RESEARCH ARTICLE

15-year follow-up of short dental implants placed in the partially edentulous patient: Mandible Vs maxilla

Eduardo Anitua [a,b,c,*], Mohammad H. Alkhraisat [b,c]

[a] Private Practice in Oral Implantology, Clínica Eduardo Anitua, Vitoria, Spain
[b] University Institute for Regenerative Medicine and Oral Implantology — UIRMI (UPV/EHU-Fundación Eduardo Anitua), Vitoria, Spain
[c] BTI Biotechnology Institute, Vitoria, Spain

ARTICLE INFO

ABSTRACT

There is paucity of the studies that assess the outcomes of short dental implants with a follow-up time higher than 10 years. This study aims to evaluate the long-term (15 years) survival and marginal bone loss around short dental implants and assess the influence of the anatomical location (mandible or maxilla) on these outcomes. A clinical retrospective study of short dental implants (≤ 8.5 mm) was conducted in a single private dental clinic. The predictor variable was the anatomical location (mandible or maxilla). The primary outcome was the dental implant survival rate. The secondary outcomes were the marginal bone loss, the prosthesis failures and the influence of anatomical location, the antagonist type, and the clinical/anatomical crown-to-implant ratio (CIR) on the marginal bone loss and implant success rate. Descriptive analysis was performed for patients' demographic data, implant details, and prosthetic variables. Kaplan–Meier method was used to assess the implant survival rate. Fifty patients with a mean age of 59 ± 10 years had a mean follow-up time of 15 years. Seventy five implants were placed being 30 in the maxilla and 45 in the mandible. The implant position did not affect significantly the implant survival. The marginal bone loss has been significantly higher in the maxilla than the mandible. The implant survival rate was 93.3%. Short dental implants could be indicated to support fixed partial prosthesis in the mandible and the maxilla. Implant position may affect the marginal bone loss around the short dental implants.

© 2018 Published by Elsevier GmbH.

1. Introduction

The clinical management of alveolar bone atrophy requires adequate treatment planning to offer the patient a therapy with less surgical complications, adequate postoperative recovery and capable to save time and costs (Anitua and Alkhraisat, 2016; Esposito et al., 2011). Patient rehabilitation with short dental implants may be the preferred treatment in atrophic alveolar bone as they have been associated with lower biological complications, decreased morbidity, costs and surgical time (Anitua et al., 2017; Bechara et al., 2017; Nisand et al., 2015; Thoma et al., 2015). Thus, short implants would save the need for vertical bone augmentation or at least reduce the amount of bone height to gain (Anitua et al., 2014a; Anitua et al., 2013a; Anitua et al., 2017; Esposito et al., 2011). Several systematic reviews have underlined the predictability of short

implants in regards to implant survival, marginal bone loss, and prosthodontic failures (Lee et al., 2014; Monje et al., 2013; Nisand et al., 2015; Srinivasan et al., 2012, 2014; Telleman et al., 2011). The use of short dental implants would reduce significantly intraoperative and postoperative complications (Lee et al., 2014; Nisand et al., 2015; Thoma et al., 2015).

However, higher number of clinical studies are needed to assess the long-term prognosis of short dental implants. Especially when the data of the life expectancy at birth in 2015 are 80.6 and 78.8 years in Europe and USA, respectively. This means that if a short dental implant is placed at age of 65, then it will be working for about 15 years. In fact, few studies are available with a mean follow-up time higher than 10 years (Anitua et al., 2014b; Lops et al., 2012; Mertens et al., 2012).

The bone quality is one of the anatomical factors that affect the success/failure of the dental implants (Bahat, 2000; Friberg et al., 1999; Jaffin and Berman, 1991). Bone quality is a collective term that refers to the mechanical properties, architecture, degree of mineralization, chemical composition and remodeling properties of bone (Shapurian et al., 2006). In the practice of implant den-

tistry, bone quality is generally assumed to be equivalent to bone density (Molly, 2006). The mandible has a higher bone density than the maxilla (Truhlar et al., 1997). The bone density is the highest in the anterior mandible and the lowest in the posterior maxilla (Truhlar et al., 1997). High implant failure rates for maxillary bone with low density have been observed (Khang et al., 2001; Tabassum et al., 2011). Similarly, implant failure has been more common in low density bone (Pagliani et al., 2013; Sennerby and Roos, 1998). Higher survival rate have been reported for implants in the mandible than those in the maxilla (Albrektsson, 1988).

