Prospective Study

Long term bone level stability on Short Implants: A radiographic follow up study

Caterina Venuleo, Sung-Kiang Chuang, Meghan Weed, Serge Dibart

Abstract: Objectives: *Placement of short endosseous implants represents a valid treatment in the setting of limited alveolar bone height. This study's objectives were: to estimate the 5 year clinical survival of Bicon™ short implant and to evaluate radiographic bone level changes around 6x5.7mm implants in comparison with longer non-6x5.7mm implants.*

Methods: *A retrospective cohort study design was used. The cohort was composed of patients who had at least one 6x5.7mm implant placed for 5 years, at least one non - 6x5.7mm implant, and who were willing to return to the dental office for radiographic evaluation. A total of 62 implants, 28 6x5.7mm (test group=short implant) and 34 non - 6x5.7mm (control group=non short implant), were placed in 20 patients (12 males and 8 females). Mean length of non - 6x5.7mm implants was 9.7 mm, ranging from 8mm to 14mm, while mean diameter was 4.30 mm (range: 3.5 to 5 mm). Bone loss, defined as the vertical difference in crestal bone level measurements, from the baseline (day of implant placement) to the 5 years follow-up, was digitally determined on periapical radiographs. Generalized linear mixed models were used for the statistical analysis.*

Result: *Five years survival rates for test and control groups were 100.0% and 96.8% respectively, but this difference was marginally not statistically significant (p=0.35). There was no significant difference between the two groups with regard to mean changes of radiographic bone levels.*

Conclusion: *Short implants with large diameter (6x5.7mm) have a long-term (>5-years) survival rate and crestal bone level maintenance similar to that observed for non - 6x5.7mm implants. The results of this radiographic study support the hypothesis that 6x5.7mm implants can be successfully used in edentulous maxillary and mandibular areas with limited bone height.*

Keywords: *Short implants and crestal bone levels.*

Caterina Venuleo[1], Sung-Kiang Chuang[3], Meghan Weed[4], Serge Dibart[2]

[1] Postdoctoral Resident
[2] Professor & Clinical Director, Dept. of Periodontology and Oral Biology

Boston University, Goldman School of Dental Medicine

[3] Asst. Professor, Dept. of OMFS, Massachusetts General Hospital and the Harvard School of Dental Medicine, Research Associate, Dept. of Biostatistics, Harvard School of Public Health, Boston, USA
[4] Research Associate, Implant Dentistry Centre, Boston, MA, USA.

Address for Correspondence:

Serge Dibart
Department of Periodontology & Oral Biology
Boston University Goldman School of Dental Medicine
100 East Newton Street
Boston, MA 02118, USA

Received for publication September 2007
Accepted after peer review September 2008
Available online Sep. 2008 at www.jmosi.com

Background

During the past decades, implant therapy has been shown to be a successful option for tooth replacement. After tooth loss, however, severely atrophic residual alveolar ridges are quite common, especially in patients who have been edentulous for a long period of time. Posterior areas of the maxilla and the mandible are areas where clinicians have greater anatomical limitations. Reduced alveolar bone height, very often represents a contraindication to implant therapy, unless a procedure such as ridge augmentation or sinus floor elevation is performed. Although widely utilized, these techniques imply greater morbidity, longer treatment times and higher costs. Sinus cavity in the maxilla and alveolar nerve proximity in the mandible are clinical situations where short implants may be considered as an alternative treatment option.

The need for long term (≥5 years) studies has been emphasized by many researchers and deeply stressed by the United States National Institute of Health

(NIH) and Institute for Dental Research (NIDCR) regarding the clinical performance of different types of implants. In particular, radiographic evaluation of crestal supporting bone loss was the main suggestion of NIH Consensus Conference in 1988. As one of the criteria for implant success, stable bone levels are believed to be critical to the long term maintenance of an implant (Smith and Zarb 1989).[1] According to these authors the mean vertical bone loss should be less than 1.5 mm during the first year and less than 0.2 mm annually following the first year of service and this value is still considerate as a limit nowadays. The loss of crestal bone has been reported to be influenced by many factors. These include surgical trauma, implant abutment microgap, bacterial infection of peri-implant tissues and biomechanical factors related to loading. The location of the microgap existing between the implant neck and the abutment represents the most common factor inducing bone loss (Piattelli et al. 2003).[2] In fact, 2 mm vertical bone resorption from this interface is considered acceptable and physiological (Hermann et al. 2000; King et al. 2002)[3,4] as comparable to the biological width. However, excessive and progressive bone loss can lead to the eventual loss of the implant (Chou et al. 2004)[5] and therefore has to be constantly evaluated over the years.

