Influence of Diameter and Length of Implant on Early Dental Implant Failure

Sergio Olate, DDS, MSc,* Mariana Camilo Negreiros Lyrio, DDS, MSc,† Márcio de Moraes, DDS, MSc, PhD,‡ Renato Mazzonetto, DDS, MSc, PhD,§ and Roger William Fernandes Moreira, JD, DDS, MSc, PhD

Purpose: To relate diameter and length of implants with early implant failure.

Patients and Methods: Implants with a cylindrical design and surface treatment by removal of titanium via acidification from 3 different manufacturers were used in this study. Two surgical procedures for submerged implants were evaluated—the placement of the implants (first surgical phase) and the procedure for reopening (second surgical phase)—before the installation of the prosthetic system. The length of the implants was classified as short (6-9 mm), medium (10-12 mm), or long (13-18 mm), and the diameter was classified as narrow, regular, or wide. The statistics were computed with SAS statistical software (SAS Institute, Cary, NC). Step-wise and \( \chi^2 \) analyses were used, in addition to univariate and multivariate logistic regression.

Results: In this retrospective study, 1,649 implants (807 maxillary and 821 mandibular) were placed in 650 patients (mean age, 42.7 years) in different areas: anterior maxilla (458), posterior maxilla (349), anterior mandible (270), and posterior mandible (551). The early survival rate for all 1,649 implants was 96.2%. Regarding diameter, the largest loss was observed in narrow implants (5.1%), followed by regular (3.8%) and wide (2.7%) implants. Regarding length, the largest loss was observed in short implants (9.9%), followed by long (3.4%) and medium (3.0%) implants. Early loss occurred in 50 implants, 31 (4.3%) of which were installed in anterior areas and 19 (2.8%) in posterior areas. According to step-wise analyses and the \( \chi^2 \) test, short implant (\( P = .0018 \)) and anterior installation of implant (\( P = .0013 \)) showed associations with early loss.

Conclusion: A significant relationship of early implant loss was observed with short implants. No relationships between early loss of implants and the osseous quality or diameter of implants were observed. These findings may be attributed to the operator’s experience with different implant designs, learning curves, or changes in technique and indications for the use of short implants from 1996 to 2004.

© 2010 American Association of Oral and Maxillofacial Surgeons


The clinical use of several designs of endosseous oral implants has become highly predictable in recent decades, related to limitations of the geometry and volume of the alveolar bone. New implant types varying in length, diameter, and shape have been continuously introduced.¹

Choice of implant depends on the type of edentulism, the volume of residual bone, the amount of...
space available for the prosthetic reconstruction, the emergence profile, and the type of occlusion. Although some studies have reported promising results, others have shown survival rates below those that are clinically acceptable. Wide-diameter implants were introduced in 1993 with indications for their use associated with 1) poor bone quality, 2) inadequate bone height, and 3) immediate replacement of non-osseointegrated fixtures or fractured fixtures.

Stress and bone-implant contact influence the stability and survival of implants. A biological impedance to the use of wide-diameter implants can be a lower blood supply because of minimum existing cancellous bone. Consequently, the total bone-implant contact may be greater, compensating for the lack of height or bone density. However, wider implants are used when bone is scarce and the influence of diameter on bone-implant contact may not translate into a clinical advantage.

On the other hand, the usefulness of small-diameter implants has to be discussed with an awareness of their potential limitations. It has been estimated that a 3.3-mm-diameter, screw-shaped, commercially pure titanium implant possesses 25% less resistance to fracture when compared with a similar regular-diameter implant. Decreasing the diameter also means increasing the risk for implant fracture because of reduced mechanical stability and increasing the risk for overload.

Clinical research shows a 91% survival rate for 3.3-mm cylindrical implants compared with a 95% survival rate for 4.0-mm cylindrical implants. Similarly, the survival rate of 3.25-mm self-tapping titanium implants (93.8%) was lower than that of 3.75-mm implants (100%) over a 3-year observation period.

Bone height restrictions are more common in the posterior regions of the maxilla and the mandible, because of either bone absorption resulting from tooth loss or even anatomic limitations, such as the position of the inferior alveolar nerve or inferior wall of the maxillary sinus.

Information on the relationship between implant length and survival, however, is limited. A study of fixed single-unit restorations showed that a relationship between implant length and success may not exist, especially over 13 mm in length. No relationship between initial mobility and implant length has been established, and mechanical analyses have supported the view that increasing the implant length may only increase the success rate to a certain extent. Block et al analyzed pullout force in a dog mandible bone and showed that after 3 months of implant installation, no significant differences were observed between the pullout force and the variation in diameter; however, they showed a significant difference related to length: 4-mm-length implants presented significantly smaller forces of extraction than the longer 8- or 15-mm implants.