The purpose of the study was to assess the long-term outcomes of short dental implants supporting a cemented fixed-partial prosthesis. The null hypothesis was the absence of significant differences between the mandible and maxilla in the long-term survival of short dental implants placed in the posterior (premolar–molar) segments, supporting a cemented fixed-partial prosthesis. The specific aims of the study were: (1) to estimate the cumulative survival rate and success rate of the short dental implants, (2) to measure the marginal bone loss around the dental implants, (3) to estimate the survival rate of the dental prostheses, and (4) to assess the influence of anatomical location, the antagonist type, and the crown-to-implant ratio (CIR) on the marginal bone loss and implant success rate.

2. Materials and methods

2.1. Study design

The investigators designed and implemented a retrospective clinical study. The manuscript was prepared according to the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) guidelines (von Elm et al., 2007). The study population was patients with dental implants who were treated in a private dental clinic in Vitoria, Spain. In this study, the case selection criteria were patients had to be older than 18 years old at the time of surgery, the insertion of at least one dental implant with a length ≤8.5 mm before December 2001, the implants were inserted in the premolar–molar region of both maxillae and the implant-supported prosthesis was a cemented fixed partial denture.

Patients were excluded as study subjects if one or more of the inclusion criteria were not satisfied. There were no specific exclusion criteria. One hundred and seventy one implants with a length ≤8.5 mm were placed in 99 patients before September 2002. A total of 60 implants in 27 patients were excluded. Forty six implants were supporting a complete prosthesis and 8 were single-unit implants. Three implants were supporting a screw-retained partial prosthesis and another 3 implants were placed in the anterior maxilla. For that, the study cohort was composed of 111 dental implants placed in 72 patients.

This study was performed following the Helsinki declaration regarding the investigation with human subjects.

2.2. Variables

The patients' demographic data (sex and age) were obtained.
The predictor variable was the anatomical location (mandible or maxilla). The primary outcome was the implant survival, defined as whether the implant is still physically in the mouth or has been removed. The cumulative implant survival rate was assessed by time-to-event analyses (Kaplan–Meir method).

The secondary outcomes were: (1) the implant success rate, (2) the marginal bone loss after loading defined as the increase in the distance between the uppermost point of the implant platform and the most coronal bone-implant contact after loading, (3) the

anatomical crown to implant ratio (the anatomical crown length divided by the implant length), (4) the clinical crown to implant ratio (the distance between the uppermost point of the crown to the marginal alveolar bone divided by the implant length), (5) the number of splinting implants, (6) the antagonist type, and (7) the survival of the dental prosthesis defined as the first definitive prosthesis is still physically in the mouth at the last visit.

2.3. Data collection methods

Dental implants were followed clinically and radiographically to identify any sign of implant failure. The implant/prosthesis survival was positively evaluated if the implant/prosthesis was present at the last follow-up. The measurement of the marginal bone loss was performed on the most recent panoramic radiograph. The linear measurements was calibrated by the known implant length (Sidexis software, Sirona, USA). The bone level recorded just after the placement of the provisional prosthesis served as a reference for the measurement of the marginal bone loss.

Before surgery, patients underwent a routine periodontal treatment before implant surgery. The treatment plan was set after clinical examination and the study of the diagnostic wax-up and cone-beam computerized tomography (CBCT) scans (Anitua et al., 2015; Anitua et al., 2012, 2013b). Patients received 2 g of amoxicillin (600 mg of clindamycin for allergic patients) 60 min before surgery and 1 g of acetaminophen 30 min preoperatively. Local anesthesia was achieved by the administration of articaine hydrochloride with epinephrine (1:100,000).

An experienced surgeon (EA) had placed all the dental implants. After the reflection of a full-thickness flap, implant sites were marked by the initial drill (1.5 mm drill) working at 850–100 rpm under irrigation. Implant site preparation was continued with diameter drills (Anitua et al., 2015; Anitua et al., 2007). The implants were wetted by plasma rich in growth factors (BTI Biotechnology Institute; Vitoria, Spain) (Anitua, 1999; Anitua et al., 2013c). For placing the dental implant, the surgical motor was set at 25 Ncm and the implants were finally seated manually by a calibrated torque wrench. The implants evaluated in this study were cylindrical and had an moderately-rough and acid-etched surface (Anitua et al., 2008).

None of the implants were immediately loaded. Non submerged healing was performed in 50 implants and submerged healing in 25 implants. The implants loading was performed 5 ± 2 months (range: 3–8 months) after insertion. The prosthetic rehabilitation was performed on surgical abutments (not at the implant platform). The definitive prosthesis was placed after 6–9 months of progressive loading with a provisional prosthesis. The occlusal scheme was the maximum intercuspation with mutual protection. The follow-up visits were normally at one week, 1, 3, 6 months after intervention and then once a year. The implant health status and complications were evaluated clinically and radiographically.

