Influence of implant dimensions and position on primary and secondary stability: a prospective clinical study in the mandible using resonance frequency analysis

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KEYWORDS Implant design; implant stability; Osseointegration; Implant stability quotient.

ABSTRACT

Aim The aim of this study was to measure primary and secondary implant stability through the resonance frequency analysis of mandibular implants and to evaluate the influence of implant diameter and length, sex, age and site.

Materials and methods Thirty-six healthy patients who had mandibular implants placed were enrolled for the study. A total of 82 OsseoSpeed TX (Astra Tech Implant System – Dentsply Implants; Mölndal, Sweden) implants were placed, with different lengths (9, 11 and 13 mm) and diameters (3.5 and 4 mm). All implants were placed according to a conventional two-stage surgical procedure. Implant stability quotients (ISQ) were recorded at implant placement (ISQ1) and 3 months later, at second surgical stage (ISQ2). Statistical analysis was performed to investigate significant differences between implant dimensions, patient sex and age, and implant position (anterior or posterior sites). SIGMAPLOT software was used for statistical analysis (significance =0.05).

Results Secondary implant stability was statistically significantly higher compared to initial ISQ values ($p<0.05$). ISQ2 values were statistically significantly higher than ISQ1 values for 3.5 mm diameter implants, for 13 mm length implants and for implants placed in anterior mandible. Age was not found to influence implant stability. Female patients showed ISQ2 values significantly higher than males.

Conclusion Some parameters such as implant dimensions and positions may influence only the secondary implant stability. Male patients have lower secondary implant stability.

INTRODUCTION

The success rate of implants is achieved by primary stability, which is a fundamental requirement for successful osseointegration and bone cell differentiation (1-2). Primary stability is defined as the absence of movement of an implant after surgical insertion (3). To optimize osseointegration and hereby reduce the time of the treatment, many different factors have to be considered, such as surgical technique, bone density, bone quality, and the geometry of the implant. The presence of these factors determines the initial implant stability, which is defined as the absence of movement after surgical insertion 4-6). Micromovement, which defines implant stability, cannot be directly measured; there are many methods for evaluating the implant stability such as the RFA. The implant stability quotient (ISQ) and insertion torque (IT) are still commonly used as proxies for the initial implant stability (7). The ISQ scale runs from 1 to 100 units, where the former is the lowest and the latter the highest degree of stability (8).
It is known that several factors can affect the ISQ values such as the effective implant length; the distance from the transducer to the marginal bone (the greater the distance from the transducer to the bone, the lower the ISQ value); the bone quality; the strength with which the transducer is torqued; the existence of soft tissue between the implant and the transducer; and the quantity of bone in contact with the implant (7-10).
The differential stability between cylindrical and tapered implants has not been investigated in depth,

only Torroella et al. monitored the ISQ changes in dental implants inserted in the anterior region of the mandible in totally edentulous patients (11).

In the literature two fundamental concepts have been illustrated.

a) Primary/mechanical stability, namely the mechanical engagement obtained at the implant placement time; it derives from implant macrodesign, bone architecture and implant drilling protocol (12).
b) Secondary/biological stability, namely the biological engagement and homeostasis by means of bone apposition to implant, which occurs after the placement of the implant, coming from different factors including implant microdesign and bone architecture plus implant loading (13).

The influence of implant length and diameter on RFA measurements is not clear and seems to vary between studies. Östman et al. and Miyamoto et al. found higher stability with increased implant diameter but decreasing stability with increasing implant length, which is explained by the fact that some long implant designs have a reduced diameter in the coronal part to minimize friction heat and to facilitate insertion (14-15). Other authors reported that the primary stability for the same implant design placed in grafted bone was significantly higher for 15 and 18 mm long implants than for 10 and 13 mm implants (16).

Bischof et al. found no influence of implant position, implant length, implant diameter and vertical position on the ISQ values of 106 implants placed in the maxilla and the mandible, which is in line with the findings from other researchers (17).

Sim and Lang reported a non significant lower stability for 8 compared with 10 mm implants at placement, but the 8 mm showed a significant increase up to 12 weeks (18). A clinical study found a higher stability for 12 than for 10 mm implants and for 4.8 mm than for 4.1 mm wide implants (19). Also Tözum and co-workers found higher ISQ values with increased implant diameter in an *in vitro* study (20).

