Original Article

A Prospective Study of Short Implant Stability in the Posterior Maxilla

Cholathee Verochana[1], Somchai Sessirisombat[1], Niyom Thamrongananskul[2] and Soontra Panmekiate[3]

[1]Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand

[2]Department of Prosthodontics, Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand

[3]Department of Radiology, Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand

Correspondence to:

Somchai Sessirisombat. Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Chulalongkorn University, 34, Henri-Dunant Rd, Patumwan, Bangkok 10330 Thailand Tel: 02-2188581 Email: ssomcha1@chula.ac.th

Abstract

In partially edentulous patients who have inadequate bone height in posterior maxilla, sinus lift surgery is a standard procedure to increase vertical bone volume before or together with implant placement. However, some patients may have existing sinus problems or conditions that are contraindicated for sinus lift surgery. Placement of short implants may be considered an alternative treatment. Poor bone quality and quantity in the posterior maxilla play an important role in implant stability, especially for short implants. The proper healing period and implant stability are utmost important factors considered for the optimal timing of implant loading, and affect implant success or failure. The objective of this study is to investigate short implant stability in the posterior maxilla within a 4-month healing period. The stability of short implants was measured by Resonance Frequency Analysis (RFA) at the time of placement and 2, 3, and 4 months after placement. The results indicated that short implants with proper macro and micro architecture gained excellent stability within 3 months.

Key words: Short implant; Stability; Resonance Frequency Analysis; RFA; ISQ

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Introduction

Current knowledge of dental implants has revolutionized the replacement of missing teeth and implant prostheses are the standard of care for edentulous patients. Most studies indicated that dental implants are highly predictable and successful. However, several studies also reported a high incidence of implant failure in the posterior maxilla which attributed to insufficient bone volume and poor bone quality.[1,2] Short alveolar height is common due to the nature of each individual jaw, severe resorption from periodontal disease or pneumatization of the sinus. Several techniques have been developed to provide sufficient bone height for implant placement. These techniques include the sinus lift and bone graft, total or segmental bone onlays in some severe cases.[3] However, these procedures are disadvantageous to patients due to increased time, cost and risk of morbidity. Therefore, bone augmentation in the posterior maxilla to facilitate further implant placement is not preferable in a number of patients. For these patients, the placement of short dental implants may be considered an option.

The definition of "short implant" is controversial. In general, 10 mm implants are more commonly referred to as "standard length implants".[3] A systematic review showed that the failure rates of implants of 6, 7, 7.5, 8, 8.5, 9, and 10 mm in length were 4.1 %, 5.9 %, 0 %, 2.5 %, 3.2 %, 0.6 %, and 6.5 % respectively.[4] The total failure rate was 4.5 %. Moreover, 57.9 % of the failure happened early before prosthetic loading.

Bone density exhibits an important factor in implant stability. High primary stability of an implant and a good surgical technic promote implant osseointegration.[5] Most studies indicated that primary stability at the time of implant placement is utmost important for implant success.[2, 6] Secondary implant stability is a biological phenomenon through the process of bone formation and remodeling at the implant-bone interface and in the surrounding bone. Therefore, it is important to have a quantitative measurement of implant stability at different times during healing and to obtain a predictable long-term success based on implant stability. According to an *in vitro* study in 1996, Meredith *et al.*[7] introduced Resonance Frequency Analysis (RFA) as a noninvasive method to measure implant stability based on basic vibration theory. The transducer attached directly into an implant or abutment could be excited by a steady state, swept frequency waveform and the response signal was measured by a dedicated frequency response analyzer to determine the stiffness of implant-bone interface and the surrounding bone. Osstell™ ISQ, (Osstell AB, Göteborg, Sweden), is a device working on the basis of RFA for measurement of implant stability. Osstell™ ISQ uses the Implant Stability Quotient (ISQ) as a scale to indicate the level of implant stability, ranging from 1 to 100. The high ISQ value indicates high stability of an implant.[8]

Several clinical studies have shown the benefits of RFA. Friberg *et al.*[9] evaluated the stability changes in 75 implants with three different designs in 15 edentulous mandibles during the healing period by RFA. The study revealed that the RFA technique was more sensitive in detecting changes of implant stability than the conventional clinical and radiographic examination. Glauser *et al.*[10] analyzed the changes of implant stability by repeated RFA measurements in 23 patients treated under an immediate/early-loading protocol during a period of one year. Eighty-one machined-surface implants with various lengths were placed in all jaw regions. They concluded that failing implants showed a continuous decrease of stability until failure. Implants with low RFA values at 1 and 2 months after placement had a high risk for future failure.