Several factors have been suggested for the study of implant length survival: implant primary stability, practitioner’s learning curve, implant surface, and osseous quality. Alterations in the preparation of the surgical site to ensure greater primary stability in sites of poor bone quality may affect implant survival. Feldman et al evaluated cumulative survival rates between short machined-surface implants and standard machined-surface implants and showed survival rates of 91.6% and 97.7%, respectively, with a statistically significant difference. They also showed that short dual acid-etched implants provided better outcomes than machined-surface implants. Surface treatment has been associated with higher rates of osseointegration, showing that porous surface implants are more effective in stimulating peri-implant osteogenesis. Several studies have attempted to minimize bone resorption and increase bone-implant contact by using different designs of implants; thread configuration, apical and cervical design, and surface treatment are used to maximize initial contact, improve initial stability, increase implant surface area, and help dissipate interfacial stress. Processes that involve the addition of hydroxyapatite and plasma spraying or the removal of titanium via acidification or sandblasting have been studied with satisfactory results. In clinical studies the long-term results show high success rates, with a shortened time for implant loading with stability of the bone-implant unit.

The aim of this study was to collect and summarize clinical data, for a period of 8 years, of patients treated by use of implants with surface treatment by removal of titanium via acidification with different implant diameters and lengths for single- and multiple-tooth restorations in a university environment, with an outcome assessment of early dental implant failure.

**Patients and Methods**

**STUDY DESIGN/SAMPLE**

The study was based on a retrospective analysis of patients who received implants between July 1996 and July 2004. We analyzed the clinical files of all patients who underwent dental implant placements at the Division of Oral and Maxillofacial Surgery, State University of Campinas, Piracicaba, São Paulo, Brazil.

The inclusion criterion was dental implant placement in patients who had undergone the second surgical phase. All implants analyzed in the study followed the protocol of 2 surgical procedures (submerged implants), and the implants were evaluated from the placement of the implants (first surgical
Results

The study consisted of 650 patients ranging in age from 13 to 84 years (mean, 42.7 years). The mean follow-up period was 249 days between the first- and second-stage surgery. Male patients comprised 34% of the sample (median age, 41.2 years), and female patients comprised 66% (median age, 43.2 years). A total of 1,649 implants were installed, with a median of 2.5 per patient. Some differences could be observed between implants in terms of apical angulation and thread design, with the Neodent implant presenting a larger-sized thread than the Conexão and SIN implants. The platform and implant connection were conventional internal and external hexagons, with no analysis performed because the implant was submerged and not submitted to dental load.

We placed 295 wide-diameter implants, 1,217 regular-diameter implants, and 137 narrow-diameter implants. With regard to length, there were 131 short implants, 635 medium implants, and 883 long implants.

The early survival rate for all 1,649 implants was 96.2%. The largest loss was observed in narrow-diameter (5.1%) implants, followed by regular-diameter (3.8%), and wide-diameter (2.7%) implants. Regarding length, the largest loss was observed in short implants (9.9%), followed by long (3.4%) and medium (3.0%) implants.

MAXILLA

There were 807 implants (49.6%) placed in the maxilla, with 458 (28.1%) in the anterior area and 349 (21.4%) in the posterior area. Of the implants in the maxilla, 28 (3.5%) were lost, 21 in the anterior area and 7 in the posterior area. Regarding diameter, 109 implants (13.5%) had a narrow diameter, 631 (78.2%) had a regular diameter, and 67 (8.3%) had a wide diameter. The majority of implants used in the maxilla were long (510 [63.2%]), followed by medium (255 [31.6%]) and short (42 [5.2%]) implants.

MANDIBLE

There were 821 implants (50.4%) placed in the mandible, with 270 in the anterior area (16.6%) and 551 (33.9%) in the posterior area. Of the implants in the mandible, 22 (2.8%) were lost, 10 in the anterior area and 12 in the posterior area. Regarding diameter, 26 implants (3.2%) had a narrow diameter, 572 (69.7%) had a regular diameter, and 223 (27.1%) had a wide diameter. The majority of implants used in the mandible were long (377 [45.9%]), followed by medium (356 [43.4%]) and short (88 [10.7%]) implants.

Statistical Relationships

Demographic variables such as gender and age did not show significant statistical differences. Step-wise analyses showed significant relationships between length of implant \( P = .0018 \) and early loss of implant and between site of installation \( P = .0013 \) and early loss of implant. Univariate analysis showed too significant a relationship between short and anterior localization of implant and early loss. When a \( \chi^2 \) analysis was done, short implants presented a signif-
significant relationship, where the possibility of early loss of implant was increased by 0.16 per unit. Early loss of implant did not show a significant statistical difference with maxillary or mandibular installation ($P = 0.4535$), but in agreement with the step-wise analysis, it did show a difference based on anterior or posterior site of installation ($P = 0.0187$): 31 implants (4.3%) with early loss were present in anterior areas and 19 (2.8%) in posterior areas.