2.4. Data analysis

Descriptive statistics were performed considering the implant and the patient as a unit of analysis. Absolute and relative frequency distributions were calculated for qualitative variables and mean values and standard deviations for quantitative variables. Shapiro–Wilk test was selected to check the normal distribution of the data. Qualitative variables were compared by χ^2 test. The t-test was selected to compare the variables of age and marginal bone loss between the mandible and the maxilla. The Mann–Whitney U test was selected to compare the variables of the crown-to-implant ratio and the follow-up time between the mandible and the maxilla. The analysis of variance (ANOVA) has been selected to assess the effect of the variables of sex, smoking, antagonist type and number

Table 1
Patients data grouped by the implant location (maxilla/mandible).

	Sex (number of patients)		Age (years)	Smoking (number of patients)	
	Male	Female		Yes	No
Maxilla	7	15	60 ± 9	8	14
Mandible	4	24	58 ± 11	5	23
p	0.137[a]		0.331[b]	0.139[a]	

[a] Chi square test.
[b] T test.
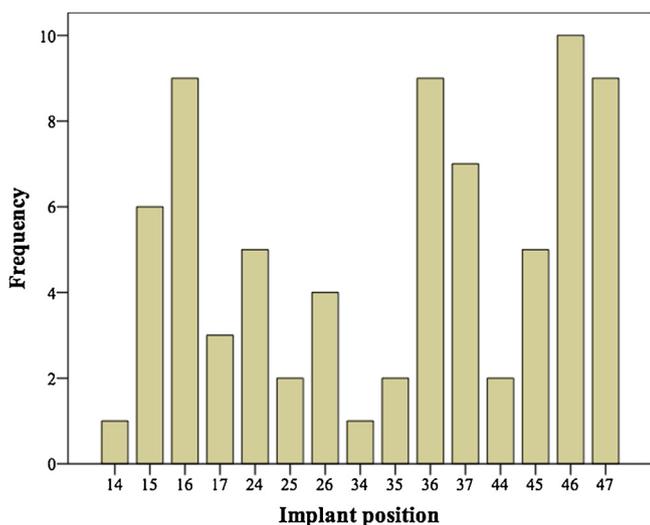
Fig. 1. Anatomical position of the placed dental implants.

Fig. 2. The cumulative implant survival rate.

of splinting implants on the MBL. Linear regression was selected to test the effect of age, crown-to-implant ratio (clinical and anatomical) and implant diameter on the marginal bone loss. The statistical significance was set at p < 0.05. SPSS v15.0 for Windows statistical software package (SPSS Inc. Released 2006. SPSS for Windows, Version 15.0. Chicago, SPSS Inc.) was used for statistical analysis.

3. Results

In this study, 111 short dental implants in 72 patients were assessed. Two patients with two implants were lost (not attending the clinic). Another 22 patients (34 implants) died. The final study sample had 75 dental implants in 50 patients.

At the time of surgery the patients mean age was 59 ± 10 years (range: 28–84 years). Eleven patients were males and 39 were females. Smoking was reported in 13 patients. Table 1 shows the demographic data grouped by the implant location. Fig. 1 shows that all implants were placed in the premolar-molar regions.

Table 2 shows the length and the diameter of the dental implants. The 91% of implants were 8.5 mm in length and the most frequent diameter was 3.75 mm. The mean follow-up time of the dental implants was 179 ± 21 months after insertion (Figs. 3 and 4). Five dental implants failed giving a survival rate of 93.3% (Fig. 2). All failures occurred in the mandible giving it a survival rate of 88.9% (Table 3). All failed implants showed an excessive marginal bone loss (>2 mm).The difference in the survival rate between the mandible and maxilla was not statistically significant (p = 0.063). There was a statistically significant difference in the number of implants to which the short implant was splinted to. The implants in the mandible were mostly splinted to one implant whereas in the maxilla they were splinted to 2 implants (Table 4).
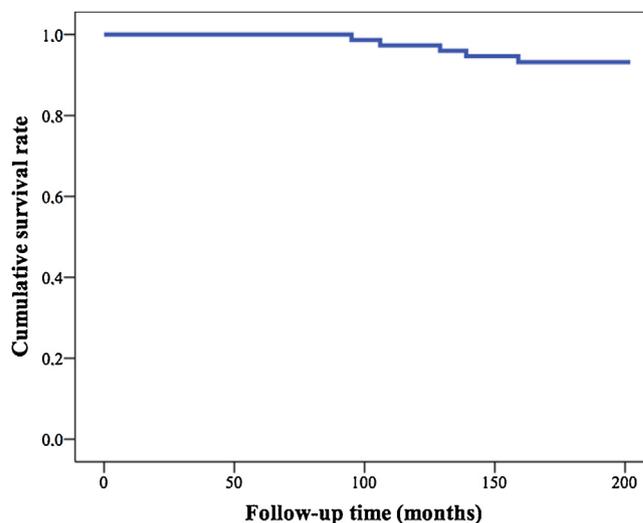
The mesial and distal marginal bone loss were less than 1 mm for all implants. The distal marginal bone loss was significantly higher in the maxilla. Table 5 shows the outcomes of the analysis of the effect of several factors of marginal bone loss. There was no significant effect of sex, age, smoking, crown-to-implant ratio, antagonist type and implant diameter on the marginal bone loss.

