

Resonance frequency analysis of implant stability in augmented and non-augmented sinus sites

Amir Moeintaghavi¹, Habibollah Ghanbari¹, Mehrdad Radvar², Reza Zare²,
Naser Sargolzaei³, Hamed Nicknam⁴

¹Professor. Oral and Maxillofacial Diseases Research Center, School of Dentistry, Mashhad University of Medical Sciences, Mashhad, Iran

²Dental Research Center, School of Dentistry, Mashhad University, Medical Sciences, Mashhad, Iran

³Dental Materials Research Center, School of Dentistry, Mashhad University of Medical Sciences, Mashhad, Iran

⁴Periodontist

Received 22 May 2015 and Accepted 11 December 2015

Abstract

Background and aim: Although there have been substantial developments in dental implant therapies, achieving good implant stability (ISQ >60) for implants inserted in augmented sinus sites appears to be challenging in comparison with non-augmented sites due to the high prevalence of bone resorption in posterior regions of maxilla. This study aimed to evaluate and compare the time required to achieve good implant stability between implants inserted in sites that had undergone a sinus augmentation procedure with implants inserted in non-augmented similar regions of maxilla.

Methods: Thirty Stroman ITI Dental Implants were inserted in 14 patients (8 females and 6 males) with average age of 55 ± 10 years. Fourteen implants were inserted in sinus augmented sites (open sinus elevation and Demineralized Freezed Bone Allograft or DFDBA) 6 months after healing (test group), and 16 implants were inserted into non-augmented posterior areas of maxilla (control group). The implant stability quotient (ISQ) for each implant was measured at the time of insertion (baseline, ISQ₀) and at 1, 2 and 3 months later (ISQ₁, ISQ₂, ISQ₃). Residual and augmented bone heights were also recorded. **Results:** The average residual bone height was 2.92 ± 0.63 mm and 10.41 ± 1.46 mm for the augmented bone height. The difference between ISQ values in the test and control groups was only significant at the baseline ($p=0.023$). No significant correlation was found between ISQ and bone height (residual and augmented), and there was no significant correlation between ISQ values and the implant diameter and length. In the test group, the differences between ISQ₀ and ISQ₁, ISQ₁ and ISQ₃ and ISQ₂ and ISQ₃ were all statistically significant ($p=0.006$, $p=0.032$, $p=0.046$). In the control group, the difference was only significant between ISQ₀ and ISQ₁ ($p=0.002$).

Conclusion: ISQ values were not statistically significant between implants inserted in natural and augmented bone six months after sinus augmentation. In other words, within the limitation of this study, the time required to achieve good stability for implants inserted in augmented sinus sites is similar to those inserted in non-augmented sites.

Key words: ISQ; sinus lift; Implant stability.

Moeintaghavi A, Ghanbari H, Radvar M, Zare R, Sargolzaei N, Nicknam H. Resonance frequency analysis of implant stability in augmented and non-augmented sinus sites. *J Dent Mater Tech* 2016; 5(1): 43-48.

Introduction

One of the reliable methods that enables implant insertion in a severely resorbed posterior maxilla is open maxillary sinus floor elevation with bone substitute grafts.(1) Implant stability has to be obtained during implant insertion and maintained over time. Achieving suitable implant stability in posterior maxillary grafted sites is challenging in comparison with non-grafted similar regions. However, recent studies have illustrated that this stability may be achieved in grafted sites.(2, 3) Resonance frequency analysis (RFA) offers a clinical measure for implant stability and presumed osseointegration.(4) Most studies have focused on implant stability in augmented posterior regions of

maxilla after osseointegration(5). Digedi et al. in 2007 perform a study to evaluate whether a good primary stability could be achieved in sites with history of a sinus augmentation procedure and the importance of different clinical factors in the determination of ISQ values at implant insertion. Sites treated with open sinus augmentation procedure could offer good primary stability after 6 months of healing. The length and diameter of the implants, together with the geometry of the implant used, were the most important factors for higher RFA values.(5).

Same authors in 2009 evaluated the ISQ values at 6 and 12 months from the implant insertion in sinus grafted and non-grafted sites. Sites treated with open sinus lift could offer good long-term stability. After 6 and 12 months, the geometric characteristics of the implant were no longer important to obtain high RFA values, and the bone-implant contact was determinant.(6).

At present, very few data are available regarding the monitoring of implant stability in augmented posterior maxillary regions versus non-augmented similar sites. This study aimed to evaluate and compare the time required to achieve good implant stability between implants inserted in sites that had undergone an open sinus augmentation procedure with implants inserted in non-augmented sites, with a particular focus on histological features.