However, there have been few studies of short implant stability, and loading protocol of short implants has not been established. Studying of short implant stability may help clinicians decide the optimal timing for functional loading to prevent failure of short implants especially in the posterior maxilla. The objective of this study is to evaluate the stability change of short implants in the posterior maxilla within the first 4 months of healing period.

Materials and methods

The study protocol was approved by the Ethics Committee of the Faculty of Dentistry, Chulalongkorn University. Fourteen patients requiring an implant-supported fixed prosthesis in the posterior maxilla were enrolled. Patients were selected according to the inclusion and exclusion criteria. Informed consent was obtained from all patients enrolled in the study. All procedures were performed at the Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Chulalongkorn University.

Inclusion criteria

- Aged over 20 years old.
- Having adequate bone height suitable for placement of implant with 7.5 mm in length and 4.2 mm in diameter.
- The edentulous space was 6 - 10 mm.
- Missing at least one permanent first premolar, second premolar, first molar, or second molar in maxilla.
- Having at least two pairs of natural posterior teeth (premolars and/or molars) occluding together on the same side in which the short implant would be placed.

Exclusion criteria

- Inadequate bone height (less than 8 mm from the alveolar crest to the sinus floor in the maxilla) as evaluated from cone-beam CT scan.
- Inadequate bone width (less than 6 mm).
- Smoking more than 10 cigarettes per day.
- Severe bruxing or clenching habits.
- Patients who have taken oral bisphosphonate for more than 3 years.
- History of chemotherapy or radiation treatment in the area of head and neck.
- Uncontrolled diabetes or other metabolic bone diseases.
- Having a need for bone or soft tissue grafting at the time of implant placement.
- No canine or natural tooth guidance on lateral movement of the jaw.
- Having severe tipping of the tooth adjacent to the edentulous area.

Surgical and prosthetic procedures

The preoperative planning was based on clinical and radiographic examinations. The panoramic radiograph (Fig. 1) was used for initial assessment of bone height at the planned surgical site, and Cone-Beam Computerized Tomography (CBCT) was used for an accurate preoperative surgical planning. A total of 15 SICmax® implants (SIC invent AG, Basel, Switzerland) with 7.5 mm in length and 4.2 mm in diameter were placed (Fig. 2).

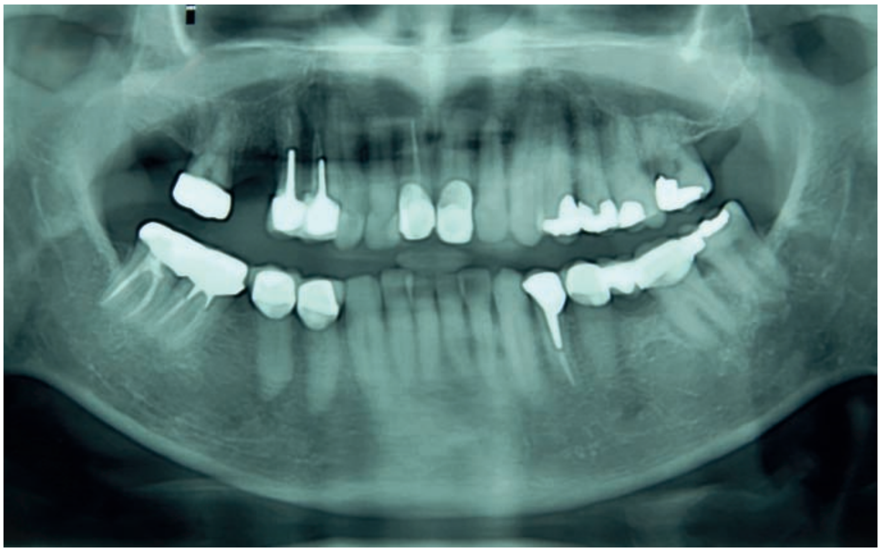

Figure 1 *Preoperative panoramic radiograph*

Figure 2 *Short implant (Ø 4.2 mm, length 7.5 mm) used in the present study*

Patients were premedicated with 1,000 mg of amoxycillin 30 minutes before operation, for those who were allergic to penicillin, 600 mg of clindamycin was prescribed. After the local anesthetic (2 % mepivacaine with 1:100,000 epinephrine) was administered, a crestal incision was done and mucoperiosteal flap was reflected. The osteotomy was performed following the surgical protocol of the manufacturer. The implant stability was measured by Osstell™ ISQ and Type 44 SmartPeg™ (Osstell AB, Göteborg, Sweden). The SmartPeg™ was mounted directly to the implant (Fig. 3) and the transducer probe of Osstell™ ISQ was held still on the buccal side aiming to the top of the SmartPeg™ (Fig. 4)

