THE INFLUENCE OF MICRO AND MACRO-GEOMETRY IN TERM OF BONE-IMPLANT INTERFACE IN TWO IMPLANT SYSTEMS: AN HISTOMORPHOMETRICAL STUDY

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SUMMARY

Objective. Many factors could affect the osseous healing of implants such as surface topography of biomaterial, the status of the bone/implant site, implant loading conditions, surgical technique and implant design. The aim of this study was to analyze the BIC of 2 different implants systems characterized by different micro and macrogeometry, that were placed in the posterior maxillary and mandibular jaws of humans, clinically unloaded and retrieved for histomorphometric analyses after 12 weeks.

Material and method. The patients were divided in two groups (Group I and II); group I was composed by 4 patients that each received in the posterior areas of mandible one type A implant [GTB- Plan1Health Amaro (UD) Italy] one type B implant (OsseoSpeed Astra Tech, Dentsply Molndal, Sweden). Group II was composed by 3 patients that each received in the posterior areas of jawsbone one type A implant [GTB- Plan1Health Amaro (UD) Italy] one type B implant (OsseoSpeed Astra Tech, Dentsply Molndal, Sweden). After 12 weeks of healing all the implants of both groups were harvested with the peri-implant bone tissues. Osseointegration process was evaluated throughout measurements of BIC.

Results. No statistical significance differences were found among the mean percentage of BIC of Group I – type A were 66,51% *versus* 49,96% in Group I – type B, as well as among the mean percentage of BIC of Group II – type A were 43.7% *versus* 60.02% in Group II – type B.

Conclusions. Our results highlight that the mean percentage of BIC after 12 weeks from the implants placement without functional loading is not influenced by the composition of the implant surface.

Key words: histomorphometry, microgeometry, macrogeometry.

Introduction

Dental implant primary stability has been demonstrated to have a pivotal role in implant survival rates. Primary mechanical stability is directly related to the quality and quantity of bone at the recipient site, as well as the type of implant used and the surgical technique used to place the implant (1-3).

Biologically, this primary stability is obtained if the marginal and/or apical areas of the implant site hold a large enough quantity of compact bone and if the spongy bone contains a sufficient number of trabeculae (4, 5).

Clinically, at the time of implant placement, this kind of primary stability is achieved by ''tight fitting'' between the implant surface and the avascular cortical bone in the marginal area of the implant bed. This intimate bone-to-implant

contact (BIC) is also the effect of the minute lateral displacement exerted in the bone tissue during implant adaptation, where the trabeculae of the marginal portion shift towards the medullar space and the sectioned blood vessels bleed. As a consequence, a blood clot forms and is trapped between the implant surface and the bone (6, 7). This blood clot will mature over the next few days and eventually be replaced by granulation tissue, woven bone and lamellar bone, producing secondary stability (8, 9).
Therefore, secondary stability is the consequence of the formation of new bone and the remodelling process in both the area of most direct contact (the bone-implant interface itself) and a more distant area (1).
Many factors could affect the osseous healing of implants such as surface topography of biomaterial, the status of the bone/implant site, implant loading conditions, surgical technique and implant design (10-15).
Several studies demonstrated that the surface roughness of titanium implants affects the rate of osseointegration, whilst the surface topography, implant design and surface seem to influence the bone apposition (16-18).
The introduction of alternative implant surfaces to the well-known and experimented turned surface, improperly called "smooth" has been motivated by better biological responses which the "rough" surfaces seemed to produce, especially in a bone of poor quality and/or associated to regenerative therapies (19-23).
Even though histological tests on humans are limited in literature, they have confirmed that there is a superior integration which is expressed in BIC percentage values greater than those reachable with the turned surfaces (24-28, 35).
Based on our current knowledge, implant roughness is defined as follows: smooth implants are those with a Sa roughness of less than 0.5 µm; in oral implants found solely on abutments generally varying between 0.1 and 0.3 µm roughness (29, 30). Minimally rough implants have a roughness (Sa) of between 0.5 to 1.0 µm and are represented by turned Brånemark and Astra Tech implants and by acid etched 3I implants.
Moderately roughened surfaces vary between 1.0 and 2 .0 µm and include almost all modern implants, such as the Astra Tech TiOblastTM and OsseoSpeedTM surfaces, Nobel TiUnite, Straumann SLA and Dentsply Cellplus designs. Finally, rough implants are those with Sa above 2.0 µm and are exemplified by plasma sprayed devices and, among implants of today, the Dentsply Frialit implant (31, 32).
The aim of this study was to analyze the BIC of 2 different implants systems characterized by different micro and macrogeometry, that were placed in the posterior maxillary and mandibular jaws of humans, clinically unloaded and retrieved for histomorphometric analyses after 12 weeks.

