Resonance Frequency Measurements of Osseointegrated Implants in Fully Edentulous Jaws after One Year of Loading.

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ABSTRACT

Purpose: The primary aim of this retrospective study was to measure the stability of implants supporting fixed prostheses in edentulous jaws after one year of loading. A second aim was to evaluate the influence of jaw, implant position, implant length and marginal bone resorptions on the stability of these implants.

Material and methods: Twelve patients received 69 machined-surface implants (5 maxillary and 7 mandibular arches), which were restored with fixed metal-acrylic resin prostheses. After one year of loading, all the implants were clinically and radiographically evaluated and Implant Stability Quotients (ISQ) recorded with Resonance Frequency Analysis (RFA). Mean maxillary and mandibular implant stability values were calculated and then further divided into three groups depending on their anterior-posterior position. Stability values were compared with the Kruskall-Wallis test and the Spearman test was used to verify any correlation between bone loss and implant stability and between fixture length and implant stability.

Results: All the implants were successfully osseointegrated with a mean implant stability value of 72.8 ISQ SD 8.2 . Mandibular implants were significantly more stable (P= 0) than maxillary ones but no differences were found among implants in different anterior-posterior positions, either in the maxilla (P=0.978) or in the mandible (P=0.977). Implant stability could not be correlated either with implant length (rs= -0.17) or with bone resorption (rs=-0.140).

Conclusions: The present study revealed a clinical trend of an ISQ of 72 with a range of 53 to 94 ISQ, as typical of osseointegrated implants in edentulous jaws. Mandibular implants (P= 0) were significantly more stable than maxillary ones.

Introduction

The long-term success rate of implant-supported fixed prostheses has been documented by a number of studies[1-4]. Failures still occur in an estimated 7.7% of machined however, Brånemark implants, which have the most extensive published of epidemiologic data, still fail in an estimated 7.7% of cases.

According to Esposito et al [5], late implant failures are mainly owing to reduced bone volume, deficient bone quality or overload. This seems crucial for distal implants that have to bear heavy loads and are frequently shorter than average because of insufficient bone height and the presence of limiting anatomical features. Biomechanical investigations warned of the higher compressive loads and bending moments borne by implants adjacent to cantilever extensions [6]. A higher failure rate was also described for short implants [7, 8], especially when placed in maxillary bone.

However, with improvements in surgical protocols and the possibility of optimizing stability in bone of reduced volume and quality, the success of shorter implants became more predictable. Indeed, several studies have suggested that the success of short implants might be as predictable as that of longer ones, permitting the avoidance of advanced surgical techniques in most cases [9-11],

Improved clinical evaluation techniques have also made it possible to monitor the stability of implants, especially those placed in bone of reduced quality and quantity, or in situations where they might be at higher risk of failure from overloading.

While it was previously difficult to detect early loss of osseointegration, and hence of stability, the advent of

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Resonance Frequency Analysis and the Osstell™ equipment may now help clinicians to assess implant stability more reliably[12]. Using this instrument, by serially measuring resonance frequency of mandibular implants, Friberg et al (13) were able to detect loss of implant stability before any clinical evidence of failure became evident. They also reported that failure of implants that carried uncontrolled loading from a removable denture during the healing phase could be avoided by unloading, after which the stability of those implants increased again, making it possible to deliver a successful fixed prosthesis to the patient[13].

Monitoring implant stability during the first year of loading may help the clinician to determine whether the implant reaches and maintains adequate bone fixation, either by taking serial measurements, or by comparing random measurements with normal stability values from the literature.

The primary aim of the this retrospective study was to measure the stability of implants supporting fixed prostheses in edentulous jaws after one year of loading, and to compare the values with published values for partially edentulous jaws[14]. A secondary aim of the study was to investigate differences between stability of implants adjacent to distal cantilevers and stability of more medially located implants. Correlations between bone loss around threads and implant stability, and between implant stability and implant length, were also sought.

MATERIALS AND METHODS

Patients

This study included 12 consecutive patients (3 men and 9 women, mean age 66.2, ranging from 56 to 74), all fully edentulous in one dental arch. All the patients were in good general health. Four of them smoked less than 8 cigarettes a day. A total of 69 implants (Brånemark System, Nobel Biocare AB, Gothenburg, Sweden) had been placed. Length, diameter and position of the implants are summarized in Table 1.