The specific purposes of this study were: 1) to assess the 5 year survival rate of short implants (5.7 mm length and 6 mm width); 2) to radiographically evaluate the crestal bone loss associated with the 6x5.7 mm implant, compared to longer implants of the same company (Bicon, Boston MA), within the same patient and same clinical scenario. A 5 year radiographic follow up was performed in order to achieve our aims.

Materials and Methods

Study Design and Sample

The patients for this retrospective cohort study were recruited from the population of patients who had at least one 6x5.7 mm (Fig. 2) implant placed by practitioners at the Faulkner Hospital or at the Implant Dentistry Centre, Boston, Massachussets, between February 1997 and February 2006. Subjects who had at least one 6x5.7 mm implant for at least 5 years of follow up and at least one non 6x5.7 mm implant within the same alveolar arch were considered eligible and included in the study. Exclusion criteria were insufficient documentations in clinical and radiographic records.

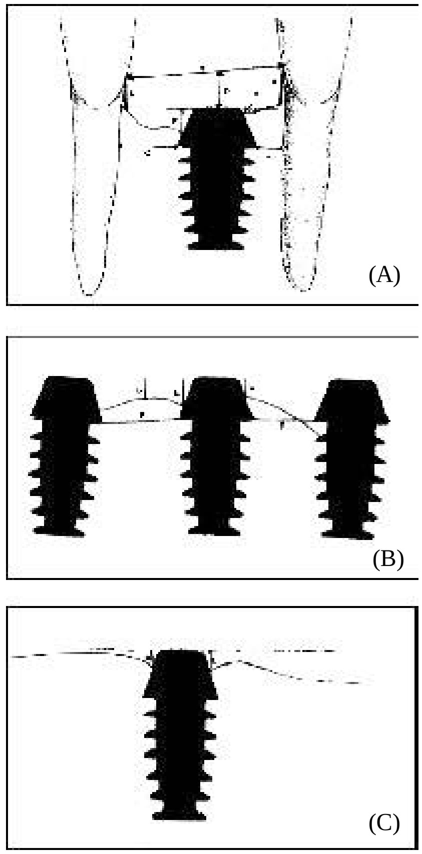

Fig. 1: A) Diagram showing crestal bone measurement for implant adjacent to natural teeth; B) Diagram with measurements for implant adjacent to implant; C) Diagram with measurements for implant not adjacent to implant or tooth.

Fig. 2: Example of 6mm (wide) x 5.7mm (long) implant used in the study.

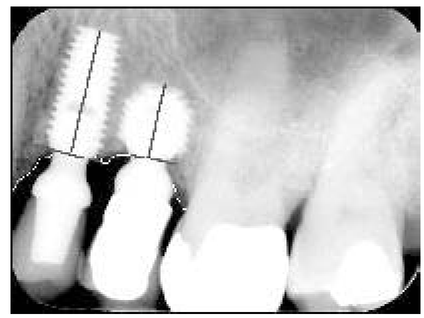

Fig. 3: Digital calibration and radiographic measurements of crestal bone levels. Here implants at last follow-up. Adjustment for magnification error was made using the following equation: Corrected crestal bone level = Measured crestal bone level x (actual implant length ¸ measured implant length). In this radiograph, short 6x5.7 mm implant in the maxilla adjacent to one natural tooth and one non-6x5.7 implant.

Study Variables

The major predictor variable was implant size. The implant that met the inclusion criteria were divided into two categories: 6x5.7 mm and non - 6x5.7 mm implants. Other study variables are listed below:

Demographics: These included patient's gender and age at the time of implant placement.

Medical History: Patient health status included smoking, any contributory disease affection and use of medication.

Anatomy: The variables included in this category were implant location (maxilla, mandible, anterior, posterior), dentition status (partially or fully edentulous), implant proximity to teeth or other implants (no adjacent teeth, one adjacent implant, one adjacent tooth, two adjacent implants, two adjacent teeth, one adjacent implant and one adjacent tooth) and bone quality (types 1 to 4). Bone quality was determined by the same operator, at time of implant placement upon examination of the contents of the flutes of a 3.5 mm reamer extracted from the osteotomy. Type 1 bone was defined as compact, bloodless bone that completely filled the flutes of the reamer. Bone quality was classified as type 4 when minimal amount or no bone filled the flutes of the reamer. Intermediate grades were classified as either type 2 or type 3 bone.