The aim of the present study was to measure primary and secondary implant stability through the resonance frequency analysis of mandibular implants and to evaluate the influence of implant diameter and length, gender, age and site.

MATERIALS AND METHODS

Study design

The study was designed as a prospective clinical study.

Patient selection

This study was conducted in accordance with the ethical principles provided by the Declaration of Helsinki and the principles of good clinical practice. Thirty-six healthy patients were enrolled for the study. All patients were informed about the study protocol and surgical risks, a written consent was obtained in all cases explaining alternatives, advantages and disadvantages of the surgical intervention. The inclusion criteria were as follows: patients aged 18 years or older; absence of medical history or conditions that could contraindicate surgery; 4 to 6 months waiting time were necessary for healing after tooth extraction; presence of sufficient residual alveolar bone volume to achieve primary implant stability without concomitant or previous bone augmentation; good oral hygiene.

Exclusion criteria were: systemic or psychological disorders that contraindicate oral surgery; neoplastic pathologies or previous treatments with bisphosphonate drugs; tobacco smoking; pregnancy and lactation; untreated periodontal conditions; absence at least of 2 mm of keratinized tissue; upper arches.

Surgical technique

A total of 82 implants (OsseoSpeed TX, Astra Tech Implant System—Dentsply Implants; Mölndal, Sweden) were placed in the mandible following a two-stage protocol according to the manufacturer's instructions. Different implant lengths (9, 11 and 13 mm) and diameters (3.5 and 4 mm) were used. The diameter of the last tool used was based on the diameter of the implants, it was 2.7 for diameter 3.5 and 3.2 for diameter 4. The main features of this kind of implant is an exclusive implant surface with a fluoride-treated nanostructure that stimulates early bone formation and provides a firmer bone-implant connection and microthreads on the neck of the implant that ensure optimal load distribution and optimal stress values. Implants were placed exclusively in the lower jaw. Implants placed in the "anterior" mandible replaced central and lateral incisors and canines; whereas in the "posterior" mandible implants replaced premolars and molars. Implants were usually positioned with the implant shoulder at the level of the alveolar bone crest and then covered with the mucosal flap. All the implants were placed in native bone and without bone regeneration. The torque was measured through the implant motor. The implants, placed with handpiece, had all torque up to 35 Ncm.

The second phase surgery was carried out at 3 months. Post-operative therapy required good oral hygiene, rinsing with mouthwash containing 0.2% chlorhexidine solution twice a day to enhance plaque control, and an evening application of the same product in gel form, as well as the administration of a non-steroidal anti-inflammatory aid (Ketoprofene 80 mg) for three consecutive days in association with oral antibiotic (Amoxicillin 1 g × 2) administration for 5 days. Sutures were removed seven days after surgery.

All implants were evaluated with peri-apical x-rays immediately after insertion and after 3 months. Definitive crowns were delivered at 4–6 months post-surgery. All prosthesis were manufactured in order to

facilitate oral hygiene procedures. No implant failures were recorded.
Implant stability quotients (ISQ) were recorded through resonance frequency analysis (RFA) at implant placement (ISQ1) and 3 months later, at second surgical stage (ISQ2) by a single operator. The ISQ was obtained installing a "Smartpeg" transducer (Integration Diagnostics AB, Göteborg, Sweden) into the fixture and approaching it perpendicularly with the handpiece probe of the Osstell (Integration Diagnostics AB, Göteborg, Sweden) device.