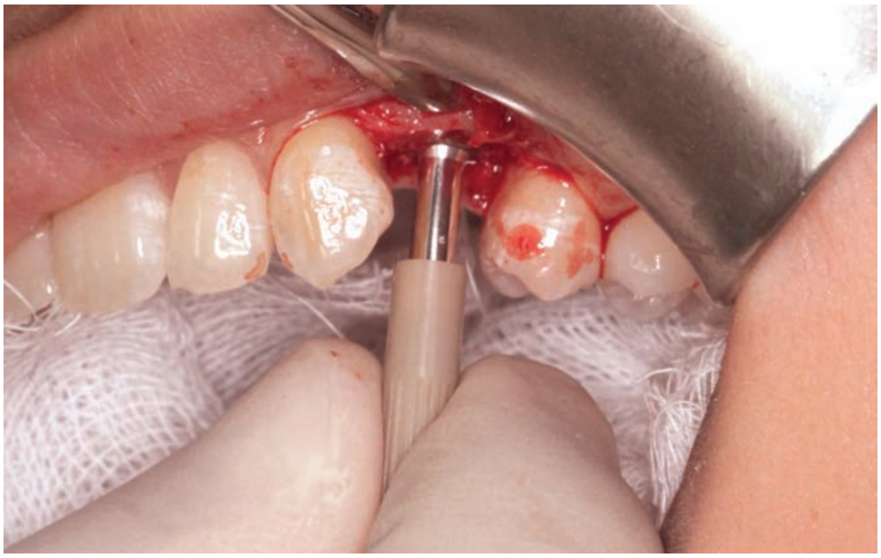

Figure 3 *SmartPeg™ mounted directly to the implant*

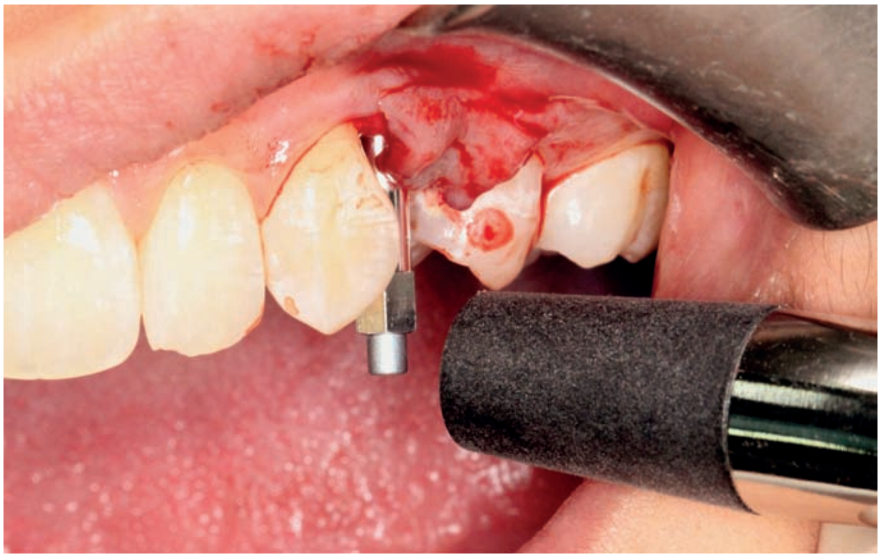

Figure 4 *Transducer probe was held on the buccal side of the SmartPeg™*

until the ISQ value was shown. The primary implant stability was recorded. Once after implant was placed, the cover screw was threaded and closure of the flap was done. Ibuprofen 400 mg was prescribed three times daily for pain control. Postoperative panoramic radiograph (Fig. 5) was taken on the day of implant placement. Two months later, the second stage surgery was done. The second implant stability was measured before a healing abutment was installed to the implant. Three months after implant placement, before an impression was taken, the third implant stability was measured. Four months after implant placement, the forth implant stability was measured, then the abutment and crown were fixed to the implant. All of the prostheses in this study were single implant crowns. Three months later, the implant prosthesis was then evaluated for success or failure using the criteria proposed by Buser *et al*.[11] Due to non-normal distribution of the data, implant stability was presented as mean ± SD, range, and median. Statistical comparison of short implant stability at different periods of time was performed using Wilcoxon signed ranks test. The level of significance for all statistical test was set at α = 0.05. The success rate of short implants was reported as percentage. Statistical analyses were determined using the Statistical Package for the Social Sciences software (SPSS) version 17.0 for Windows (SPSS Inc., Chicago, USA).