The mean follow-up time of the prosthesis was 153 ± 44 months. There was no statistically significant differences in the type of the antagonist and the crown-to-implant ratio. Four prostheses in the maxilla were modified due to the loss of neighboring tooth/implant. Three prostheses failed in the mandible due to the failure of supporting implant (3 prostheses). Another 3 prostheses were modified due to the loss of neighboring tooth/implant. Two more prostheses were renewed to change their design.

4. Discussion

This study aimed to analyze the long-term outcomes of short dental implants placed in the maxilla and the mandible. The null hypothesis has been the absence of significant differences between the mandible and maxilla in the long-term survival of short dental implants placed in the posterior (premolar–molar) segments, supporting a cemented fixed-partial prosthesis. The specific aims of the study were the long-term cumulative survival rate of the short dental implants, the marginal bone loss, the prosthesis survival rate and the influence of anatomical location, the antagonist type, and the crown-to-implant ratio (CIR) on the marginal bone loss and implant success rate. The outcomes of this study strengthen the indication of the short dental implants in the maxilla and the mandible. The 15 years-survival rate of the short implants was 93.3% and the marginal bone loss was less than 1 mm.

Several definition have been described for the short dental implants (Atieh et al., 2012; Srinivasan et al., 2012, 2014; Telleman et al., 2011; Thoma et al., 2015). The threshold length, below which the dental implant has been considered as short, has been varying from <10 mm, ≤8.5 mm, ≤8 mm, <8 mm to 6 mm (Atieh et al., 2012; Srinivasan et al., 2012, 2014; Telleman et al., 2011; Thoma et al., 2015). Which is a reflection of changing in the definition of standard length implant and an evidence of the predictability of short dental implants. In this study, all implants with a length ≤8.5 mm has been considered as short dental implants.

In the posterior sectors, Reich et al. have observed that the residual well-rounded ridges with reduced height, and ridges with

Table 2
Implant dimensions grouped by the implant location (maxilla/mandible).

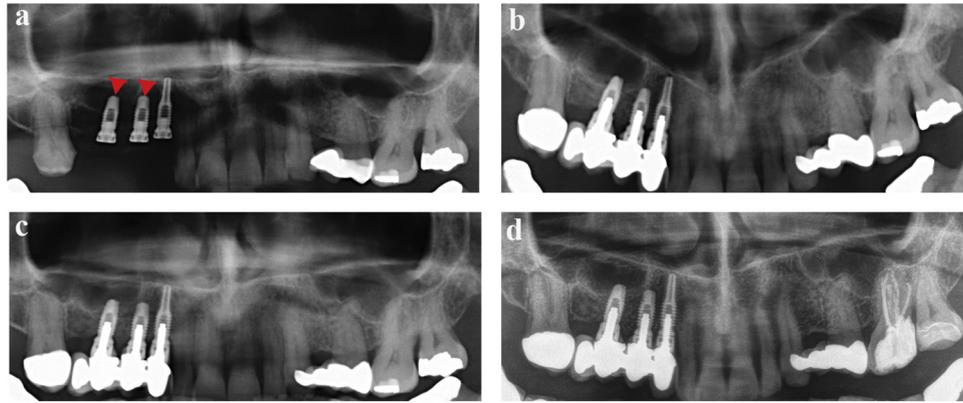|	Length (number of implants)		Diameter (number of implants)				
	7.5 mm	8.5 mm	3.3 mm	3.75 mm	4.0 mm	4.5 mm	5.0 mm
Maxilla (30 implants)	4	26	1	9	12	6	2
Mandible (45 implants)	3	42	9	16	9	10	1
p	0.282[a]		0.115[a]				

[a] Chi square test.

