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Fixed prosthetic restorations with sandblasted surface implants: long-term results of a clinical study.

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Abstract: Sandblasting is a standard procedure used for treating the implant surface to enhance the osseointegration with known clinical success. This retrospective cohort study aimed to evaluate the long-term clinical outcomes of sandblasted implants. Two hundred fifty-five MG Osseous screw implants were placed in 81 patients using a two-stage surgical technique and conventional loading protocol (three-months). Implant and prosthetic clinical findings were evaluated during a 15-years follow-up. Four implants were lost during the healing period, and 103 fixed prostheses were placed over the 251 implants left: 58 single-crowns, 31 partially fixed bridges, and 14 full-arch fixed restorations. Fourteen implants were lost during the follow-up period. Clinical results indicated an implant survival rate of 92.9%. 11.8% of implants showed peri-implantitis as the primary biological complication. The mean marginal bone loss was 1.76 ± 0.38 mm, ranging from 0.9 to 2.8 mm. The most frequent complication was mechanical prosthodontic complications (20.9%). Sandblasted surface implants inserted in both maxillary and mandibular areas produce favorable outcomes and stable tissue conditions when a delayed loading protocol is followed.

Keywords: dental implants; long-term evaluation; osseointegration; prosthesis and implants; sandblasted surface

1. Introduction

Implant therapy is a widely used treatment in patients suffering from dental loss. Implant-supported prostheses are often used in the rehabilitation of partially or totally edentulous patients [1,2]. The clinical success of dental implant therapy is directly related to a successful osseointegration process, which is the consequence of a series of biological processes that occur after the surgical insertion of a dental implant into the alveolar bone [3].

Nowadays, with the improvement of new coating materials and new surface treatments, the osseointegration process is highly successful, and it is directly related to the microscopic connection between the implant surface and the host bone tissue [3,4]. The dental implant surface features, such as roughness or topography, and the chemical composition can cause different biological responses [5]. These characteristics can be influenced by the surface treatment received by the implant and may lead to an increase in the contact area between the implant and the surrounding bone (BIC), improving the biocompatibility and osteoinductive or osteoconductive properties and enhancing the osseointegration [6].

After introducing the mechanized implants, different surface modifications have been developed and applied over the implant surface by various procedures. These techniques can be additives, such as titanium plasma spray or coating with different elements, can be subtractive, such as sandblasting or acid-etching, or a combination of two or more of the mentioned techniques [7,8]. Sandblasting is a standard procedure used for treating the implant surface and is performed by projecting particles of alumina, hydroxyapatite, silica, or titanium dioxide. The effect produced on the implant surface is related to the type and size of the particle impacted, the pressure and temperature [9].

The advancement of technology in the treatment of implant surfaces has improved the level of osseointegration and the predictability of the clinical outcomes. Cellular responses, as of adherence, migration, and proliferation, can be mediated by sandblasted surfaces, which indicates a strong relationship between surface roughness and cellular attachment, especially with osteoblastic activity [10-11]. Also, animal studies demonstrated that sandblasted surface implants showed a higher level of osseointegration by reverse torque testing and histological evaluation during the bone healing and bone-implant interface [12-15].

Some studies have reported the clinical outcomes of partially and totally edentulous patients treated with sandblasted implants. Mertens et al. [16] evaluated the long-term survival rate of maxillary edentulous patients rehabilitated with implant-supported fixed prostheses in an 11-years prospective study. Seventeen patients received six to eight sandblasted implants. After the follow-up, fifteen patients treated with 94 implants were reevaluated. Three implants were lost in one patient. One prosthesis had to be removed. The mean marginal bone loss was 0.88 mm. The implant survival rate was 96.8% [16]. Al-Nawas et al. [17] conducted a 10-years retrospective study evaluating the clinical outcomes of 516 implants blasted with titanium dioxide particles (TiO₂) placed in 108 patients. Most of the implants were placed in the fully edentulous mandible (74%) and 15% in partial edentulism. Twenty-three implants were placed in post-irradiated patients and 64 implants in patients who were irradiated after receiving the implant treatment. Fifty-three implants had to be removed in 26 patients. Twenty-one implants were lost before loading, 18 implants were lost because of peri-implantitis, and nine implants broke. The 10-year implant survival rate was 87.7% [17].