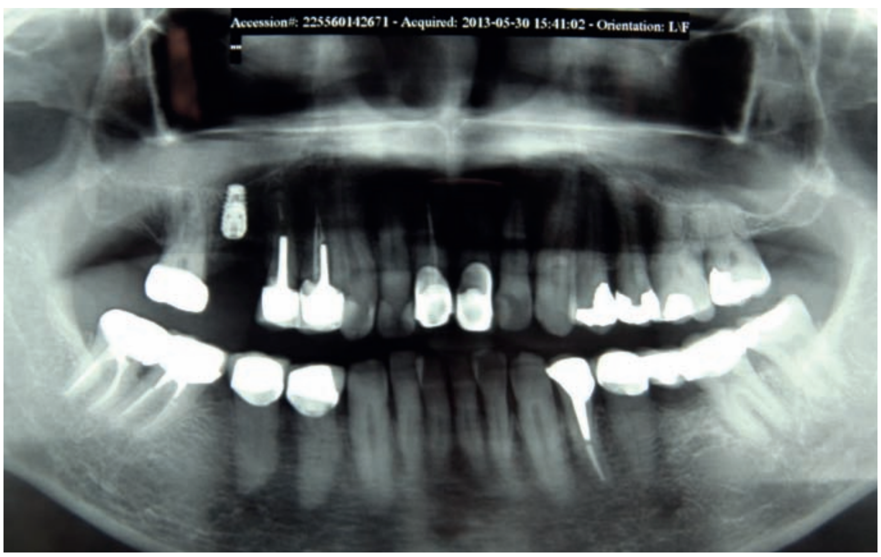

Figure 5 *Postoperative panoramic radiograph*

Results

A total of 14 partially-edentulous patients were enrolled in the study. Fifteen short implants (7.5 mm in length and 4.2 mm in diameter) were placed in the posterior maxilla. One implant failed to osseointegrate during the second stage surgery and was excluded during the study. All other implants were restored. The patients' demographic data was shown in Table 1.

The ISQ values of 14 implants (in 13 patients) were analyzed. Range, mean ± SD and median ISQ values of short implants in the posterior maxilla were presented in Table 2. The median ISQ values at the time of implant placement and at 2, 3, and 4 months after implant placement were continuously increasing (Fig. 6). Comparing to the stability at implant placement (ISQ 0), the median ISQ values at 3 and 4 months after implant placement were increasing significantly. The median ISQ value at 2 months after placement was also increasing but not statistically significant.

Table 1 Patient demographic data

Descriptive data	N	%
Number of patients	14	100
Age (year)		
Mean ± SD	44 ± 16.5	
Sex		
Male	4	28.6
Female	10	71.4
Smoking		
Yes	2	14.3
No	12	85.7
Number of patients	15	100
Success	14	93.3
Failure	1	6.7
Implant position		
Premolar	6	40.0
Molar	9	60.0
Duration of tooth loss before implant placement		
< 6 months	7	50.0
6 - 12 months	1	7.1
> 12 months	6	42.9

Abbreviation: SD = standard deviation

Table 2 *The ISQ values of implants in the posterior maxilla*

Stability (ISQ)	Max	Min	Mean ± SD	Median
Insertion (ISQ 0)	79.0	32.0	70.1 ± 11.8	73.0
2 months (ISQ 2)	80.0	65.0	74.1 ± 4.1	74.5
3 months (ISQ 3)	82.0	68.0	77.6 ± 3.9	78.0
4 months (ISQ 4)	84.0	71.0	78.7 ± 3.3	79.5