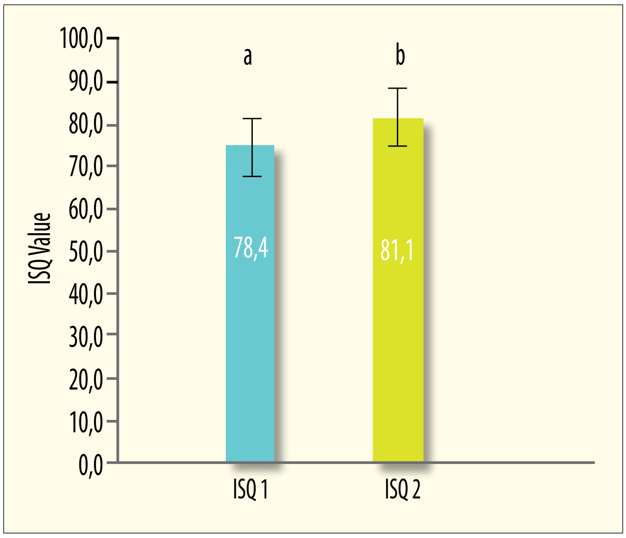

FIG. 1 Paired t test for implant stability quotient (ISQ) values at implant placement (ISQ1) and after 3 months (ISQ2). Different lowercase letters indicate statistically significant differences among the groups.

Statistical analysis

Statistical analysis was performed to investigate significant differences between implant dimensions, patient gender and age, and implant position (anterior or posterior sites). SIGMAPLOT software was used for statistical analysis (significance =0.05).

RESULTS

Secondary implant stability was statistically significantly higher compared to initial ISQ values ($p<0.05$) (Fig. 1).
ISQ2 values were statistically significantly higher than ISQ1 values for 3.5 mm diameter implants, for 13 mm length implants, for female patients and for implants placed in anterior mandible (Fig. 2, 3, 6).
Age was not found to influence implant stability (Fig. 4).
Female patients showed ISQ2 values significantly higher than males (Fig. 5).

DISCUSSION

Selecting an implant that provides adequate primary stability in the bone bed is essential to achieve clinical success. Primary stability depends on the bone quality, surgical technique, and implant design (12).
In low density bone sites, the dental implant macrodesign needs to guarantee an acceptable primary stability; the stability tends to increase with length and width, so long and wide implants are still preferable. However, their installation requires sufficient thickness

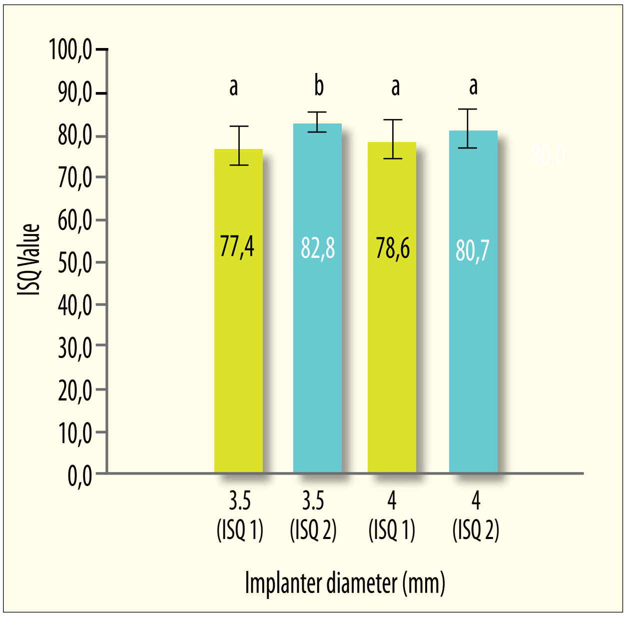

FIG. 2 Tukey's multiple comparison test of ISQ1 and ISQ2 values for 3.5 and 4 mm diameter implants. Lowercase letters indicate statistically significant differences among the diameters within the ISQ 1 or 2 values.

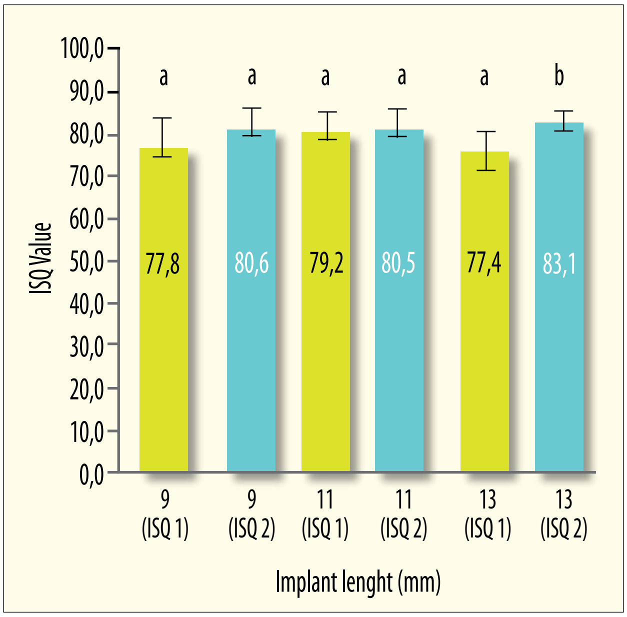

FIG. 3 Tukey's multiple comparison test of ISQ1 and ISQ2 values for 9, 11 and 13 mm implants. Lowercase letters indicate statistically significant differences among the length within the ISQ 1 or 2 values.

