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ORIGINAL ARTICLE

Distance between implants has a potential impact of crestal bone resorption

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Abstract *Objectives:* Around dental implants exists a "biologic width" of few millimeters that have to be preserved in order to not have adverse effect on soft and hard tissues around implant. Because the minimum distance between adjacent implants has not been determined yet, we therefore, decided to perform a retrospective study on a series of spiral family implants (SFIs) to verify the minimum inter-implants' distance that has an impact on crestal bone resorption.
Materials and Methods: Fifty-nine implants were investigated with a mean follow-up of 14 months. Implant diameter was 3.75, 4.2, 5 and 6 mm in 11 (18.6%), 29 (49.2%), 17 (28.8%) and 2 (3.4%) SFIs. Implant length was shorter than 13 mm, equal to 13 mm and 16 mm in 23 (39%), 23 (39%) and 13 (22%) SFIs. Implants were inserted to replace 13 incisors (22%), 7 cuspids (11.9%), 30 premolars (50.8%) and 9 molars (15.3%). Twenty-seven fixtures were inserted in post-extractive sockets and the remaining 32 in healed bone; 36 (61%) were immediately loaded. In addition to the above mentioned implant-related factors, several host- and surgery-factors were investigated. Independent samples T-test, univariate and multivariate analysis were used to detect those variables associated with the clinical outcome.

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Results: Data were evaluated with a two steps statistical analysis (i.e. univariate and multivariate) after having grouped implants in two series: those with an implant-implant distance less of 1.8 mm and those with an implant-implants distance greater than 1.8 mm. In univariate analysis, post-extractive implants and number of prosthetic units were statistically significant. In multivariate analysis, only post-extractive implants have a significant adverse effect on crestal bone resorption. *Conclusions:* Adjacent implants inserted with a distance lower and higher than 1.8 mm have difference in crestal bone resorption but this difference is not statistically significant in a short period follow up. This could due to the specific implant used that has a reverse conical neck. No statistical difference was detected between implant subtypes. Post-extractive implant insertion is the major determinant in terms of peri-implant bone resorption in a short period follow-up.

1. Introduction

The phenomenon of the establishment of a zone of ''biological width'' has been a challenging and demanding procedure for many years. In its most simplified form, biological width refers to the height of the junctional epithelium and connective tissue attachment, located between the base of the sulcus and the alveolar bone crest, and it is defined as the distance necessary for a healthy existence of bone and soft tissue from the most apical extent of a dental restoration (Abdulazizal et al., 2005; Berglundh and Lindhe, 1996; Listgarten et al., 1991; Berglundh et al., 1991; Schroeder et al., 1981; Grunder, 2000; Choquet et al., 2001).

Because the bone crest constitutes the base for the soft tissue, alterations in the peri-implant bone level will affect the position of the soft tissue margin, which in turn will have a significant impact on the aesthetic outcome of the implant therapy (Cardaropoli et al., 2003). The consequences of increased loss of peri-implant bone support have been reported with decreasing distance between the implant and the tooth (Esposito et al., 1993). Furthermore based on the finding that the bone crest was more apically located at sites with <3 mm inter-implant distance than at sites where the implants were standing >3 mm apart, Tarnow et al. (2000) suggested that not only vertical bone loss but also lateral bone loss at implants could have an effect on the level of the bone crest between two implants.

The bony support between a tooth and an implant or between two implants has been shown to be an important criterion in creating or preserving the papilla (Choquet et al., 2001; Hartman and Cochran, 2004). For example, when the measurement from the interproximal coronal contact point to the crest of bone is 5 mm or less, the papilla is present almost 100% of the time (Garber et al., 2001). Tarnow et al., (1992) reported a mean papillary height between two adjacent implants as 3.4 mm. One difficulty in maintaining or re-forming a papilla between two implants is that the biological width around an implant usually is located apical to the implant abutment connection. In the aesthetic zone, the distance from alveolar crest to the adjacent tooth cementoenamel junction should be 3–5 mm to achieve ideal implant localization (Tarnow et al., 2003) and appropriate space for the peri-implant sulcus to form.

