3-Year Survival Estimates of Short (less than or equal to 6 mm) Length Implants and the Relationship to Crown-to-Implant Ratios

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Dedication

This thesis is dedicated to my family, Sa, friends and all those who believe in the richness of learning.

Abstract

INTRODUCTION: The literature regarding survival of short implants is conflicting. Furthermore, excessive crown-to-implant ratios have been cited in the literature as being detrimental to implant survival. Hence, the purpose of this study was to determine the 3-year survival estimates, and the relationship between crown-to-implant ratios and survival of short, roughened, plateau-design implants. Additionally, risk factors for failure were evaluated.

MATERIAL AND METHOD: This retrospective cohort study involved 341 patients who possessed at least 1 single ≤6mm length plateau-design implant supported restoration that had been surgically placed between August 2000 and June 2007. An electronic chart review was conducted to acquire data on patient demographics, implant location, bone density, length of time in function and/or implant failure, as well as the most recent digital periapical radiographs in which the entire crown and implant were visible. Data analysis was conducted utilizing appropriate univariate and multivariate regression statistics, as well as non-parametric Kaplan-Meier survival analysis in order to determine the overall 3-year survival rate.

RESULTS: Data from 573 single implant-supported fixed restorations were tabulated and included in the study. 13 implants failed overall. The 3-year Kaplan-Meier survival analysis adjusted for clustered observations was found to be 93.9%. The average (SD) crown-to-implant ratio of implants that were in function was 2.06 (0.4), and the average (SD) crown-to-implant ratio of those that failed was 2.02 (0.3). This difference was not statistically significant. Results from the multivariate model found quality of bone, and history of adjacent endodontically treated teeth to be statistically associated with implant failure, with hazard ratios of 13.2 and 2.7 respectively ($P \leq 0.05$).

CONCLUSIONS: The results of this study suggest that the survival of short, roughened, plateau-design dental implants is comparable to implants of traditional lengths, which suggests that these implants are a clinically acceptable option where alveolar bone height is limited or anatomic limitations exist

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1. INTRODUCTION

Since the introduction of the Branemark implant system in 1982, the use of root-form endosseous dental implants as tooth replacements in both completely and partially edentulous patients has become mainstream dentistry. Branemark and his investigators established that if sufficient bone quality and quantity exist, it is possible to integrate a machined titanium root form dental implant into human jawbone, and subsequently use such implants as support for fixed dental prostheses.[1,2]

Implant and implant prosthetic success rates are often higher than traditional natural tooth supported prostheses; however different risk factors for implant longevity have emerged over the years.[3] Implant failure has been associated with poor bone quality, short length implants, narrow diameter implants, parafunction, gender, infection, implant location, and smoking. Some of these factors can be more important than others, however the greatest risk resides in the association of 2 or more of these characteristics.[4] Having better information about these risk factors will enhance the clinician's ability to choose among different treatment options while accounting for the patient's preferences and wishes in order to optimize implant treatment success.[5]

A very common challenge encountered in the use of oral implants is the presence of reduced alveolar ridge height.[4,] A radiographic study of 431 partially edentulous patients done by Oikarinen et al.,[6] revealed that the existing posterior bone height was at least 6 mm in only 38% of maxillae and 50% of the mandibles examined. This is of particular concern when observed in the posterior areas of the mandible and the maxilla, where the mandibular nerve and the maxillary sinus, respectively, are to be avoided. [7]

Aggressive treatment options for reduced alveolar ridge height call for bone grafting the area followed by the placement of dental implants.[8,9,10,11] Griffin and Cheung[12] listed several surgical interventions often required to develop implant sites including guided bone regeneration with or without tenting screws, distraction osteogenesis, sinus augmentation, and nerve transposition. The authors conceded that while these methods have obtained a level of success, some patients reject multiple surgeries and are discouraged by additional treatment duration and financial burden. Also to date, the evidence relating to the predictability of surgically increasing vertical ridge height (other than sinus augmentation) is inadequate. At the same time, a prosthetic solution sometimes is not applicable because of inadequate interarch space. [12]