This retrospective cohort study aimed to evaluate the long-term clinical outcomes of fixed prosthetic restorations over sandblasted implants using a two-stage surgical technique and conventional loading protocol.

Our null hypothesis is that the use of sandblasted (RBM) implants to support different types of fixed prosthetic restorations results in successful treatment concerning implant and prosthetic survival rate.

2. Materials and Methods

2.1. Sample description

This retrospective cohort study included patients with partial or total edentulism who required fixed prosthodontic restorations with dental implants. All surgeries and prosthetic procedures were developed in the School of Dentistry of the Seville University, Spain, from July 2004 to January 2006. The study was conducted according to the principles outlined in the Declaration of Helsinki [18] on clinical research involving humans. All patients signed a double informed written consent for implant placement and been part of the clinical study. The ethical committee of the University of Seville approved the study.

2.1.1. Demographic distribution

81 patients were included in the study, being 38 males and 43 females with ages ranged from 18 to 69 years old (mean age 44.6 yrs.)

2.1.2. Inclusion and exclusion criteria

The inclusion criteria were being older than 18 years old, good systemic health status (American Society of Anesthesiologists (ASA) I or II) or controlled systemic diseases, and no need for bone regeneration techniques.

The exclusion criteria were the presence of uncontrolled chronic systemic disease (diabetes, cardiovascular disease), smoking more than ten cigarettes per day, coagulation disorders, alcohol or drug abuse, and the use of any medication or health alteration that contraindicates implant treatment. The presence of a previous history of periodontal disease was not an exclusion criteria.

2.2. Diagnosis and treatment plan

Treatment planning included diagnostic casts to evaluate intermaxillary relations, clinical photographs, and panoramic radiographs (Figure 1). Most of the patients were evaluated with computerized tomography when required.

2.3. Surgery Protocol

All patients received prophylactic antibiotic therapy one hour before surgery (500 mg amoxicillin and 125 mg clavulanic acid) and continued taken the antibiotic plus 600 mg ibuprofen postoperatively, one capsule every eight hours for seven days. The use of chlorhexidine mouthwash was recommended twice-daily for one month. All patients were treated under local anesthesia with articaine with adrenaline.

A mucosal flap approach was made, and the implants were inserted in the selected place following a prosthodontic guided plan. The drilling protocol was the one recommended by the manufacturer (MozoGrau®, Valladolid, Spain), and the minimum insertion torque was 35 Ncm. All implants were inserted delayed, in a healed bone with a two-stage surgical technique. No bone or soft tissue graft was applied.

Second-stage surgery was performed three months after implant placement, and healing or prosthetic abutments were placed. Functional loading was completed when the insertion torque achieved at least 35 Ncm. Definitive prostheses were placed approximately three weeks after second-stage surgery (Figure 2).

2.4. Follow-up

Follow-up visits were scheduled at 3- and 6-months after prosthesis placement and every year during a mean period of 188.2 months (ranged between 176 and 193 months). The success criteria were established as implant stability and the absence of radiolucency around the implant, mucosal suppuration, or pain. Marginal bone loss was determined by an intraoral digital radiograph taken perpendicular to the long axis of the implant. The control procedures were performed blindly for the researchers.

2.5. Implant Characteristics

MG Osseous screw implants (MozoGrau®, Valladolid, Spain) were used for all patients, with resorbable blast media (RBM) surface (Figure 3) and external hexagonal connection.

2.6 Statistical Evaluation.

The software SPSS 18.0 (SPSS Inc., Chicago, IL, USA) was used for data evaluation. Descriptive statistics were used to describe the results as mean $\pm$ standard deviation. Chi-squared test and two-way ANOVA with Tukey's PostHoc test were used for statistical analysis establishing the level of significance with a $p < 0.05$.