Abbreviations: ISQ = Implant stability quotient; SD = Standard deviation

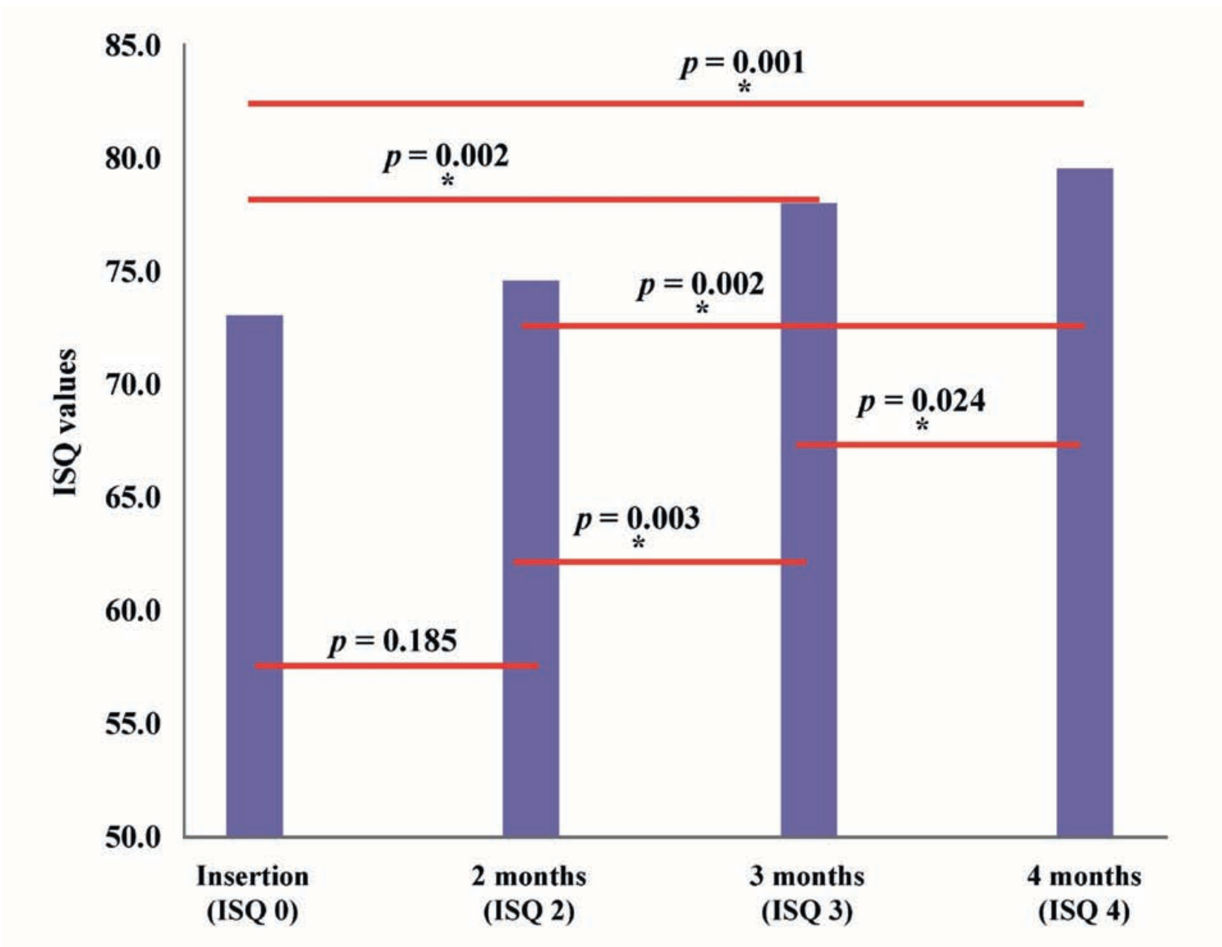

Figure 6 *Median ISQ values of short implants at different periods of time. Asterisks depict significant differences ($p < 0.05$); p-value as Wilcoxon Signed Ranks test; N = 14.*
X-axis represented the time after implant insertion (0, 2, 3, 4 months).
Y-axis represented stability of the implants reported as median ISQ value due to the non-normal distribution of data.

Discussion

Several studies confirmed that RFA is a reliable method to indicate implant stability. An *in vitro* study by Huang *et al*. demonstrated that the 3D bone-implant contact percentage (3D BIC %) has strongly positive correlation to the ISQ values.[12] Park *et al*. presented similar results in their experiment that 16 implants placed in rabbit tibias.[13] This study also demonstrated significant correlation between the BIC % and primary stability of implants. Al-Moaber *et al*. studied stability changes of 2 different implant systems during a healing period of 8 weeks in beagle dogs using RFA and evaluated periimplant bone healing using microcomputed tomography (micro-CT).[14] The study confirmed the efficacy of RFA in determining the implant stability and the healing status of bone around dental implants.