An alternative approach in cases where a limited amount of bone height is available is to use short implants of less than 10mm of length, instead of the standard range 10 to 16 mm. [13,14] This strategy avoids the need for bone augmentation procedures and simplifies treatment. However, the combination of increased interarch distances due to natural resorption of the alveolar ridge, the consequent limited available bone and the use of short implants, produces crown-to-implant ratios that may be considered excessive.[14] Unfortunately, the influence of crown-to-implant ratios on implant survival has not been evaluated thoroughly.[15]

The literature regarding the survival of short implants is mixed. Short implants are widely perceived to have a greater risk of failure compared with standard length implants, because of increased loading of the supporting bone and reduced resistance to lateral forces.[16] A number of publications have lent support to this view, reporting poorer outcomes for shorter machined implants compared to longer ones.[2,17,18,19,] In contrast, some investigators found that implant length did not significantly influence outcome for implants with non machined surfaces.[20,21,22] In a recent report on 1,030 implants placed in private practice, Nedir et al.[22] found that the survival rate for short implants was equal to that for longer implants when used to support single crowns or fixed partial dentures of 2 to 4 units in length.

In bone of poor quantity and quality, some investigators have suggested increasing implant diameter as a way to increase tolerance to occlusal forces, improve initial stability, and provide a favorable stress distribution to the surrounding bone.[13,14] The literature regarding wide diameter (>3.75mm) implants is also mixed. Some studies have shown that wide diameter implants have favorable results, particularly in the posterior mandible.[23,24,25,26,27] Others have demonstrated survival rates below those clinically acceptable.[28,29,30]

Some authors believe that the combination of a short implant length with a wide diameter is a clinically acceptable option in cases where limited bone is available, especially in the posterior maxilla and mandible. [13,14] The literature regarding short, wide-diameter implants is scarce and heterogenous. In a review of study outcomes with short implants ($\leq$ 7 mm), Hagi et al. [31] found that only one study involved the use of endosseous threaded dental implants with lengths less than 7 mm. These investigators assessed machined threaded implants of two short lengths (6 or 7 mm) and three different diameters (3.75, 4.0, and 5.0 mm). The shortest implants used in their study were 5.0 mm in diameter and 6.0 mm in length. These implants performed rather poorly resulting in a mandibular failure rate of 33.3%. [28] Conversely, Gentile et al. in 2005, found a 1-year survival rate of 92.2% for a 6 x 5.7 mm plateau designed rough surface implant .[13]

These conflicting results suggest the need for additional research efforts aimed at elucidating successful applications and recommendations for the use of short, wide-diameter implants.

2. PURPOSE

The purpose of this study was to determine the 3 year survival estimates, and the relationship of crown to implant ratios to implant survival of short, wide-diameter hydroxyapatite coated dental implants (Bicon Dental Implants, Boston, MA). Additionally risk factors for failure were evaluated.

3. MATERIAL AND METHODS

Study Design/Sample

This was a restrospective cohort study, consisting of a sample of patients who had at least one short (≤ 6mm) Bicon dental implant (Bicon, Boston, MA) placed at the Implant Dentistry Centre, a private dental practice located in Boston, MA, during the period from August 18, 2000 to June 6, 2007. All the implants were placed and restored by experienced clinicians. Institutional approval was obtained for the study.

A chart review was conducted to acquire data on patient demographics, implant location, bone density, length of time in function and/or implant failure. Periapical digital radiographs were measured to obtain crown and implant lengths. Data collection was accomplished by 2 independent examiners.

Digital Radiograph Data Collection

An electronic chart review was conducted to attain the most recent digital periapical radiographs in which the entire crown and implant were visible. All radiographs were made using the paralleling technique. Radiographs with gross distortion, poor contrast, and displaying poor definition of the implant-crown outline were eliminated from the study. No other exclusion criteria were utilized in this investigation. Radiographic images were solely in digital format, and were measured with a software program (DIGORA; Soredex, Tuusula, Finland) utilizing a measuring tool with 3x magnification. Each implant crown image was measured from the most coronal portion of the crown to the coronal portion of the implant and from the coronal portion of the implant to its apex. Measurements were recorded to the nearest 0.1mm. The crown-to-implant ratios were calculated by dividing the length of the crown by the length of the implant(Fig 4.1). Random samples of 50 implants were measured by the same examiner at the beginning and the end of the data collection in order to determine intra-examiner agreement. The initial and final measurements needed to be within 0.5mm to be in agreement.

