The maintenance of peri-implant bone and biologic sealing of soft tissue are key factors for determining the success and survival rates of dental implants. Radiographic marginal bone loss (MBL) is one of the implant success criteria and might suggest physiologic bone loss or increased risk of implant failure.1,2 There are a wide range of etiologic factors that can impact MBL, such as soft tissue thickness,3 prosthetic connection (external or internal),4 loading protocol (immediate, early, or delayed),5 smoking habit,6 plaque accumulation,3 abutment height,7 and also connection and disconnection of the healing abutments or screws during the prosthesis fabrication procedure.8–10

A recent meta-analysis has assessed the relationship of abutment height and MBL and identified that long abutment heights (> 2 mm) presented less MBL compared to shorter abutments.11 Another study suggested that short abutments appear to present greater bone loss irrespective of mucosal thickness.12 On the other hand, Lee et al13 reported that abutments should not exceed 4 mm in height. These previous studies highlight that the correct selection of abutment height is critical to reduce risk of bone loss and its undesirable clinical effects and to provide adequate esthetics. Likewise, the establishment of predictive factors for abutment height selection can be very useful when dentists consider the placement of a definitive abutment in the implant placement procedure.

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Assessment of Surgical and Radiographic Parameters for Abutment Height Selection: A Prospective Study with 1-Year Follow-up

Alejandro Elizalde Hernández, DDS¹/Mateus de Azevedo Kinalski, DDS, DSc, PhD¹/Otávio Amaral de Andrade Leão, BPE, MSc²/César Dal'molin Bergoli, DDS, MSc, PhD¹/Fernanda Faot, DDS, MSc, PhD¹/Mateus Bertolini Fernandes dos Santos, DDS, MSc, PhD¹

Purpose: The "one-abutment, one-time" concept entails the placement of a definitive abutment at the time of implant placement, without removal during prosthesis manufacture, with the aim to promote a safer environment for the peri-implant tissues. Identifying surgical and radiographic parameters that can assist with the abutment height selection would facilitate the adoption of the one-abutment, one-time concept. Therefore, the aim of this study was to assess the role of surgical and radiographic parameters as predictive factors for abutment height selection in implant-retained single crowns. Materials and Methods: This prospective study assessed the role of surgical and radiographic measurements in the implant survival and success rates and marginal bone loss in implant-retained single crowns. Implants were placed in both healed sites and extraction sockets, and the distances between the implant platform and alveolar bone crest, implant platform and gingival margin, and buccal gap (when present) were recorded using a straight periodontal probe. Digital radiographs were made at implant placement (T₀), abutment height selection (Tₐ), and 1-year follow-up (Tᵢ), and the distance between the implant platform and the alveolar bone crest (mm) was assessed. Linear regression models and Pearson correlation were used to assess the influence of primary and secondary outcomes on abutment height. Results: A total of 130 implants were placed in 68 patients. The mean surgical distance between the bone crest and the implant platform was 1.71 ± 1.01 mm, and the mean distance from the gingival margin to the implant platform was 3.94 ± 1.90 mm, while at the abutment selection appointment, the mean transmucosal height was 3.58 ± 1.50 mm. A high linear correlation was found between the selected abutment height and two primary outcomes: the radiographic implant platform to alveolar bone crest distance at T₀ (r² = 0.66; P < .001) and the transmucosal height at Tₐ (r² = 0.81; P < .001).

Conclusion: Radiographic measurements of the distance between the implant platform and the alveolar bone crest at implant placement can serve as an important parameter to select the abutment height for definitive restorations. Int J Oral Maxillofac Implants 2022;37:1037–1043. doi: 10.11607/jomi.9446

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¹Graduate Program in Dentistry, Federal University of Pelotas, Pelotas, RS, Brazil.
²Graduate Program in Epidemiology, Federal University of Pelotas, Pelotas, RS, Brazil.

