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Changes in resonance frequency analysis assessed by Osstell mentor during osseointegration: comparison between immediately loaded implants and control implants without load

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ABSTRACT

Aim The aim of this prospective clinical study was to evaluate the changes in resonance frequency analysis (RFA), assessed by Osstell Mentor, obtaining information on the implant stability quotient (ISQ) during implants tissue integration for immediately loaded and non-loaded control implants.
Materials and methods A total of 40 implants, 20 implants with no immediate loading (control) and 20 immediately loaded implants (test), were placed in 15 patients. ISQ implants was evaluated at baseline and at 6 and 8 weeks. Provisional crowns were removed at 8 weeks, when the definitive restoration was placed. Data of control and test implants and maxillary and mandibular areas were statistically compared.
Results At 8 weeks, all implants were integrated and there were no major postoperative complications. A statistically significant difference was found only at baseline between test and control maxillary implants ($p=0.009$) but not at 6 or 8 weeks ($p>0.05$).
Conclusion Immediate loading procedures may be applied with primary stability ISQ values >60 and inserted with a force of ≥30 N. The Osstell Mentor RFA may offer an objective method to determine when implant stability is adequate for immediate loading.

KEYWORDS Dental implants; Immediate loading, ISQ, RFA.

INTRODUCTION

Single-stage surgery with immediate loading has proven to be a predictable procedure to restore edentulous areas (1-3). However, although widely reported in the mandible, there are few studies on its effectiveness in the maxilla (molars and premolars) (4), where this approach has been contraindicated under certain circumstances (5). Innovations in implant design, such as the development of new surfaces, have facilitated immediate loading. Experimental studies have demonstrated that implants with modified surfaces (sandblasted, large grit, acid etched) have greater bone-implant contact and resistance to lateral forces in comparison to those with machined surfaces (6, 7). The indication for immediate loading generally depends on the subjective evaluation of the primary stability of the implant and its changes over time.
The assessment of primary stability is frequently based on the resistance offered by tissues or on the torsion force required for the implant insertion, while any variations have conventionally been evaluated by percussion test with mirror handle or by counterclockwise torsion test (8). Resonance frequency analysis (RFA) has been proposed as a non-invasive and non-destructive means to measure implant integration and detect stability changes over time (9). This approach has been used to determine changes in the bone-implant interface

and to assess the relationship with surrounding tissues (10, 11). It has also been applied to determine whether implants are sufficiently stable for the final restoration (12) and to identify "risk implants" (13). Two RFA systems are currently available: an electrical device in direct contact with the smart peg and a magnetic one that takes measurements at a distance of a few millimeters. Osstell Mentor (Osstell AB, Göteborg, Sweden) fourth generation magnetic models formed by a transducer and a smart peg with a magnet in the part screwed into the implant. The magnet is activated for 1 ms by a magnetic pulse from the transducer, producing free vibration of the smart peg and the consequent induction of a voltage in the transducer that represents the RFA measurement signal. The values obtained are quantified in implant stability quotients (ISQs), and the clinical significance of scores is defined by the manufacturer as follows: ISQ value <60, high risk of failure; ISQ value=60-90, optimal integration; and ISQ value>90, bone necrosis (14).

The objective of this study was to assess implant stability by means of a fourth-generation RFA device, and to compare ISQ values between immediately loaded and non-loaded implants in the same patient, same area and same bone type at different time points.

MATERIAL AND METHODS

Study population

The study sample was randomly selected among patients attending for implant treatment at the Periodontics and Implants Master Clinic of the School of Dentistry of the University of Granada, Granada (Spain). Sixty-seven patients were initially examined and only 15 (10 males and 5 females) with age ranging 40 to 65 years met the inclusion criteria. The perido of the study was from January to March 2013. The study was approved by the Ethics Committee of the University of Granada, Granada (Spain) and all the patients signed an informed consent. Inclusion criteria were as follows: stable occlusion; implant sites where extractions were performed more than one year ago; need of implants in the same quadrant and region of the arch; good systemic and oral health, bone volume adequate to insert implants with diameter of 4 mm and length of ≥8 mm; similar bone quality in the treatment sites; at least 30N of torque at the implant placement. Exclusion criteria were: any disease that could affect the implant treatment; smoking habit; drug treatments that could affect implant treatment and radiographic presence of bone defects.