3. Results

Two hundred fifty-five implants were placed in 81 partially and totally edentulous patients, 38 males, and 43 females. No significant statistical differences were found related to sex and age (chi-square test, $p = 0.104$). Five patients (6.2%) were totally bimaxillary edentulous, four patients (4.9%) totally maxillary edentulous, and 72 (88.9%) patients were partially edentulous.

Fourteen patients (17.3%) had a previous history of periodontitis, 27 patients (32.5%) were smokers, and 85.7% of patients with a previous history of periodontitis were also smokers ($n = 12$) (Table 1).

Of the 255 implants placed, 37 (14.5%) had a diameter of 3.4 mm., 108 (42.4%) had a diameter of 3.75, and 110 (43.1%) had a diameter of 4.25 mm. 60 (23.5%) implants were 10 mm. in length, 8 (3.1%) were 11.5 mm., and 187 (73.4%) were 13 mm. 148 (58%) implants were inserted in the maxilla, and 107 (42%) implants were placed in the mandible. 83 (32.5%) implants were placed in the anterior area and 172 (67.5%) implants in the posterior area. Four implants (1.6%) were lost during the healing period before loading due to a lack of osseointegration (Table 2).

Regarding the prostheses designed, a total of 103 fixed prostheses were placed in the 81 patients over the 251 remaining implants after the healing period (three months). The prostheses were distributed in the following way (Table 3). In essence, 58 single crowns were placed in 44 patients, 31 partially fixed bridges supported over 2 to 4 implants were placed in 28 patients, over a total of 79 implants, 14 full-arch fixed restorations were placed in 9 patients (5 patients were full-bimaxillary edentulous, and 4 patients were full-maxillary edentulous), over a total of 114 implants.

During the follow-up period, 29 implants (11.3%) were associated with peri-implantitis being 14 of them lost. These implants were classified as delayed failures (Figure 4). The peri-implantitis was more frequent, showing statistically significant differences in those patients with a previous history of periodontitis (68.9%) (Chi-square test, $p = 0.0438$). The peri-implantitis was also more frequent in smoking patients (62.9%) with statistically significant differences (Chi-square test, $p = 0.0356$). The cumulative survival rate for all implants was 92.9%.

The mean marginal bone loss was 1.76 mm. (S.D. 0.38 mm.), ranging from 0.9 to 2.8 mm during the time interval from the implant insertion to the 15-year follow-up evaluation. In patients with a previous history of periodontitis, this marginal bone loss was 1.80 ± 0.44 , while in patients without periodontitis was 1.73 ± 0.40 . These differences did not show statistical significance (ANOVA; $p = 0.3347$). Regarding the smoking habit, the marginal bone loss was 1.84 ± 0.46 for smoking patients and 1.73 ± 0.42 for non-smoking patients, with no statistical differences (ANOVA; $p = 0.3057$).

Seventeen patients (20.9%) showed some kind of mechanical prosthodontic complications (ceramic chipping, loss/fracture of the prosthetic screw) over 38 implants. Two fixed partial bridges and seven single crowns had to be renewed (Table 4).

4. Discussion

The present retrospective study reports on the survival rate of dental implants with a sandblasted surface in partially and totally edentulous patients. Our results yielded an implant survival rate of 92.9% in delayed loaded implants. A total of 81 patients received sandblasted implants in the School of Dentistry, University of Seville, and had a 15-years follow-up. Only patients with good quality and quantity of bone were selected to be part of this study, so no grafting materials or barrier membranes were used. The clinical protocol included a submerged surgical technique, and loading was performed after three months of healing.

The implant surface characteristics play an essential role in the osseointegration process. This process is related to the interaction between the implant surface and the host's bone tissue [4,5]. Nowadays, most of the implants are moderately rough, and their surfaces have been treated by sandblasting, acid-etching, anodization, or other techniques. Long-term studies have reported excellent outcomes on treatments performed with rough implant surfaces [19,20].

Sandblasting is one of the most frequent surface treatments to enhance the osseointegration, and many dental implant systems widely use it [5, 13, 21]. During this procedure, small particles with different sizes of alumina or titanium oxide are projected onto the implant surface, producing changes in its topography and creating depressions, valleys, and pits. The size of the particles usually varies between 25 and 250 μm , and the roughness created on sandblasted surfaces usually has a S_a between 1-2 μm [9, 11, 13, 21].