A spiral implant is a conical internal helix implant with a variable thread design which confers the characteristic of self drilling, self tapping and self bone condensing. The spiral implant family (SIF) is composed by two types of implants, the Spiral Implant (SPI) and the Spiral Flare Bevel (SFB). This last has a reverse conical head that allows for an increased volume of crestal bone around the implant neck. That accounts for some additional benefits such as a closer placement of adjacent implants without compromising health tissues and aesthetic outcome.

Because the SFIs are on the market since the last 10 years and no report is available on the effect of implants' distance on crestal bone resorption, we decide to perform a retrospective study on a series of SFIs to analyze their clinical outcome.

2. Material and methods

2.1. Patients

In the period between May 2004 and November 2007, 86 patients (55 females and 31 males) with a median age of 53 years were operated and 234 spiral family implants (SFIs, 3D Alpha Bio, Pescara, Italy) were inserted. The last check-up was performed in October 2008, with a mean post loading follow-up of 14 months.

Subjects were screened according standard inclusion criteria: (Degidi et al., 2006, 2007, 2008) i.e. controlled oral hygiene and the absence of any lesions in the oral cavity; in addition, the patients had to agree to participate in a post-operative check-up program.

Exclusion criteria were as follows: bruxism, smoking more than 20 cigarettes/day, localized radiation therapy of the oral cavity, antitumor chemotherapy, liver, blood and kidney diseases, immunosuppressed patients, patients taking corticosteroids, pregnant women, inflammatory and autoimmune diseases of the oral cavity, poor oral hygiene.

2.2. Data collection

Before surgery and in the follow-up period, radiographic examinations were done with the use of orthopantomograph and CT scans.

In each patient, peri-implant crestal bone levels were evaluated by the calibrated examination of orthopantomograph X-rays (Ortoralix SD, Gendex, Milano, Italia). A periapical radiograph was impressed by means a customized Rinn holder device. This device was necessary to maintain the X-ray cone perpendicular to a film pieced parallel to the long axis of the implant. The endoral X-rays were taken using a long X-ray tube at 70 kW of power, and developed in acid in a dark room according to standard procedures; they were scanned, transferred to a computer and saved in an uncompressed TIFF format for classification.

Each file was processed with the Window XP Professional operating system using the Photoshop 7.0 (Adobe, San Jose,

CA), and shown on a 17″ SXGA TFT LCD display with a NVIDIA GÈ Force FX GO 5600, 64 MB video card (Acer Aspire 1703 SM-2.6). Each image was modified using the fit-on-screen function (maximized screen) and the necessary adjustments in contrast, brightness and magnification were made. The measurements were taken at the highest level of resolution possible through the ''grid and ruler'' program options using various metric scales. Knowing the known dimensions of the implant and having located various points of reference on the profiles of the X-rayed fixtures (edge of the platform, bone crestal level, total length of the implant), it was possible to take linear measurements on the computer and thus execute a proportional metric calculation comparing the known dimensions of the implant's geometric design with those of the examined X-ray images. This made it possible to establish the distance from the mesial and distal edges of the implant platform to the point of bone-implant contact plus the visible crown (expressed in tenths of a millimeter) as an expression of marginal bone resorption. The proportional calculation of the measurements also made it possible to establish, where present, any distortion in the X-ray images for further screening, thereby reducing the margin of error of the analysis to a minimum.

Measurements were recorded before surgery, after surgery and at the end of the follow-up period. The measurements were carried out mesially and distally to each implant, calculating the distance between the implant abutment junction and the bone crestal level. The X-rays was calibrated by using an internal standard that was the implant' length. The bone level recorded just after the surgical insertion of the implant was the reference point for the following measurements. The measurement was rounded off to the nearest 0.1 mm.

In addition, following parameters were considered: absence of persisting pain or dysesthesia, absence of peri-implant infection with suppuration, absence of mobility, and absence of persisting peri-implant bone resorption greater than 1.5 mm during the first year of loading and 0.2 mm/years during the following years (Albrektsson and Zarb, 1998).