Study Variables

The predictor variables (risk factors or exposures) were grouped into the following categories:

1. **Implant variables:** The sample consisted of three implant sizes; 4.5 mm x 6 mm, 5 mm x 6 mm, and 6 mm x 5.7 mm (Fig 4.2 and 4.3). Implant staging and delayed or immediate implant placement were recorded.

2. **Demographic variables:** The gender and age of the patient at the time of implant placement were recorded.

3. **Health-status variables:** Health Status of the patient was classified according to the American Society of Anesthesiology (ASA) system: ASA 1 for healthy patients, ASA 2 for patients with mild systemic disease, and ASA 3 for moderate or severe systemic disease. In addition, it was recorded whether the patient had a medical condition that could have compromised wound healing, such as immunosuppression or diabetes, and current tobacco use status.

4. **Anatomic variables:** The anatomic variables recorded included implant position (maxilla, mandible, anterior, posterior), implant proximity to teeth or other implants (no adjacent teeth, 1 adjacent tooth, 2 adjacent teeth, 1 adjacent implant, 2 adjacent implants, 1 adjacent tooth and 1 adjacent implant), and bone quality (types 1 to 4). Bone quality was ascertained clinically at the time of implant placement according to the clinicians' judgment . In general, following the withdrawal of an osteotomy reamer, an assessment of the bone in the flutes was conducted in terms of quantity and appearance. Bone quality was classified as type 1 if the bone was compact, near bloodless cortical bone. Type 2 bone appeared as red and filled the flutes of the reamer. If no bone remained in the flutes the bone quality was classified

as type 4. If the findings were intermediate between those described for types 2 and 4, the bone was categorized as type 3 (Fig 4.4, 4.5, 4.6, 4.7).

5. **Ancillary procedures:** Ancillary procedures recorded were defined as treatments designed to enhance the recipient site. This category included internal or lateral sinus lifts, barrier membranes, autologous and synthetic bone-substitute grafting, and ridge split procedures.

The primary outcome variable, implant failure, was defined as removal of the implant. The duration of implant survival was computed by calculating the time between implant placement and the date of the last follow-up or implant removal. The duration of implant survival was reported in months.

Statistical Analysis

A database utilizing Microsoft Excel 2007 (Microsoft, Redmond, WA) was used to tabulate all of the data recorded from the chart review. Data analysis was performed using SAS PC version 9.2 2002-2008 (SAS Institute, Cary, NC) statistical software. Appropriate uni-, bi-, and multivariate survival statistics were used. Nonparametric Kaplan-Meier survival analysis was used to determine the survival rate. Bivariate analyses was performed using Cox proportional hazard regression analysis to determine candidate risk factor associated with implant failure ($P \leq 0.15$) for inclusion in a multivariate Cox model adjusted for clustering of implants ($P \leq 0.05$). Z-test was used to determine the crown-to-implant ratio means for failed and non-failed implants.

4. FIGURES

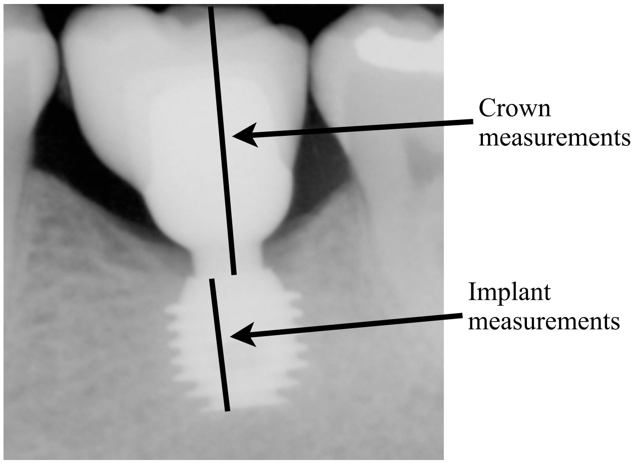

Figure 4.1. Summary of radiographic measurements.

