A Comparison of Implant Stability between Implant Placed without Bone Graft versus with Bone Graft Using Guided Bone Regeneration Technique: A Resonance Frequency Analysis

R. Janyaphadungpong, A. Pimkhaokham

***Abstract*—**This prospective clinical study determined the insertion torque (IT) value and monitored the changes in implant stability quotient (ISQ) values during the 12 weeks healing period from implant placement without bone graft (control group) and with bone graft using the guided bone regeneration (GBR) technique (study group). The relationship between the IT and ISQ values of the implants was also assessed. The control and study groups each consisted of 6 patients with 8 implants per group. The ASTRA TECH Implant System™ EV 4.2 mm in diameter was placed in the posterior mandibular region. In the control group, implants were placed in bone without bone graft, whereas in the study group implants were placed simultaneously with the GBR technique at favorable bone defect. IT (Ncm) of each implant was recorded when fully inserted. ISQ values were obtained from the Osstell® ISQ at the time of implant placement, and at 2, 4, 8, and 12 weeks. No difference in IT was found between groups (P = 0.320). The ISQ values in the control group were significantly higher than in the study group at the time of implant placement and at 4 weeks. There was no significant association between IT and ISQ values either at baseline or after the 12 weeks. At 12 weeks of healing, the control and study groups displayed different trends. Mean ISQ values for the control group decreased over the first 2 weeks and then started to increase. ISQ value increases were statistically significant at 8 weeks and later, whereas mean ISQ values in the study group decreased over the first 4 weeks and then started to increase, with statistical significance after 12 weeks. At 12 weeks, all implants achieved osseointegration with mean ISQ values over the threshold value (ISQ>70). These results indicated that implants, in which GBR technique was performed during implant placement for treating favorable bone defects, were as predictable as implants placed without bone graft. However, loading in implants placed with the GBR technique for correcting favorable bone defects should be performed after 12 weeks of healing to ensure implant stability and osseointegration.

***Keywords*—**Dental implant, favorable bone defect, guided bone regeneration technique, implant stability.

I. Introduction

ORAL rehabilitation using titanium dental implant has been extensively performed since the osseointegration concept was introduced by Brånemark in 1969. Long-term successful outcomes of dental implants were supported by several studies [1]-[3]. However, reduction in alveolar ridge width after tooth extraction may cause horizontal bone defects at the planned implant site, including dehiscence and fenestration defects which can compromise the long-term success rate, the stability of the implant and the esthetic outcome of the definitive restoration. Different bone augmentation techniques have been generated to correct these horizontal bone defects. A GBR technique is one of the most popular surgical procedures, using grafting materials combined with barrier membranes to maintain and stimulate the growth of new bone into the defect sites.

Implant stability or absence of mobility has been identified as a prerequisite to achieve osseointegration, and proposed as one of the factors affecting implant loading and long-term success [4], [5]. Previous studies have described different methods for accessing implant stability, including both invasive and non-invasive clinical test methods. One non-invasive quantitative method used IT measurement. IT is the torque value required to seat the implant into the osteotomy site during the thread placement procedure [6]. However, this method cannot be used after implant placement. Resonance frequency analysis (RFA) is a recent non-invasive electronic measuring device to monitor changes in implant stability with highly repeatable and reliable results [7]-[9]. The stiffness of the implant-bone complex was determined by the Osstell apparatus (Integration Diagnosis AB, Gothenburg, Sweden). This displays as an ISQ value, ranging from 1 (lowest stability) to 100 (highest stability). An acceptable ISQ is between 55 and 85 with an average of 70 [10]-[13]. An ISQ value below 55 should be regarded as a warning sign, and unloading and allowing a longer period of healing should be considered. However, less clinical studies have been performed in evaluating IT values and RFA of the ASTRA TECH Implant System™ EV placed without bone graft versus with bone graft using the GBR technique. Therefore, the primary objectives of this clinical study were to compare IT values and monitor the longitudinal changes in ISQ value as a reflection of the stability between implants placed in bone, with and without horizontal bone graft, using the GBR technique. The secondary objective was to assess the relationship between the IT and ISQ values of the implants.

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II. Materials and Methods

The population consisted of patients seeking dental implant treatment at the Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand. The study protocol was submitted to and approved by the Ethics Committee for Human Research of the Faculty of Dentistry, Chulalongkorn University. All patients were informed about the study protocol and signed informed consent forms prior to starting the treatment.