All the surgery was performed by one surgeon (P.B.) in accordance with a standard two stage surgical technique[15]. All maxillary posterior osteotomies were adapted to the softer bone by drilling to slightly smaller diameters relative to the diameters of the implants. This technique has been reported to provide maximal implant stability in soft bone [16].

According to the case records, the surgeon reported good primary stability for all the implants, although no ISQ values were recorded.

Abutment connection was performed after a minimum of 3 months for the mandible and 6 months for the maxilla, after which fixed metal-acrylic resin Brånemark-type prosthesis were delivered. The mean length of the cantilevers distal to the last implants was 10,8 mm.

Implant stability measurement

After one year of functional loading the prostheses were removed to gain access to the implants and to measure resonance frequencies using the Osstell™ Instrument (Integration Diagnostic, Savedalen, Sweden). Transducers were positioned perpendicular to the bony crest so that the output cable was in a buccal direction. Data were collected on a PC using dedicated software (Osstell™ Data Manager, Integration Diagnostic). Because of the differences in bone density, the data were separated into two groups for implants placed in the maxillary and the mandibular arches.

Table 1: Length (mm) of placed implants. All the implants were 4mm diameter unless otherwise specified .

		Implant length					
	Patient	7	8.5	10	13	15	18
Maxilla	1			1		5	
	2			2 ø5		2	2
	3				1	1	4
	4			2 ø5		4	
	5			2	1	2	2
Maxilla	6	6					
	7				4 ø3.75	2	
	8	4		1			
	9				1	5	
	10				5 ø3.75		
	11	5					
	12					5	

Table 2: Lengths (mm) and positions of placed implants.

	Maxilla			Mandible		
Length	Distal	Medial	Mesial	Distal	Medial	Mesial
7				6	6	3
8.5						1
10	7					
13	2			3	3	4
15	1	6	7	5	5	2
18		4	4			

These groups were then further subdivided into three groups according to their position: distal, medial and mesial (Tab.2). In the case of a bridge supported by six implants, 'distal' implants were those adjacent to cantilevers, 'mesial' implants the most anterior ones and 'medial' implants were those between the two other groups. If an odd number of fixtures was present, implants were divided so that the odd one was included in the 'mesial' group (Fig.1). A mean ISQ value was calculated for each group.

Radiographic measurement of bone height

Using the parallelling technique, intraoral radiographs were taken at the time of abutment connection to check the fit of the framework, and then again at the time of resonance frequency measurement one year later. The radiographs were digitized and analyzed using 'ImageJ', a freeware software package (NIH, USA http://rsb.info.nih.gov/ij/). Crestal bone levels were measured as the vertical distance from the implant/abutment connection to the bone contact. Measurements were made at the distal and mesial side of each implant and a mean value per implant was then calculated.

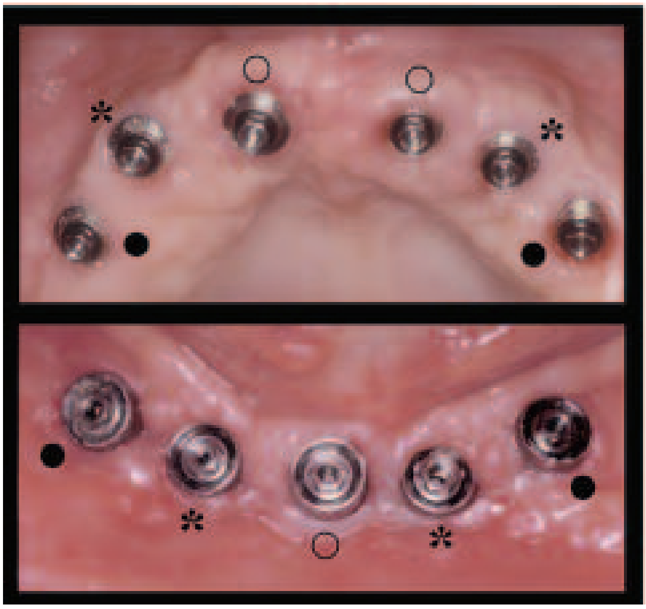

FIG 1: Implant grouping according to their position:
*O distal implants, * medial implants, • mesial implants.*

Statistical analysis

The Mann-Whitney test was used to evaluate differences between the ISQ values of fixtures in the upper and lower jaws. The Kruskal-Wallis test was used to identify significant differences in stability between the distal, mesial and medial groups due to implant position.