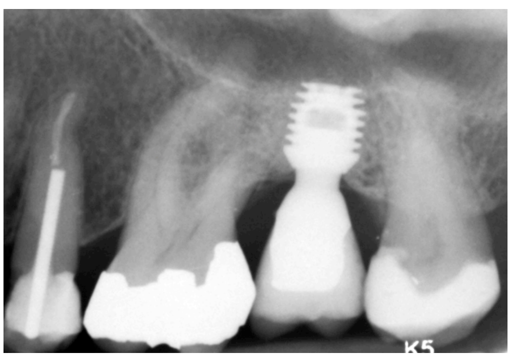

Figure 4.2. A 5mm x 6mm Implant.
Note the level of the Maxillary Sinus, and Crown-to-Implant Ratio.

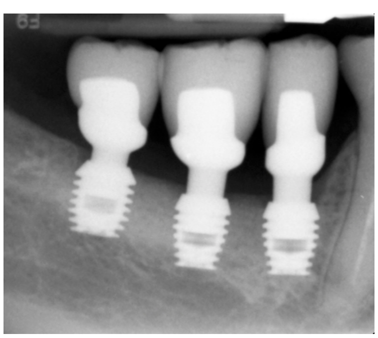

Figure 4.3. Two 4.5mm x 6mm Implants and one 5mm x 6mm Implant.
Note the proximity of the IAN and the Crown-to-Implant Ratios.

Figure 4.4. Bone quality type 1 if bone was compact, near bloodless cortical bone

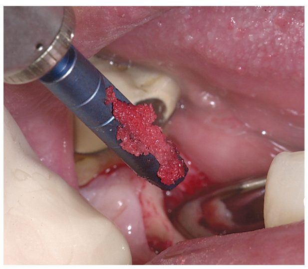

Figure 4.5. Bone quality type 2 if bone appeared red and filled the flutes of the reamer

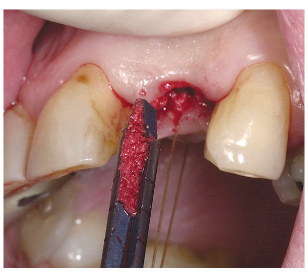

Figure 4.6. Bone quality type 3 if findings were intermediate between types 2 and 4

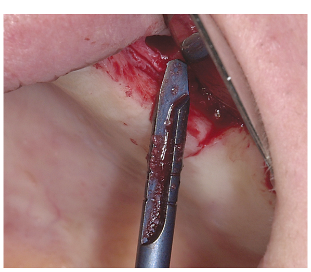

Figure 4.7. Bone quality type 4 if no bone remained in the flutes

5. RESULTS

Between August 2000 and June 2007, 341 subjects had at least one short implant placed and were eligible for the study. All implants were placed using a two-stage surgical protocol, and therefore no implants were immediately loaded. A total of 573 HA-coated, plateau-design implants were placed. Of the 573 implants, 137 (23.9%) were 4.5mm x 6mm, 347 (60.6%) were 5mm x 6mm, and 89 (15.5%) were 6mm x 5.7mm

557 (97.6%) of the implants were placed in healthy patients or patients who had mild systemic disease (ASA ≤ 2), and 23 (4%) implants were placed in smokers. The majority of implants (90.3%) were placed in type 3 (48.0%) or type 4 (42.3%) bone.

The most common location for implant placement was the posterior mandible (46.9%), followed by the posterior maxilla (37.4%), anterior maxilla (15.4%), and anterior mandible (0.5%). Implants were most commonly placed between 2 teeth (27.2%), and between 1 tooth and 1 implant (27.2%). The majority of implants (72.2%) were delayed placement, and only 27.8% were immediately placed. 45 (7.8%) implants required augmentation procedures at the time of placement, and 71 (12.4%) required augmentation prior to implant placement.

The intra-examiner Kappa score for the assessment of agreement for implant length measurements was 1.00. The Kappa score for crown length measurements was found to be 0.80.

Table 6.1 summarizes the Kaplan-Meier survival analysis adjusted for clustered observations for the investigation. Of the thirteen failures that occurred overall, eight occurred in type 4 bone, and 4 occurred in type 3 bone. All failed implants had been definitively restored prior to failure. The majority of implant failures (n=10) occurred during the first year, 1 failure occurred during the second year and 2 failures occurred during the third year. The 3-year Kaplan-Meier survival analysis adjusted for clustered observations was found to be 93.9%.