Implant specific variables: They included implant length (5.7 to 14 mm), diameter (3.5 to 6 mm), well size (2 to 3 mm), coating (uncoated, Titanium Plasma Spray [TPS] or Hydroxyapatite [HA] coated).

Surgical variables: Implant staging (one or two stages), immediate post extraction or delayed placement, bone augmentation procedures and time when they were performed, type of bone, use of membrane, presence, type of complications and time of occurrence were the study surgical variables. For each implant, the date of implant placement, dates of follow up radiographs and date of implant removal (if applicable) were recorded.

Table 1: Descriptive Statistics

VARIABLES Total Subjects = 20		Group 0 Non - 6x5.7 mm		Group 1 6x5.7 mm	
		Implants	%	Implants	%
Gender					
Male		18	52.9	20	71.4
Female		16	47.1	8	28.6
Smoker					
No		30	88.2	26	92.9
Yes		4	11.8	2	7.1
Jaw Location					
Maxilla		18	52.9	5	17.9
Mandible		16	47.1	23	82.1
Anterior-Posterior Location					
Ant		13	38.2	1	3.6
Post		21	61.8	27	96.4
Bone Quality					
Type 2		5	20.0	8	32.0
Type 2.5		1	4.0	1	4.0
Type 3		4	16.0	8	32.0
Type 4		15	60.0	8	32.0
Implant Specific					
Diameter	3.5	8	23.5	NA	NA
	4	8	23.5	NA	NA
	4.5	8	23.5	NA	NA
	5	9	26.5	NA	NA
	6	1	3.0	28	100.0
Length	5.7	NA	NA	28	100.0
	8	15	44.1	NA	NA
	11	18	53.9	NA	NA
	14	1	3	NA	NA
Well	2	20	58.8	NA	NA
	3	14	41.2	28	100.0
Coating	Uncoated	6	17.6	13	46.4
	TPS	10	29.4	9	32.1
	HA	18	53.0	6	21.4
Placement	Delayed	23	67.6	26	92.9
	Immediate	11	32.4	2	7.1
Staging	No	8	24.2	0	0.0
	One	7	21.2	12	42.9
	Two	18	54.6	16	57.1

Table 2: Radiographic Bone levels

	Group 0 Non -6x5.7 mm	Group 1 6x5.7 mm
Overall Crestal Change of Bone Levels*	-0.08 mm (k0=27)	-0.03 mm (k1=21)
Crestal Change of Bone Levels at 1 year*	-0.20 mm (k0=1)	NA mm (k1=0)
Crestal Change of Bone Levels at > 1 year*	-0.07 mm (k0=26)	-0.03 mm (k1=21)

** Average in mm of measurements mesial and distal to the implant.*
k = number of implants

Table 3: Univariate Analysis of Factors associated with Change in Bone Levels °

		Subjects	***P* value**
Mean age		20	0.79
Gender (female)		20	0.75
Smoker		20	0.72
Medical Compromised		20	0.85
		implant	***P* value**
Jaw location		62	0.25
Ant-Post		62	0.20
Quality of bone		62	0.73
Implant diameter		62	0.85
Implant length		62	0.76
Implant well		62	0.73
Coating		62	0.88
Staging		62	0.42
Immediate placement		62	0.13
Augmentation	Pre-augment	62	0.74
	Peri-augment	62	0.98
	Post-augment	62	0.80

° statistically significant at $p \leq 0.20$

Implant failure was defined as removal of the implant. Time between date of implant placement and patient's last visit or implant removal was defined as implant survival. To be considered successful, the implants had to meet the following requirements: 1) patient and dentist satisfaction regarding the implant supported restorations from the esthetic and functional point of view; 2) absence of pain, discomfort, infection attributable to the implants; 3) stability of the implants when tested clinically; 4) vertical bone loss inferior to 0.2 mm per year, after the first year of function. (Albrektsson et al. 1986).[6,7]