2.3. Implants

A total of 234 SFIs were inserted: among them 59 were adjacent, 37 (62.7%) inserted in female and 22 in males (37.3%), and therefore, were considered in this retrospective study. Patient' median age was 55 ± 14 years (min–max 26–80 years) and average crestal bone resorption was 1.7 ± 0.8 mm (min–max 0–3.6 mm). The mean follow-up was 14 months. Fourteen SPI and 45 SFB were inserted, 22 (37.3%) in the mandible and 37 (62.7%) in the maxilla.

Implant diameter was 3.75, 4.2, 5 and 6 in 11 (18.6%), 29 (49.2%), 17 (28.8%) and 2 (3.4%) SFIs, respectively. Implant length was less than 13, 13 and 16 mm in 23 (39%), 23 (39%) and 13 (22%) SFIs, respectively. Implants were inserted to replace 13 incisors (22%), 7 cuspids (11.9%), 30 premolars (50.8%) and 9 molars (15.3%). Twenty-seven fixtures were inserted in post-extractive sockets and the remaining 32 in healed bone; 36 (61%) were immediately loaded.

2.4. Surgical and prosthetic technique

All patients underwent the same surgical protocol. An antimicrobial prophylaxis was administered with 500 mg Amoxycillin twice daily for 5 days starting 1 h before surgery. Local anesthesia was induced by infiltration with articaine/epinephrine and post-surgical analgesic treatment was performed with 100 mg Nimesulid twice daily for 3 days. Oral hygiene instructions were provided.

After making a crestal incision a mucoperiosteal flap elevated. In several cases a mucotomy was performed. Implants were inserted according to the procedures recommended. The implant platform was positioned at the alveolar crest level. Sutures, if used, were removed 14 days after surgery. In case of delayed loading the provisional prosthesis was provided after 24 weeks from implant insertion and in all cases the final restoration was usually delivered within an additional 8 weeks. The number of prosthetic units (i.e. N.P.U. = implant/crown ratio) was about 0.86. Sixteen (27.1%) implants were inserted in patients with totally edentulous jaw. The antagonists were natural teeth and prosthetic crowns in 29 (49.2%) and 30 (50.8%) cases, respectively. Implants carried fixed restoration in all cases. All patients were included in a strict hygiene recall.

2.5. Statistical analysis

Independent samples T-test was used to detect if any statistical difference exists between two groups: fixtures with good clinical outcome and ''failed'' implants (i.e. those with peri-implant bone resorption greater than 1.5 mm during the first year of loading and 0.2 mm/years during the following years).

In addition univariate (i.e. Log rank test) (Dawson-Saunders and Trapp, 1994) and multivariate analyses (i.e. Cox algorithm) (Cox and Oakes, 1984) were used to detect those variables which have an impact on crestal bone resorption.

3. Results

Since there is a general agreement that the absence of persisting peri-implant bone resorption greater than 1.5 mm during the first year of loading and 0.2 mm/years during the following years (Albrektsson and Zarb, 1998) are related to a good clinical outcome, we detected two groups of implants: 27 implants had good clinical outcome (peri-implant crestal bone resorption 1.77 ± 0.32 mm) whereas 32 failed (1.81 ± 0.27 mm). Independent samples T-test did not detect any statistical difference ($p = 0.411$) between two groups.

Then we match the two groups against several variables: implant length (lower, equal or higher than 13 mm), diameter (3.75, 4.2, 5 and 6) and subtype (SFB and SPI); age and gender of patients; upper/lower jaw, site (incisors, canine, premolars and molars) and post-extractive/healed bone; type of prosthesis (removable vs. fixed), N.P.U. (divided as N.P.U. = 1, $0.5 \leqslant$ N.P.U. < 1, N.P.U. < 0.5), type of edentulism (total vs. partial), and type of antagonist element (prosthetic vs. natural tooth).

In univariate analysis (i.e. an analysis where each single variable is compared with the two groups of implants – with low and high bone resorption), post-extractive implants and N.P.U. were statistically significant (see Table 1, Kaplan–Meier algorithm, Log rank = 8.23 df = 1 $p = .0041$ and Log rank = 19.92 df = 3 $p = .0002$).

In multivariate analysis (i.e. an analysis were all variables which have passed the previous test are compared with the two groups of implants – with low and high bone resorption),

Table 1 Univariate analysis: post-extractive implants and N.P.U. have a significant p value.