Materials and Methods

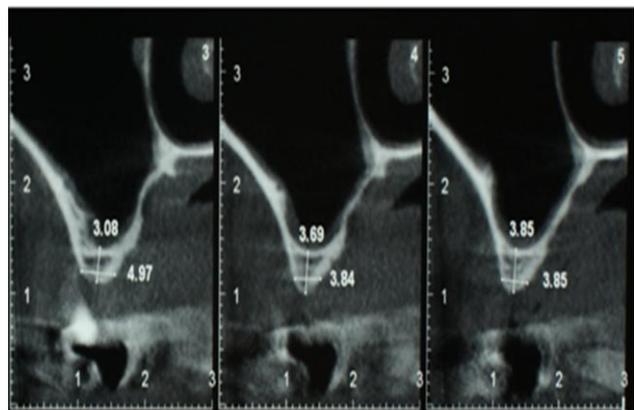
Patients

Fourteen patients (8 females and 6 males) whose age ranged from 55 ± 10 years were selected who required posterior maxillary implantation. Written consent to use their data for research was obtained from each patient prior to their inclusion. The exclusion criteria were as follows: 1) any history of sinusitis or sinus surgery; 2) a history of localized radiation of the oral cavity; and 3) patients undergoing chemotherapy or who were otherwise immunocompromized. A total of 30 standard ITI implants (Straumann, Swiss) were distributed with 14 implants in the test group(site that had undergone open sinus augmentation) and 16 implants in the control group(Matched non-augmented posterior maxillary sites).

Surgical technique

In the test group, an open sinus lift procedure (trap door technique) was performed in patients with a residual bone height of less than 4 mm (Fig. 1). DFDBA (Tissue Regeneration Co., Iran) was used as the graft material. Antimicrobial prophylaxis was administered with 625 mg co-amoxiclav (Loghman Co., Iran) qds 2 days before surgery. A crestal incision was performed and a full thickness flap was reflected. A lateral window was

created with a piezosurgery device (Mectron, Italy). Using a trap door technique, the sinus membrane was elevated and DFDBA was applied to the site. A resorbable membrane (Tutogen, Sweden) was placed and the flap was sutured. Six months postoperatively, implants were inserted according to a strict protocol following the manufacturer's instruction in the augmented site. In the control group, the residual bone height was suitable for implantation and implants were inserted.



before the open sinus lift surgery

ata collection

In the test group, before the sinus lift procedure, residual bone height was recorded by Cone Beam CT(CBCT). Six months postoperatively, a new CBCT was performed to measure the augmented bone height(Fig. 2). The diameter and length of implants was also recorded, and were found to be similar in both groups (diameter: 4.1 and 4.8 mm, and length: 10 mm). The ISQ of each implant was measured with an Ostell device (Integration Diagnostic AB, Savedalen, Sweden) on the day of surgery (baseline, ISQ₀) and monitored in the first month (ISQ₁),second month (ISQ₂) and third month (ISQ₃) post-implantation in each group.

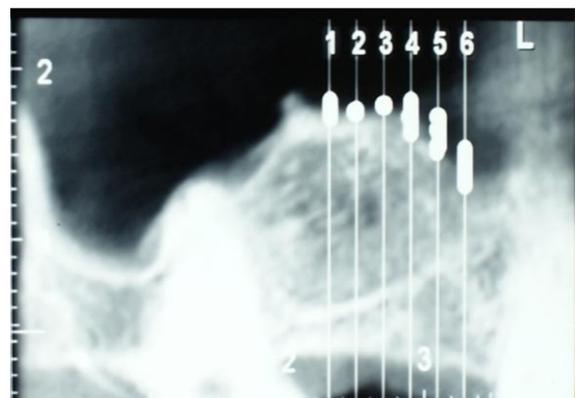


Figure 2. Augmented bone height in the same patient 6 months after the sinus lift surgery.

Histological evaluation

Ten bone samples were collected (7 samples from the test group and 3 samples from the controls). Each sample was approximately 4 mm in length and 2 mm in diameter, and was obtained during implant drilling with a trephine. The biopsies were placed in 10% formalin. The sections were ground and polished to a final thickness of $4 \pm 10 \mu\text{m}$. They were then observed under a light microscope after Hematoxylin and Eosin staining.

