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ORIGINAL ARTICLE

Evaluation of Peri-Implant Bone Reduction Levels from Superimposition Perspective: Pilot Study among Ukrainian Implantology Practice

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Abstract

Objective: To evaluate the possibility and efficiency of using adapted peri-implant bone evaluation method based on the principle of graphical superimposition and compare it to the possibilities of using sagittal sections of CBCT results to register the dynamics of peri-implant bone changes during the first year of implant functioning. **Material and Methods:** 108 pairs of DICOM data sets were selected and pre-anonymized and coded in Planmeca Romexis® Viewer software. Each pair of datasets consisted of a CBCT file, obtained immediately after the installation of a dental implant, and one year after its operation. The first method of peri-implant bone changes evaluation was carried out by analyzing the sagittal sections of the CBCT data from the mesial and distal sides of the implant. The second method was followed by original algorithm, which included specific steps of superimposition of graphical images. **Results:** Superimposition method helped to establish volumetric parameter of circular bone reduction around dental implants after 1 year of their functioning. Such average values for the maxillary distal implants were 3.547 mm3, maxillary frontal implants – 3.118 mm3, mandibular distal implants – 2.614 mm3, mandibular frontal implants – 2.456 mm 3. Correlation values between averages of vertical bone loss parameters and volumetric bone loss parameters riches r=0.954. Among all patients the highest peri-implant bone reduction rates were observed in the distal and frontal areas of the maxilla, even though statistical difference among such parameters of implants installed at the areas of mandible and maxilla was not significant ($p > 0.05$). Such observation was established during the analysis of results obtained both by digital sagittal cross section from CBCT results and by superimposition method. **Conclusion:** Using the superimposition principle allows us to evaluate the individual indicator of volumetric bone loss at the peri-implant region. The possibility of taking into account the parameters of bone tissue volume reduction, instead of just geometrical parameter of bone height, allows to individualize the parameters of bone loss among patients of different prosthetic rehabilitation group.

Keywords: Dental Implants; Alveolar Bone Loss; Cone-Beam Computed Tomography.

Introduction

The use of dental implants as intraosseous supports for different designs of prosthetic constructions demonstrates high rates of success both in 5 and in 10 years prospective [1-4]. Such method of treating the patients with symptoms of partial and full adentia, according to previous studies, usually exceeds 90% level of success [5-8].

But ongoing improvement of dental implant technologies and methods arguments the need to develop optimized and adapted systems of criteria, based on which clinician can objectively summarized success of different implants due to specific conditions of every individual clinical situation. In many years different systems were provided to verify implant success rate based on different criteria, latter includes criteria provided by some authors [6-8], and such provided by consensus conference of International Congress of Oral Implantologists (ICOI) in Pisa in 2007 [9]. All mentioned above criteria systems could be categorized as those that were developed based on the need, modification of implant treatments options, and raise of overall implant success rates that were registered during last few decades. Due to their content, criteria provided by several authors [6-8], and ICOI are almost the similar and differ only in terms of the methodological approach to the evaluation of certain parameters.

However, the evaluation of the success criteria at the implant level in all of the above mentioned systems takes a leading place, and according to a systemic review, in all of 25 analyzed studies, those parameters that includes pain, bone loss, radiolucency, mobility and infections were the primary for assessing by doctors [10]. Even though, such parameters are well categorized, there is still a problem of choosing specific methods for their registration and adequate objective interpretation. Specifically, the issue of adequate approach for assessing the level of bone loss at the peri-implant region remains unresolved [11]. Some authors have summarized that bone loss after the first year of implant functioning should not exceed 1,5 mm [10]. Implant Quality Scale provided by ICOI describes success criteria from the point of bone loss as no more than 2 mm of radiographic bone reduction from initial surgery [9].

Previous studies indicate the possibility of using methods of peri-apical radiography, orthopantomography and cone-beam computer tomography (CBCT) to assess bone loss at peri-implant area. The most widely used method is periapical radiography, but such method still is operator sensitive and not enough reliable [9,12,13]. On the other hand, such method allows only registering bone changes from the medial and distal sides of dental implant, and does not include the possibility to find out the exact volume of circular bone loss around intraosseous titanium element.

Relevant progress of medical field arguments the need to develop individualized (customized) methods of treatment, prevention and diagnostics of different disease. Such trend is also reliable for implant dentistry, because only individualized protocols of diagnostics can help us to develop new methods of early peri-implant pathology evaluation with the use of which we can adapt evidence-based methods of treatment.

The objective of this study was to evaluate the possibility and efficiency of using adapted peri-implant bone evaluation method based on the principle of graphical superimposition and compare it to the possibilities of using sagittal sections of CBCT results to register the dynamics of peri-implant bone changes during the first year of implant functioning.

Material and Methods

Sample

The initial stage of the study envisaged the formation of a study sample, consisting of a set of CBCT data (all gathered from the Planmeca ProMax 3D Classic, voxel size 100 µm, isotropic) of patients who had undergone dental implantation at the University Dental Clinic, Uzhhorod National University, Uzhhorod, Ukraine.

At this stage, an analysis of the medical documentation of patients of the University Dental Clinic was conducted among patients who undergone the procedure of dental implantation in the last 5 year. Number of such patients was 1061.