Table 6.2 summarizes the crown-to-implant ratios for the investigation. The crown-to-implant ratios for the implants in function ranged from 0.96 to 3.43, and for the implants that failed ranged from 1.39 to 2.47. The average (SD) crown-to-implant ratio of implants that were in function was 2.06 (0.4), and the average (SD) crown-to-implant ratio of those that failed was 2.02 (0.3). This difference was not statistically significant.

The univariate analysis (Table 6.3) did identify several variables for possible inclusion in a multivariate model ($P \leq 0.15$), including bone quality, adjacent endodontically treated tooth, and sinus lift. These variables as well as biologically important variables (age, gender) were included in the multivariate analysis.

The multivariate model (Table 6.4) found quality of bone, and history of adjacent endodontically treated tooth to be statistically associated with implant failure. The hazard ratios were 13.2 and 2.7 respectively ($P \leq 0.05$).

6. TABLES

Table 6.1 - Kaplan-Meier Survival Analysis of Short Implants

Time (Months)	Short Implants at Risk	Survival %	95% CI
0	573	100 %	100% – 100%
12	562	97.7 %	95.2% – 98.5%
24	561	97.4 %	95.2% – 98.5%
36	559	93.9 %	86.1% – 97.4%

Table 6.2 - Crown-to-Implant Ratios of Short Implants

Measurement	Survived	Failed
Mean	2.06	2.02
SD	0.40	0.33
Minimum C-I ratio	0.96	1.39
Maximum C-I ratio	3.43	2.47

Table 6.3 – Univariate Analysis

Variables	Hazard Ratio	95% CI	*P*
Age at Implant Placement	0.99	0.96 - 1.03	0.66
Gender	0.92	0.29 – 2.96	0.89
ASA Status	1.43	0.45 – 4.50	0.54
Medically Compromised	0.89	0.28 – 2.83	0.84
History of Adjacent Root Canal Treated Tooth	2.82	1.25 – 6.35	0.01
Bone Quality	3.51	1.76 - 6.84	0.02
Implant Diameter	1.03	0.26 – 4.04	0.96
Implant Length	0.25	0.00 – 13.73	0.49
Ridge Augmentation	0.59	0.09 – 4.00	0.59
Sinus Lift	3.09	0.93 – 10.35	0.07

Table 6.4 - Multivariate Cox Model

Variables	Hazard Ratio	95% CI	*P*
Age at Implant Placement	0.98	0.94 – 1.03	0.43
Gender	0.49	0.04 – 5.41	0.56
Bone Quality	13.24	1.24 – 141.73	0.03
History of Adjacent Root Canal Treated Tooth	2.67	1.10 – 6.47	0.03
Sinus Lift	4.57	0.41 – 51.15	0.22

7. DISCUSSION

In patients with advanced levels of alveolar bone resorption, the treatment with dental implants is often problematic and may require additional surgical intervention to augment bone levels. An alternative approach, in cases where a limited amount of bone is available, is to use short implants, 6 to 8 mm in length, instead of the standard range of 10 to 16 mm. [16]

The aims of this study were to determine the 3 year survival estimates, the crown –to-implant ratios of single tooth implant- supported restorations, and to identify risk factors for failure of short, wide–diameter, HA coated surface dental implants. (Bicon Dental Implants, Boston, MA).

The overall 3 year survival estimate for Bicon implants in this cohort was 93. 9%. This result is consistent with the findings of Vehemente et al. and Gentile et al. Vehemente et al.[5] found 1-year and 5-year survival rates of 95.2% and 90.2% respectively. Gentile et al[13] found survival rates for 6 x 5.7 mm implants and non 6 x 5.7 mm implants of 92.2% and 95.2 % respectively.

The use of short implants has long been associated with low success rates. Their use has also been discouraged from a biomechanical point of view, when combined with poor bone quality and high occlusal loads. However, advances associated with implant design and surface morphology, combined with improved surgical techniques have given reason to change previous beliefs concerning the survival of short implants. Recent clinical studies indicate that short implants may support most prosthetic restorations quite adequately.[32] ten Bruggenkate and colleagues published the results of a 7-year follow up trial with a recorded success rate of 93.8% for 253, 6-mm long implants. [7] In another study, Paulo Malo and associates found a cumulative survival rate of 96% for 7-mm implants after 5 years. [32] In a recent systematic review and meta-analysis, Kotsovilis and coworkers found that there was not a significant difference in survival between short (≤8 or <10 mm) and conventional (≥10 mm) rough-surface implants in totally or partially edentulous patients. [33] These recent studies confirm the results presented in this, indicating that short implants are a viable option to restore areas where the amount of bone is limited.