Materials and methods

Implants

We tested two commercially available implant systems with a different macro and microgeometry. One implant systems – Type A [GTB-Plan1Health Amaro (UD) Italy] is characterized by a controlled and gradual load distribution through double threads with gradual height profile and a geometrically complex horizontal and vertical platform shifting (BioPlatform, patent pending), with a single prosthetic platform for all diameters. The implant screws are entirely covered, up to the interface fixture-abutment, with Osseogrip®, characterized by a micro-sandblasting through HA of medical degree and Sa = 0.5 µm.
The second one – Type B (Astra Tech, Dentsply Molndal, Sweden) characterized by single threads maintaining the same angle and height profile for all the length of the fixture with minute threads on the implant neck (MicroThreads™) and fluoride-modified nanostructure implant surface (OsseoSpeed™) with a Sa = 1.6 µm.

Patient selection and evaluation

Candidates for this study were consecutive patients from private practice who presented with atrophic, edentulous posterior maxillae or mandible and met strict selection criteria (Table 1). Each candidate was subjected to a diagnostic evaluation. Medical and dental histories were evaluated, and an oral examination was conducted to assess current health status and to identify any pathologies that required treatment before the study. A computerized tomography scan was conducted to ensure the total absence of sinus pathology and to evaluate the residual alveolar bone height and the bone quality.

The patients were divided in two groups (Group I and II); group I was composed by 4 patients that each received in the posterior areas of mandible one type A implant [3,6 mm in diameter and 6,5 mm in length GTB- Plan1Health Amaro (UD) Italy] one type B implant (4 mm in diameter and 8 mm in length OsseoSpeed Astra Tech, Dentsply Molndal, Sweden).

Group II was composed by 3 patients that each received in the posterior areas of jawsbone one type A implant [3,6 mm in diameter and 6,5 mm in length GTB- Plan1Health Amaro (UD) Italy] one type B implant (4 mm in diameter and 8 mm in length OsseoSpeed Astra Tech, Dentsply Molndal, Sweden).

All the implants were placed according to the suggested procedures provided by each manufacturer. In particular, all the implants were placed, by the same operator, in crestal position using "one stage" technique with a healing abutment at an adequate gingival height.

After 12 weeks of healing all the implants of both groups were harvested with the peri-implant bone tissues. In the remaining sockets new implants were placed following a planned restoration for the patient.

Each samples were retrieved en bloc and placed in 10% formaldehyde for 24 hours, thereafter were subjected to a series of dehydration and in filtration procedures; finally, the samples were embedded in a methacrylate-based resin (Technovit 9100; Heraeus Kulzer GmbH, Wehrheim, Germany) according to the manufacturer's instructions. After polymerization, the embedded samples were cut at the center of the implant along its long axis with a diamond saw (Isomet 2000; Buehler, Ltd., Lake Bluff, IL), were subjected to grinding and polishing using a series of SiC abrasive papers to a final thickness of approximately 30mm, and were then toluidine blue stained; finally, the sections were histomorphologically evaluated under light optical microscope. Histomorphometric evaluation was performed using an optical microscope (Axio Imager.M2, Carl Zeiss, Germany) attached to a digital camera (Axiocam ICc3, Carl Zeiss, Germany). The acquired digital images were analyzed by a single and calibrated examiner blind to experimental groups and periods. Osseointegration process was evaluated throughout measurements of BIC.

