Are Intraoral Radiographs Accurate in Determining the Peri-implant Marginal Bone Level?

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**Purpose:** The primary objective of this study was to assess the accuracy of periapical radiographs in determining the peri-implant marginal bone level. The accuracy of the linear measurements on radiographs was considered as the absolute difference between the true, intraoperative or surgical marginal bone level measurements (direct bone measurements during surgical procedures) and the radiographic measured distances. The secondary aims were to identify the variables influencing the radiographic evaluation (arch: mandible/maxilla; implant location: anterior/posterior; timing of implant placement: “early delayed” and “prolonged delayed”). The influence of vestibular and palatal/lingual crestal bone levels was also investigated. **Materials and Methods:** STROBE guidelines were followed. As soon as the implant was inserted, the marginal bone levels were recorded using a straight periodontal probe (intraoperative or surgical measurements). At the same time, periapical radiographs were taken. To standardize the radiographic images, periapical radiographs were acquired using the long-cone parallel technique and film holding system. All radiographs were analyzed by two examiners blinded to the surgical measurements. Intraclass correlation coefficient (ICC) was employed to assess the intraobserver and interobserver variability. The descriptive statistics, t test, and multivariate statistics were used; the threshold for statistical significance was $P \leq .05$.

**Results:** Two hundred sixty-eight implants were inserted in 142 patients. The interobserver agreement was 0.980; the intraobserver variability was 0.990 and 0.993. The mean difference between the radiographic and surgical measurements was 0.45 mm (range: 0 to 8 mm; SD: 1.76). Comparing the radiographic and surgical measurements, a statistically significant difference ($P = .000$) was detected. None of the variables considered (arch, implant location, and timing of implant placement) significantly influenced the accuracy. Neither the vestibular alveolar edge ($P = .908$) nor the lingual/palatal ($P = .485$) significantly influenced the accuracy.

**Conclusion:** The periapical radiograph statistically significantly overestimates the level of peri-implant marginal bone compared with surgical measurements. The arch, implant location, timing of implant placement, and level of vestibular or lingual/palatal alveolar edge do not influence deviation between the intraoperative peri-implant marginal bone level measurements and the radiographically determined marginal bone levels. Int J Oral Maxillofac Implants 2018;33:847–852. doi: 10.11607/jomi.5352

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level measurements (direct bone measurements during surgical procedures) and the marginal bone levels measured by means of periapical radiographs are statistically significantly different. Given that the surgical measurement is the reference, the smaller the difference is between the surgical and radiographic measurements, the greater the accuracy of the radiographic measurements.

The secondary objectives were:

• to identify the variables that affect the peri-implant marginal bone level radiographic evaluation (arch: mandible/maxilla; implant location: anterior/posterior; timing of implant placement: “early delayed” and “prolonged delayed”)
• to assess the influence of vestibular and palatal/lingual crestal bone levels on the radiographic measurements: as the periapical radiography is bi-dimensional, the overlap between buccal and palatal/lingual bone levels could prevent the correct determination of the peri-implant marginal bone levels

An assumption was made that statistically the intraoperative (surgical) measurements and the marginal bone levels measured using periapical radiographs are significantly different.

Moreover, it was assumed that at least one variable could influence the accuracy of periapical radiographs.

MATERIALS AND METHODS

The study was executed at the Department of Oral and Maxillofacial Sciences of “Sapienza” University of Rome between February 2014 and February 2016. A prospective cohort study design was used, in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology guidelines (STROBE). The approval of the local ethics committee was obtained (#304/07). The inclusion and exclusion criteria as well as the preoperative radiographic examinations used are the same as those already described in previous publications.\(^2\,\,^3\,\,^5\) A two-piece, tapered implant was used (SM Torx Implant System, DiolMplant). The implant shoulder was machined, and the coronal part of the implant body was characterized by microthreads. The implant lengths were 10, 12, and 14 mm; the diameters were 3.8 and 4.1 (narrow), 4.5 and 5.0 (regular), and 5.3 mm (wide). The implants were inserted by raising a mucoperiosteal flap. When implants were inserted, the marginal bone levels were recorded with a straight periodontal probe (Williams Probe, Hu Friedy). Depending on the positioning of the marginal bone level, the following values were recorded:

