The Effect of Recipient Jaw and Implant Dimensions on Pre- and Post-Loading Dental Implant Stability: A Prospective Clinical Study

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ABSTRACT

Background: Implant stability is a mandatory factor for dental implant (DI) osseointegration and long-term success. The aim of this study was to evaluate the effect of implant length, diameter, and recipient jaw on the pre- and post-functional loading stability.

Materials and methods: This study included 17 healthy patients with an age range of 24-61 years. Twenty-two DI were inserted into healed extraction sockets to replace missing tooth/teeth in premolar and molar regions in upper and lower jaws. Implant stability was measured for each implant and was recorded as implant stability quotient (ISQ) immediately (ISQ0), and at 8 (ISQ8) and 12 (ISQ12) weeks postoperatively, as well as post-functional loading (ISQPFL). The pattern of implant stability changes throughout the study period and its correlation with the recipient jaw and the DI dimensions were evaluated.

Results: There was a significant difference in ISQ values throughout the study. DI stability in the maxilla was significantly higher than that in mandible for the ISQ0, with no significant effect for the rest time points. The effect of implant diameter was significant with DI of 4.1mm diameter being more stable. While for the length, there was no significant difference regarding its effect on ISQ values throughout the study period.

Conclusions: DI inserted in the maxilla demonstrated better primary stability with no effect of recipient jaw on secondary stability and after functional loading, also DI with wider diameter had better stability throughout the study whereas DI length showed no significant effect on stability.

Keywords: Implant stability, implant dimensions, recipient jaw. **(Received: 25/9/2021, Accepted: 31/10/2021)**

INTRODUCTION

Many factors directly affect the success of dental implant (DI) treatment, which could be considered a challenge to clinicians. One of these factors is the implant stability, which is of two types, primary and secondary [(1)]. Primary stability is the mechanical engagement of an implant within the surrounding bone, while bone regeneration and remodeling determine the secondary (biological) stability [(2)].

Alveolar bone quantity and quality, length, diameter, and form of the implant, as well as the surgical technique, are also among the clinical factors that affect dental implant stability [(3, 4, 5)]. For this reason, it is believed that factors that can increase the contact area between the implant and the surrounding bone, such as the implant shape and dimensions (length and diameter) can increase the implant stability, and should be taken into account as they can play a role in the formation of the bone-to-implant contact [(6)].

Different methods have been advocated to evaluate DI stability, such as torque at the time of implant placement, resistance to reverse torque, and resonance frequency analysis (RFA) [(7)].

The Osstell® device (Göteborg, Sweden) has been introduced to provide an objective measurement of DI primary stability and to monitor the changes in the stability over the healing/ osseointegration period. Many experimental and clinical studies showed an increase in RFA values during healing period after implant placement. These increased implant stability quotient (ISQ) values could be attributed to increased bone anchorage [(8, 9)].

The absence of micro-movements is a necessary condition for successful implant osseointegration, and it can be obtained by achieving stable implant immediately post-insertion (primary stability) and during healing period (secondary stability) [(10)]. Therefore, the aim of the present study was to evaluate the influence of DI dimensions (length and diameter) and recipient jaw on the pre- and post-loading implant stability.

MATERIALS AND METHODS

This prospective clinical study was performed at the Department of Oral and Maxillofacial Surgery, College of Dentistry, University of Baghdad during the period extending from July 2019 through February 2021. The study protocol was reviewed and approved by the Research Ethics Committee of the College of Dentistry, University of Baghdad (protocol number 034118).

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The study included 17 consecutive patients who met the eligibility criteria.

To be included, patients had to be over 18 years of age, having single or multiple missing teeth in the posterior maxilla or mandible with healed extraction sites of a minimum of 6 months, and exhibiting sufficient vertical (at least 10 mm) and horizontal (at least 5 mm) dimensions of the alveolar bone that are considered surgically straightforward cases according to SAC classification [(11)].

