Scanning Electron Microscopy Observations of Osseointegration Failures of Dental Implants that Support Mandibular Overdentures

Nesreen El-Mekawy, BDS, MSc, PhD,* Mohammed M. Fouad, BDS, MSc, PhD,†
Youssry M. El-Hawary, BDS, MSc, PhD,‡ Mohamad A. Al-Shahat, BDS, MSC, PHD,§ and Reem El-Gendy, PhD||

Aim: *Investigating possible failure causes of mandibular implants after their immediate loading with an overdenture retained with bilateral bar attachments, using scanning electron microscope.*

Patients and Methods: *Twenty edentulous male patients were included in the present study. Each patient had 2 fixtures inserted in the canine and the first molar areas on each side of the mandible. After abutments screwing, the 2 fixtures on the same side were splinted with a bar, and immediately loaded with an overdenture. Implants mobility was assessed on weekly basis. Failed implants were removed, and examined by scanning electron microscope.*

Results: *The failed implants, removed after 4 weeks of treatment, showed an intimate contact of mineralized and osteoid tissues with dense collagen-rich matrix in the apical third of implants. Furthermore, newly developed bone was observed at the same area in implants removed after 7 weeks. However, there was no evidence of such growth at the middle and/or cervical thirds in either case.*

Conclusion: *Lack of osseointegration at the middle and cervical thirds of the root could be a possible cause of implant failure. Early loading by an overdenture retained with bilateral bars is considered a major contributing factor to incomplete osseointegration of the supporting implants. (Implant Dent 2013;22:645–649)*

Key Words: immediately loaded implants, scanning electron microscope

The primary aims of treating edentulous patients with implant-retained overdentures are to reduce pain and discomfort and to improve functions (retention, stability).[1] It is also imperative to highlight the positive effect of such treatment on the psychological well-being of the patients.

Osseous integration of dental implants has been proved successful in the treatment of edentulous cases with implant-retained overdentures.[2] Various schemes and protocols of overdenture exist and many involve multiple implants, bar attachment, and immediate or early loading. There are many controversial outcomes for these protocols that are often determined by different factors such as patient's systemic condition, quality of bone and the type of loading, implant placement position, and the type of implant.[3,4]

*Assistant Professor, Department of Removable Prosthodontics, Faculty of Dentistry, Mansoura University, Mansoura, Egypt.
†Associate Professor, Department of Removable Prosthodontics, Faculty of Dentistry, Mansoura University, Mansoura, Egypt.
‡Associate Professor, Department of Oral Biology, Faculty of Dentistry, Mansoura University, Mansoura, Egypt.
§Professor, Department of Oral Medicine and Periodontology, Faculty of Dentistry, Mansoura University, Mansoura, Egypt.
||Post Doctoral Research Fellow, WELMEC, Center of Excellence in Medical Engineering, Department Of Oral Biology, Leeds Dental Institute, Leeds University, United Kingdom; Assistant Lecturer, Department of Oral Pathology, Faculty of Dentistry, Suez Canal University.

Reprint requests and correspondence to: Nesreen El-Mekawy, BDS, MSc, PhD, 1 Mecka Street, extension from Gyhan Street, Mansoura 35516, Egypt, Phone: 0020127884473, E-mail: nesreen_elmekawy@yahoo.com

ISSN 1056-6163/13/02206-645
Implant Dentistry
Volume 22 • Number 6

DOI: 10.1097/01.id.0000433934.99474.75

Implant attachment using a bar is recommended in the case of using more than 2 implants and is considered to be superior to the attachment-only-retained format.[5] Payne and Solomons[6] stated that distal support by 2 bars placed bilaterally provides a far more stable mandibular overdenture.

Immediate loading protocols have been mostly applied to allow the rehabilitation of completely edentulous mandible. Immediate/early loading has the advantages of providing immediate restoration of esthetics and functions, reducing the number of patient visits, reducing the morbidity of a second surgical intervention, and facilitating the functional rehabilitation of the patient.[7] Furthermore, the success rate of immediately loaded overdentures was comparable to those of conventionally loaded ones.[2]

Using surface treated implants can improve the osseointegration process, promotes healing, and reduces healing time.[4] Surface modifications of dental titanium implants are accomplished by roughening or by altering the chemical composition. Various methods have been developed to create rough surfaces, for example, titanium plasma spraying, grit blasting, acid etching, and anodization. Coating of dental titanium implants with calcium phosphate (CaP) ceramic is the most frequently used method for altering the chemical surface composition.[8,9]