- Positive number (coronal to implant shoulder), zero (at the implant shoulder), or negative number (apical to the implant shoulder). The marginal bone level value was rounded to the nearest millimeter. The distance between the same reference point (implant shoulder) and the edge of peri-implant marginal bone at four sides around the implant was measured (in the middle of the distal and mesial implant surface and in the middle of the vestibular and lingual/palatal implant surface) (Fig 1). All clinical measurements were performed by one examiner, an expert prosthodontist and oral surgeon (M.C.). At the same time, the marginal bone level was also registered by means of periapical radiographs (Fig 2). To standardize the periapical radiographic images, the long-cone parallel technique and the Super-Bite (Kerr Corporation) film holding system were used. The x-ray film was aligned in parallel to the long axis of the implants. Exposures were made with an intraoral radiation unit (Oralix AC, Gendex) using a cylindrical tube head, 2.5-mm aluminum filtration, and a focal spot distance of 200 mm. The exposure settings were 70 kV ± 1.12 mAs. Digital radiographs were saved via a digital intraoral imaging system (DenOptix QST Digital X-ray Phosphor Plate System, Gendex), and direct measurements were performed using dental imaging software (VixWinPRO, Gendex). The mesial and distal marginal bone level measurements (ie, the linear measurements between the implant shoulder and the marginal bone level) could be either a positive number, zero, or a negative number as previously outlined. Contrast and brightness of the digital images were adjusted using the same software. To reduce the symmetric imaging error in the vertical plane, the distortion of each individual radiograph was determined, and the radiographic measurements were adjusted according to this distortion for each individual radiograph. The measurements were calibrated by means of an object of known dimension—the known implant length or width. As well as during the intraoperative measurements, the radiographic marginal bone level values were rounded to the nearest millimeter. All radiographs were analyzed independently by two examiners blinded to the surgical measurements. The intraobserver and interobserver variability was assessed using the intraclass correlation coefficient (ICC). An estimated ICC close to 1 states that the correlation is strong. A P value ≤ .05 was set as the significance level. The accuracy of peri-implant marginal bone level radiographic measurements was assessed by comparing the values measured on radiographs to the intraoperative values. For the comparison with the radiographic measurements, the mesial and distal intraoperative values were used. The predictor variables, ie, the clinical factors that may affect the radiographic measurements, resulting in a difference between the
intraoperative measurements and the radiographic measurements, were classified as follows2,3,5:

- Arch: maxilla or mandible
- Implant position: anterior or posterior
- Timing of implant placement: distinguished between "early delayed" and "prolonged delayed"

The influence of vestibular or lingual/palatal alveolar bone edge (ie, the height of the alveolar ridge measured in correspondence to the implant in the middle of the vestibular and lingual/palatal implant surface) on the radiographic assessment of marginal bone levels was evaluated as well.

**Statistical Analysis**
The statistical analysis was performed at implant level. Descriptive statistics and t test were used to detect

![Fig 1](image1.png) Surgical, intraoperative peri-implant marginal bone level measurements of a prolonged delayed implant inserted in the premolar area of the maxilla. The values were recorded in the middle of the distal and mesial implant surface and in the middle of the vestibular and palatal implant surface.

![Fig 2](image2.png) Periapical radiograph obtained at the time of implant placement with the long-cone parallel technique and the Super-Bite (Kerr Corporation) film holding system.
whether the intraoperative and the radiographic marginal bone level measurements were statistically significantly different. Multivariate statistics were used to evaluate if arch, implant location, and timing of implant placement statistically significantly affect the accuracy of radiographic measurements (difference between the radiographic and intraoperative marginal bone measurements). To evaluate the influence of vestibular or palatal/lingual crestal bone levels on the difference between the surgical and radiographic measurements, multivariate statistics were also used. Data were evaluated using statistical analysis software (SPSS v. 17.0, IBM Corporation). The statistical significance was set at the level of \( P \leq .05 \) for all evaluations.

### RESULTS

Two hundred fifty patients were examined for inclusion in the study. Of the 250 patients, 85 were declared as not in compliance with the requirements. Twenty-three patients did not assent to the study. A total of 142 patients were in succession included in this study and given treatment (\( n = 85 \) women [59.9%]; \( n = 57 \) men [40.1%]; age range at time of implant placement, 21 to 78 years; mean, 55.08 years [SD: 12.43]). A total of 268 implants were placed. Considering the implant location, 38 implants were anterior (14.2%) and 230 posterior (85.8%). When the variable arch is considered, 146 implants were inserted in the maxilla (54.5%) and 122 in the mandible (45.5%). One hundred eighty-two implants were “early delayed” (67.9%) and 86 “prolonged delayed” (32.1%).

Considering the radiographic measurement reliability, the interobserver agreement (ICC) was 0.980. The intraobserver variability evaluated using ICC was 0.990 and 0.993. Given the excellent interobserver and intraobserver agreement, the radiographic measurements were considered. The values of surgical and radiographic measurements are shown in Table 1. Comparing the radiographic values to surgical measurements, a mean difference of 0.45 mm was determined (range: 0 to 8 mm; SD: 1.76). The radiographic analysis significantly overestimated \( (P = .000) \) the level of peri-implant marginal bone. The variables arch, implant location, and timing of implant placement did not significantly influence the accuracy of radiographic measurements. Regarding the influence of vestibular and palatal/lingual crestal bone levels on the accuracy of the periapical radiograph, neither the vestibular alveolar edge \( (P = .908) \) nor the lingual/palatal alveolar edge \( (P = .485) \) significantly influenced the accuracy.