Patients were excluded if they had signs of active or chronic infection in the implant zone, history of radiotherapy to the head and neck, history or were currently under treatment with drugs that may alter bone metabolism, and patients who were heavy smokers or presented with severe periodontitis.

The patients received a total of 22 bone level tapered DIs (Straumann®. Basel, Switzerland). All procedures were performed under local anesthesia. After reflection of a full-thickness mucoperiosteal flap, the implant bed was prepared through sequential drilling according to the manufacturers' instructions, and the implants were inserted about 0.5 mm subcrestally. DIs used in this study were 3.3mm and 4.1mm in diameter with 8mm, 10mm, and12mm in length.

Implant stability measurement

Implant stability was measured using the Osstell® Mentor (Göteborg, Sweden) and was recorded as ISQ value. The measurements were repeated 2 times for each implant, with buccolingual and mesiodistal directions and the average of these measurements was recorded. Implant stability was measured immediately after implant insertion (primary stability, ISQ0), after 8 weeks, at the time of healing abutment placement (ISQ8), and after 12 weeks (secondary stability, ISQ12). The implant stability was also measured after about 25 weeks of functional loading (ISQ post-functional loading, ISQPFL).

The outcome variables of this study included the ISQ changes during the study period and their correlation with the recipient jaw (maxilla and mandible) and DI dimensions (diameter and length).

Statistical analysis

The descriptive statistics included the mean (standard deviation, SD) and the median of the continuous variables and the percentages of the categorical variables. The Shapiro-Wilk test was used to determine the normality of distribution of the continuous variables. The inferential statistics included using the Friedman test with the multiple comparison test, the unpaired t-test, Mann Whitney U test, and the Kruskal Wallis test. The significance level was $P< 0.05$.

RESULTS

This study included 17 patients with an age range of 24-61 years and a mean (SD) of 42.9 (9.8) years, they consisted of 11 (64.7%) females and 6 (35.3%) males. The patients received 22 DIs, the mean number of implants per individual was 1.3. Seventeen DIs (77.3%) were inserted in the mandible and the remaining 5 (22.7%) were installed in the maxilla. The distribution of DIs according to the dimensions is summarized in the **Table 1**.

Table 1: The Distribution of DIs according to the dimensions

Implant dimensions		Number	%
Width/mm	4.1	13	59.1
	3.3	9	40.9
Length/mm	8	4	18.2
	10	11	50
	12	7	31.8

All DIs were osseointegrated and functional at the end of the study with an early success rate of 100%.

The implant stability recorded throughout the study is summarized in **Table 2**. Generally, there was a significant difference in implant stability, the multiple comparison test revealed that there was a non-significant decrease in implant stability at 8 weeks followed by a significant increase at 12 weeks and after functional loading **(Fig. 1)**.

Table 2: The implant stability recorded throughout the study period

Implant stability /ISQ	ISQ0	ISQ8	ISQ12	ISQ PFL	P-value
Mean	69.27	66.95	73.50	78.41	< 0.000*
SD	6.37	5.03	4.92	4.06	
Median	69.00	70.00	73.00	78.00	

ISQ, implant stability quotient; SD, standard deviation; * Friedman test

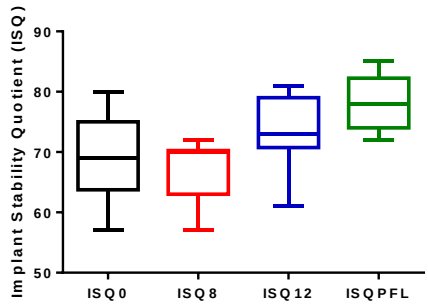

Figure 1: Box plot showing the difference in implant stability throughout the time points of the study

The effect of the recipient jaw

There was a significant difference in implant stability recorded immediately after insertion (primary stability). However, the implant stability recorded after 8, 12 weeks (secondary stability) and after functional loading demonstrated non-significant differences between the mandible and the maxilla (**Table 3 and Fig. 2**).