Correspondence to: Dr Mateus B. F. dos Santos, School of Dentistry, Federal University of Pelotas, 457 Gonçalves Chaves Street, Room 502, Pelotas, RS, Brazil, 96015-560. Email: mateus.santos@ufpel.edu.br

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known as the “one abutment, one-time” concept, which is reported to provide adequate maintenance of soft tissue sealing and biologic width.\textsuperscript{9,10} The selection of abutment height is dependent on several factors, such as 3D position of the implant, interocclusal space, and the necessity of an adequate emergence profile to provide a biologic width that will maintain peri-implant health and to avoid a greyish appearance when using titanium abutments. The abutment height selection is especially important when performing immediate loading, as inadequate selection of a high abutment height could impair the esthetics due to exposure of the metallic part of the abutment, while the selection of a short abutment height might increase the risk of MBL.\textsuperscript{7} Therefore, this prospective observational study aimed to assess how the choice of abutment height is influenced by (1) surgical parameters (implant platform to alveolar bone crest distance, implant platform to gingival margin distance, and buccal gap, when present) and (2) radiographic measurements (distance between the implant platform and alveolar bone crest at implant placement). The relationship between these parameters was evaluated to identify potential predictors for abutment height selection in implant-retained single crowns after 1 year of follow-up. This study hypothesized that both surgical and radiographic measurements can serve as predictive factors for abutment height selection.

**MATERIALS AND METHODS**

**Study Design**
This prospective study was designed to assess the role of surgical and radiographic parameters as predictive factors for abutment height selection in implant-retained single crowns and is reported according to the STROBE guidelines.\textsuperscript{14} The study protocol was in accordance with the Helsinki Declaration and was reviewed and approved by the Institutional Ethics Committee (Protocol 2.792.042). The study protocol was also registered prior to its beginning (ReBEC TRIAL: RBR-463SK7). The study was conducted from January 2018 to March 2020.

**Eligibility Criteria**
The adopted inclusion criteria were: (1) at least 21 years of age; (2) requires rehabilitation with at least one implant; (3) adequate bone dimensions for implant placement without the need for guided bone regeneration procedures; (4) good general health that allows dental implant surgery; (5) availability for dental appointments at the institution; and (6) signed informed consent given by the patient.

Patients with uncontrolled systemic diseases (eg, hypertension, metabolic bone disease, diabetes mellitus), need for guided bone regeneration or sinus elevation for implant placement, and/or with a history of radiation therapy in the head and neck regions were excluded from the study.

**Clinical Procedures**
All surgeries were performed by a previously calibrated team composed of three surgeons who followed the same protocol and standards. Patients were examined, and a treatment plan was customized for each patient. Specific information about two tapered implant systems with Morse taper connections was given to the patients, and they subsequently chose their preferred implant system (Neodent Straumann or Arsys, FGM Dental Group).

The implant placement procedure followed the manufacturer’s recommendations. When the gap between the implant platform and the buccal bone wall exceeded 2 mm, a synthetic calcium phosphate material (Nanosynt, FGM Dental Group) was used to fill the gap. Afterward, abutment height selection was performed with a Morse taper height measurer instrument by measuring the tissue thickness from the top of the implant platform to the crest of the gingiva at its highest point. This measurement was considered as the transmucosal height. The abutment height was subsequently chosen by subtracting 2 mm from the transmucosal height (Fig 1) and the implant-abutment set protected by one of the options as follows: (1) cover screw, (2)
healing abutment, or (3) provisional crowns. For the provisional crowns, the general characteristics of these restorations were made considering the guidelines by González-Martín et al.15 for the general characteristics of the critical and subcritical contours for immediate and delayed implants. A conventional loading protocol for the implants was adopted, and patients were rescheduled after a period of 4 to 6 months to receive their definitive restorations. When provisional crowns were made, they remained below the occlusal plane, without any centric or eccentric occlusal contacts.

Primary Outcomes: Surgical Measurements

Implants were placed in both healed sites and extraction sockets, and the distances between the (1) implant platform and alveolar bone crest, (2) implant platform and gingival margin, and (3) buccal gap (when present) were recorded using a straight periodontal probe (Fig 2).