Correlations between implant length versus their stability and between implant stability versus crestal bone loss were ascertained using Spearman's rank test for correlation analyses.

RESULTS

At one year, the implants were clinically stable and asymptomatic. The mean ISQ value after one year of functional loading was 72.84 ISQ SD 8,28 (range 53 to 94). A statistical difference was found between mean maxillary and mandibular ISQ values (respectively 67.6 ±7.9 and 76.6 ±6.1; Zt= 4.8 P=0) (Fig.2). In Figure 3, all ISQ levels after one year are represented.

Figure 4 shows the mean ISQ values for maxillary implants according to their grouping by position. No statistical differences were found between distal fixtures adjacent to the cantilevers, and their medial or mesial counterparts (H=0.019, P=0.977). Figure 4 shows the corresponding mean ISQ values for mandibular implants, and again no statistically significant differences were found (H=0.111, P=0.987).

No correlation was found between the lengths of the implants and their stability (rs= -0.17, P=0.150) (Fig.6).

There was a mean radiographic bone loss of 0.3 ±0.5mm (range 0 to 1.5mm) between the time of abutment connection

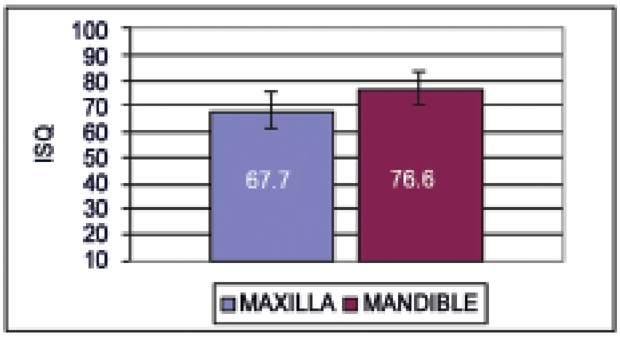

FIG. 2 Mean ISQ for mandibular and maxillary implants. Mandibular implants were more stable (P<0.05).

and the time of resonance frequency measurement one year later; but there was no correlation between bone loss and implant stability (rs=-0.140 P=0.231) (Fig.7).

DISCUSSION

Mean mandibular and maxillary ISQ values found in this study are similar to those of osseointegrated machined implants in partially edentulous jaws published in a previous study (14), where the stability of successfully integrated Brånemark machined implants ranged from ISQ 57 to 82 with a mean of ISQ 69. The present data show greater stability of implants in the mandible than in the maxilla, probably due to differences in bone density. This finding is in accordance with previous studies in partially edentulous subjects when mandibular implants also showed higher stability values [14, 17].

Resonance Frequency analysis using the Osstell™ was applied in the present study to determine whether heavier loads carried by implants adjacent to cantilevers would cause detectably harmful effects. Biomechanical investigation has demonstrated that distal implants connected to fixed full prostheses support large compressive loads and are subjected to bending moments that might reach double the applied load because of the cantilever effect (6). In addition, epidemiological data seem to suggest that overloading might be a possible cause of late implant failures (5). However, no clear information on the magnitude of stresses that cause bone change, whether resorption or remodelling, is to be found in the literature, and consequently the precise mechanism for loss of integration from overloading is still unclear.

As shown in figures 4 and 5, no differences in ISQ values were found between distal implants and the more anterior ones. ISQ values of all the implants adjacent to cantilevers were similar to their more medial counterparts, therefore demonstrating that the increased load they bear might not be a clinical disadvantage or be biologically damaging.

However, when considering the present data, it has to be taken into account that ISQ values at the time of implant placement were not recorded, since Osstell™ was not yet available. Therefore it is possible that changes in implant stability due to loading over the one year period were not detected. Nevertheless, the favourable stability of the implants closer to cantilevers was not unexpected, considering well documented reports on fixed full-arch rehabilitations supported by only four implants in the maxilla and three in the mandible, that show high implant survival rates despite the limited implant support[18,19]. A full understanding of the biomechanical capacity of these rehabilitations has not yet been developed because of the difficulty in quantifying bone healing, mineralization and turnover at the implant interface [20, 21]. However, despite this lack of biomechanical data, the clinical effectiveness of implant supported cantilevered prostheses cannot be disputed.