Some experimental *in vitro* studies have reported that a rough surface promotes the attachment, proliferation, and differentiation of osteoblasts [11]. Moreover, human mesenchymal stem cells are essential to the biologic process of osseointegration that participates in wound healing and differentiation to osteoblasts [22]. Another *in vitro* study evaluated the behavior of human mesenchymal stem cells on zirconia and commercially pure titanium with different surface topographies (micro-polished, sandblasted, sandblasted + acid-etched) [23]. The culture cellular proliferation ability at 1-, 3- and 7-days was significantly higher in sandblasted zirconia surface and sandblasted titanium surface at 7-days. Alkaline phosphatase activity was higher on sandblasted surfaces than on the rest of the surfaces. Also, the gene expression analysis reported being significantly higher in sandblasted surfaces at 14-days. These results showed that sandblasted surfaces improve the proliferation and osteogenesis differentiation of human mesenchymal stem cells [23].

Pontes et al. [24] conducted an *in vivo* study with the aim of evaluating the influence of the implant position onto the bone in the bone-implant contact (BIC), comparing both conventional and immediate loading in sandblasted implants. Thirty-six sandblasted implants were inserted in the edentulous mandible of six dogs. Three implants were placed in each hemimandible, in crestal and subcrestally position, and submitted to an immediate loading protocol (24 hours) or conventional loading protocol (four months). Ninety days after loading, the histomorphometric analysis showed no statistical differences between the BIC values from immediate to conventional loading, suggesting that the different implant position and the loading protocol does not affect to the BIC value in sandblasted surfaces [24].

Also, the macroscopic design is crucial for achieving primary stability and develop a proper osseointegration process. In fact, in the present study, the MG Osseous screw implants have a macroscopic design ideal for a two-stage surgical protocol (non-submerge technique) and a hexagonal external connection. A clinical study showed successful results with the same type of implants inserted in the anterior area of the edentulous mandible [25]. This study evaluated primary stability by resonance frequency analysis expressed in terms of implant stability quotient (ISQ) on the day of surgery (primary stability) and at the time of the healing abutment insertion,

three months after placement (secondary stability) in a conventional two-stage surgical procedure. The implant survival rate was 97.1%. The mean ISQ value for implants with a diameter of 3.75 and 4.25 mm was 78.4 ± 5.46 and 80.83 ± 5.35 respectively at the time of placement, and 76.68 ± 4.34 and 78.22 ± 6.87 respectively, at the second surgical stage [25].

In the present study, the bone healing process was successful for a delayed loading protocol in all the fixed prosthesis types. After the healing period (three months), second-stage surgery was developed. All patients received abutments mounted directly over the external hexagonal connection, and the definite prostheses were delivered three weeks after second-stage surgery. 100% of the prostheses were fixed (single crown, fixed bridge, or full-arch rehabilitation). The clinical findings in this long-term follow-up study suggest that sandblasted surface implants inserted in both maxillary and mandibular areas produce favorable outcomes and stable tissue conditions when a delayed loading protocol is followed.

Similar results were reported in several studies that evaluated the clinical success with sandblasted implants [19, 26-28]. A recent meta-analysis reveals that sandblasted surfaces have better behavior than mechanized surfaces in healthy subjects [26]. In this meta-analysis, sixteen randomized controlled trial studies were evaluated, with a total of 722 implants (362 sandblasted and 360 mechanized). The results showed that the risk for failure was 74-80% lower for sandblasted implants when compared to mechanized surfaces after 1 to 6 years [26]. A systematic review reported survival rates of implants with different surfaces (turned, plasma-sprayed, sandblasted, acid-etched, anodized, sandblasted, and acid-etched) with a 10-years follow-up or longer [19]. Sixty-two clinical studies were included in this review showing a survival rate between 82.9% to 100%. Nine studies were focused on sandblasted surfaces and included the evaluation of 1803 implants with a cumulative survival rate of 89.7% to 95% [19].