Table 1 - Inclusion-Exclusion criteria adopted for the study.

Inclusion criteria	Exclusion criteria
Deficient maxillary posterior ridge 2 to 4 mm in height unilaterally or bilaterally	Pathological condition of the sinus
Non smoker	Current or past history of radiotherapy in the surgical zone
Willingness to participate in the study and to provide a signed informed consent	Immunosuppressive status or serious medical condition
Free of periodontal diseases	

Mean percentage of BIC and statistical analysis

This parameter indicated the surface of the implant directly apposed by bone matrix and was expressed as the percentage of the implant surface at each side and for each section. Two different counts and percentages were calculated by considering only 1 side as the total length of the implant interface. Statistical significance was determined using the 2-tailed paired Student t test. A P value of < 0.05 was considered significant.

Results

Figures 1 and 2 summarize the results of the histomorphometric analysis, performed on sections with a lower magnification.

No statistical significance differences were found among the mean percentage of BIC of Group I – type A were 66,51% *versus* 49,96% in Group I – type B, as well as among the mean percentage of BIC of Group II – type A were 43.7% *versus* 60.02% in Group II – type B.

In particular, Figure 1 showed no statistical significance differences among the percentage of BIC in Group I receiving in mandibular position type A and type B implant systems.

Figure 2 showed no statistical significance differences among the percentage of BIC in Group II receiving in maxillary position type A and type B implant systems.

Moreover histological analysis showed the close contact between the implants' surface and the bone tissue in both Groups (Figures 3-8).

Figures 5 and 6 evidence a different bone behavior at platform level even if the implant of both group were placed in crestal position: in Group I the bone growth is characterized by an on and inside BioPlatform growth whilst these not happen in the same area of Group II implant.

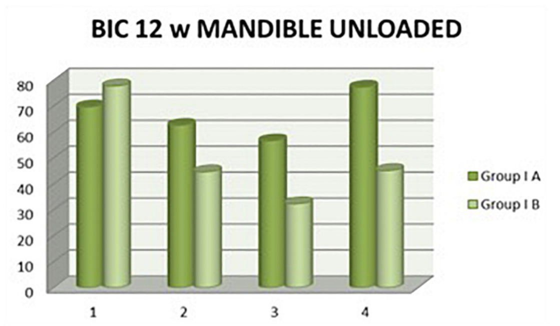

Figure 1
Values of percentage of BIC in Group I. No statistical significance differences among the percentage of BIC in Group I receiving in mandibular position type A and type B implant systems.

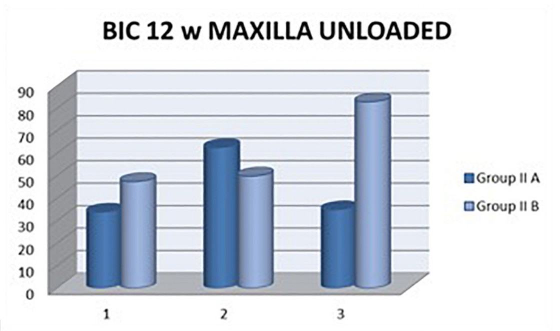

Figure 2
Values of percentage of BIC in Group II. No statistical significance differences among the percentage of BIC in Group II receiving in mandibular position type A and type B implant systems.

Discussion

Bone-to-implant contact is traditionally evaluated by calculating the percentage of implant surface directly apposed to mineralized bone without discernible interposition of soft connective tissue at the light microscopic level (23, 33).