Also to be considered is the absence of any correlation between implant length and stability. This finding agrees with other studies that suggested the effectiveness of short implants in supporting fixed prostheses in case where small bone volumes are present and critical anatomic structures are to be avoided (9-11). Short implants might be regarded as a viable alternative to more complicated grafting techniques that, although well accepted, increase morbidity, cost and duration of the implant treatment. On the other hand, it also must be borne in mind that advanced surgical procedures might restore lost bone volume and be advantageous in terms

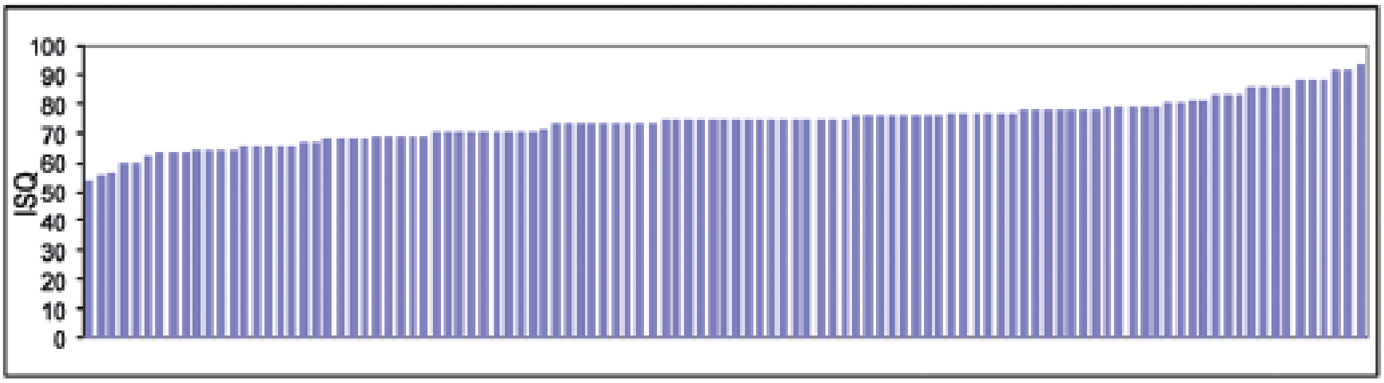

FIG.3 ISQ levels after one year of loading for each of the implants studied.

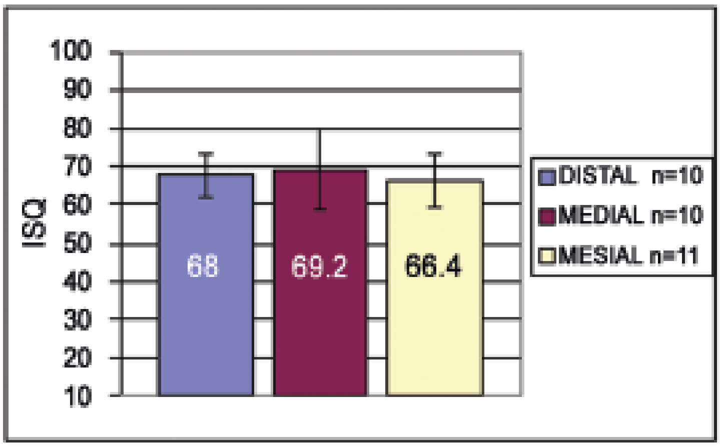

FIG.4 Mean ISQ of maxillary implants placed in the different positions. No significant differences were found.

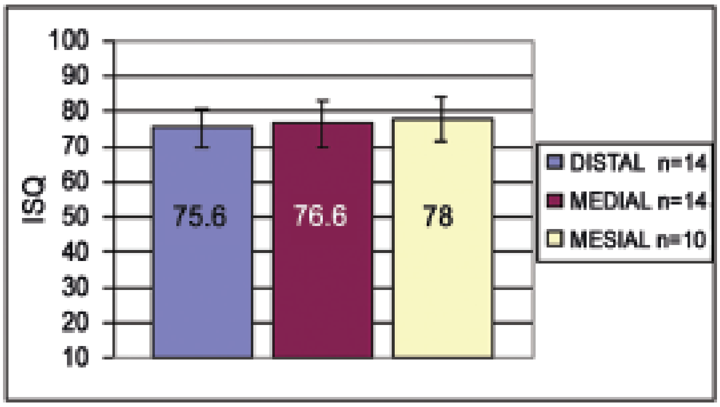

FIG.5 Mean ISQ of mandibular implants placed in the different positions. No significant differences were found.

of improved appearance and function of the final prosthesis.