Surgical protocol

A total of 40 dental implants (Essential Cone® (EC), Klockner® Implant System), 20 implants with no immediate loading (control) and 20 immediately loaded implants (test), were inserted. Implants presented a sandblasted and acid-etched surface. In each patient, implants were placed in the same quadrant and region of the arch (Table 1).

Implants were immediately loaded or no immediately loaded according to a randomized procedure established by www.randomization.com which automatically generated random numbers and assigned implants to control or group test. This online program uses a JavaScript random number generator to produce customized sets of random numbers, thus guaranteeing that participants (implants) are randomly assigned to each group (control or test). Crestal incision was made to elevate a full-thickness flap. The implant bed was drilled at 800-1200 rpm depending on the bone consistency, strictly following the protocol recommended by the manufacturer. Implant insertion was first conducted manually and then, after stabilization, with at least 30N calibrated dynamometric wrench. It was obtained in all cases by infra-drilling of the implant bed. All patients received written information on postoperative care and medication (1 g amoxicillin every 8 h for 4 days, 600 mg ibuprofen for 3-7 days, and 0.12% chlorhexidine mouthrinse every 12 h). Sutures were removed after 7 days and patients were examined at 6 and 8 weeks.

RFA assessment

After insertion, dental implants baseline stability was assessed using a fourth-generation RFA device (Osstell Mentor®; Osstell AB, Göteborg, Sweden), recording the implant stability quotients (ISQs). The implants with ISQ values within the range established by the manufacturer (60-90) were immediately loaded, while the non-loaded implants (control) were closed using the closing screw of the implant system. The area was then sutured to ensure a stable closing of the area. Stability of the implants was also determined at 6 and 8 weeks after their placement. Implant stability was always assessed before withdrawing the crown and/or the closing screw

POSITION	11	14	15	16	22	24	25	26	35	36	37	46	44	47	TOTAL
Test	1	3	1			2	3			4		5		1	20
Control			1	3	1		2	3	1	1	2	2	1	3	20
Length (mm	10	10	10	10	10	10	10	10	10	10	8	10	10	10	

TABLE 1 Distribution, number and length of the implants inserted

and directing the transducer signal in a bucco-lingual or bucco-palatal direction.

Immediate loading procedure

Provisional crowns were directly prepared in the mouth. After inserting implants and suturing the area, an Octacone® 12° (Klockner® Implant System) taper connection was screwed in place. An octagonal titanium coping was then placed to avoid rotation of the provisional crown, which was a preformed acetate crown (3M ESPE®) filled with self-curing resin and perforated in the occlusal area for the fixing screw. After polishing and reshaping of the gingival margin of the crown, it was inserted in the mouth, applying a 10N torsion force to the fixing screw, avoiding damage and improving tissue adaptation. Crowns were placed in occlusion, releasing lateral contacts. All implants supported individual crowns, implants were not splinted in any case. Provisional crowns were removed at 6 weeks for RFA measurements and were maintained until 8 weeks, when, after X-ray control, they were lastly removed for the final RFA measurement. The definitive crowns were then placed for the final restoration.

Statistical analysis

All statistical analyses were performed using SPSS software v 20.0 (SPSS Inc., New York, NY, USA). Mean (±standard deviation) implant RFA values (ISQ units) were calculated for test and control groups and for maxilla and mandible. Student's t test was used because, despite differences in variances, samples had always the same size and the distribution was approximately normal. To compare between groups and between maxillary and mandibular areas $p<0.05$ was considered significant.

RESULTS

Clinically, there were no major postoperative complications. Treated areas showed no alterations, and good wound-healing was observed 7 days post-surgery. There were no statistically significant differences between mean ages and groups ($p>0.05$). Table 2 shows ISQ mean values and standard deviation (SD) in test and control implants at baseline, 6 and 8 weeks. At baseline, maxillary implants showed higher ISQ values, however, they tend to decrease at 6 and 8 weeks. On the contrary, mandibular implants showed lower ISQ values at baseline; this values tend to increase at 6 and 8 weeks (Table 2).
P values between ISQ values for all implants localizations are shown in Table 3. A statistically significant difference was found at baseline in testvs control maxillary implants ($p=0.009$) but not at 6 or 8 weeks ($p>0.05$).
Control, non-loaded implants, in both maxilla and mandible showed a tendency to an increase in ISQ values, with no statistically significant differences ($p>0.05$). Test, immediately loaded implants presented a tendency for initial ISQ values to decrease from loading to 6 weeks, with stabilization at 8 weeks and even the beginning of a slight recovery was observed (Fig. 1). In the maxilla, test implants showed a decrease in ISQ values, whilst in the control implants an increase was found between