Statistical analysis

ISQ values in different groups and time points had normal distribution, so repeated measures ANOVA with external factor was used for statistical analysis. Due to observed interaction between groups and time, single analysis was performed using repeated measures ANOVA and two sample t test to compare ISQ in different time points in each group and in each period of time between groups, respectively. The correlation between the ISQs and with other variables, such as implant diameter and residual and augmented bone height were carried out with Pearson correlation test. A p-value <0.05 was considered to be significant.

Results

No membrane perforations occurred during the sinus lift procedure. The implant survival was 100% after 3 months and no adverse reaction to bone materials was recorded. The mean residual bone height in the test group was $2.92 \pm 1.46\text{mm}$ and $11.21 \pm 1.23\text{mm}$ in the controls. The mean augmented bone height was $10.41 \pm 1.46\text{mm}$. The mean ISQ value in both groups is shown in Fig. 3. The difference between ISQ values in both groups was only significant at the baseline ($p=0.023$). The correlation between ISQ values and residual or augmented bone height were not statistically significant. No statistically significant correlations were found between ISQ values and implant diameter in both groups (Table 1 and 2). The correlations between the ISQ₀, ISQ₁, ISQ₂ and ISQ₃ values in each group were evaluated. In the test group, correlations between ISQ values were significant between ISQ₀ and ISQ₁ ($r=0.690$, $p=0.006$), ISQ₁ and ISQ₃ ($r=0.569$, $p=0.034$) and ISQ₂ and ISQ₃ ($r=0.540$, $p=0.046$). In the control group, the correlation was significant only between ISQ₀ and ISQ₁ ($r=0.716$, $p=0.002$).

Histological findings

No evidence of necrosis, inflammation or foreign body reactions were detected in each sample. In the test group, a trabeculated pattern was noted, interspersed with DFDBA particles (osteoconduction) (Fig. 4). In two samples, there was some evidence of osteoinduction

detected by stromal mesenchymal cells with osteoblastic activity and some small bone trabeculae found in these areas (Fig. 5).

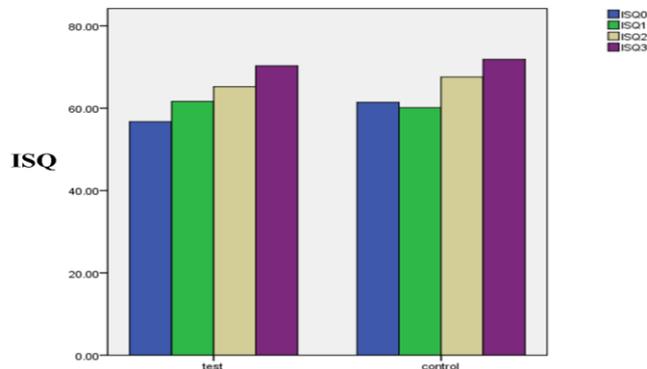


Figure 3. ISQ values in both the test and control groups in different time points (base line and after 1,3 and 6 months)

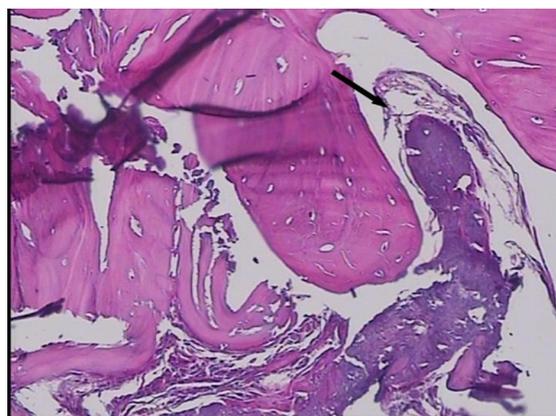


Figure 4. DFDBA materials and bone trabeculae are seen parallel to each other (H&E, $\times 40$)

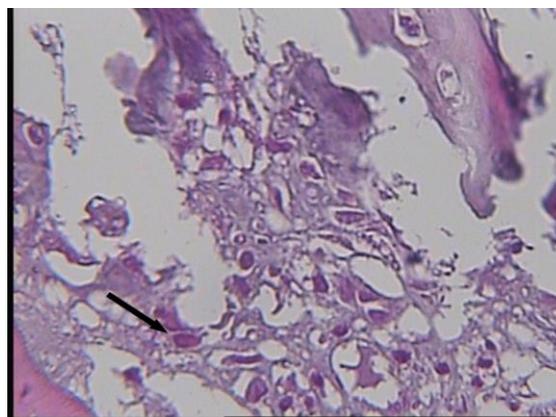


Figure 5. Small bone trabeculae formed by the osteoinduction of DFDBA (H&E, $\times 100$)