Despite, the high success rate of implant-retained overdenture with bar attachment in enhancing osseointegration. Failure of osseointegration is the major cause of implant failure. It accounts for 2% to 3.4% of early and late implant failure in healthy patients. This percentage dramatically rises to 7.4% to 12.5% in patients with compromised systemic health.[10]

The efficacy of osseointegration is typically determined by dental radiography during patients follow-up. However, more comprehensive method is required to assess failed implant systems and the percentage of bone surface coverage via top-down approaches such as scanning electron microscopy (SEM).[11] The SEM images of the surfaces of implants removed from their bony crypts before embedding have often displayed the presence of variable amounts of adherent material presumed to be bone and or/extracellular matrix (osteoid) at the implant jaw interface.[12]

The aim of this study was to evaluate the failure of immediately loaded implants used to support mandibular overdentures retained by bilateral posterior bar attachment by investigating to the amount of bone surface coverage via SEM.

Patient Selection Criteria

Twenty completely edentulous male patients of 57 to 72 years old (mean age, 65 years) were included in this study after signing an informed consent. All included participants showed high levels of compliance with the treatment and had good general health. Only those patients with sufficient mandibular residual ridges (minimum of 12-mm bone height above the mandibular canal as verified by panoramic radiographs),[13] (corrected) were selected for this study. Patients' exclusion criteria included patients suffering from bone related systemic diseases, patients with a systemic condition that would put them at risk when in surgery, patients under or post chemo or radiotherapy. Furthermore, smokers and patients with abnormal habits such as bruxism or clenching were excluded from this study. Alcohol, drugs, or medication dependent patients were also excluded.

Surgical Design and Positioning of Implants

Surgical planning was predominantly based on clinical inspection and orthopantomograms. Each patient was initially diagnosed using diagnostic digital panoramic radiography, to evaluate the alveolar bone quality and height. Digital panoramic radiographs were also used to plan the proposed implants positions and establish their relation to vital structures, in addition to determining the proper implant length. After maxillary and mandibular impressions, jaw relation records and try-in were completed, 4 guidance holes were drilled in the decided implant insertion positions (2 holes at #22, #27 regions and 2 holes at #19, #30 regions) to be used for surgical guidance during implants placement. After tissue punch and drilling, 4 acid-etched roughened titanium (ART) screw type fixtures (Dyna Helix TM Implants, Holland) were surgically inserted in the #22, #27 regions (of 13 mm length and 3.6 mm width) and #19, #30 regions (of 10 mm length and 3.6 mm width). According to the manufacturer instructions,[14] bar abutments were screwed into the fixtures with a single slot screwdriver. The 2 implants on each side of the mandible were splinted with prefabricated instant adjusting bar (IAB; Dyna Dental Engineering bv, Bergen op Zoom, The Netherlands) to retain the immediately loaded mandibular overdenture.

Two riders for each IAB bars were incorporated in the fitting surface of the mandibular overdenture directly in patient's mouth, within 24 hours from implant insertion.

The patients were prescribed a soft diet and were asked not to remove the

Table 1. Implant Mobility Assessment 4 to 7 weeks After Insertion of Mandibular Overdentures Retained With Bilateral Bar Attachments

Patients	Posterior Right Implant	Anterior Right Implant	Anterior Left Implant	Posterior Left Implant
1	0	0	0	0
2	1	0	0	0
3	0	0	0	1
4	0	0	0	0
5	0	0	0	0
6	1	0	0	0
7	0	0	0	0
8	1	0	0	0
9	0	0	0	1
10	0	0	0	1
11	1	0	0	0
12	0	0	0	1
13	0	0	0	0
14	0	0	0	0
15	0	0	0	1
16	0	0	0	1
17	1	0	0	0
18	0	0	0	0
19	0	0	0	0
20	0	0	0	1
No of mobile implants	5	0	0	7

1 indicates Mobile implant; 0, Immobile implant.

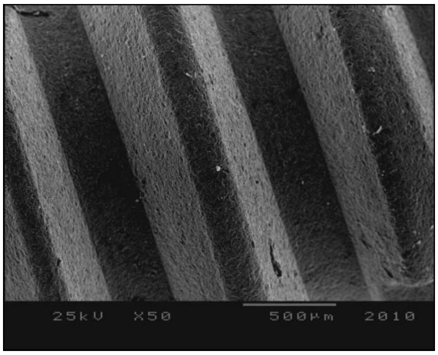

Fig. 1. SEM of control unused ART screw type implant.(25 kV, magnification × 50).