Secondary Outcomes: Radiographic MBL

Digital periapical radiographs were done at implant placement ($T_0$), abutment height selection ($T_a$), and 1-year follow-up ($T_f$; Fig 3). All radiographs were taken by a single operator (M.A.K.) with a paralleling technique so that the cervical implant platform and threads were visible. MBL was measured by a blinded researcher (M.A.K.) who imported the images in ImageJ software (ImageJ 1.47v, National Institutes of Health) and assessed the distance between the implant platform and alveolar bone crest in the mesial and distal areas. The average of both values was considered for each implant.16
Descriptive statistics were used, including the mean and standard deviation (SD) of surgical parameters and radiographic marginal bone measurements. Data were compiled from the patient records to a specific spreadsheet (Microsoft Excel, Microsoft). Data were then exported into statistical analysis software (STATA 16.0, Stata). Sample description was performed using number and frequency distribution (%), and the comparison for MBL after 1 year of loading according to length, diameter, position on the arch, and type of protection was assessed by the t test for dichotomic variables and one-way analysis of variance (ANOVA) for polyphonic variables. Linear regression models and Pearson correlation coefficients were used to assess the influence of primary and secondary outcomes on abutment height. Additionally, the quality of the models was evaluated through $R^2$, Akaike information criterion (AIC), and Bayesian information criterion (BIC). Statistical significance was set at $\alpha = .05$ for all analyses.

**RESULTS**

A total of 130 implants were placed in 68 patients. The average age of the included patients was $50.95 \pm 11.65$ years, ranging from 25 to 84 years. The sample was mostly composed of women ($67.6\%$), and the main reported general health condition was controlled hypertension ($27.9\%$). Most implants ($65.38\%$) were placed in healed sites, and only $27.69\%$ required bone grafting in the buccal gap (Table 1).

Table 2 presents the values of the different surgical and radiographic measurements. The mean surgical distance between the bone crest and the implant platform was $1.71 \pm 1.01$ mm, while the mean distance from the gingival margin to the implant platform was $3.94 \pm 1.90$ mm. At the time of abutment selection appointment, the mean transmucosal height was reduced to $3.58 \pm 1.50$ mm.

When the primary and secondary outcomes were checked for correlation with the abutment height, all outcomes presented statistically significant differences; however, only distance from the radiographic implant platform to the alveolar bone crest at $T_0$ ($r^2 = 0.66$; $P < .001$) and transmucosal height ($r^2 = 0.81$; $P < .001$) presented a high linear correlation with the outcome.

The mean transmucosal height of implants placed in healed sites was $3.07 \pm 1.31$ mm, while this value was $4.38 \pm 1.38$ mm in implants placed in extraction sockets. The average selected abutment height was $2.24$ mm for implants placed in healed sites and $3.01$ mm for implants placed in extraction sockets. Although statistically significant differences were observed when comparing these groups ($P < .001$), a weak correlation was found ($r^2 = 0.19$).
Table 3 presents the outcomes of linear regression models between abutment height and the primary and secondary outcomes, where the $r^2$ values represent the percentage of the abutment height variability that is accounted for in the models. Among the assessed outcomes, the radiographic distance from the implant platform to the alveolar bone crest at implant placement (T0) and the transmucosal height presented high $r^2$ values, suggesting that they can be used to predict and assist with the abutment height selection.

Adjusted linear regression between abutment height and primary (surgical probing) and secondary outcomes (radiographic marginal bone measurements) showed that both models were generally very similar, explaining approximately 70% of the outcome. However, these values did not differ much from the model based solely on the transmucosal height.

When assessing the secondary outcomes, a mean MBL of 0.95 mm was observed between the implant platform and the alveolar bone crest; however, no correlation was observed between MBL and abutment height ($r^2 = -0.09; P = .41$). Finally, regarding MBL, the use of provisional restorations ($P = .002$) and longer implants ($P = .02$) had a positive effect on marginal bone maintenance (Table 4).