In the present study, the Osstell™ ISQ was used with type 44 SmartPeg™ to measure the stability of short implants placed in the posterior maxilla on the day of placement and after 2, 3, and 4 months respectively. The SmartPeg™ can resonate in two perpendicular directions automatically – hence providing two ISQ values, the higher and the lower ones, in non-homogenous bone. In cases of two different ISQ values, we chose the lower one to represent the stability of short implants. The reason we chose the lower ISQ values is because the dental implants will be loaded with occlusal forces in all different directions when functioning. The result demonstrated that short implant stability was gradually increasing during the 4-month healing period. At 2 months, short implant stability was not significantly different from the primary stability. However, the stability at the 3rd and 4th month was significantly different from the primary stability. This might indicate that the osseointegration process gradually gained and the increased ISQ values would be represented the strength of the implant-bone connection that achieved 3 months after implant placement.

Primary stability of an implant is utmost important for implant success. It prevents micromovement and enhances the osseointegration process of an implant. Factors influencing the primary stability include bone quality and quantity, implant design and configuration, and surgical techniques.[15] In this study, all implants placed were 7.5 mm long and 4.2 mm wide. Therefore the primary stability of the implants in this study was directly dependent only on the quality and quantity of bone at each implant site. According to the Misch bone density classification, bone density has been classified using CT scan into five categories, D1 - D5. D1 bone refers to dense cortical bone (> 1,250 Hounsfield units), while D5 bone is very soft bone with incomplete mineralization and large trabecular spaces (< 150 Hounsfield units).[16] Several studies demonstrated that D3 and D4 bone types are common in posterior maxillary areas which are relatively soft or poor-quality bone.[17,18] This might be an explanation of the higher failure rates of dental implants in the posterior maxilla found in many studies.[1,19] In the present study, a total of 15 implants were placed in posterior maxilla using two-stage approach. One implant in a 45 year old female patient failed to osseointegrate. During the second stage surgery, the failed implant which had good initial stability (68 ISQ) was rotated hence it was removed. The early success rate of short implants in this study was 93.3 %.

The secondary stability is a biological phenomenon caused by bone healing and remodeling around an implant known as osseointegration. Factors influencing the osseointegration process include implant related factors, the state of implant site, primary stability, and adjunctive therapies such as bone grafting.[20] Each patient who enrolled in this study must have enough bone volume for short implants with no additional bone grafting. Furthermore, two-stage surgical approach was used and wearing of removable partial denture was not allowed after implant placement. According to the previous studies, the weakest stability period of implants was found during 3 to 6 weeks after placement.[21-23] Therefore, the second stage surgery was performed at 2 months after placement. In the present study, one short implant was placed with poor primary stability (32 ISQ). The ISQ values of this implant increased to 65, 68, and 71 at 2, 3, and 4 months respectively. At three months after loading, this implant was still functioned with good stability and the periapical radiograph revealed no bone loss.

One of the most important factors influencing osseointegration process is chemical and physical properties of implant surface.[20] Titanium has been the most widely used material for dental implants. Nowadays, most implant systems are rough-surface implants. Numerous studies have demonstrated that rough-surface implants have better stability and higher success than smooth-surface implants.[24] Sandblasted with Large grits and Acid etched (SLA) surface is the most popular among other implant surfaces. The SLA implants have demonstrated good outcomes both *in vivo*[25,26] and long-term clinical studies.[27] ,In this study, the SICmax® implants which have SLA surfaces showed excellent primary and secondary stability, and showed good clinical outcomes.

Balleri *et al*.[28] reported normal ISQ values of 45 successfully osseointegrated implants at 1 year after loading. The mean ISQ value was 69 which was ranging from 57 to 82 for all clinically stable implants. There was no correlation between stability and implant length. The result was very similar to the study of Glauser *et al*.[10] which showed the mean ISQ value of 70 for successful implants at 1 year after placement. The results of this study demonstrated that the mean ISQ value at implant placement was 70.1 and the mean ISQ values at 2, 3, and 4 months after placement were 74.1, 77.6, and 78.7 respectively. These ISQ values might indicate that bone healing and remodeling occurred gradually with in the first 4 months and short implants with SLA surfaces could provide strong implant-bone connection leading to successfully integrated within 3 months after placement.

Conclusion

In conclusion, this study indicated that short implants are effective for fixed implant prostheses in the posterior maxilla of partial edentulism when there is not enough bone height for normal length implants. RFA is a reliable method to evaluate implant stability which may help clinicians to consider an appropriate timing for prosthetic loading. The results of this study indicated that at 3 months after placement, short implants in the posterior maxilla showed a high level of ISQ value suitable for functional loading. However, other factors must be considered for each individual patient and a long-term follow-up should be done to assess the long-term success of short implants.

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