Most of the authors have evaluated the long-term follow-up for sandblasted implants restored with fixed and removable prosthesis. Our study has addressed the evaluation only for fixed prosthesis, resulting in a slightly higher survival rate [27].

These encouraging outcomes are confirmed by other authors who also evaluated sandblasted surfaces [28,29]. A prospective study evaluated the cumulative survival rate of submerged sandblasted implants after ten years of prosthetic loading [28]. One hundred ninety-nine implants were placed in 36 patients: 16 maxillary edentulous patients and 20 mandibular edentulous patients. Ninety-one implants were placed in the upper jaw, and 108 implants were inserted in the lower jaw. Fixed prostheses were delivered after a healing period of 3 to 6 months. Six implants failed during the first year of follow-up (three in the mandible and three in the maxilla), giving a cumulative survival rate of 96.9% and concluding that rehabilitations with titanium dioxide-blasted implants are indicated for treating edentulous patients [28].

The early or delayed placement after tooth extraction of single sandblasted implants was evaluated in a prospective study in the anterior maxilla [29]. Twenty consecutive patients were treated with a single tooth replacement in the aesthetic area of the anterior maxilla. Ten implants were placed following an early protocol (four weeks after extraction), and another ten implants were inserted following a conventional delayed protocol (twelve weeks after extraction). The cumulative implant survival rate was 100% after ten years. Two implant-supported crowns had to be renewed because of ceramic fracture. The survival rates were similar between the early and delayed protocols [29].

Marginal bone loss is considered an essential biological and clinical parameter for long-term implant success. The loss of the marginal bone can be affected by several factors, such as the implant surface, where the surface roughness can lead to an increase of the interlocking between bone and titanium. Another factor that may affect bone loss is the primary closing and healing of the soft tissue around the implant [30]. Czumbel et al. [26] developed a systematic review regarding marginal bone loss in mechanized and sandblasted implants and did not found significant differences between both surfaces. However, Åstrand et al. [31] found a higher marginal bone loss in the lapse of time between the implant placement and the prosthetic

connection in mechanized implants when compared with sandblasted implants. Our results showed a marginal bone loss of 1.76 ± 0.38 mm, ranging from 0.9 mm to 2.8 mm after a 15-years follow-up. This bone loss was higher than the results described in other studies [16, 17, 19, 28]. This high bone loss might be explained by the fact that many patients included in our study were smokers (32.5%) and showed a previous periodontal disease history (17.4%). Some studies have already confirmed a trend to show a higher marginal bone loss in smoker patients treated with sandblasted implants [28].

The prosthodontic complications were frequent in our study. Seventeen patients (20.9%) showed some kind of technical complication: ceramic chipping, loss, or fracture of the prosthetic screw. Two fixed bridges, and seven single crowns had to be restored or renewed, resulting in a prosthodontic survival rate of 91.3%. Technical complications, as porcelain fractures or loss of the prosthetic screw, are relatively common in other studies with a long follow-up period [17, 28, 29]. These complications raised to 6.7% in the study reported by Mertens et al. [16] about patients with full-arch maxillary restorations. A recent study showed a high prevalence of technical complications in 47.7% of patients restored with fixed full-arch implant-supported prostheses associated with implant diameter, abutment/implant connection and retention system [32].

The most important complication in our study in biological terms was peri-implantitis. During the follow-up period, 29 implants (11.8%) were associated with this disease, and 14 implants were finally lost. It is widely known that the prevalence of peri-implantitis is elevated. Smoking and a previous history of periodontal disease are identified as risk factors for peri-implantitis [33,34]. A prospective analysis aimed to determine marginal bone loss and the prevalence of peri-implantitis in patients treated with sandblasted implants [35]. One hundred subjects with a total of 291 implants were evaluated during a 10-years follow-up. 12% of the patients and 5% of the implants showed signs of peri-implantitis. 13 implants in 7 patients exhibited progressive bone loss and had to be removed. The implant survival rate was 96% [34]. Degidi et al. [36] also developed a 10-years evaluation of 193 implants. They found a total of 35 implants (18.13%) with signs of inflammation, reporting 26 patients (32.5%) with signs of mucositis associated with inflammation and bleeding after probing. Sixteen implants (8.29%) placed in 14 patients (17.5%) ended in peri-implantitis.