Fig. 3. Radiographic images showing a case treated with short dental implants in the maxilla. (a) The placement of the dental implants, (b) the insertion of the definitive prosthesis, (c) 3 years of follow-up and (d) 16 years of follow-up. Arrow head indicated 8.5 mm long implants.
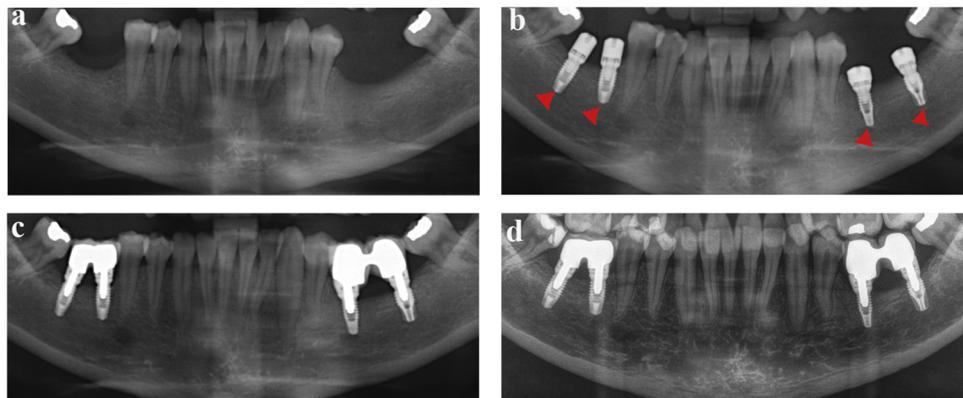

Fig. 4. Radiographic images showing a case treated with short dental implants in the mandible. (a) Before treatment, (b) placement of the dental implants, (c) the insertion of the definitive prosthesis, and (d) 16 years of follow-up. Arrow head indicated 8.5 mm long implants.

Table 3
Implant-centred outcomes grouped by the implant location (maxilla/mandible).

	Follow-up (months)		Mesial MBL (mm)	Distal MBL (mm)	Implant failures	Prosthesis failures
	Implant	Prosthesis				
Maxilla (30 implants)	182 ± 14	166 ± 29	0.52 ± 0.67	0.74 ± 0.53	0	4
Mandible (45 implants)	184 ± 14	170 ± 28	0.41 ± 70	0.40 ± 0.62	5	8
p	0.879[a]	0.559[a]	0.495[b]	0.03[b]	0.059[c]	0.120[c]

[a] Mann–Whitney U test.
[b] T test.
[c] Chi square test.

Table 4
Prosthesis-centered outcomes grouped by the implant location (maxilla/mandible).

	Antagonist		Crow-to-implant ratio		Splinting	
	Periodontal ligament	Osseointegration	Anatomical	Clinical	1 Implant	2 Implants
Maxilla (30 implants)	13	17	1.5 ± 0.3	1.6 ± 0.4	9	21
Mandible (45 implants)	18	27	1.4 ± 0.4	1.6 ± 0.4	32	13
p	0.835[a]		0.541[b]	0.901[b]	0.000[a]	

[a] Chi square test.
[b] Mann–Whitney test.

Table 5
Factors influencing the marginal bone loss.

Variables	Categories	Mesial MBL (mm)	P value	Distal MBL (mm)	P value
Sex	Male	0.33 ± 0.53	0.460[a]	0.61 ± 0.56	0.290[a]
	Female	0.50 ± 0.72		0.51 ± 0.62	
Smoking	Yes	0.34 ± 0.77	0.419[a]	0.45 ± 0.56	0.848[a]
	No	0.48 ± 0.66		0.55 ± 0.62	
Antagonist	Periodontal ligament	0.45 ± 0.72	0.304[a]	0.44 ± 0.50	0.891[a]
	Osseointegration	0.51 ± 0.65		0.61 ± 0.67	
Number of splinting implants	One implants	0.40 ± 0.64	0.355[a]	0.50 ± 0.63	0.736[a]
	Two implants	0.53 ± 0.74		0.57 ± 0.58	
Age			0.967[b]		0.083[b]
Anatomical CIR			0.534[b]		0.546[b]
Clinical CIR			0.347[b]		0.490[b]
Implant diameter			0.431[b]		0.158[b]

[a] ANOVA.
[b] Linear regression.

depressed bone level have been predominant in the posterior segments (Reich et al., 2011). Short dental implants are indicated when a deficiency of the residual alveolar height is present. For that, this study has focused on short implants placed in the posterior (premolar–molar regions) segments of the maxillae.