Discussion

Implants may be lost before a second-stage procedure (early failures) or after prosthetic rehabilitation (late failures). The rates of early failures have been reported to vary between 1.5% and 21%. Implant failures have been associated with factors such as poor bone quality, parafunction, insufficient jawbone volume, initial implant instability, and overload. Related to the site of placement (anterior or posterior), we found a relationship with early loss of the implant using step-wise and $\chi^2$ analysis, but when univariate and multivariate logistic regression were used, this variable did not present a relationship; in fact, type of bone (maxilla or mandible) did not show significant statistical differences. This finding can be related with the osseous quality identified at the time of surgery, promoting a change in surgical technique. On the other hand, a second hypothesis might be that osseous class does not influence the early loss of implants but might have an influence later when implants are loaded prosthetically. Degedi et al. did not find a significant difference associated with bone quality (maxilla or mandible) when evaluating survival of narrow- or wide-diameter implants. However, they found a different success rate according to length and diameter, with a better outcome with regard to reduced crestal bone loss over time for shorter (<13 mm) or narrower (5.0 and 5.5 mm) implants.

Our study related early implant loss with length of implant but not diameter, and our results are in agreement with the literature review. Univariate significance for early loss was found at $P < 0.001$, and the logistic regression showed that 6- to 9-mm short implants have a 0.16 times increased chance of early failure. In the long term, the length of the implant could be more important than the diameter, because before oral cavity exposure and loading, vertical osseous loss is present, and it can be close to 0.2 mm per year; in the future, the implant may lose important contact between bone and implant surface.

The surface treatment is an important issue. Some studies have related surface treatment with more osseointegration of the implant; indeed, osseointegration requires less time with enhanced surfaces, and the implant can be loaded in the early stages.

Loaded implants or stress support characteristics were not evaluated in this study, because all of the implants were submerged before early loss analysis. In this clinical study, bone-implant contact was not evaluated, limiting this evaluation to loss of implant because of absence of osseointegration. Schierano et al. reported greater bone-implant contact in implants with surface treatment; we believed that such a treatment could be applied to implants used in this study. These implants underwent surface treatment by removal of titanium via acidification; generally, the manufacturers do not present the particular characteristics of surface treatment, and this study is no exception.

Implant design was not included in this analysis because it is more associated with the impact of forces related to prosthesis use. This report relates cylindrical implant status in the submerged phase until the second surgery.

LENGTH OF IMPLANT

Some articles showed clearly that short implants failed more often than longer implants. However, others reported that implant length did not appear to significantly influence the survival rate. Several factors have been suggested to explain this, such as the implant’s primary stability, the practitioner’s learning curve, and the quality of the patient’s bone. In addition, it should be noted that some of the studies that reported lower survival rates with short implants used a routine surgical protocol independent of bone density.

For this study, short implants showed significant statistical differences with early loss of implant. The implant procedures were performed by students enrolled in a program in oral and maxillofacial surgery or implant dentistry. We can speculate that operators’ learning curves could be a reason for the different reported outcomes with short or long implants between the studies. Stellingsma et al. showed different cumulative survival rates in 2 studies, with 88% in the first and 100% in the second. The learning curve could be the reason for this difference. Installation of short implants is done when insufficient bone is present; quality and angulation of burn can influence implant stability and early loss of implants.

DIAMETER OF IMPLANT

When one is considering narrow-diameter implants, it should be noted that all the studies included in this structured review have reported low failure rates. These figures could be explained by adapted and atraumatic preparation techniques, as well as the careful patient selection in terms of biomechanical conditions and bone density. In addition, narrow-diameter implants would have been considered in
clinical situations in which limited space or bone availability disallowed the use of standard-diameter implants. Ivanoff et al suggested that the increased failure rate of 5-mm-diameter implants was associated with the operators' learning curves, poor bone density, implant design, and the use of this implant diameter when primary stability could not be achieved with a standard-diameter implant. This view was supported by the study of Hultin-Mordenfeld et al, in which wide-diameter implants were placed in unfavorable situations, such as poor bone density and compromised bone volume.

In a study by Krennmair and Waldenberger, with 114 patients followed up for 12 to 114 months, only 2 maxillary implants lost osseointegration, but no differences were found between the wide-diameter implants and the standard- or smaller-diameter implants. Renouard and Nisand showed that these controversial results occur because initial studies have not provided clear technical indications regarding short or wide implants and because of limited experience with new implant designs (short- and wide-diameter implants), operator's learning curve, and the use of machined-surface implants. Regarding early loss of implants with different designs, few data exist and more research is necessary. In our study, the diameter of the implant did not influence early loss.

In this retrospective longitudinal study, the length of the implant and anterior installation area influenced early implant loss. This influence was not observed for diameter in terms of early implant failure.

Acknowledgment

The authors thank Dr.rika Harth-Chu for helpful revision of the manuscript.

References