Only patients meeting the following inclusion criteria were accepted in the study: 1) Age over 21 years, 2) Systematically healthy (ASA I or II) with no contraindications against oral surgical interventions, 3) A healed ridge with more than 6 months after extraction in the posterior mandibular region, 4) Sufficient residual bone volume at the planned implant site (the bone height must be adequate to prevent damage to vital structure with sufficient bone width for the implant to be placed according to the treatment plan in a prosthetically ideal position), 5) Implant placement with one-staged protocol, 6) Implants placed without horizontal bone graft must be entirely surrounded by bone with at least 1 mm, 7) For implants placed simultaneously using the GBR technique, patients were presented with favorable bone defects [14] as exposed implant surfaces during placement, and required the GBR procedure to improve implant support and final esthetic outcome, 8) All implants achieved optimum primary stability with an IT value of at least 15 Ncm. Exclusion criteria were: 1) Heavy smokers (>10 cigarettes/day), 2) History of alcoholism or drug abuse, 3) Severe medical conditions or on medication that affected bone or wound healing (i.e. uncontrolled diabetes mellitus, on intravenous bisphosphonate), 4) Pregnancy, and 5) The presence of infection at or adjacent to the surgical sites. Patients who met all these inclusion criteria were accepted in the study. Computed tomography scans with radiographic stents were performed before surgery to classify the patients into the different groups.

A. Surgical Procedure

All patients received antibiotic (1 g of amoxycillin) and analgesic (500 mg of Ponstan) prior to the surgery. A mouth rinse with 0.1% of an aqueous solution of chlorhexidine was given for 2 minutes. The surgical area was anesthetized locally and a crestal incision with a full thickness mucoperiosteal flap was raised to access the site. The alveolar site was prepared according to the manufacturer's drilling sequence with external irrigation. An ASTRA TECH Implant System™ EV (Dentsply Implants, Mölndal, Sweden) 4.2 mm in diameter was inserted in a prosthetically ideal position at the marginal bone level or slightly below. A healing abutment was installed into the fixture, followed by repositioning and suturing the mucoperiosteal flap. Post-surgical antibiotics and analgesic therapy used amoxycillin for 5 days and Ponstan for 3 days. Oral hygiene was controlled with chlorhexidine 0.1% mouth rinse for 14 days.

B. GBR Procedure

In case of exposed implant surface and presented with a favorable bone defect, which was the width of the defect less than one third of the mesio-distal dimension between the adjacent teeth [14]. The GBR procedure was performed following the protocol outlined by [15], [16]. Small autogenous bone chips collected at the time of the osteotomy site preparation were soaked in blood in a sterile dish and placed directly on the exposed implant surface. The deproteinized bovine bone mineral (Bio-Oss®, Geistlich Pharma AG, Wolhusen, Switzerland) mixed with blood was then used as a second layer over the autogenous bone. Non-crosslinked collagen membrane (Bio-Gide®, Geistlich Pharma AG, Wolhusen, Switzerland) was cut into two strips, moistened with blood, applied with a double-layer technique to improve membrane stability and extended 2–3 mm onto the intact bony borders of the defect. Releasing incisions might be performed for primary closure with a tension-free flap.

C. IT Measurement

During the implant insertion, the IT value was recorded with a calibrated torque wrench attached to the fixture. The initial torque was set at 10 Ncm and increased in steps of 5 Ncm. The final IT value (Ncm) of each implant was recorded when it was fully inserted.

D. ISQ Measurement

Implant stability was measured by an Osstell® ISQ (Osstell AB, Integration Diagnosis, Gothenburg, Sweden). A standardized SmartPeg (type 49, SmartPeg, Integration Diagnostics AB) was hand-screwed into the implant fixture with the aid of a mount at 4−5 Ncm of torque. Immediately after implant placement, the probe of the device was held close to the peg in buccal and mesial direction, and the ISQ measurement was performed and served as baseline. Thereafter, the ISQ was further recorded at 2, 4, 8, and 12 weeks after implant placement. To perform the measurement at each time point, the healing abutment was gently removed and the peg was hand-screwed into the fixture. All measurements were performed by one trained evaluator.

E. Statistical Analysis

The data were analyzed using the statistical software (IBM SPSS Statistics 18.0, IBM Corp, Armonk, NY). The normality of the data was tested with the Shapiro-Wilk W-test. The data distribution was normal and the t-test was used to compare the two groups. ANOVA with the Post-Hoc test for pairwise comparison was used to compare more than two groups. For repeated measurements, repeated ANOVA was used. Statistical significance was set at a P value of 0.05.