Table1. Correlation between ISQ and Implant diameter in different time points in test group

		ISQ0	ISQ1	ISQ2	ISQ3
Implant diameter	N	14	14	14	14
	r(Pearson correlation)	-0.19	-0.78	0.172	0.018
	P value	0.948	0.791	0.557	0.953

Table2. Correlation between ISQ and Implant diameter in different time points in control group

		ISQ0	ISQ1	ISQ2	ISQ3
Implant diameter	N	16	16	16	16
	r(Pearson correlation)	-0.418	-0.243	-0.116	0.038
	P value	0.107	0.364	0.668	0.890

Discussion

As mentioned previously, the mean residual bone height was 2.92 ± 0.63 mm. Zitsmann determined the lateral technique to be the most effective method whenever residual bone height is less than 4 mm (7). The mean augmented bone height in the test group after 6 months post-augmentation was 10.41 ± 1.46 . According to the clinical status of patients during surgery and the type of bone material used (pure DFDBA in this case), partial resorption of bone material appeared to have occurred. This may have been caused by blood capillary penetration and the contents of DFDBA, including type I collagen fibers and BMPs. (8, 9, 10) Mardinger also illustrated that the augmented bone height was dependent on the type of graft material used and the time after augmentation surgery (11).

The significant difference between ISQ values in both groups at the baseline could be attributed to a lower bone quality in the test group. As previously mentioned, the difference had disappeared after the first month, and this could be explained by the occurrence of osseointegration. As shown by Lai et al., there was no significant difference between type III and IV bone quality after 16 weeks post-implantation (12). Furthermore, Huwiler et al. found no relationship between bone trabecular connectivity (BTC) and bone volume density (BVD) with ISQ values after 8 and 12 weeks post-implantation (13). There was no relationship between ISQ values and bone height (residual vs. augmented), as shown when Urban et al. determined an equal success with minimal and moderate residual bone heights (14).

There was no statistically significant difference between ISQ values (Table 1) with implant features (diameter/length), which was in agreement with the study by Degidi et al.(6) As mentioned previously, the difference in control group between ISQ values was only significant between ISQ0 and ISQ1 ($p=0.002$). Borges et.al showed no significant changes in RFA values after osseointegration had occurred (14).

In the test group, the difference between ISQ0 and ISQ1 was significant ($p=0.006$), but the differences continued to be significant between ISQ0 and ISQ3 and ISQ2 and ISQ3 ($p=0.034$ and $p=0.046$). This could be explained by the lower mean ISQ0 value in the test group (52.8) in comparison with the control group (61.43).These findings were in accordance with other studies, including those by Lai et al., Sim et al. and Balleri et al.(12, 16, 17).

The histological findings of this study regarding the biocompatibility and osteoconductivity of DFDBA were in agreement with those found by Commac et al. and Schwartz et al.(18,19) Some evidence for this has been attributed to osteoinduction, which was seen in this study and that by Groeneveld et al., but still remains a matter of debate.(20).

Conclusion

ISQ values were not statistically significant between implants inserted in natural and augmented bone six months after sinus augmentation. In other words, within

the limitation of this study, the time needed to obtain optimum ISQ values in implants inserted in sinus-augmented areas was similar to those recorded in non-augmented sites. DFDBA is a suitable material for sinus graft procedures, but it may be better to be applied in combination with other graft materials in order to prevent graft resorption.