Table 4 Mean and Standard Deviation of MBL After 1 Year of Loading (Tf) Grouped According to Implant Length, Diameter, Position on the Arch, and Type of Protection

There are several ways to select the abutment height for implant-retained prostheses. The most common method is based on the assessment of the transmucosal height after osseointegration. However, when placing implants in extraction sockets, the assessment of the transmucosal height may be impaired due to the absence of properly healed peri-implant tissue. In this way, it is important to highlight that inadequate selection of the abutment height might promote an increased risk of MBL and affect the esthetics through exposure of the metallic part of the abutment. This prospective study is one of the few that assesses surgical measurements (implant platform to alveolar bone crest distance, implant platform to gingival margin distance, and buccal gap, when present) and radiographic measurements (distance between the implant platform and...
alveolar bone crest at implant placement) as parameters for abutment height selection, as well as its influence on MBL in implant-retained single crowns after 1 year of follow-up.

The hypothesis of this study, that both surgical and radiographic measurements can serve as predictors for abutment height selection, was partially accepted since the present findings suggest that all studied outcomes presented statistically significant differences; however, only the radiographic implant platform to alveolar bone crest distance at implant placement ($r^2 = 0.66$; $P < .001$) and transmucosal height after osseointegration ($r^2 = 0.81$; $P < .001$), which is the gold standard for abutment height selection, presented a high linear correlation with the selected abutment heights. Hence, these associations could be considered an interesting piece of evidence during the abutment selection phase, reducing subjective decisions, the necessity of abutment changes, and consequently, the risk of MBL.

The abutment height selection is a critical step during treatment with implant-retained prostheses. The type of bone site where the implant is placed (extraction sockets or healed sites), the loading protocol (early, immediate, or delayed), and the 3D position of the implant (subcrestally, bone level, or tissue level) are important factors that can influence this procedure. Although implants that received early and immediate loading present similar MBL changes, the postoperative changes in both soft and hard tissues are more visible in implants placed in extraction sockets due to the healing process that occurs after tooth extraction.

The biologic width of dental implants extends from the bone-to-implant contact to approximately 3 to 4 mm of distance from the gingival margin of the peri-implant mucosa to the bone-implant connection. It serves as biologic protection against microorganisms and impacts the soft and hard tissue formation around the implants. In this context, it is important to consider that selection of an inadequate abutment height would create the need for abutment exchange, which may disturb the peri-implant mucosal barrier and subsequently cause MBL. Moreover, the one-abutment, one-time concept suggests the placement of a definitive abutment to provide a safer environment for the peri-implant tissues, while repeated abutment disconnections could significantly increase MBL. In this way, the findings of the present study can be useful for dentists considering the adoption of the one-abutment, one-time concept by providing supporting evidence that radiographic measurements can serve as an important parameter to select the abutment height for the definitive restorations, thus avoiding risk of inadequate abutment height selection and the need for further abutment changes.

Previous studies have suggested an association between MBL and biologic width and prosthetic abutment height, highlighting the importance of adequate abutment selection. Although the present study did not observe a correlation between MBL and abutment height ($r^2 = -0.09$; $P = .41$), it has to be emphasized that the present study was not designed to especially address this correlation. Therefore, the authors believe that the abutment height might affect the reduction or attenuation of MBL in the long term, and this needs clarification by further research.

It is important to highlight some limitations of the present study. First, this was a prospective study without restrictive inclusion criteria as a randomized controlled trial would have; thus, confounding factors and the absence of a control group should be considered when considering the external validation of the present findings. Second, the surgical measurements in the present study were performed with periodontal probes and could be subject to imprecision depending on the operators; however, the study was developed with a previously calibrated team of operators. Lastly, the statistical approach adopted in the present study should be considered a limitation in fully providing evidence to consider the use of radiographic measurements as predictors for abutment height selection. Although the present study has included a large number of parameters and presented a detailed statistical analysis, the sample size of this study might be a limiting factor in assessing the real role of those parameters. Therefore, the authors emphasize the need for new studies including bigger samples to improve the understanding of the actual role of surgical and radiographic parameters in abutment height selection. However, the authors consider the statistical methods used to be adequate, and the findings of this study could suggest that the assessed parameters can help dentists in the abutment height selection phase, but these parameters cannot be considered definitive predictors.

CONCLUSIONS

Within the limitations of this study, it is possible to suggest that the radiographic distance from the implant platform to the alveolar bone crest at implant placement can serve as an important parameter for the selection of the abutment height for the definitive restoration.

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