Albrektsson and Johansson hypothesized that at least 50% BIC is necessary for a stable prosthetic result, but this has not been clinically validated (24, 34). Although clinical and radiographic examinations are useful in evaluating the treat-

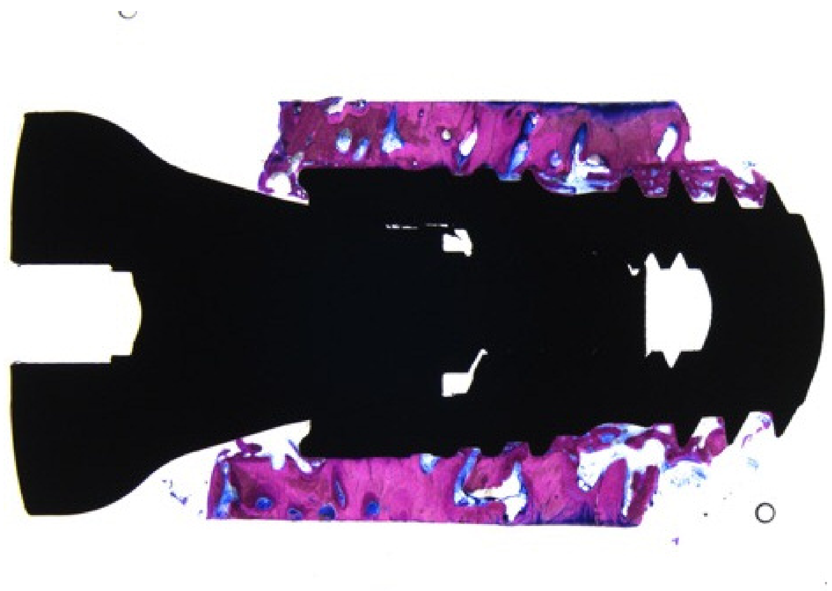

Figure 3
Hystologic section of Group I – A implant portion.

Figure 4
Hystologic section of Group I – B implant portion.

ment outcome of implants placed in sinus grafts, histologic analysis is the only reliable means of quantifying the percentage of BIC achieved in regenerated tissue (23).
Our results, in terms of mean percentage of BIC after 12 weeks of the placement of the implant systems tested, evidenced a non-statistical significance differences among in Group I receiving in mandibular position type A and type B implant systems as well as in Group II receiving in maxillary position type A and type B implant systems.
These data may suggest that the osseointegration process is not exclusively influenced by the roughness of the implant surface, in fact we do no detect a difference testing two implant sys-

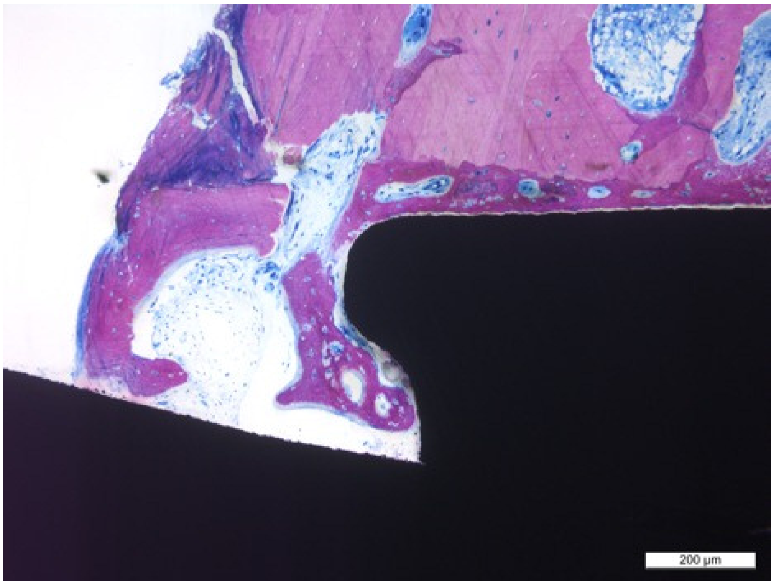

Figure 5
Hystologic section of Group II – A implant portion. The bone growth is on and inside the BioPlatform.