### DISCUSSION

In the present study, the difference between the intraoperative measurements of peri-implant marginal bone levels and the marginal bone levels evaluated using periapical radiographs was determined. The hypothesis that a difference would be present was confirmed by the results: the radiographic analysis significantly overestimated the marginal bone compared with the surgical measurements.

The secondary objectives were to determine if variables such as arch, implant location, timing of implant placement, and vestibular and palatal/lingual crestal bone levels influenced the accuracy of peri-implant marginal bone level radiographic evaluation. The hypothesis about the existence of at least one variable associated with greater inaccuracy of periapical radiographs was not confirmed by the results.

In terms of study limitations, the evaluation of marginal bone level took place by means of standardized digital periapical radiographs without any customization of the radiographic jig. To compare bone levels over time, the radiographic film position has to be similar. \(^1\) Individualizing standard film holders can resolve the problems that originate from a different projection in a research environment, but this is not easy to achieve in daily practice. \(^1\) Over the years, many efforts have been made to standardize periapical radiographs. \(^10\) The paralleling technique is currently the most commonly used method to visualize minute bone changes. If the paralleling technique is applied without additional devices to ensure true parallelism (when the film and implant are not in parallel and the focus-object distance is below 380 mm), radiographic measurement of marginal bone level reaches only a precision of 0.5 mm. \(^11\) Considering the determined

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**Table 1** Crestal Bone Levels Measured Radiographically and Surgically \( (n = 268) \)

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Min</th>
<th>Max</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>rx.T0 m.</td>
<td>1.29</td>
<td>-3.70</td>
<td>8.20</td>
<td>1.49</td>
</tr>
<tr>
<td>rx.T0 d.</td>
<td>0.77</td>
<td>-6.80</td>
<td>6.50</td>
<td>1.56</td>
</tr>
<tr>
<td>s.m.T0 m.</td>
<td>0.80</td>
<td>-7.00</td>
<td>7.00</td>
<td>2.09</td>
</tr>
<tr>
<td>s.m.T0 d.</td>
<td>0.36</td>
<td>-5.00</td>
<td>7.00</td>
<td>1.97</td>
</tr>
<tr>
<td>s.m.T0 v.</td>
<td>-0.69</td>
<td>-8.00</td>
<td>3.00</td>
<td>1.89</td>
</tr>
<tr>
<td>s.m.T0 p/l.</td>
<td>-0.06</td>
<td>-10.00</td>
<td>5.00</td>
<td>1.84</td>
</tr>
</tbody>
</table>

Marginal bone levels measured at the time of implant insertion. \( r x . T 0 . m . = \) mesial marginal bone level measured radiographically; \( r x . T 0 . d . = \) distal marginal bone level measured radiographically; \( s . m . T 0 . m . = \) intraoperative (surgical) mesial marginal bone level measurement; \( s . m . T 0 . d . = \) intraoperative (surgical) distal marginal bone level measurement; \( s . m . T 0 . v . = \) intraoperative (surgical) vestibular marginal bone level measurement; \( s . m . T 0 . p / l . = \) intraoperative (surgical) palatal/lingual marginal bone level measurement.
precision of 0.5 mm, in this study, the values were rounded to the nearest millimeter.

In order to make the analysis as objective as possible, all the surgeries, the intraoperative measurements, and the intraoral periapical radiographs were performed by an experienced operator (M.C.), and two researchers, experts in implantology and dental radiology, evaluated the periapical radiographs independently.

Considering the detection threshold for marginal bone loss using periapical radiographs, if the real clinical conditions were considered, Ahlqvist et al 12 stated that the recognition limit for marginal bone loss was above 0.47 mm. These considerations support the choice of rounding the radiographic measurements to the nearest millimeter. In this way, the radiographic and clinical measurements have been rounded using the same criterion. This makes the measurements comparable in the current analysis.