Further speculation on the present results could be made on the basis of table 2 where it is shown that a number of 10mm implants were placed in the soft bone of maxillary posterior areas, yet they all reached ISQ values of over 60. This finding is confirmed by Friberg et al, who showed that when using an adapted surgical technique and prolonged healing time, implants placed in soft bone achieve the same stability as those placed in denser bone. Changes in bone density from healing and loading are likely to be the reason for this favourable stability [13, 22].

The last observation concerns the insignificance of minor bone losses on implant stability. Unfortunately, because ISQ values were not recorded at the time of surgery in the present study, it is not possible to say if the stability of the implants studied after one year may have been influenced by minor bone losses that occurred during the year.

Finally, it has to be clearly pointed out that although prognostic rates based on ISQ after varioys intervals have been reported for machined Brånemark and ITI-SLA implants[23, 24], the ISQ value measures the rigidity of the implant-bone interface at the moment of the registration only, and to date, it is still not and may never be possible to make a reliable long term prognosis for osseointegration, reached based on ISQ values alone. Formation of new bone and its remodelling might continue over the whole first year of implant function and therefore changes in the stiffness of the bone-implant interface certainly do occur during this period[13, 22]. Nevertheless, monitoring implant stability during the first year of loading might be useful to assess the maintenance of implant stability during peri-implant bone remodelling, and to appraise the performance of implants under loading. Availability of base line measurements, although of no prognostic value, might help the clinician to evaluate when the implant has reached, and whether is maintains a safe degree of stability.

In conclusion, an ISQ value of more than 69 with a range of 57 to 82, as probably descriptive of osseointegrated implants, was observed in this study. In addition, this study seems to suggest that, in fully edentulous jaws, the stability of distal implants is not affected by the higher compressive loads they bear in comparison to their anterior counterparts, at least as detectable using resonance frequency. Further investigation is needed to establish the ISQ threshold each implant has to reach at a given bone site to successfully bear a functional load.

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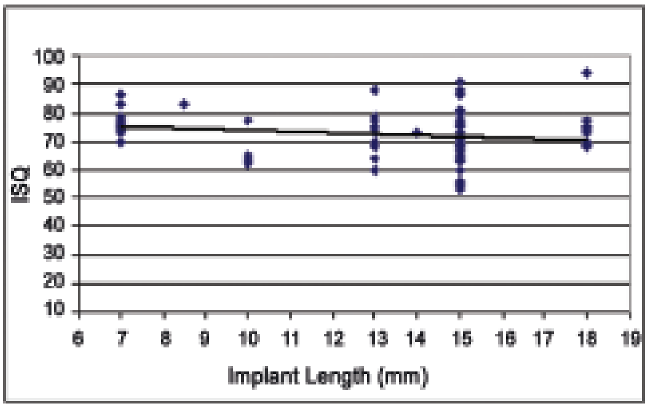

FIG.6 ISQ values plotted against implant lengths. No significant correlation found.

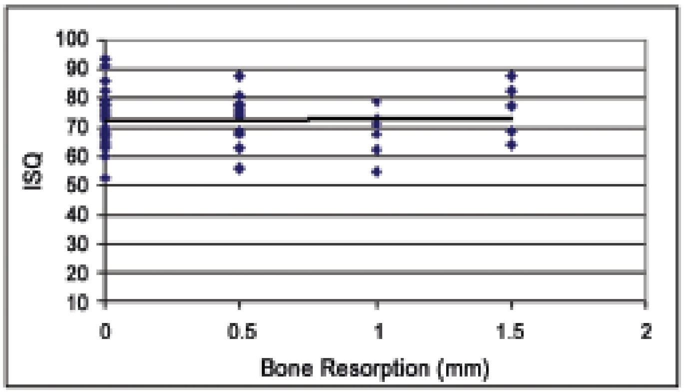

FIG.7 ISQ values plotted against marginal bone loss. No significant correlation found.

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