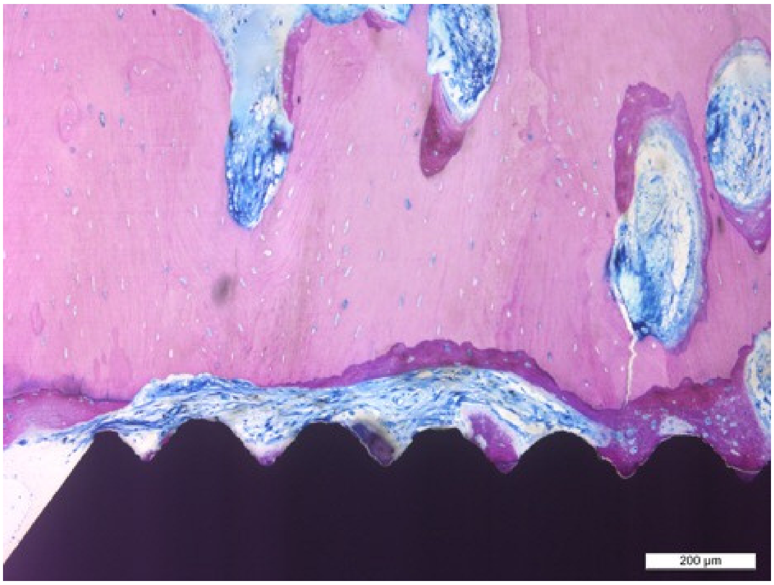

Figure 6
Hystologic section of Group II – B implant portion at platform level.

tems characterized by differences in term of roughness. To corroborate this hypothesis is the consideration that the mean percentage of BIC obtained by our samples is not influenced by the functional loading of the implant system. In fact the functional loading may represent an important biological variable in term of BIC values. Moreover we obtain no statically significance difference in both group, receiving, in different anatomical site characterized by different type of bone (maxilla and mandibular bone), both of implant systems tested. So our results are related only to microgeometry and macrogeometry of the implant systems.
Within the limit of our study, our results highlight that the mean percentage of BIC after 12 weeks from the implants placement without functional loading is not influenced by the com-

Figure 7
Hystologic section of Group I – A.

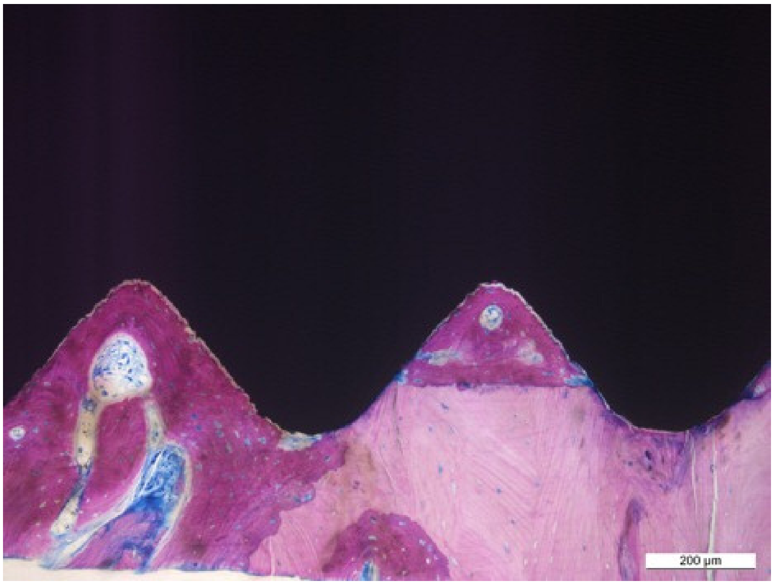

Figure 8
Hystologic section of Group I – B.

position of the implant surface. Certainly more studies are required to better to assess the role of the micro and macrogeometry in the osseointegration process.

Conflict of interest

None.