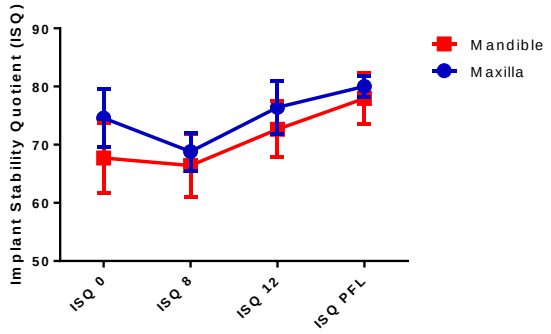

Figure 2: Line graph showing the difference in implant stability in the maxilla and the mandible

The effect of implant dimensions

With respect to DI diameter, wider implants (4.1mm) demonstrated significantly higher implant stability than DI with 3.3 mm diameter in all measurement times, but the differences were significant only in secondary stability and after functional loading **(Table 4 and Fig. 3)**.

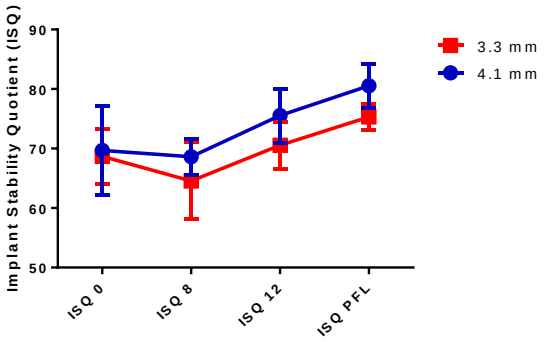

Figure 3: Line graph showing the difference in implant stability in relation to DI diameter

Analysis of the DI length demonstrated that there were non-significant differences in implant stability in all measurement times **(Table 5 and Fig. 4)**.

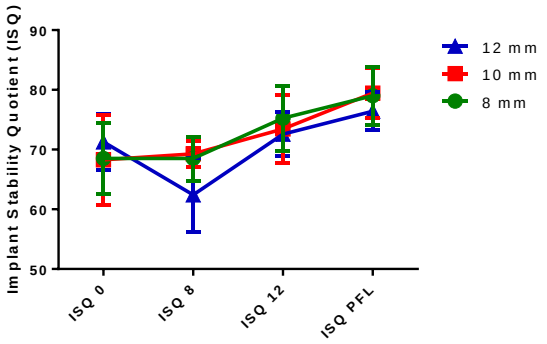

Figure 4: Line graph showing the difference in implant stability throughout the study in relation to DI length

Table 3: The differences in implant stability between the maxilla and the mandible

Measurement Time	Maxilla n=5			Mandible n=17			P-value
	Mean	SD	Median	Mean	SD	Median	
ISQ 0	74.60	4.93	76.00	67.71	5.98	69.00	0.0325 *
ISQ 8	68.80	3.27	70.00	66.41	5.40	70.00	0.5563 *
ISQ 12	76.40	4.51	79.00	72.65	4.82	73.00	0.1792 *
ISQ PFL	80.00	1.87	80.00	77.94	4.44	77.00	0.3085 *

ISQ, implant stability quotient; SD, standard deviation; * Mann Whitney U test

Table 4: The differences in implant in relation to DI diameter

Measurement Time	Implant diameter 4.1mm (*n*=13)			Implant diameter 3.3mm (*n*=9)			P-value
	Mean	SD	Median	Mean	SD	Median	
ISQ 0	69.69	7.521	72.00	68.67	4.583	69.00	0.7200 †
ISQ 8	68.62	3.042	70.00	64.56	6.444	67.00	0.3044 *
ISQ 12	75.54	4.557	77.00	70.56	3.972	73.00	0.0153 †
ISQ PFL	80.54	3.666	81.00	75.33	2.236	74.00	0.0012 †

ISQ, implant stability quotient; SD, standard deviation; † Unpaired t test; * Mann Whitney U test