Change in bone levels over time were obtained by direct measurements on non standardized, digital periapical radiographs (Digora System, Soredex, Helsinki, Finland). Magnification error was made using the following equation: Corrected crestal bone level = Measured crestal bone level x actual implant length ÷ measured implant length. On each image, measurements in millimeters were calibrated based on the known implant length (manufacturing standards) as represented in Fig. 3. For each implant the radiographic variables were divided according to the category the implant belonged to. The categories were: implant adjacent to tooth mesially or distally, tooth mesial and distal of implant, implant adjacent to implant mesially or distally, implant mesial and distal of implant, nothing adjacent described in Fig. 1. Bone levels were measured vertically and perpendicularly from implant abutment interface to crestal bone level at both mesial and distal surfaces. Distance between implants or natural teeth was measured horizontally after calibration. For the rate of bone loss data measurements taken from the distal and mesial sites were first averaged for each implant.

Data analysis

A database was created using Microsoft Excel® (Microsoft, Inc, Redmond, WA). SAS® PC-version 9.1 (2002-2003) (SAS Institute, Carey, NC) statistical software was used for data and statistical analysis. Descriptive statistics were computed for all study variables.

Some patients might have more than one dental implant producing clustered observations. To adjust for clustered, correlated observations, Generalized Linear Mixed effects models (GLM models) using

Table 4: Multivariate Analysis ($p \leq 0.05$)

	Parameter estimate	Standard Error	P value
Group 1 (6 x 5.7 mm)	-0.057	0.25	0.82
Group 0 (Non 6 x 5.7mm)	0.00	reference	reference
Age (increase per year)	0.0024	0.016	0.89
Gender (female)	-0.010	0.40	0.98
Location (Posterior)	0.21	0.28	0.46
Immediate	-0.34	0.33	0.32

regression analysis was applied to identify risk factors associated with crestal bone loss. Potential risk factors for crestal bone changes were identified using the univariate GLM regression model and were considered as potential predictor variables if $p \leq 0.15$. Variables meeting this criterion were included in the multivariate clustered GLM regression model to identify variables statistically associated ($p \leq 0.05$) with the outcome with the addition to the three biologic important predictors, age at implant placement, gender, and the main predictor group (short versus non short implants).

Results

Between February 1997 and February 2003, 20 subjects had at least one 6x5.7 mm implant placed at least for five years and met the study inclusion criteria. Total of 62 implants, 28 6x5.7mm (test group = group 1 = short implant group) and 34 non-6x5.7mm (control group = group 0 = non short implant group), were sampled from 20 patients (12 males and 8 females).

Demographic study variables are summarized in Table 1. Mean length of non-6x5.7mm implants was 9.7 mm, ranging from 8mm to 14mm and with a mean diameter of 4.30 mm (range: 3.5 to 5 mm). The mean duration of the clinical and radiographic follow up was 55 months (+/- 31.3) for Group 0 and 68.1 months (+/- 18.0) for group 1. Smoking habit was reported by 11.8% and 7.1% of group 0 and 1 respectively. Fifty three percent of the implants belonging to group 0 and 17.9% of group 1 were placed in the maxillary arch. The majority of the implants (61.8% group 0 and 96.4% group 1) were placed in the posterior segments. Five years survival rates for group 0 and group 1 were 100.0% and 96.8% respectively, but this difference was not statistically significant (p=0.35). Table 2 summarizes the changes in peri-implant crestal bone levels over time. Overall the mean changes in radiographic bone levels were -0.08 mm for group 0 implants and -0.03 mm for group 1 implants (average of mesial and distal levels). Mean change in bone levels for group 0 implants at 1 year was -0.20 mm. Mean changes in bone levels for period longer than one year were -0.07 mm and -0.03 mm for group 0 and 1 respectively.

Table 3 summarizes univariate analysis used to identify association between individual study variables and peri-implant crestal bone loss. Implant placement in posterior segments of the jaws and immediate placement were considered statistically significant ($p \leq 0.20$) and implant placement in the maxillae resulted near statistically significant. Therefore these parameters were included in the multivariate analysis.

In the adjusted multivariate model (Table 4) the association between crestal bone loss and implant location in posterior segments of maxilla or mandible and immediate placement were considered near statistically significant ($p \leq 0.05$).