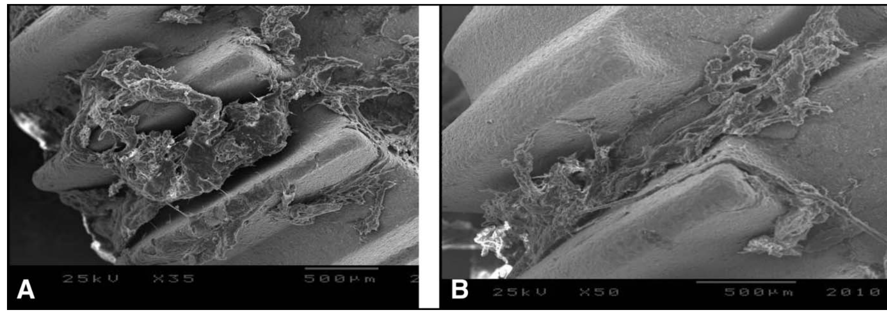

Fig. 2. SEM of the apical third of failed ART screw type implant after 4 weeks of insertion, showing no dense extracellular matrix (**A**, 25kV, magnification × 35. **B**, 25 kV, magnification ×50).

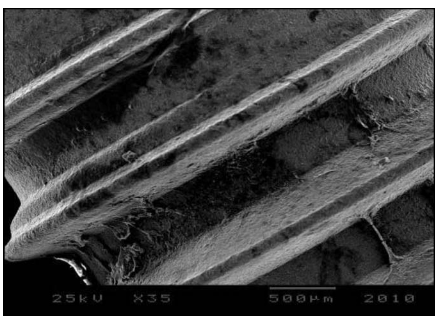

Fig. 3. SEM of the cervical and middle thirds of failed ART screw type implant after 4 weeks of insertion, showing scarce fibers on the implant surfaces with failure of formation of extracellular matrix. (25 kV, magnification, ×35).

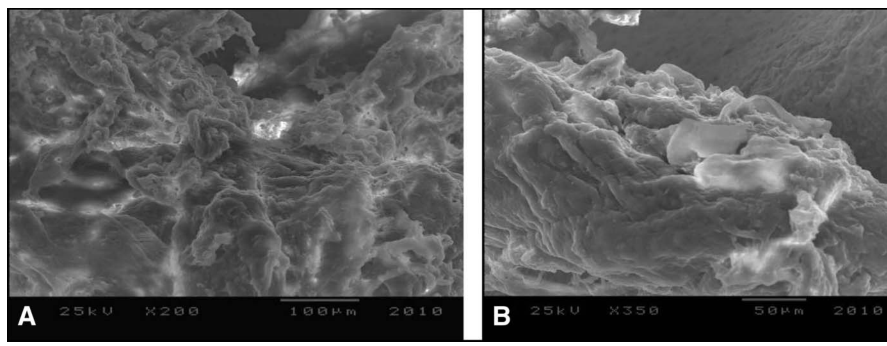

Fig. 4. SEM of the apical third of failed ART screw type implant after 7 weeks of insertion, showing well-organized extracellular matrix with entrapping cells that looks like lamellar bone integrated at the implant surfaces (**A**, 25 kV, magnification, 3 ×200, and **B**, 25 kV, magnification, ×350).

Fig. 5. SEM of the cervical and middle thirds of the failed ART screw type implant after 7 weeks of insertion, showing peeling off of some of the implant coating at the implants surface (25 kV, magnification, ×35).

overdenture during mastication for 1 week. They were also instructed not to brush the operated areas and rinse it instead with 0.12% chlorhexidine mouthwash 3 times per day for 14 days.

Implant mobility assessment was assessed manually using the handles of 2 dental mirrors on either sides of implant bucco-lingually as described by Gatti et al.[15] This was done weekly during the first 3 months after the insertion. The range of mobility was determined according to a mobility scoring system, where 0 = no mobility and 1 = any obvious mobility. The implants with a score of 1 (obvious mobility) were considered failed implants. Failed implants were gently unscrewed under local anesthesia and were carefully removed under aseptic conditions, to be examined by the SEM.