References

1. Meredith N, Friberg B, Sennerby L, Aparicio C. Relationship between contact time measurements and PTV values when using the Periotest to measure implant stability. Int J Prosthodont. 1998;11(3):269-75.
2. Gargari M, Prete V, Pujia M, Ceruso FM. Development of patient-based questionnaire about aesthetic and functional differences between overdentures implant-supported and overdentures tooth-supported. Study of 43

patients with a follow up of 1 year. ORAL and Implantology. 2012;5(4):86-91.
3. Gargari M, Ottria L, Morelli V, Benli M, Ceruso FM. Conservative zirconia-ceramic bridge in front teeth. Case report. ORAL and Implantology. 2015;7(4):93-98.
4. Lang NP, Jepsen S. Implant surfaces and design. Clin Oral Implants Res. 2009;20(S4):228-31.
5. Ottria L, Zavattini A, Ceruso FM, Gargari M. Maxillofacial prosthesis (P.M.F): In a case of oral-nasal communication post-surgery and post-radiotherapy. ORAL and Implantology. 2014;7(2):46-50.
6. Tatullo M, Marrelli M, Falisi G, Rastelli C, Palmieri F, Gargari M, Zavan B, Paduano F, Benagiano V. Mechanical influence of tissue culture plates and extracellular matrix on mesenchymal stem cell behavior: A topical review. International Journal of Immunopathology and Pharmacology. 2016;29(1):3-8.
7. Marrelli M, Falisi G, Apicella A, Apicella D, Amantea M, Cielo A, Bonanome L, Palmieri F, Santacroce L, Giannini S, Di Fabrizio E, Rastelli C, Gargari M, Cuda G, Paduano F, Tatullo M. Behaviour of dental pulp stem cells on different types of innovative mesoporous and nanoporous silicon scaffolds with different functionalizations of the surfaces. Journal of biological regulators and homeostatic agents. 2015;29(4):991-997.
8. Albrektsson T. Direct bone anchorage of dental implants. J Prosthet Dent. 1983;50(2):255-61.
9. Gargari M, Prete V, Pujia A, Ceruso FM. Full-arch maxillary rehabilitation fixed on 6 implants. ORAL and Implantology. 2013;6(1):1-4.
10. Adell R, Lekholm U, Rockler B, Brånemark PI. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. Int J Oral Surg. 1981;110:387-41.
11. Diamanti MV, Del Curto B, Barlattani A, Bollero P, Ottria L, Pedeferri M. Mechanical characterization of an innovative dental implant system. J Appl Biomater Biomech. 2009 Jan-Apr;7(1):23-8.
12. Bahat O, Sullivan RM. Parameters for successful implant integration revisited part I: immediate loading considered in light of the original prerequisites for osseointegration. Clin Implant Dent Relat Res. 2010;12 Suppl 1:e2-12.
13. Depprich R, Zipprich H, Ommerborn M, et al. Osseointegration of zirconia implants compared with titanium: an in vivo study. Head Face Med. 2008;11 (1):30-4.
14. Javed F, Almas K, Crespi R, Romanos GE. Implant surface morphology and primary Implant surface morphology and primary stability: is there a connection? Implant Dent. 2011;20(1):40-4.
15. Clementini M, Ottria L, Pandolfi C, Bollero P. A Novel Technique to Close Large Perforation of Sinus Membrane. ORAL and Implantology. 2013;6(1):11-14.
16. Junker R, Dimakis A, Thoneick M, Jansen JA. Effects of implant surface coatings and composition on bone integration: a systematic review. Clin Oral Implants Res. 2009;20(4):185-20.
17. Sykaras N, Iacopino AM, Marker VA, Triplett RG, Woody RD. Implant materials, designs, and surface topographies: their effect on osseointegration. A literature review. Int J Oral Maxillofac Implants. 2000; 15(5):75-90.
18. Gargari M, Comuzzi L, Bazzato MF, Sivolella S, di Fiore A, Ceruso FM. Treatment of peri-implantitis: Description of a technique of surgical 2 detoxification of the implant. A prospective clinical case series with 3-year follow-up. ORAL and Implantology. 2015;8 (1):1-11.
19. Hansson S, Norton M. The relation between surface roughness and interfacial shear strength for bone-anchored implants. A mathematical model. J Biomech. 1999;32(8):829-36.
20. Cooper LF. A role for surface topography in creating and maintaining bone at titanium endosseous implants. J Prosthet Dent. 2000;84(5):522-34.
21. Hansson S. Surface roughness parameters as predictors of anchorage strength in bone: a critical analysis. J Biomech. 2000;33(10):1297-303.
22. van Steenberghe D, De Mars G, Quirynen M, Jacobs R, Naert I. A prospective split-mouth comparative study of two screw-shaped self-tapping pure titanium implant systems. Clin Oral Implants Res. 2000;11(3):202-9.
23. Schüpbach P, Glauser R, Rocci A, et al. The human bone-oxidized titanium implant interface: A light microscopic, scanning electron microscopic, back-scatter scanning electron microscopic, and energy-dispersive x-ray study of clinically retrieved dental implants. Clin Implant Dent Relat Res. 2005;7(S1):36-43.
24. Ivanoff CJ, Hallgren C, Widmark G, Sennerby L, Wennerberg A. Histologic evaluation of the bone integration of TiO(2) blasted and turned titanium microimplants in humans. Clin Oral Implants Res. 2001;12(2):128-34.
25. Rocci A, Martignoni M, Burgos PM, Gottlow J, Sennerby L. Histology of retrieved immediately and early loaded oxidized implants: light microscopic observations after 5 to 9 months of loading in the posterior mandible. Clin Implant Dent Relat Res. 2003;5(S1):88-98.
26. Ivanoff CJ, Widmark G, Johansson C, Wennerberg A. Histologic evaluation of bone response to oxidized and turned titanium micro-implants in human jawbone. Int J Oral Maxillofac Implants. 2003;18(3):341-8.
27. Rocci A, Martignoni M, Gottlow J. Immediate loading of Brånemark System TiUnite and machined-surface implants in the posterior mandible: a randomized open-ended clinical trial. Clin Implant Dent Relat Res. 2003;5(S1):57-63.
28. Rocci A, Rocci M, Rocci C, Scoccia A, Gargari M, Martignoni M, Gottlow J, Sennerby L. Immediate loading of Brånemark system TiUnite and machined-surface implants in the posterior mandible, part II: a randomized open-ended 9-year follow-up clinical trial. Int J Oral Maxillofac Implants. 2013 May-Jun;28(3):