Discussion

Short implants offer several surgical advantages compared to longer implants. The use of short implants in the posterior regions reduces the need for bone augmentation procedures prior to or in conjunction with implant placement in the maxilla and the mandible. Shorter implants reduce the surgical risk of sinus perforation or mandibular paresthesia, with an overall reduction in surgical complications. Due to the decreased length of the drills and implants, the osteotomy preparation implies less risk of overheating the bone. Insertion of drills and implants results also easier in small intra arch spaces. In case of apical root proximity short implant can be the only possible choice. From the patient's point of view, shorter implants reduce treatment time, discomfort and overall costs related to graft procedures. All these factors make short implants a highly attractive restorative option.

The purpose of this retrospective study was to estimate the 5 year survival and success rate of the 6x5.7 mm short implant, and to evaluate the crestal bone levels of the same implant in comparison with longer implants from the same company. The survival rate at 5 years for a sample of 28 short implants was 100.0% and the mean bone loss was 0.03 mm. These values were comparable to the values calculated for the non -6x5.7 implant group.

A 1998 study by ten Bruggenkate and associates reported a 6 year survival rate of 94% for a 6 mm long Straumann implants.[8] Similarly, Friberg and coworkers found the 5 years survival rate to be 95.5% for a cohort of short Brånemark system implants.[9] Davarpanah and colleagues found a success rate at 3 years of short Osseotite implants of 98.4%.[10]

Fugazzotto in 2004 evaluated 7 to 9 mm long implants placed in posterior region of the maxilla and showed a success rate of 95.1 % up to 84 months of function.[11]

Hagi and coworkers in their recent study, concluded that dental implant surface geometry is a major determinant in how well this implants perform in short lengths, defined in that study as < 7mm.[12] While threaded implants showed higher failure rates in short versus longer length, sintered porous surfaced implants performed well in short lengths. Moreover, various researchers using Finite Elemental Analysis (FEA) have demonstrated that horizontal and vertical occlusal forces placed on implants were distributed primarily in the crestal bone, rather than along the entire implant/bone interface. These findings led the group of Lum to conclude that short implants serve as well as longer ones.[13,14,15] However, finite element method is a computer simulation technique which considers human bone of the jaws as a uniform structure material; dense cortical bone and trabecular marrow space which form human bone, are not considered in this type of analysis and therefore results still seem of limited relevance.

Implant diameter should also be

considered as an important clinical variable. It has been suggested that increasing implant diameter could compensate for decrease of length. Himmlova and colleagues showed that an increase in the implant diameter decreases the stress around the implant neck more than an increase in the implant length, as a result of a more favorable distribution of the simulated masticatory forces.[16]

Although several studies in the literature have shown that short implants have risk factors and therefore higher failure rate compared to longer implants,[17,18,19] several recent studies seem to prove the good long term prognosis of the short implants. It has been shown that also the crown/implant ratio do not seem to be a major risk factor in case of favorable force orientation and load distribution. Tawil and coworkers in 2006 evaluated the bone loss around short implants (>10mm) and concluded that these implants are a long term viable solution in sites with reduced bone height even when the prosthetic parameters exceed the normal values but under force parafunction control.[20]

All the work previously cited confirmed the results presented in this study and offer promising and further applications for the 6x5.7 mm short implant. Prospective follow up study and larger sample size are in progress.

Conclusion

Within the limitations of the present study, the short implant (6x5.7 mm) showed a survival rate at 5 years of 100.0% which was not statistically significant different when compared to longer implants (>8 mm) of the same company. Radiographic bone levels measured mesially and distally to the 6x5.7 mm implants at 5 years were comparable to the bone levels around longer implants. Clinical parameters, including gingival and restorative evaluations were also comparable between the two groups. However, this study showed that placement in posterior maxillary regions and immediate placement could affect the long term crestal bone stability. 6x5.7 mm implants in case of limited bone height are a predictable option for the treatment of edentulous patients.

Acknowledgments

The authors would like to thank the clinicians, in particular Dr. Rainier Urdaneta, and the support staff of Implant Dentistry Centre, Boston MA, for their cooperation in this study and the access to patient records. The authors would also like to acknowledge the support of the computing facilities at the Harvard University, School of Public Health, Boston, MA and at the Harvard – MIT Data Center Cambridge, MA for access to statistical software. This project was supported by the Educational Grant (LLC) by Bicon, Boston MA.