SCANNING ELECTRON MICROSCOPY

To evaluate the failed implants for SEM, the specimens were cleaned with 5% sodium hypochlorite for 20 minutes at room temperature to remove the risk of contamination. They were rinsed in 0.1 mol per 1 cacodylate buffer (pH 7.4) 3 times. They were then fixed in a 1% osmium tetroxide solution in 0.1 mol per 1 cacodylate buffer (pH 7.4) for 90 minutes before dehydration by a graded series of ethanol. The samples were then immersed in isoamyl acetate, and were critical-point dried with liquid carbon dioxide. The samples were finally mounted on stabs, coated with gold in a vacuum device before being examined by the SEM[16] (Jeol-JSM-5200LV Scanning microscopy).

RESULTS

Implant Mobility Assessment

Mobility was detected in 12 posterior implants out the total 80 implants inserted, during routine mobility assessment at weeks 4 and 7 after insertion of the immediately loaded implants (Table 1).

SEM Imaging

SEM examination of control/unused implant showed the roughness produced by the acid etching process. At low magnification, the implants looked rather clean (Fig. 1).

SEM images of the failed implants removed from the patients after 4 weeks demonstrated the presence of dense mineralized tissue that seemed like osteoid, a collagen-rich extracellular matrix. These dense tissues were in intimate contact with the implant at the interface at the apical third of the failed implants. Obvious lamellar bone formation was not detected at this stage (Fig. 2). The examination of the cervical and middle thirds of the same failed implants revealed scarce individual fibers on the implant surfaces, and no organized extracellular matrix was detected at these areas (Fig. 3).

After 7 weeks of insertion, SEM of failed implants demonstrated formation of much denser, well-organized extracellular matrix with cells entrapped in them resembling mature lamellar bone, in contact with the implant surface at the apical third (Fig. 4). However, this organized matrix was again missing at the middle and cervical thirds of the implant. Consistent partial peeling off of the implant coating were detected on the cervical and middle thirds of the failed implants removed at 7 weeks (Fig. 5).

DISCUSSION

The use of attachment-retained implant overdentures is functionally superior to conventional dentures and is a cost-effective alternative to fixed implant dental prostheses.[2]

The biological fixation of endosseous dental implants is a matter of great interest, mostly due to the increase in the use of many types of implants in clinical practice. Bone in growth results from a complex process, in which mechanics and biology play a major role.[17]

In this study, ART screw type fixtures were used to enhance bone formation and osseointegration. ART screw type implant fixtures help to stabilize the initial blood clot and wound against the titanium surface, which helps bone formation on the surface and plays a relevant role in the implant long-term success. This early stabilization seems to be particularly required under demanding circumstances such as immediate loading in posterior jaw areas.[18]

Prefabricated IABs were used to splint the implants on each side of the jaw, to eliminate possible micromotion when immediately loaded with a provisional overdenture. In such cases, implants splinting is of utmost importance to avoid fibrous tissue formation and inhibition of osseointegration.[19]

Three-dimensional (3D) imaging techniques such as cone beam CT offer maximum accuracy and width information that 2D techniques cannot. However, 2D digital panoramic radiography seems to provide a faster, simpler, less costly, and low-dosage presurgical diagnostic tool compared to 3D imaging. These characters have favored our choice of using digital panoramic radiography in this study, to confirm the presence of sufficient bone height above the mandibular canal. Furthermore, when a safety margin of at least 12 mm above the mandibular canal is respected, panoramic radiography seems to be a sufficient tool for evaluation of bone height before the insertion of posterior mandibular implants. This respectable height enhances implant osseointegration and eliminates the need for using 3D imaging techniques.[20,21]

The surface treatment using acid etching to create rough surface of fixtures was developed as a way of reducing the healing period through accelerating and improving the osseointegration process,[4,8] which was proven by our SEM micrographs, which demonstrated the integration of newly developed bone like material in intimate contact with the apical one-third of the examined implants. This was an indication of osseointegration at this early stage of the study (4–7 weeks), which was also confirmed by the findings reported by Guiha et al.[22] However, it is also indicated that the osseointegration was only confined to the apical one-third and was limited if at all present in the middle and cervical thirds. This limited osseointegration seemed to have directly contributed to failure of complete integration leading to the implants' mobility and finally failure of the implants. These results were contradicting to what Izze et al[23] have found in their retrieved implants, where complete osseointegration was reported in their study. However, the implants that they have used in their study have a wettable, highly hydrophilic, and microstructured surface.[23] Furthermore, other studies showed that immediately loaded implants can survive for years before failure.[24]