III. Results

In the control group of 6 patients (1 male and 5 females) with a mean age of 60.5 $\pm$ 3.63 years, 8 implants were placed in bone without horizontal bone graft. In the study group of 6 patients (1 male and 5 females) with a mean age of 50.63 $\pm$ 8.62 years, 8 implants were placed simultaneously using the GBR technique to correct the favorable bone defect. None of the implants failed during the 12 weeks healing period, and the

overall implant survival rate was 100%.

A. IT Value

IT value ranged between 15 and 45 Ncm. The mean IT values of the control and study groups were 26.25 ± 6.94 Ncm and 30.63 ± 9.80 Ncm, respectively (Fig. 2). Statistically significant differences were not found between the two groups (P = 0.320).

B. ISQ

The mean ISQ values of the control group were 76.31 ± 4.03 at baseline, 68.31 ± 5.99 after 2 weeks, 71.69 ± 3.22 after 4 weeks, 75.19 ± 4.00 after 8 weeks and 76.69 ± 3.39 after 12 weeks (Figs. 1, 2). The mean ISQ values of the study group were 68.81 ± 7.36 at baseline, 65.13 ± 7.40 after 2 weeks, 60.50 ± 10.98 after 4 weeks, 72.75 ± 2.84 after 8 weeks and 76.44 ± 2.65 after 12 weeks (Figs. 1, 2). Statistically significant differences in mean ISQ values between the control and study groups were found at baseline (P = 0.024) and after 4 weeks (P = 0.024) (Fig. 2).

C. Variation of ISQ during the Healing Period

The variation in ISQ after the 12 weeks healing period was 0.38 ± 6.41 for the control group and 7.63 ± 7.22 for the study group, respectively, and the difference was not statistically significant difference (P = 0.052) (Fig. 2).

Two groups displayed a significantly different increasing trend (Fig. 1). In the control group, mean ISQ values decreased over the first 2 weeks and then started to increase. Statistically significant differences were found between the mean ISQ values at 2 weeks and at 8 weeks (P = 0.007), at 2 weeks and at 12 weeks (P = 0.036), and at 4 weeks and at 12 weeks (P = 0.036). In the study group, mean ISQ values decreased over the first 4 weeks and then started to increase. Statistically significant differences were found only between mean ISQ values at 8 weeks and 12 weeks (P = 0.010).

D. Relationship between IT Value and the Primary and Secondary ISQ

For all 16 implants, the mean IT value was 28.44 ± 8.51, and mean ISQ value was 72.56 ± 6.92 at baseline and 76.56 ± 2.94 after 12 weeks. Significant difference was not found either between IT and mean ISQ value at baseline (P = 0.775) or after 12 weeks (P = 0.484) (Table I).

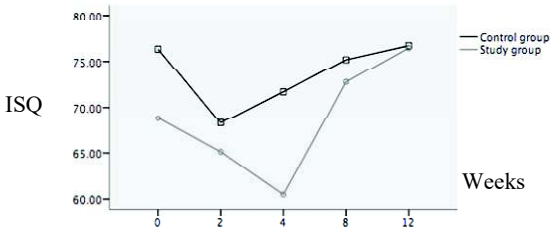

Fig. 1 The mean ISQ between implant placement and after 12 weeks for the control and study groups

	Control group (N=8)	Study group (N=8)	P Value
Insertion torque value	26.25 ± 6.94	30.63 ± 9.80	0.320
ISQ at baseline	76.31 ± 4.03	68.81 ± 7.36	**0.024***
ISQ after 2 weeks	68.31 ± 5.99	65.13 ± 7.40	0.359
ISQ after 4 weeks	71.69 ± 3.22	60.50 ± 10.98	**0.024***
ISQ after 8 weeks	75.19 ± 4.00	72.75 ± 2.84	0.182
ISQ after 12 weeks	76.69 ± 3.39	76.44 ± 2.65	0.872
Variation in ISQ	0.38 ± 6.41	7.63 ± 7.22	0.052

* refer to the corresponding statistically significant groups

Fig. 2 ISQ of the control group and study group

TABLE I
IT VALUE VERSUS ISQ AT BASELINE AND AFTER 12 WEEKS

	N	Mean	P value
IT value	16	28.44 ± 8.51	
ISQ at baseline	16	72.56 ± 6.92	0.775
ISQ after 12 weeks	16	76.56 ± 2.94	0.484