Bibliography

1. Smith DE, Zarb GA. Criteria for success of osseointegrated endosseous implants. J Prosthet Dent 1989; 62(5):567-72.
2. Piattelli A, Vrespa G, Petrone G, Iezzi G, Annibali S, Scarano A. Role of the Microgap Between Implant and Abutment: A Retrospective Histologic Evaluation in Monkeys. J Periodontol. 2003;72(9):1146-1150.
3. Hermann JS, Buser D, Schenk RK, Higginbottom FL, Cochran DL. Biologic width around titanium implants. A physiologically formed and stable dimension over time. Clin Oral Implants Res. 2000;11(1):1-11.
4. King GN, Hermann JS, Schoolfield JD, Buser D, Cochran DL. Influence of the size of the microgap on crestal bone levels in non-submerged dental implants: a radiographic study in the canine mandible. J Periodontol. 2002;73(10):1111-7.
5. Chou CT, Morris HF, Ochi S, Walker L, DesRosiers D. Crestal bone loss associated with the Ankylos implant: loading to 36 months. J Oral Implantol. 2004;30(3):134-43.
6. Albrektsson T, Zarb G, Worthington P, Eriksson AR. The long-term efficacy of currently used dental implants: a review and proposed criteria of success. Int J Oral Maxillofac Implants. 1986;1(1):11-25.
7. Weng D, Jacobson Z, Tarnow D, Hurzeler MB, Faehn O, Sanavi F, Barkvoll P, Stach RM. A prospective multicenter clinical trial of 3i machined-surface implants: results after 6 years of follow-up. Int J Oral Maxillofac Implants. 2003;18(3):417-23.
8. ten Bruggenkate CM, Asikainen P, Foitzik C, Krekeler G, Sutter F. Short (6 mm) nonsubmerged dental implants: Results of a multicenter clinical trial of 1 to 7 years. Int J Oral Maxillofac Implants 1998 ;13 :791-798.
9. Friberg B, Grondhal K, Lekholm U, Brånemark P-I. Long term follow-up of severely atrophic edentulous mandibles reconstructed with short Branemark implants. Clin Dent Relat Res 2000;2:184-189.
10. Davarpanah M, Martinez H, Celletti R, Alcoforado G, Tecucianu JF, Etienne D. Osseotite implant: 3 year prospective multicenter evaluation. Clin Implant Dent Relat Res 2001 ;3 :111-118.
11. Fugazzotto PA, Beagle JR, Ganeles J, Jaffin R, Vlassis J, Kumar A. Success and failure rates of 9 mm or shorter implants in the replacement of missing maxillary molars when restored with individual crowns: preliminary results 0 to 84 months in function. A retrospective study. J Periodontol. 2004;75(2):327-32.
12. Hagi D, Deporter DA, Pilliar RM, Arenovich T. A targeted review of study outcomes with short (d”7 mm) endosseous dental implants placed in partially edentulous patients. J Periodontol 2004;75(6): 798-804.
13. Lum LB. A biomechanical rationale for the use of short implants. J Oral Implantol 1991;17:126-131.
14. Matsushita Y, Kitoh M, Mizuta K, Ikeda H, Suetsugu T. Two-dimensional FEM analysis of hydroxyapatite implants: diameter effects on stress distribution. J Oral Implantol. 1990;16(1):6-11.
15. Holmes DC, Loftus JT. Influence of bone quality on stress distribution for endosseous implants. J Oral Implantol 1997;23:104-111.
16. Himmlova L, Dostalova T, Kacovsky A, Konvickova S. Influence of implant length and diameter on stress distribution: a finite element analysis. J Prosthet Dent. 2004;91(1):20-25.
17. Winkler S, Morris HF, Ochi S. Implant survival to 36 months as related to length and diameter. Ann Periodontol 2000;5:22-31.
18. Lazzara R, Siddiqui AA, Binon P. Retrospective multicenter analysis of 3I endosseous dental implants placet over a five-year period. Clin Oral Implants Res 1996;7:73-83.
19. Scurria MS, Morgan V, Guckes AD, Li S, Koch G. Prognostic variables associated with implant failure. A retrospective effectiveness study. Int J Oral Maxillofac Implants 1998;13 :400-406.
20. Tawil G, Aboujaoude N, Younan R. Influence of prosthetic parameters on the survival and complication rates of short implants. Int J Oral Maxillofac Implants 2006;21(2):275-282.