Short dental implants could be indicated to support fixed partial prosthesis in both maxillae. The survival of the short dental implants after a mean follow-up time of 15 years has been 93.3%. Few studies are available on the survival of short dental implants with a mean follow-up time higher than 10 years (Anitua et al., 2014b; Lops et al., 2012; Mertens et al., 2012). In a previous study, Anitua et al. have assessed 111 short implants (≤8.5 mm in length) for a mean follow-up time of 10.3 years (Anitua et al., 2014b). All the implants have been placed in the premolar–molar regions and the implant success rate has been 98.9%. In the study by Mertens et al., all the 8 mm- and 9 mm-long implants (52 implants in 14 patients) have survived the follow-up time of 10.1 years (Mertens et al., 2012). Forty two implants (15 in maxilla and 27 in mandible) have been placed in posterior regions. Lops et al. have followed 8-mm long implants (108 implants) for 13.2 years showing a survival rate of 92.3% (Lops et al., 2012). In that study, 80 short implants were placed in posterior maxilla and mandible and 4 has failed (3 in the maxilla). In the present study, there has been no significant differences in the implant survival between the maxilla and the mandible. However, all the implant failures have been in the mandible. These failures were not early failures and could be considered as biological complications (marginal bone loss >2 mm), probably due to peri-implantitis (Sailer et al., 2012).

The insertion of short dental implants in the posterior regions of both maxillae has not provoked excessive marginal bone loss after loading. This is comparable to previously published studies. In one study, the mean marginal bone loss has been 1 and 0.9 mm on the mesial and the distal aspects of the implant, respectively (Anitua et al., 2014b). There has been no significant differences in marginal bone loss between the mandible and the maxilla. Another study have measured 1.2 mm (mesial) and 1.5 mm (distal) of marginal bone loss after loading (Lops et al., 2012). The marginal bone loss in the study by Mertens has been higher in the mandible (0.37 mm) than the maxilla (0.15 mm) (Mertens et al., 2012). In the present study, more marginal bone loss has been measured in the maxilla than the mandible. Although it has not been statistically significant, more males and more smokers were found in the maxilla group. Several systematic reviews have reported that the marginal bone loss has been significantly higher in smoker than nonsmokers (Clementini et al., 2014; Chrcanovic et al., 2015b; Moraschini and Barboza, 2016; Strietzel et al., 2007). Chrcanovic et al., in a system-

atic review, have report a significantly higher marginal bone loss in men than women (Chrcanovic et al., 2015a).

The present study suffer from several limitations that include the absence of implant lengths ≤6 mm and the sample size. However, the type of the prosthesis, its retention mechanism, the implant design and the surface type were equal in the study groups. All the short implants in this study has been splinted and not immediately loaded. The measurements of marginal bone loss have been performed on a panoramic radiograph. However, the measurements were performed after 1:1 calibration of the radiograph. This would render the measurements sufficiently accurate for clinical use (Schulze et al., 2000).

5. Conclusions

Short dental implants could be indicated to support fixed partial prosthesis with a survival of 93.3% after a mean follow-up time of 15 years. The implant position (mandible/maxilla) has no influence on the implant survival although significantly more marginal bone loss has been observed in the maxilla. The insertion of short dental implants in the posterior regions of both maxillae has not provoked excessive marginal bone loss after loading. Future controlled and prospective clinical research is needed to assess the long-term outcomes according to the loading protocol.

Acknowledgments

References

Albrektsson, T., 1988. A multicenter report on osseointegrated oral implants. J. Prosthet. Dent. 60, 75–84.

Anitua, E., 1999. Plasma rich in growth factors: preliminary results of use in the preparation of future sites for implants. Int. J. Oral Maxillofac. Implants 14, 529–535.

Anitua, E., Alkhraisat, M.H., 2016. Is alveolar ridge split a risk factor for implant survival? J. Oral Maxillofac. Surg. 74, 2182–2191.

Anitua, E., Alkhraisat, M.H., Miguel-Sanchez, A., Orive, G., 2014a. Surgical correction of horizontal bone defect using the lateral maxillary wall: outcomes of a retrospective study. J. Oral Maxillofac. Surg. 72, 683–693.

Anitua, E., Alkhraisat, M.H., Orive, G., 2013a. Novel technique for the treatment of the severely atrophied posterior mandible. Int. J. Oral Maxillofac. Implants. 28, 1338–1346.

Anitua, E., Alkhraisat, M.H., Pinas, L., Orive, G., 2015. Efficacy of biologically guided implant site preparation to obtain adequate primary implant stability. Ann. Anat. 199, 9–15.