		MEAN ISQ BASELINE	MEAN ISQ 6 WEEKS	MEAN ISQ 8 WEEKS
TEST IMPLANTS	TOTAL	66.75 (SD 9.503)	65.35 (SD 6.752)	65.80 (SD 5.625)
	MAXILLARY	70.90 (SD 7.430)	66.60 (SD 5.232)	65.80 (SD 4.686)
	MANDIBULAR	62.60 (SD 9.857)	64.10 (SD 7.767)	65.80 (SD 6.97)
CONTROL IMPLANTS	TOTAL	58.95 (SD 9.583)	62.60 (SD 6.443)	64.95 (SD 5.165)
	MAXILLARY	60.20 (SD 8.753)	63.10 (SD 5.646)	64.50 (SD 4.686)
	MANDIBULAR	57.70 (SD10.667)	62.10 (SD 7.430)	65.40 (SD 6.603)

TABLE 2 Mean and standard deviation (SD) ISQ values in test implants and control implants at baseline, 6 and 8 weeks.

IMPLANTS LOCALIZATION	BASELINE (P)	6 WEEKS (P)	8 WEEKS (P)
Total maxillary/ mandibular	0.095	0.407	0.794
Test maxillary /control maxillary	0.009*	0.168	0.492
Test mandibular /control mandibular	0.300	0.564	0.894
Test maxillary /Test mandibularr	0.049*	0.411	1.000
Control maxillary /control mandibular	0.574	0.739	0.709

TABLE 3 P values between ISQ values for all implants localizations, at baseline, 6 and 8 weeks. * ($p<0.05$ was established as statistical significant difference)

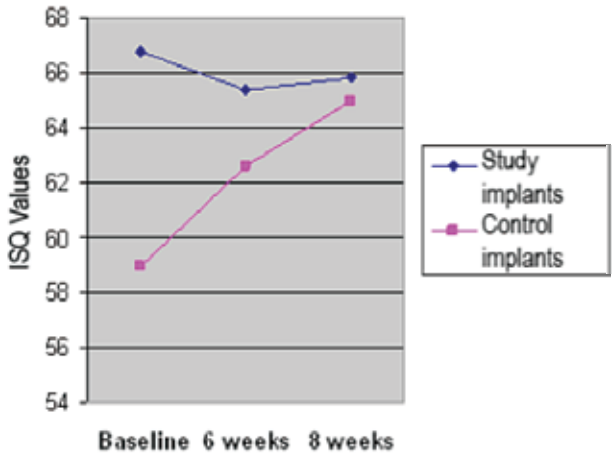

FIG. 1 Comparison of ISQ values between study and control implants.

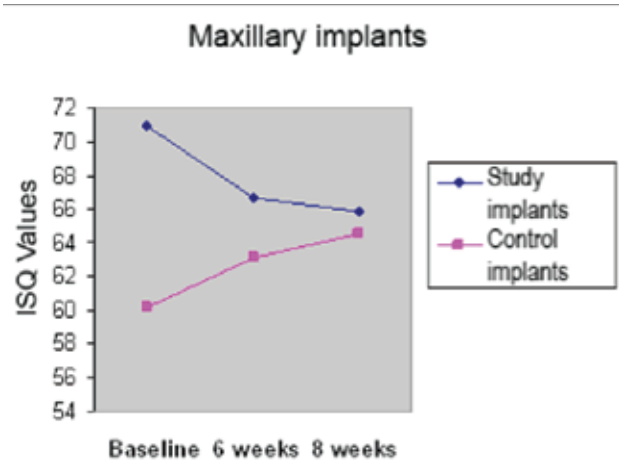

FIG. 2 Comparison of ISQ values between study and control maxillary implants

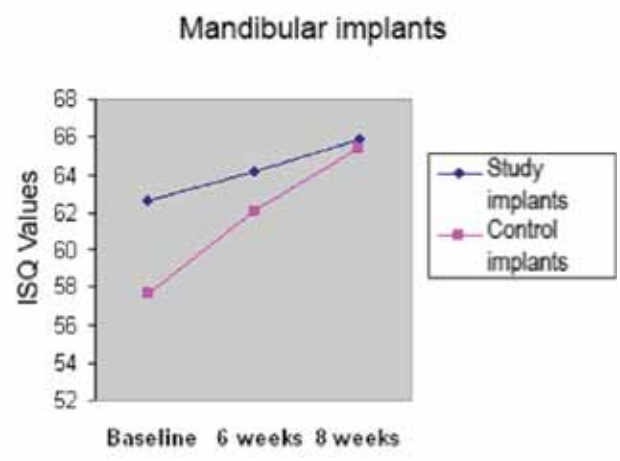

FIG. 3 Comparison of ISQ values between study and control mandibular implants.