Bone density is directly proportional to its strength. Less dense bone may demonstrate a reduction of strength by 50% to 80% compared to higher density bone. In a review of clinical implant data from 1981 to 2001 by Goodacre et al.,[3] implants loaded in lower density bone averaged higher failure rates (16%) compared to more ideal bone quality (4%). The posterior regions of the jaws usually have less dense bone than the anterior regions. [34] In a multicenter report in 2003 by Weng et al.,[35] the posterior maxilla reported a 25% failure rate when short implants were used to support the prosthesis. In our study, implants were most commonly placed in type 3 and type 4 bone, 495 (90.3%). These results may indicate that these implants are useful in the restoration of areas with poor bone quality.

The average crown to implant ratios found in this study exceeds what clinicians would consider favorable for a crown-to-root ratio associated with a natural tooth. The average (SD) crown –to-implant ratio of implants that were in function was 2.06 (0.4), the average crown-to-implant ratio of those that failed was 2.02 (0.33). The difference between these ratios was not statistically significant. Schulte et al. [36] found similar results in a sample of 889 single tooth implants (Bicon). In their study, the average crown –to-implant ratio of implants that were in function was 1.3, and the average crown-to-implant ratio of those that failed was 1.4. In a more recent study that included 309 Bicon implants, Birdi et al. [37] found that the average (SD) crown-to-implant ratio was 2.0 (0.4) and no associations between crown-to-implant ratio and first bone-to-implant contact levels were found. These results suggest that the crown-to-implant ratio should not be used to predict implant survival nor considered a risk factor for failure with the implants used in this study.

In the present analysis of the risk factors for implant failure, variables were selected that were biologically important. The bivariate analysis identified age at implant placement, gender, quality of bone, history of adjacent endodontically treated tooth, and sinus lift as variables for possible inclusion in a multivariate model. The multivariate model found quality of bone to be statistically associated with implant failure. This finding is consistent with the results of das Neves et al.,[4] in an analysis of longitudinal studies of short implants. In this analysis, it was found that bone quality was related to failure in most studies (22 out of 31) and conclude that bone quality seemed to be a critical deciding factor in association with implants ≤ 7 mm long in determining the failure rate.

History of adjacent endodontically treated tooth was also found to be statistically associated with implant failure. Brisman et al[38] reported 4 cases in which implants failures occurred adjacent to asymptomatic endodontically treated teeth with no clinical or radiographic evidence of pathology. All four patients had at least two implants placed and in each case, the implant adjacent to the endodontically treated tooth failed. Green et al[39] reported that 26% of endodontically treated teeth with a normal radiographic appearance still had histological signs of inflammation. An asymptomatic endodontically treated tooth may be harboring a chronic infection, which may be the cause of implant failure.

In the other hand, Doyle et al,[40] in a retrospective study evaluating factors affecting outcomes for single tooth implants and endodontic restorations found that the presence of adjacent endodontically treated teeth was not associated with the outcomes of implant treatment. The literature regarding the outcome of implants adjacent to endodontically treated teeth is scarce and mixed.[41] This finding requires additional research to establish validity

The limitations of this study include those associated with the retrospective design, lack of clinician calibration, and the use of a single private practice facility where all implants were placed.

8. CONCLUSIONS

The results of this study suggest that the survival of short, roughened, plateau-design dental implants is comparable to implants of traditional lengths, which suggests that these implants are a clinically acceptable option where alveolar bone height is limited or anatomic limitations exist. In addition, bone quality and history of adjacent root canal treated tooth were identified as risk factors statistically associated with implant failure. The crown-to-implant ratios for implants in function ranged from 0.96:1 to 3.43:1 and for the implants that failed ranged from 1.39:1 to 2.47:1. The crown-to-implant ratios mean of the implants that were in function was similar to the crown-to-implant ratios of the implants that failed and the difference was not statistically significant.

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