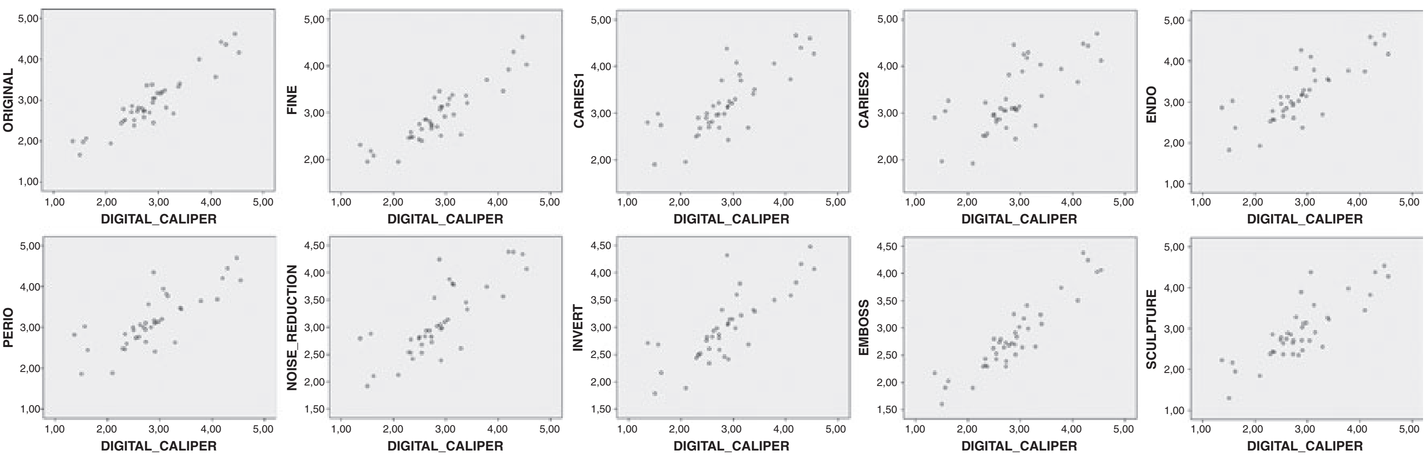

Fig. 4. Comparison of the measures obtained with the protocols tested and the digital caliper.

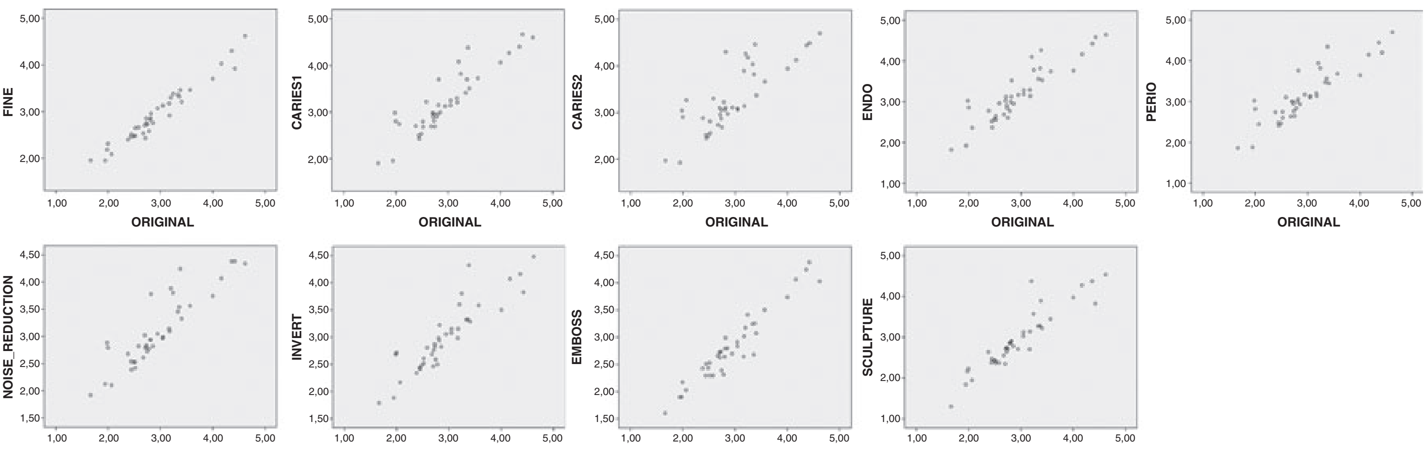

Fig. 5. Comparison of the measures obtained with the original images and images with filters.

Table 2. **Median, minimum, maximum, confidence interval (CI), and *P* values for the measurements performed on each protocol and with the digital caliper (*n* = 40)**

	Median Value	Minimum value	Maximum value	95% CI Lower bound	95% CI Upper bound	Global *P*-value
Digital caliper	2.81	1.37	4.54	2.62	3.10	<0.0001
Original	2.81	1.66	4.62	2.72	3.16	
Fine	2.84	1.95	4.62	2.74	3.13	
Caries 1*, ¶	3.06	1.90	4.67	3.00	3.43	
Caries 2*, ¶	3.10	1.93	4.70	3.07	3.52	
Endo*, ¶	3.07	1.82	4.64	2.96	3.40	
Perio*, ¶	3.04	1.87	4.70	2.94	3.36	
Noise reduction	2.94	1.92	4.38	2.88	3.30	
Invert	2.90	1.79	4.48	2.80	3.20	
Emboss	2.77	1.30	4.53	2.69	3.16	
Sculpture	2.71	1.60	4.38	2.61	3.02	

*Statistically different from the digital caliper ($P < 0.05$).
¶Statistically different from the original images ($P < 0.05$).

those with the emboss filter, corroborating another study that evaluated the accuracy on cephalometric landmarks (Leonardi et al. 2010).

To the best of our knowledge, this is the first study which inquired whether the emboss and sculpture filters improve bone level measurements. The better results of the emboss filter may be attributed to the enhancement of the bone level and the reduced influence of the visual perception of the grayscale, which is critical for the evaluation of bone level. Therefore, we suggest that the emboss filter may be valuable when the adjustment of brightness and contrast is critical. Clinical studies are required to clarify the present findings.

In conclusion, additionally to the original images, the fine and emboss filters resulted in the most precise measures when compared to the measurements of the digital caliper. The caries 1, caries 2, endo, and perio filters were less accurate for measuring the peri-implant bone level. Thus, when one analyzes the peri-implant bone level in digital radiographs, preference should be given for the original images, the fine or emboss filters. The caries 1, caries 2, endo, and perio filters should be avoided to this specific task.

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