of the alveolar crest (21).
Resonance frequency analysis (RFA) is a method used to determine stability (the level of osseointegration) in dental implants. Utilizing RFA involves sending magnetic pulses to a small metal rod temporarily attached to the implant. As the rod vibrates, the probe reads its resonance frequency and translates it into an ISQ value (14, 22). RFA measurements are used to assess the stability of the implant immediately after placement, as well as to measure the stability during the healing time. This helps the dentist determine if further healing time (osseointegration) is needed before the prosthetic tooth is attached, as well as to identify patients at risk with compromised bone tissue, or other risk factors. Moreover, RFA is a simple and non invasive method (22-23).
Is important to know whether the instruments used to perform the measurement were calibrated, and the operators had been trained, because the Osstell could generate false results if it doesn't work well. Moreover, in various studies the variation was very wide for the same sample (18).
Acil and colleagues postulated that immediately after implant insertion, relaxation would begin to take place. This can affect the ISQ measurements as well as bone contact measurements. Furthermore, it is well known that both ISQ measurements and bone contact measurements could also be affected by the visco-elastic behavior of the bone and possible concomitant relaxation, which takes place immediately after implant insertion (24).
Bone density is a major determinant of RFA measurement as shown in numerous studies. A positive correlation between ISQ units and bone density as assessed with the Lekholm and Zarb index, with insertion torque measurements and with quantitative CT has been demonstrated (19). Implant stability is usually higher in the mandible than in the maxilla due to the fact that mandibular bone is often denser than in the maxilla.

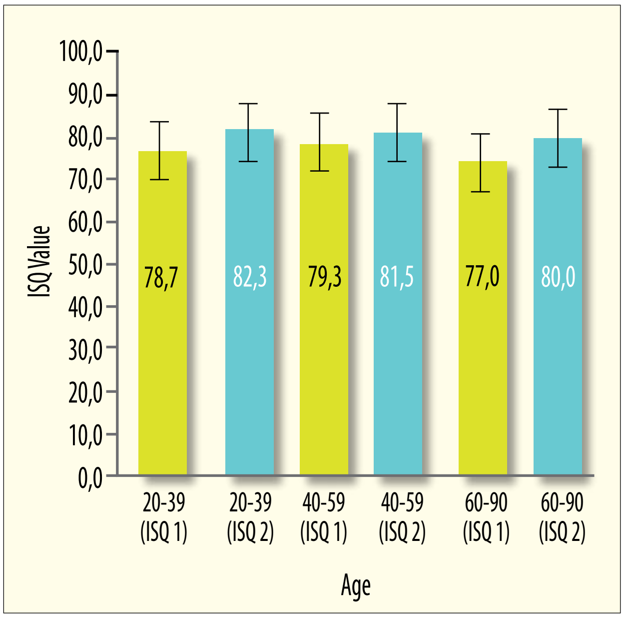

FIG. 4 One Way Analysis of Variance of ISQ1 and ISQ2 values for different age ranges. There are no statistically significant differences (P = 0,257).