IV. DISCUSSION

The present study reported the data of IT value and ISQ values obtained from the ASTRA TECH Implant System™ EV over the 12 weeks healing period. The primary objectives were to determine IT and ISQ values as a reflection of the implant stability between implants placed in bone, both without and with horizontal bone graft using the GBR technique. The secondary objective was to assess the relationship between IT and ISQ values of the implant. Results determined that implant placement with horizontal bone graft using the GBR technique at favorable bone defect had no impact on IT value; however, horizontal bone graft affected ISQ values at the time of implant placement and at 4 weeks. Moreover, there was no correlation between IT and ISQ values at baseline or after the 12 weeks healing period.

A. IT Value

The IT value was considered relative to the primary implant stability to prevent any micromovement. Previous studies reported on the IT value of implants placed in bone with bone defect. Turkyilmaz et al. [17] determined the IT value of 84 implants placed in the mandible of human cadavers with 5 different vertical defect depths, with the mean IT value 28.9 ± 7 Ncm. Shin et al. [18] placed implants in bovine rib bone both without and with bone defect. They reported a significantly higher IT value in the no defects group than in any of the defects groups. In this study, statistically significant differences were not found between implants placed in bone without bone graft and implants placed together with horizontal bone graft using the GBR technique at favorable bone defect (P = 0.320). Disagreement between these results could be associated with the different bone type, defect type and size used in study.

B. ISQ

During the healing period, the initial (primary) stability

obtained from mechanical retention between implant and bone, it decreased over time through osteoclastic activity, whereas the secondary stability increased with bone formation and remodeling over the implant surface. Three weeks after implant placement is considered as a critical period, and the lowest stability is expected due to the primary stability decreased and the secondary stability has not yet achieved [19], [20]. This critical period was matched in this study, with both control and study groups recording the lowest mean ISQ values at 2 weeks and 4 weeks after implant placement. In addition, results indicated that the primary and secondary ISQ values were not closely correlated. The control group with high primary ISQ values appealed to show unaltered secondary ISQ values. On the other hand, the study group with low primary ISQ values, secondary ISQ values tended to increase after osseointegration. Some previous studies reported similar results that implants with primary ISQ values more than 70 tended not to increase in strength with time [12].

After 12 weeks of healing, the control and study groups displayed a different increasing trend. For the control group, mean ISQ values decreased over the first 2 weeks and then started to increase, with ISQ value increases statistically significant after 8 weeks and later. In the study group, the mean ISQ values decreased over the first 4 weeks and then started to increase, with ISQ value increase statistically significant after 12 weeks. However, at 12 weeks, all implants were osseointegrated with mean ISQ values more than 70 and at an acceptable level [10], [12]. Results at the 12 weeks follow-up suggested that implants placed in bone with horizontal bone graft using the GBR technique were as predictable as those without horizontal bone graft. Furthermore, loading in implants placed with horizontal bone graft should wait until 12 weeks to ensure greater stability and osseointegration, whereas implants placed in bone without bone graft could be loaded at 8 weeks.

Further research with larger sample sizes and longer follow-up periods is required. In addition, a histomorphometric investigation of the healing characteristics at each time point of implant placement in bone, both with and without bone graft using the GBR technique should be conducted.

C. Relationship between IT Value and the Primary and Secondary ISQ

Results showed that IT values were not associated with either primary or secondary ISQ values. Some previous studies reported no relation between IT and primary ISQ values [21], [22], whereas others reported correlation [17], [23], [24]. Few authors have studied the relation between IT and secondary ISQ values. However, [24] reported no correlation between them, similar to the results presented here.

V. Conclusion

Due to the limitation of the study, the data of IT value and ISQ values were obtained from the ASTRA TECH Implant System™ EV over the 12 weeks healing period. The following conclusion could be drawn.

No difference in IT was found between two groups.

The ISQ values in the implants placed in bone without horizontal bone graft were significantly higher than in the implants placed with horizontal bone graft using the GBR technique at the time of placement and at 4 weeks.

No correlation between IT and ISQ values was found at baseline and after the 12 weeks healing period.

Implants placed in bone with horizontal bone graft using the GBR technique were as predictable as those placed without horizontal bone graft. Loading in implants placed with horizontal bone graft should allow 12 weeks to ensure greater stability and osseointegration.

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