insertion and 8 weeks (p>0.05) (Fig. 2). In both test and control implants between insertion and 8 weeks (p>0.05) an increase in ISQ values was present (Fig. 3).

DISCUSSION

The criteria for the immediate loading of implants and its advantages and disadvantages remain controversial. Some authors have proposed that the criteria for immediate loading are the torsion force applied at the time of insertion and the bone characteristics, while others have established clinical criteria, including the results of percussion tests with mirror handle and probing or radiographic examinations (8). Other researchers have described the surface treatment of the implant as critical to the appropriateness of immediate loading (6,7). To date, however, no study has established objective criteria for taking this clinical decision. Some authors suggested to use repeated implant stability measurements in order to identify implants at risk of failure (15,16). Thus, Glauser et al. (15) demonstrated a continuous decrease in stability in some immediately loaded implants clinically failed after one year, despite their high initial primary stability, while Sennerby et al. (16) observed a correlation between marginal bone loss and implant stability in a study on a dog model.

There is an evident need for a simple and objective method to quantify implant stability at immediate loading, and RFA measurements appear to be a promising candidate for this purpose (9). In this study, stability was measured by using the Osstell Mentor (Osstell AB, Göteborg, Sweden) transducer. It has been reported (8) that the direction in which the transducer is used may affect measurements. In the present study, all measurements were standardized and conducted in the same direction (buccal to lingual or palatine) by a single operator. Fischer et al. (17) followed up 139 maxillary implants in 24 patients at 3 and 5 years and found that the implant failure was associated with ISQ values <54. In the present study, an ISQ value >60 was a criterion for immediate implant loading.

The magnitude and type of loading on the restoration is a key parameter in immediately loaded implants (14, 18), when parafunctions are a major risk factor for implant failure. In our patients, the prosthetist carried out meticulous occlusal adjustments at follow-up sessions in all the provisional/temporary crowns restorations, ensuring the absence of interference or any lateral movement. Although all implants in our study were inserted with the same torsion force (>30N), the Osstell ISQ measurements revealed differences in their stability. Hence, the measurement of ISQ units appears to offer an objective method to quantify implant stability, to decide the timing of loading and to evaluate implant stability during the first stages of integration. However, as noted by Aparicio et al. (8), the need to develop an

ISQ value scale that can define the characteristics of the bone-implant interface or quantitatively assess integration still remains.

We observed a decrease in ISQ values in maxillary implants, but a small increase in mandibular implants, and the difference between mandibular and maxillary values was significant at baseline. This may be explained by a higher amount of cortical bone in the mandible, where bone remodeling takes place between the first and fourth week, producing newly formed bone; bone remodeling occurs later in the more spongy bone of the maxilla. These results are in line with previous reports (9,19-22). Globally, a small progressive decrease in stability values from baseline to 8 weeks was found in the present study. Previous studies on immediately loaded implants evidenced an initial decrease in stability that was reversed after 3 months, attributing this behavior to bone remodeling and to the load exerted by the restoration (23-28).We found an increase in the stability of non-loaded implants (in both mandible and maxilla) between baseline and measurements at 8 weeks, when the provisional restoration was removed. Glauser et al. (29) studied 81 implants over a 1-year period and also found that the stability of loaded implants initially decreased and then increased when the load was removed.

In conclusion, implants with primary stability (with ISQ> 60) and inserted with a force of ≥ 30 N demonstrated optimal clinical behavior during the integration period after immediate loading. The timing of implant loading in this initial phase did not influence the success rate. The Osstell Mentor® RFA system offered an objective method to determine whether implant stability was adequate for immediate loading. Since immediate loading was not performed on implants with ISQ < 60, following the manufacturer's assessment, we cannot draw conclusions on the immediate loading of implants with lower ISQ values. Further researches are required to develop an ISQ value scale that yields reliable information on the characteristics of the bone-implant interface and the state of integration.

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