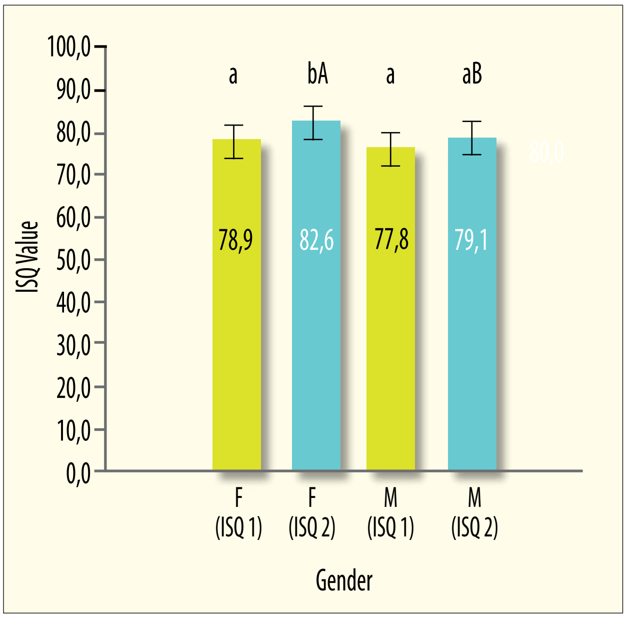

FIG. 5 Tukey's multiple comparison test of ISQ1 and ISQ2 values for male and female patients. Lowercase letters indicate statistically significant differences among the sex within the ISQ 1 or 2 values. Uppercase letters indicate statistically significant differences between the ISQ 1 or 2 values within gender.

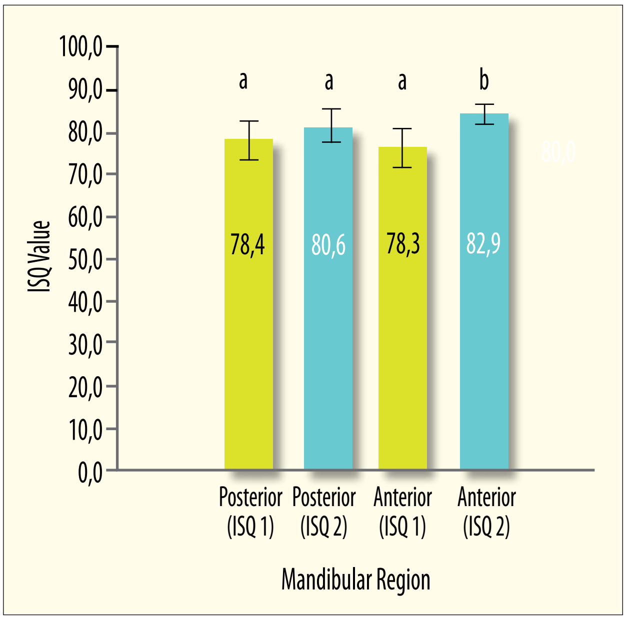

FIG. 6 Tukey's multiple comparison test of ISQ1 and ISQ2 values for different mandibular regions (frontal and posterior). Lowercase letters indicate statistically significant differences among the region within the ISQ 1 or 2 values.

It is also possible to find differences when comparing anterior and posterior sites within each jaw (25-27).

Research has shown that ISQ measurements can provide the clinician with valuable information about the present state of bone-implant interface. Together with clinical/ radiographic findings it seems like as the technique can be used to support decision-making during implant treatment and follow-up with regard to healing times, loading protocol and identification of implants at risk for failure (9-10).

In this study we used 9, 11 and 13 mm long implants with a diameter of 3.5 and 4 mm, although other authors reported significantly higher ISQ values for implants with larger diameters. The results suggest that gender is a significative factor for ISQ2 values. Further studies are necessary to compare and verify all the methods for evaluating implant stability and comparing the values obtained. It would also be interesting if we could have correlated the values, and even if the measurements had been made by one method, we could have compared them with others performed at different times.

CONCLUSION

The RFA technique provides with clinically relevant information about the state of the implant–bone interface at any stage after implant placement. It is likely that ISQ measurements can be used as one additional parameter for diagnosis of implant stability and decision-making during implant treatment and follow-up. Some parameters such as implant dimensions and positions may influence only the secondary implant stability. Male patients have lower secondary implant stability.

Author's contributions

Carlo Rengo and Antonio Nappo equally contributed. Concept/Design: Carlo Rengo, Antonio Nappo. Data curation: Carlo Rengo. Drafting article: Carlo Rengo, Giuseppe Pantaleo. Critical revision: Giuseppe Pantaleo, Gianrico Spagnuolo. Data analysis/statistics: Gianrico Spagnuolo. Project administration: Marco Ferrari. Supervision: Marco Ferrari.

Conflict of interest

No potential conflict of interest relevant to this article was reported.

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