Anitua, E., Begona, L., Orive, G., 2012. Controlled ridge expansion using a two-stage split-crest technique with ultrasonic bone surgery. Implant Dent. 21, 163–170.

Anitua, E., Begona, L., Orive, G., 2013b. Clinical evaluation of split-crest technique with ultrasonic bone surgery for narrow ridge expansion: status of soft and hard tissues and implant success. Clin. Implant Dent. Relat. Res. 15, 176–187.

Anitua, E., Carda, C., Andia, I., 2007. A novel drilling procedure and subsequent bone autograft preparation: a technical note. Int. J. Oral Maxillofac. Implants 22, 138–145.

Anitua, E., Flores, J., Alkhraisat, M.H., 2017. Transcrestal sinus floor augmentation by sequential drilling and the use of plasma rich in growth factors. Int. J. Oral Maxillofac. Implants 32, e167–e173.

Anitua, E., Orive, G., Aguirre, J.J., Andia, I., 2008. Clinical outcome of immediately loaded dental implants with plasma rich in growth factors: a 5-year retrospective study. J. Periodontol. 79, 1168–1176.

Anitua, E., Pinas, L., Begona, L., Orive, G., 2014b. Long-term retrospective evaluation of short implants in the posterior areas: clinical results after 10-12 years. J. Clin. Periodontol. 41, 404–411.

Anitua, E., Tejero, R., Alkhraisat, M.H., Orive, G., 2013c. Platelet-rich plasma to improve the bio-functionality of biomaterials. BioDrugs 27, 97–111.

Atieh, M.A., Zadeh, H., Stanford, C.M., Cooper, L.F., 2012. Survival of short dental implants for treatment of posterior partial edentulism: a systematic review. Int. J. Oral Maxillofac. Implants 27, 1323–1331.

Bahat, O., 2000. Branemark system implants in the posterior maxilla: clinical study of 660 implants followed for 5 to 12 years. Int. J. Oral Maxillofac. Implants 15, 646–653.

Bechara, S., Kubilius, R., Veronesi, G., Pires, J.T., Shibli, J.A., Mangano, F.G., 2017. Short (6-mm) dental implants versus sinus floor elevation and placement of longer (>=10-mm) dental implants: a randomized controlled trial with a 3-year follow-up. Clin. Oral Implants Res. 28, 1097–1107.

Clementini, M., Rossetti, P.H., Penarrocha, D., Micarelli, C., Bonachela, W.C., Canullo, L., 2014. Systemic risk factors for peri-implant bone loss: a systematic review and meta-analysis. Int. J. Oral Maxillofac. Surg. 43, 323–334.

Chrcanovic, B.R., Albrektsson, T., Wennerberg, A., 2015a. Dental implants inserted in male versus female patients: a systematic review and meta-analysis. J. Oral Rehabil. 42, 709–722.

Chrcanovic, B.R., Albrektsson, T., Wennerberg, A., 2015b. Smoking and dental implants: a systematic review and meta-analysis. J. Dent. 43, 487–498.

Esposito, M., Cannizzaro, G., Soardi, E., Pellegrino, G., Pistilli, R., Felice, P., 2011. A 3-year post-loading report of a randomised controlled trial on the rehabilitation of posterior atrophic mandibles: short implants or longer implants in vertically augmented bone? Eur. J. Oral Implantol. 4, 301–311.

Friberg, B., Sennerby, L., Meredith, N., Lekholm, U., 1999. A comparison between cutting torque and resonance frequency measurements of maxillary implants. A 20-month clinical study. Int. J. Oral Maxillofac. Surg. 28, 297–303.

Jaffin, R.A., Berman, C.L., 1991. The excessive loss of Branemark fixtures in type IV bone: a 5-year analysis. J. Periodontol. 62, 2–4.

Khang, W., Feldman, S., Hawley, C.E., Gunsolley, J., 2001. A multi-center study comparing dual acid-etched and machined-surfaced implants in various bone qualities. J. Periodontol. 72, 1384–1390.

Lee, S.A., Lee, C.T., Fu, M.M., Elmisalati, W., Chuang, S.K., 2014. Systematic review and meta-analysis of randomized controlled trials for the management of limited vertical height in the posterior region: short implants (5 to 8 mm) vs longer implants (>8 mm) in vertically augmented sites. Int. J. Oral Maxillofac. Implants 29, 1085–1097.

Lops, D., Bressan, E., Pisoni, G., Cea, N., Corazza, B., Romeo, E., 2012. Short implants in partially edentuolous maxillae and mandibles: a 10 to 20 years retrospective evaluation. Int. J. Dent. 2012, 351793.