References

1. Adell R, Eriksson B, Lekholm U, Brånemark PI, Jemt T. Long-term follow-up study of osseointegrated implants in the treatment of totally edentulous jaws. *Int J Oral Maxillofac Implants*. 1990 winter; 5(4):347-59.
2. Albrektsson T, Dahl E, Enbom L, Engevall S, Engquist B, Eriksson AR, Feldmann G, Freiberg N, Glantz PO, Kjellman O, et al. Osseointegrated oral implants. A Swedish multicenter study of 8139 consecutively inserted Nobelpharma implants. *J Periodontol*. 1988 May; 59(5):287-96.
3. Raghoobar GM, Timmenga NM, Reintsema H, Stegenga B, Vissink A. Maxillary bone grafting for insertion of endosseous implants: results after 12-124 months. *Clin Oral Implants Res*. 2001 Jun; 12(3):279-86.
4. Meredith N, Alleyne D, Cawley P. Quantitative determination of the stability of the implant-tissue interface using resonance frequency analysis. *Clin Oral Implants Res*. 1996 Sep;7(3):261-7
5. Degidi M, Daprile G, Piattelli A, Carinci F. Evaluation of factors influencing resonance frequency analysis values, at insertion surgery, of implants placed in sinus-augmented and nongrafted sites. *Clin Implant Dent Relat Res* 2007; 9:144–149.
6. Degidi M, Daprile G, Piattelli A. RFA values of implants placed in sinus grafted and nongrafted sites after 6 and 12 months. *Clin Implant Dent Relat Res*. 2009 Sep; 11(3):178-82.
7. Zitzmann NU, Schärer P. Sinus elevation procedures in the resorbed posterior maxilla. Comparison of the crestal and lateral approaches. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 1998 Jan; 85(1):8-17.
8. Schwartz-Arad D, Herzberg R, Dolev E. The prevalence of surgical complications of the sinus graft procedure and their impact on implant survival. *J Periodontol*. 2004 Apr; 75(4):511-6.
9. Nishibori M, Betts NJ, Salama H, Listgarten MA. Short-term healing of autogenous and allogeneic bone grafts after sinus augmentation: a report of 2 cases. *J Periodontol*. 1994 Oct; 65(10):958-66.
10. Wallace SS, Froum SJ, Tarnow DP. Histologic evaluation of a sinus elevation procedure: a clinical report. *Int J Periodontics Restorative Dent*. 1996 Feb; 16(1):46-51.
11. Mardinger O, Chaushu G, Sigalov S, Herzberg R, Shlomi B, Schwartz-Arad D. Factors affecting changes in sinus graft height between and above the placed implants. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2011 Jan; 111(1):e6-11.
12. Lai HC, Zhang ZY, Wang F, Zhuang LF, Liu X. Resonance frequency analysis of stability on ITI implants with osteotome sinus floor elevation technique without grafting: a 5-month prospective study. *Clin Oral Implants Res*. 2008 May; 19(5):469-75. Epub 2008 Mar 26
13. Huwiler MA, Pjetursson BE, Bosshardt DD, Salvi GE, Lang NP. Resonance frequency analysis in relation to jawbone characteristics and during early healing of implant installation. *Clin Oral Implants Res*. 2007 Jun; 18(3):275-80. Epub 2007 Mar 12.
14. Urban IA, Lozada JL. Implants placed in augmented sinuses with minimal and moderate residual crestal bone: results after 1 to 5 years. *Int J Oral Maxillofac Implants*. 2010 Nov-Dec; 25(6):1203-12.
15. Borges FL, Dias RO, Piattelli A, Onuma T, Gouveia Cardoso LA, Salomão M, Scarano A, Ayub E, Shibli JA. Simultaneous Sinus Membrane Elevation and Dental Implant Placement without Bone Graft: A 6-Month Follow-Up Study. *J Periodontol*. 2010 Nov 8.
16. Sim CP, Lang NP. Factors influencing resonance frequency analysis assessed by Osstell mentor during implant tissue integration: I. Instrument

- positioning, bone structure, implant length. *Clin Oral Implants Res.* 2010 Jun; 21(6):598-604.
17. Balleri P, Cozzolino A, Ghelli L, Momicchioli G, Varriale A. Stability measurements of osseointegrated implants using Osstell in partially edentulous jaws after 1 year of loading: a pilot study. *Clin Implant Dent Relat Res.* 2002;4(3):128-32
 18. Cammack GV 2nd, Nevins M, Clem DS 3rd, Hatch JP, Mellonig JT. Histologic evaluation of mineralized and demineralized freeze-dried bone allograft for ridge and sinus augmentations. *Int J Periodontics Restorative Dent.* 2005 Jun; 25(3):231-7
 19. Schwartz Z, Goldstein M, Raviv E, Hirsch A, Ranly DM, Boyan BD. Clinical evaluation of demineralized bone allograft in a hyaluronic acid carrier for sinus lift augmentation in humans: a computed tomography and histomorphometric study. *Clin Oral Implants Res.* 2007 Apr; 18(2):204-11.
 20. Groeneveld EH, van den Bergh JP, Holzmann P, ten Bruggenkate CM, Tuinzing DB, Burger EH. Mineralization processes in demineralized bone matrix grafts in human maxillary sinus floor elevations. *J Biomed Mater Res.* 1999;48(4):393-402

Corresponding Author:

Amir Moeintaghavi
 Professor. Oral and Maxillofacial Diseases Research Center,
 School of Dentistry, Mashhad University of Medical Sciences,
 Mashhad, Iran
 Post code: 91735-984
 Tel: 09155023227
 Email: Moeentaghavia@mums.ac.ir