Table 5: The differences in implant stability in relation to DI length

Measurement Time	Implant length 8mm (*n*=4)			Implant length 10mm (*n*=11)			Implant length 12mm (*n*=7)			P-value
	Mean	SD	Median	Mean	SD	Median	Mean	SD	Median	
ISQ 0	68.50	5.916	68.00	68.27	7.564	69.00	71.29	4.716	69.00	0.7649*
ISQ 8	68.50	3.697	70.00	69.27	2.149	70.00	62.43	6.214	59.00	0.0950*
ISQ 12	75.25	5.439	76.00	73.45	5.628	73.00	72.57	3.735	73.00	0.6760*
ISQ PFL	79.00	4.899	80.00	79.45	4.156	78.00	76.43	3.155	74.00	0.3652*

ISQ, implant stability quotient; SD, standard deviation; * Kruskal Wallis test

DISCUSSION

Implant stability can be defined as the absence of clinical mobility, based on mechanical stability criteria. This can be considered one of the clinical signs of implant osseointegration in the bone [(12)]. The results of this study demonstrated that there was a drop in implant stability during the early postoperative period that was manifested as a reduction in ISQ values 8 weeks after implant insertion followed by an increase that is extended progressively into the 12th week postoperatively and even after loading the implants. This drop in implant stability, although it was non-significant, is associated with the resorption of peri-implant bone during the early postoperative period that represents the transition from the primary to the secondary stability. This resorption was demonstrated by Berglundh et al., [(13)] in an animal study, where the authors observed that during the first 4 weeks after implant insertion, the bone responsible for the primary stability was resorbed and replaced by new viable bone, they also noted that, despite this remodeling process, the implants remain stable. This pattern of implant stability change during the pre-loading phase is also demonstrated in other clinical studies. Han et al. [(14)] followed the ISQ values of 25 DIs at baseline, 4 days, 1, 2, 3, 4-, 6-, 8- and 12-weeks post-surgery, and they observed that the ISQ decreased by 3-4 values after installation and reached the lowest values at 3-4 weeks and then increased steadily for all implants and up to 12 weeks. **Koshy et al., [(15)]** showed similar pattern of changes in ISQ values over the course of healing/ osseointegration, and reported a decrease of 4-5 ISQ units post implant installation, while Rosen et al. [(16)] reported a range of 3 to 9 units for this physiological dip in DI stability. The mean difference of the physiological reduction in ISQ values, in this study, was 2.32 units, which could be considered lower than those figures reported by previous studies**.**

Primary stability is a requisite at the time of implant placement and it is related to the local bone quality and quantity, implant geometry (length, diameter, and type), and placement technique [(17)]. In the present study, the recipient jaw had no significant effect on ISQ values except for the primary stability, where maxillary implants demonstrated higher stability, however, on examining the data, it can be observed that DIs inserted in the mandible maintained better stability during the early postoperative period obtaining a mean difference of -1.3 ISQ values compared to that of the maxillary DIs that was much higher (-5.8 ISQ values). Vollmer et al. [(18)] observed a

positive association between primary implant stability and localization (mandibular vs. maxillary), although, the authors reported an increased ISQ values between insertion and exposure (secondary stability) which was significantly correlated with healing time and was higher in the maxilla.

The ISQ values of the secondary stability and after functional loading were higher for all DIs in comparison to ISQ0 and ISQ8 irrespective to the recipient jaw. The results are in agreement with other authors [19] who found no substantial effect of DI site with respect to its bone quality on secondary stability.

The higher post functional loading implant stability in comparison with the other time points of measurement that was reported in this study, was also observed by other authors, who stated that loading of dental implants increases the secondary stability of the implants as well as the mineralization of peri-implant bone, and that the main effective factor was the time from implant insertion to post functional loading [20, 21]. This could be explained by Wolff's law, which states that the bone will remodel itself and increase its firmness in response to mechanical stimulation and repeated load [22].