5. Conclusions

Within the limits of the present long-term follow-up clinical study, we can conclude that the use of sandblasted (RBM) implants to support different types of fixed prosthetic restorations results in successful treatment concerning implant and prosthetic survival rates. The marginal bone loss was high, which was an expected fact, considering the high number of smoking patients participating in this study. The use of sandblasted implants constitutes a predictable option when strict selection criteria and clinical planning are applied.

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Figure Legends:

Figure 1. Panoramic radiographs were taken (a) before treatment as part of the diagnosis and treatment plan and (b) after implant placement and prostheses delivery during the 15-years follow-up.

Figure 2. Clinical protocol. (a) implant placement with mucosal flap approach, (b) impression coping at three months post-placement, (c) final single crown delivery.

Figure 3. (a) Macroscopic design and scanning electron microscope (SEM) images of the sandblasted (RBM) surface (MozoGrau®, Valladolid, Spain), at a magnification of (b) x1000 and (c) x5000.

Figure 4. Long-term biological complications. Intraoral radiograph on the right upper central incisor with marginal bone loss and peri-implantitis.

Tables:

Table 1. Description of the sample distribution, according to the following parameters: type of edentulism, previous history of periodontitis, and smoke habit.

Patient Description n=81 (100%)		
Type of Edentulism	Totally n=9 (11.2%)	Partially n=72 (88.9%)
Periodontitis History	Yes n=14 (17.3%)	No n=67 (82.7%)
Smoke Habits	Smoker n=27 (33.3%)	Nonsmoker n=54 (66.7%)
85.7% of patients with a previous history of periodontitis were also smokers (n=12)		

Table 2. Distribution of the implant characteristics: diameter, length, location, and area of placement, and preloading percentage of failure/success.

Implant Description			n=255 (100%)
Diameter	3.4 mm	3.75 mm	4.25 mm
	37 (14.5%)	108 (42.4%)	110 (43.1%)
Length	10 mm	11.5 mm	13 mm
	60 (23.5%)	8 (3.1%)	187 (73.4%)
Location	Maxilla	Mandible	
	148 (58%)	107 (42%)	
Area	Anterior	Posterior	
	83 (32.5%)	172 (67.5%)	
Percentage of Failure/Success	Failure preloading	Success preloading	
	4 (1.6%)	251 (98.4%)	

Table 3. Description of the prosthesis type distribution between the total number of patients and implants used to support them.

Prosthesis Type	Patients n=81 (100%)	Implants n=251 (100%)
Single crown	44 (54.3%)	58 (23.1%)
Fixed bridge	28 (34.6%)	79 (31.5%)
Full-arch fixed	9 (11.1%)	114 (45.4%)

Table 4. Description of the complications presented in the implants during the 15-year follow-up.

Complication Type	+	-
Early Implant Loss	4 implants (1.6%)	251 implants (98.4%)
Delayed Implant Loss	14 implants (5.5%)	237 implants (92.9%)
Total Implant Loss	18 implants (6.5%)	237 implants (92.9%)
Peri-implantitis	29 implants (11.8%)	222 implants (88.2%)
Technical complications	38 implants (14.9%)	213 implants (85.1%)
Mean marginal bone loss: 1.76 mm (S.D. 0.38 mm.)		

Figures

Figure 1

Panoramic radiographs were taken (a) before treatment as part of the diagnosis and treatment plan and (b) after implant placement and prostheses delivery during the 15-years follow-up.

Figure 2

Clinical protocol. (a) implant placement with mucosal flap approach, (b) impression coping at three months post-placement, (c) final single crown delivery.

Figure 3

(a) Macroscopic design and scanning electron microscope (SEM) images of the sandblasted (RBM) surface (MozoGrau®, Valladolid, Spain), at a magnification of (b) x1000 and (c) x5000.

Figure 4

Long-term biological complications. Intraoral radiograph on the right upper central incisor with marginal bone loss and peri-implantitis.