Mertens, C., Meyer-Baumer, A., Kappel, H., Hoffmann, J., Steveling, H.G., 2012. Use of 8-mm and 9-mm implants in atrophic alveolar ridges: 10-year results. Int. J. Oral Maxillofac. Implants 27, 1501–1508.

Molly, L., 2006. Bone density and primary stability in implant therapy. Clin. Oral Implants. Res. 17 (Suppl 2), 124–135.

Monje, A., Chan, H.L., Fu, J.H., Suarez, F., Galindo-Moreno, P., Wang, H.L., 2013. Are short dental implants (<10 mm) effective? A meta-analysis on prospective clinical trials. J. Periodontol. 84, 895–904.

Moraschini, V., Barboza, E., 2016. Success of dental implants in smokers and non-smokers: a systematic review and meta-analysis. Int. J. Oral Maxillofac. Surg. 45, 205–215.

Nisand, D., Picard, N., Rocchietta, I., 2015. Short implants compared to implants in vertically augmented bone: a systematic review. Clin. Oral Implants Res. 26 (Suppl. 11), 170–179.

Pagliani, L., Sennerby, L., Petersson, A., Verrocchi, D., Volpe, S., Andersson, P., 2013. The relationship between resonance frequency analysis (RFA) and lateral displacement of dental implants: an in vitro study. J. Oral Rehabil. 40, 221–227.

Reich, K.M., Huber, C.D., Lippnig, W.R., Ulm, C., Watzek, G., Tangl, S., 2011. Atrophy of the residual alveolar ridge following tooth loss in an historical population. Oral Dis. 17, 33–44.

Sailer, I., Muhlemann, S., Zwahlen, M., Hammerle, C.H., Schneider, D., 2012. Cemented and screw-retained implant reconstructions: a systematic review of the survival and complication rates. Clin. Oral Implants Res. 23 (Suppl. 6), 163–201.

Schulze, R., Krummenauer, F., Schalldach, F., d'Hoedt, B., 2000. Precision and accuracy of measurements in digital panoramic radiography. Dentomaxillofac. Radiol. 29, 52–56.

Sennerby, L., Roos, J., 1998. Surgical determinants of clinical success of osseointegrated oral implants: a review of the literature. Int. J. Prosthodont. 11, 408–420.

Shapurian, T., Damoulis, P.D., Reiser, G.M., Griffin, T.J., Rand, W.M., 2006. Quantitative evaluation of bone density using the Hounsfield index. Int. J. Oral Maxillofac. Implants 21, 290–297.

Srinivasan, M., Vazquez, L., Rieder, P., Moraguez, O., Bernard, J.P., Belser, U.C., 2012. Efficacy and predictability of short dental implants (<8 mm): a critical appraisal of the recent literature. Int. J. Oral Maxillofac. Implants 27, 1429–1437.

Srinivasan, M., Vazquez, L., Rieder, P., Moraguez, O., Bernard, J.P., Belser, U.C., 2014. Survival rates of short (6 mm) micro-rough surface implants: a review of literature and meta-analysis. Clin. Oral Implants Res. 25, 539–545.

Strietzel, F.P., Reichart, P.A., Kale, A., Kulkarni, M., Wegner, B., Kuchler, I., 2007. Smoking interferes with the prognosis of dental implant treatment: a systematic review and meta-analysis. J. Clin. Periodontol. 34, 523–544.

Tabassum, A., Meijer, G.J., Walboomers, X.F., Jansen, J.A., 2011. Biological limits of the undersized surgical technique: a study in goats. Clin. Oral Implants Res. 22, 129–134.

Telleman, G., Raghoebar, G.M., Vissink, A., den Hartog, L., Huddleston Slater, J.J., Meijer, H.J., 2011. A systematic review of the prognosis of short (<10 mm) dental implants placed in the partially edentulous patient. J. Clin. Periodontol. 38, 667–676.

Thoma, D.S., Zeltner, M., Husler, J., Hammerle, C.H., Jung, R.E., 2015. EAO Supplement Working Group 4 — EAO CC 2015 Short implants versus sinus lifting with longer implants to restore the posterior maxilla: a systematic review. Clin. Oral Implants Res. 26 (Suppl. 11), 154–169.

Truhlar, R.S., Orenstein, I.H., Morris, H.F., Ochi, S., 1997. Distribution of bone quality in patients receiving endosseous dental implants. J. Oral. Maxillofac. Surg. 55, 38–45.

von Elm, E., Altman, D.G., Egger, M., Pocock, S.J., Gotzsche, P.C., Vandenbroucke, J.P., Initiative, S., 2007. The strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. Lancet 370, 1453–1457.