Various studies have confirmed the occurrence of mandibular deformations during jaw opening and protrusion, and have reported that the lateral pterygoid muscles are mainly involved in causing mandibular flexure during these tasks.[25,26]

The early mobility and failure of some of the posterior implants in this study, can be also a direct result to the stresses induced on the splinted implants as a result of mandibular deformation (flexure) during jaw opening and protrusion. It was indicated by Fischman[27] that flexure was reduced with all splint types. However, splints were never able to completely eliminate mandibular flexure. Hence, splinted implants are subject to some kind of stress one way or another. Over the time, no matter how limited the stress and flexure transmitted to the implant are, they will eventually contribute to some kind of damage at the bone-implant interface.[28] This was evident in this study, by the damage and peeling off of the implant coating, detected at the cervical and middle thirds of the failing implants after 7 weeks of insertion.

Immediate/early loading may have also contributed to early mobility and failure of bone formation and osseointegration of these implants. Many previous studies[29,30] revealed that immediate functional loading of implants in the posterior area of the mandible poses a potential clinical risk because of the amount of micromotion that it allows. They suggested that the immediate loading approach should be strictly limited to implants inserted in the inter-foramina area of the mandible in edentulous patients. Other studies showed that progressive gradual loading leads to more favorable crestal bone reaction as opposed to immediate functional loading.[31]

CONCLUSION

In conclusion of this study, SEM images of failed implants demonstrated that failure of implants supporting mandibular overdentures retained with bilateral bar attachments and immediately loaded can be mainly attributed to failure of complete osseointegration throughout the whole length of the implant and its confinement to the apical one-third. Early loading by an overdenture retained with bilateral bars is considered a major contributing factor to incomplete osseointegration of the supporting implants as well as the loss of the implant coatings. Additional investigation is required to determine the suitable loading technique in terms of time, design, and quantity of load application to the overdentures retained by bilateral bars to avoid failure of implants and to ensure proper and complete osseointegration. Investigating progressive loading versus functional loading of the implants by overdenture is also required.

Disclosure

The authors claim to have no financial interest, either directly or indirectly, in the products or information listed in the article.

Acknowledgments

This work was partially supported by staff of Scanning Electron Microscope Center of Tanta University, Tanta, Egypt. R. El-Gendy is funded by Centre of Excellence in Medical Engineering funded by the Wellcome Trust and EPSRC, under grant number WT 088908/Z/09/Z.

References

1. Tolstunov L. Management of biomechanical complication of implant-supported restoration of a patient with combination syndrome: A case report. *J Oral Maxillofac Surg.* 2009;67:178–188.

2. Laurito D, Lamazza L, Spink MJ, et al. Tissue-supported dental implant prosthesis (overdenture): The search for the ideal protocol. A literature review. *Ann Stomatol (Roma).* 2012;3:2–10.

3. Krennmair G, Krainhöfner M, Piehslinger E. Implant-supported maxillary overdentures retained with milled bars: Maxillary anterior versus maxillary posterior concept—A retrospective study. *Int J Oral Maxillofac Implants.* 2008;23:343–352.

4. Calvo-Guirado JL, Ortiz-Ruiz AJ, Negri B, et al. Histological and histomorphometric evaluation of immediate implant placement on a dog model with a new implant surface treatment. *Clin Oral Implants Res.* 2010;21:308–315.

5. Strong SM. Conversion from bar-retained to attachment-retained implant overdenture: Case report. *Dent Today.* 2006;25:66, 68–70.

6. Payne AG, Solomons YF. The prosthodontic maintenance requirements of mandibular mucosa- and implant-supported overdentures: A review of the literature. *Int J Prosthodont.* 2000;13:238–243.

7. Cooper LF, Rahman A, Moriarty J, et al. Immediate mandibular rehabilitation with endosseous implants: Simultaneous extraction, implant placement, and loading. *Int J Oral Maxillofac Implants.* 2002; 17:517–525.

8. Le Guéhennec L, Soueidan A, Layrolle P, et al. Surface treatments of titanium dental implants for rapid osseointegration. *Dent Mater.* 2007;23:844–854.

9. Carimo Marino LA, Deliberador TM, Zielak JC, et al. Microstructural and topographical characterization of different surface treatments of a surgical titanium alloy for dental implants. *Implant Dent.* 2012;21: 207–212.