In the past, using analog x-ray machines, the same kind of film and the same radiation parameters were employed.1 Nowadays, the availability of digital radiographs has enabled standard and, henceforth easier, image contrast management.1,13 Considering the use of a photostimulable phosphor system, the system used in the present study, the image contrast may be modified using dedicated software, making it easier to compare the images of the different follow-ups.13 Another aspect that must be considered is represented by the lower resolution of phosphor plate radiography. Although the phosphor plate resolution performance is inferior to that of film, it is sufficiently adequate for the needs of oral radiology.4

Evaluating the possible difference between the intraoperative measurements of peri-implant marginal bone levels and the bone levels determined using periapical radiographs, Caulier et al 14 stated that the periapical radiographs underrate the real peri-implant bone loss, as evaluated histomorphometrically in an experimental animal study. In a study aimed at evaluating the accuracy and reliability of radiographic techniques for measurement of the marginal bone level around oral implants in human corpses, the radiographic measurements were found to be higher (overestimated) than the real measurements.9 The difference, however, was not statistically significant (P > .05).9 Isidor, in a study aimed to evaluate the clinical probe level, radiographic bone level, and histologic bone level around implants in monkeys,15 demonstrated that radiographic assessment estimated the loss in marginal bone level around implants better than clinical probing with or without a standardized probing force, also concluding that radiographic evaluation tends to underestimate the marginal bone loss. These findings have been confirmed by the results of the present clinical study: comparing the radiographic analysis with surgical measurements, the radiographic analysis significantly overestimates the level of peri-implant marginal bone compared with surgical measurements.

Considering all the limits of periapical radiography, cone beam computed tomography (CBCT) has been proposed in the evaluation of marginal bone levels. Raes et al 16 carried out a comparison between marginal bone level measurements on periapical radiographs and CBCT around a sample of implants. A mean difference of 0.47 mm (range: –0.47 to 3.13 mm), with a very good significance level (P < .001), was detected between periapical radiographs and CBCT, the latter systematically underrating the bone level. According to De Bruyn et al, 1 although the periapical radiographic technique is a two-dimensional technique and may underestimate the presence of vestibular and lingual/palatal defects, it remains the most reliable method for measuring the peri-implant marginal bone level.

Considering the possible sources of error, Brägger et al 17 stated the presence of a learning curve when the peri-implant bone levels were assessed. In order to reduce the risk of error, in the present study, periapical radiographs were evaluated by experienced operators who had previously participated in similar studies.2,3 Brägger et al 17 also pointed out that measurement errors may be related to variation in projection. A symmetric imaging error in the vertical plane occurs frequently in patients with atrophic mandibles when there is a limited mouth opening or when the implant-supported prosthetic restoration is high and the x-ray film is too short to reach the area of interest.18 In these cases, it is difficult to obtain a parallelism between the implant and the periapical radiograph, maintaining an orthogonal x-ray beam. The symmetric imaging error in the vertical plane can be easily corrected by referring the thread pitch or implant length for calibration.1 In the present study, as already described,2,3 the distortion of each individual radiograph was determined, and the radiographic measurements were adjusted according to this distortion for each individual radiograph.

Sewerin, in a study conducted in 1990,10 analyzed how the buccolingual bone size, along with angulations of the implant axis to the central x-ray beam, and position of the implant (buccal, central, lingual) affect the peri-implant marginal bone level measurements. The risk of overestimating bone height was greater when the width of the alveolar ridge was higher, when the angulation between the implant axis and central x-ray beam/film plane was higher than 1 degree, and when the position of the implant was lingual.10 In the present study, variables such as arch, implant location, and timing of implant placement did not influence...
the accuracy of the peri-implant marginal bone level radiographic evaluation. Similarly, vestibular and palatal/lingual crestal bone levels did not influence the accuracy.

As stated by De Bruyn et al, the implant-abutment interface is a readily detectable reference point for follow-up measurements. On the contrary, the recognition of the reference point on the interface between the alveolar bone and implants is difficult, and can be a possible source of error. While in the past, the implant shoulder was positioned at the alveolar bone level, today some implants are placed below the alveolar bone. In this case, it is incorrect to consider the first contact between the bone and implant, the so-called bone-to-implant contact, but the distance between the implant shoulder and the marginal bone should be considered. This distance may be zero if the bone level coincides with the implant shoulder, it can be a positive value if it is more coronal than the implant shoulder, and it is a negative value when the bone level is more apical than the implant shoulder.8

CONCLUSIONS

The peri-implant marginal bone level analysis on radiographs statistically significantly overestimates the level of peri-implant marginal bone compared with intraoperative or surgical measurements. This difference between a measured value and its true value can be considered an observational error (or measurement error). When the long-cone parallel technique and a film holding system were used, taking care to parallel the alignment of digital radiographs in the film holder to the long axis of the implants, variables such as arch, implant location, and timing of implant placement did not affect the peri-implant marginal bone level radiographic evaluation. Although the periapical radiography is bi-dimensional, vestibular and palatal/lingual crestal bone levels did not prevent the correct determination of peri-implant marginal bone levels.

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