In this study, wider implants had better effect on implant stability throughout the study period with significant difference of both ISQ12 and ISQPFL time points, a finding that was also supported by other studies; Gomez-Polo et al., [19] in their longitudinal clinical study, evaluated the effect of DIs with 3.75 and 4.25mm diameter on ISQ. They concluded that wider diameter implants had a positive effect on both primary and secondary stability. Han et al., [14] on the other hand, observed no significant difference between DIs with 4.1 and 4.8mm implant diameter.

The diameter of dental implant is one of the factors that affect the stress distribution, especially, in the cervical portion of the DI. Studies have shown that wider implants result in better distribution of the masticatory forces [23]. Accordingly, the success of posterior implants is related to the increased surface area therefore, wide-diameter and long DIs are recommended in the posterior region [24]. In the present study, the implant diameter proved to be an influential factor, where lower stability was recorded in DIs with a narrower diameter which is in line with other studies [19]. Whereas other investigators found significant relation between implant diameter and primary stability only, [18, 25, 26] others found the significant effect was on secondary stability only [27].

Analyzing the effect of DI length on implant stability revealed that there was no significant relation between implant length and stability throughout the study period. Although some studies have reported that shorter implants have less contact with the surrounding bone, which may result in lower implant stability. [28, 29] The literature reports inconsistent results with respect to the relationship between implant stability and implant length. Ghanem et al. [1] reported direct effect of implant length on the stability and osseointegration of implants inserted immediately into freshly extracted sockets. Other studies demonstrated that the primary implant stability was only influenced positively by the implant length, [19, 26, 30] whereas Rengo et al. [27] stated that only the secondary implant stability was affected by implant length. On the other hand, Aragoneses et al. [31] reported a direct relationship between implants of a smaller length and greater ISQ values with this relation being most evident in maxilla.

The main limitation of this study is related to its small sample size which can make obtaining relevant generalization difficult.

CONCLUSIONS

In conclusion, all DIs were osseointegrated and stable at the end of the study irrespective to the recipient jaw, also DI with a wider diameter had better stability throughout the study whereas DI length showed no significant effect on implant stability.

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المستخلص

استقرار زعات الأسنان هو عامل إلزامي لإدماج الزرعة في العظم والنجاح على المدى الطويل .الهدف من هذه الدراسة كان لتقييم تأثير طول الزرعة وقطرها وموقعها في الفك العلوي او السفلي على استقرار الزرعة الأولي وبعدالتحميل الوظيفي .

شملت هذه الدراسة 17 مريضا بدون اي تاريخ مرضي، تتراوح أعمارهم بين 24 و61 عاما. تم اجراء عمليات زراعة الاسنان لوضع 22 زرعة في التجاويف الملتئمة بعد قلع الاسنان لفترة لا تقل عن ستة اشهرلتعويض الاسنان الخلفية المفقودة في كلا الفكين. تم قياس الاستقرار الاولي والثانوي لكل زرعة بالاضافة الى قياس الاستقرار بعد التحميل الوظيفي. تم تقييم تغير نمط استقرار الزرعات وعلاقته بابعاد الزعات وموقها في الفكين.

كان هناك فرق كبير في قيم استقرار الزرعات طول فترة الدراسة، وكان استقرار الزرعات بالفك الاعلى اعلى بكثير من الفك الاسفل لقيم الاستقرار الاولي فقط مع عدم وجود اي تاثير ذا دلالة احصائية لبقية الفترات الزمنية. وكانت الزرعات ذات القطر 4.1 مليمتر أكثر استقرارا من الزرعات ذات القطر 3.3 مليمتر طول فترة الدراسة. اما بالنسبة لطول الزرعات فلم تظهر النتائج اي تأثير له طول فترة الدراسة.

اظهرت نتائج الدراسة ان الاستقرار الاولي للزرعات في الفك الاعلى كان أفضل من الفك الاسفل مع زيادة استقرار الزرعات في كلا الفكين عند نهاية الدراسة. وكان القطر الاوسع أكثر استقرار، في حين لم يظهر الطول اي تاثير كبير على استقرار الزرعات.