Variable	Log rank	Degree of freedom	Significance
Implant length	5.61	2	.0606
Implant diameter	6.81	3	.0781
Implant type	0.96	1	.3266
Maxilla/mandible	0.35	1	.5521
Implant site	9.15	3	.0274
Post-extractive	8.23	1	.0041
N.P.U.	19.92	3	.0002
Edentulness	0.07	1	.7864
Antagonist	1.01	1	.3160

Table 2 Multivariate analysis.

Variable	Significance p value
Age	.3030
Gender	.8067
Post-extractive	.0140
N.P.U.	.7631

only post-extractive implants have a significant adverse effect on crestal bone resorption (Table 2, Cox regression).

4. Discussion

Around dental implants exists a ''biologic width''. This biologic width will form at implant placement and is not correlated to implant loading (Vaillancourt et al., 1995, 1996). It has been hypothesized that a certain width of the peri-implant mucosa is required to enable a proper epithelial-connective tissue attachment and, if this soft tissue dimension is not satisfied, bone resorption will occur to ensure the establishment of attachment with an appropriate biological width (Tarnow et al., 2000). Biological width is a physiologically formed and stable dimension as is found around teeth (Berglundh and Lindhe, 1996; Abrahamsson et al., 1996) and represents the distance necessary for a healthy existence of bone and soft tissue from the most apical extent of a dental restoration (Abdulazizal et al., 2005).

Our data do not detect significant statistical difference in crestal bone resorption over time between fixtures inserted at lower or higher distance than 1.8 mm. This fact could be due to the implant type: in fact the SFB has a reverse conical head that allows for an increased volume of crestal bone around the implant neck. That accounts for some additional benefits such as a closer placement of adjacent implants without compromising health tissues and aesthetic outcome. This results are different to those previously reported by Saadoun et al., which recommended to keep a distance of 2 mm between cervical implant face and natural tooth and greater than 3 mm cervical distance between two implants to minimize the amount of crestal bone loss (>1.5 mm), better soft tissue fill and proper papilla bone support (Saadoun and LeGall, 1992; Buser et al., 2004). If this distance is compromised there is a greater probability of resorption of interproximal alveolar crest to the level of implants.

An additional reason for alveolar crest bone resorption between implants could be microgap between implant and abutment. Hermann et al. (2000) reported that their results clearly show that bone loss resulted from the creation of a microgap. The crestal bone will resorb and create a distance from the bacteria eventually present in the microgap. Callan et al. (1998) found that approximately 4.2 years after prosthetic restoration, bone loss of more than 3 mm was observed in implants of different types where the microgap was located in a subgingival position, whereas completely different results were obtained when the location of the microgap was at or above the gingival margin. In previous studies, the epithelial attachment was more apical and always located below the microgap in submerged implants (Cochran et al., 1997; Weber et al., 1996). The epithelium could migrate beyond the bacteria and the microgap in an attempt to isolate the infection. This significant inflammatory response of the soft tissues leads a proliferation of the epithelium and subsequent response to reestablish the dimension of the biological width. These events could be responsible for the approximately 2 mm of distance that is presented apical to the microgap (Hermann et al., 1997, 2000). Our data demonstrated that microgap have a low impact in our series since type of prosthetic restoration has no statistical impact on bone resorption.

Among the other studied variables (i.e. implant length, diameter and subtype; age and gender of patients; upper/lower jaw, site and post-extractive/healed bone; type of prosthesis, N.P.U., type of edentulism, and type of antagonist element), post-extractive implants and N.P.U. were statistically significant in univariate analysis (Table 1) whereas in multivariate analysis, only post-extractive implants have a significant adverse effect on crestal bone resorption (Table 2). This result can be due to the short follow-up (i.e. about 1 year) where post-surgical crestal bone remodeling effect is higher.

In conclusion, adjacent implants inserted with a distance lower and higher than 1.8 mm have difference in crestal bone resorption but this difference is not statistically significant in a short period follow up. This could due to the specific implant used that has a reverse conical neck. No statistical difference was detected between implant subtypes. Post-extractive implant insertion is the major determinant in terms of peri-implant bone resorption in a short period follow-up.

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