10. Snauwaert K, Duyck J, van Steenberghe D, et al. Time dependent failure rate and marginal bone loss of implant supported prostheses: A 15-year follow-up study. *Clin Oral Investig.* 2000;4:13–20.

11. Giannuzzi LA, Phifer D, Giannuzzi NJ, et al. Two-dimensional and 3-dimensional analysis of bone/dental implant interfaces with the use of focused ion beam and electron microscopy. *J Oral Maxillofac Surg.* 2007;65:737–747.

12. Budd TW, Nagahara K, Bielat KL, et al. Visualization and initial characterization of the titanium boundary of the bone-implant interface of osseointegrated implants. *Int J Oral Maxillofac Implants.* 1992;7:151–160.

13. Ural Ç, Bereket C, Şener İ, et al. Bone height measurement of maxillary and mandibular bones in panoramic radiographs of edentulous patients. *J Clin Exp Dent.* 2011;3:5–9.

14. RK B. Dyna Instant Adjusting Bar Connection Manual engels. in Dyna Dental Engineering BV. Netherland. 2004: 5–7.

15. Gatti C, Haefliger W, Chiapasco M. Implant-retained mandibular overdentures with immediate loading: a prospective study of ITI implants. *Int J Oral Maxillofac Implants.* 2000;15:383–388.

16. Matsuda M, Satoh Y, Ono K. Scanning electron microscopic and light microscopic observations on morphological changes of freeze-dried bone implantation in rats: Comparison with fresh autogenous bone transplantation. *Histol Histopathol.* 1992;7:393–403.

17. Koebke J, Jansen D, Knifka J. Microradiographic and histological analyses of 17 long standing human dental implants. *Anatomy*. 2009;3:45–48.

18. Degidi M, Petrone G, Lezzi G, et al. Histologic evaluation of 2 human immediately loaded and 1 titanium implants inserted in the posterior mandible and submerged retrieved after 6 months. *J Oral Implantol.* 2003;29:223–229.

19. Hansson HA, Albrektsson T, Brånemark PI. Structural aspects of the interface between tissue and titanium implants. *J Prosthet Dent.* 1983;50:108–113.

20. Christensen GJ. Why switch to digital radiography? *J Am Dent Assoc.* 2004;135:1437–1439.

21. Vazquez L, Saulacic N, Belser U, et al. Efficacy of panoramic radiographs in the preoperative planning of posterior mandibular implants: A prospective clinical study of 1527 consecutively treated patients. *Clin Oral Implants Res.* 2008;19:81–85.

22. Guiha R, Caffessse R, Llambes F. SEM of retrieved etched screw implant 3 weeks after placement: A case report. *Implant Dent.* 2004;13:257–261.

23. Iezzi G, Degidi M, Piattelli A, et al. A histological and histomorphometrical evaluation of retrieved human implants with a wettable, highly hydrophilic, hierarchically microstructured surface: A retrospective analysis of 14 implants. *Implant Dent.* 2013;22:138–142.

24. Vantaggiato G, Iezzi G, Fiera E, et al. Histologic and histomorphometric report of three immediately loaded screw implants retrieved from man after a three-year loading period. *Implant Dent.* 2008;17:192–199.

25. De Marco TJ, Paine S. Mandibular dimensional change. *J Prosthet Dent.* 1974;31:482–485.

26. Regli CP, Kelly EK. The phenomenon of decreased mandibular arch width in opening movements. *The J Prosthet Dent.* 1967;17:49–53.

27. Fischman B. The rotational aspect of mandibular flexure. *J Prosthet Dent.* 1990;64:483–485.

28. Zarone F, Apicella A, Nicolais L, et al. Mandibular flexure and stress build-up in mandibular full-arch fixed prostheses supported by osseointegrated implants. *Clin Oral Implants Res.* 2003;14:103–114.

29. Romanos GE, Nentwig GH. Immediate versus delayed functional loading of implants in the posterior mandible: A 2-year prospective clinical study of 12 consecutive cases. *Int J Periodontics Restorative Dent.* 2006;26:459–469.

30. Ericsson I, Nilner K. Early functional loading using Brånemark dental implants. *Int J Periodontics Restorative Dent.* 2002; 22:9–19.

31. Khorshid HE, Hamed HA, Aziz EA. The effect of two different immediate loading protocols in implant-supported screw-retained prostheses. *Implant Dent.* 2011; 20:157–166.