891-5.
29. Diamanti MV, Del Curto B, Barlattani A, Bollero P, Ottria L, Pedeferri M. Mechanical characterization of an innovative dental implant system. Journal of Applied Biomaterials and Biomechanics. 2009;7(1):23-28.
30. Spinelli D, Ottria L, De Vico GD, Bollero R, Barlattani Jr, A, Bollero P. Full rehabilitation with nobel clinician® and procera implant bridge®: Case report. ORAL and Implantology. 2013;6(2):25-36.
31. Albrektsson T, Wennerberg A. Oral implant surfaces: Part 1-review focusing on topographic and chemical properties of different surfaces and in vivo responses to them. Int J Prosthodont. 2004;17(5):536-43.
32. Albrektsson T, Wennerberg A. Oral implant surfaces: Part 2-review focusing on clinical knowledge of different surfaces. Int J Prosthodont. 2004;17(5):544-64.
33. Trisi P, Marcato C, Todisco M. Bone-to-implant apposition with machined and MTX microtextured implant surfaces in human sinus grafts. Int J Periodontics Restorative Dent. 2003;23:427-37.
34. Albrektsson T, Johansson C. Quantified bone tissue reactions to various metallic materials with reference to the so-called osseointegration concept. In: Davies JE, ed. The Bone-Biomaterial Interface. Toronto, Ontario, Canada: University of Toronto Press; 1991:357-63.
35. Baggi L, Di Girolamo M, Vairo G, Sannino G. Comparative evaluation of osseointegrated dental implants based on platform-switching concept: influence of diameter, length, thread shape, and in-bone positioning depth on stress-based performance. Comput Math Methods Med. 2013;2013:250929. doi: 10.1155/2013/250929. Epub 2013 Jun 19. Erratum in: Comput Math Methods Med. 2014;2014:467358. Baggi Luigi [added]; Di Girolamo Michele [added].

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