The criteria for further inclusion in the study group were as follows: 1) the presence of symptoms of partial or complete adentia at the time of the patient's referral to the clinic; 2) the absence of concomitant somatic diseases, and adjacent absolute contraindications that would restrict the procedure of dental implantation; 3) the presence of a sufficient bone volume according to the X-ray examination results, which would rule out the need for bone augmentation procedures; 4) provision of prosthetic rehabilitation of the patients with the use complete removable dentures, single crowns and three-units dental bridges supported by dental implants; 5) the presence of primary CTBT diagnostic data registered right after the implantation procedure, and the CBCT file of the control diagnostics in the database of X-ray images.

Due to the inclusion criteria, 108 pairs of DICOM data sets were selected which in order to ensure ethical standards of research, were pre-anonymized and coded in Planmeca Romexis® Viewer software. Each pair of datasets consisted of a CBCT file, obtained immediately after the installation of a dental implant, and file obtained one year after its operation. Any additional CBCT diagnostics of patients in the design of this study was not provided, and the research was based only on already pre-existed CBCT data sets.

Among 108 pairs of patients data sets their prosthetic rehabilitation was provided by single crowns supported by implants in 36,11% cases (39 patients), by full overdentures supported with O-ring or Locator abutments on implants in 41.47% clinical cases (45 patients), by 3-units bridges supported by implants in 22.22% cases (24 patients). All implants noted at patients medical cards were K3ProImplants (Sure Type with 4.0 and 4.5 mm in diameter).

Data Collection

X-ray assessment of bone changes at the peri-implant regions was performed by comparing the initial level of bone around dental implant and level that was established one year after implantation with the use of two methods.

The first method of peri-implant bone changes evaluation was carried out by analyzing the sagittal sections of the CBCT data from the mesial and distal sides of the implant relatively to the points of the first bone contact with the implant platform from the mesial (point A) and distal (point B) sides. Changes of those points position through the year of observation was registered as criteria of bone changes with further calculation of average values from mesial and distal indicators.

The second method of evaluating peri-implant bone changes was followed by original algorithm provided by authors which included the next steps: 1) segmentation of the area of interest from the CBCT data set with the isolation of the implant placement area (includes dental implant and 2 cm of bone around it) at the InVesalius 3.1.1 Software using manual segmentation tool; 2) transformation of the obtained segmented image of areas of interest from the *.dcm format to the *.stl format in the 3DSlicer software; 3) carrying out the superimposition phase of the received stl-files from the data set obtained immediately after implantation and one year after the operation in the MeshLab software using Iterative Closest Point (ICP) algorithm and Global Alignment instrument; 4) determination of the absolute volume reduction of bone tissue at the per-implant region by segmentation the area of non-matching between images in the MeshLab Software; 5) import of segmented area of bone changes in the Materialise Mimics Software (Materialise NV) and registration of absolute bone changes parameters in mm3 values.

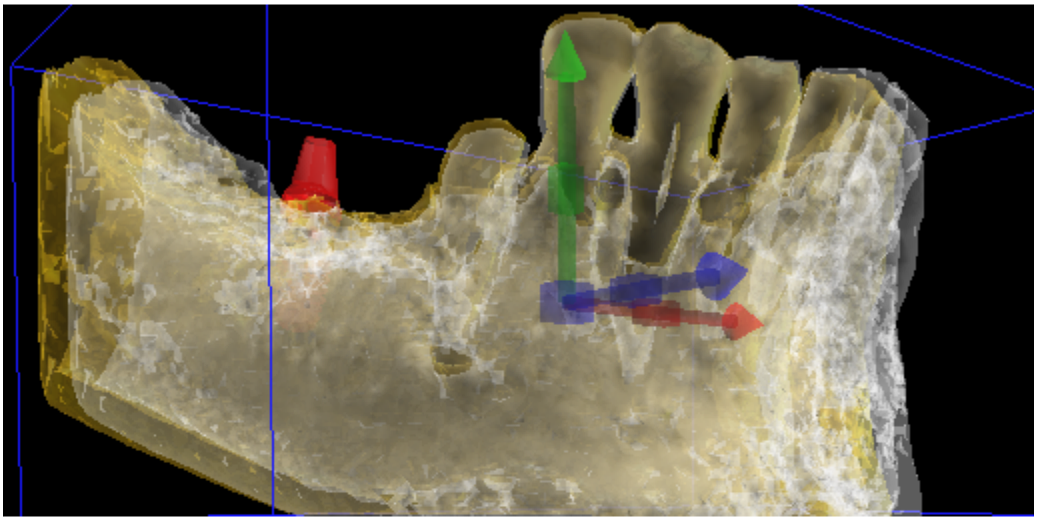

Figure 1. Schematic illustration of superimposition principle.

Bland and Altman plots were used to find out possible relationship of the discrepancies between the bone level measurements on distal and mesial side of implants and the average values of vertical bone reduction [15].

Statistical Analysis

To evaluate the relationship between two methods used to evaluate peri-implant bone changes formally, the difference between the methods was regressed on the average of these methods. Pearson's r was use to measure of possible linear correlation between two variables of bone reduction registered by two methods mentioned above. Linear and quadratic regression analyses were provided for modeling the relationship between a scalar dependent variable (bone reduction value/volume) and independent variables (age parameter and prosthetic design). All statistical analysis was provided in Microsoft Excel software (Microsoft Office 2016, Microsoft).

Results

Retrospective analysis of patients from study sample found out that the gender distribution of males and females among 108 patients was presented by 64 males (59.26%) and 44 females (40.74%). All the patients depends on their parameter of age registered at the header of DICOM file and relatively even distribution by the age decades could be categorized on four age groups: from 35 to 44 years – 26 patients, from 45 to 54 years – 29 patients, from 55 to 64 years – 29 patients, and older than 65 years – 24 patients. Implantation at the maxilla was performed in 61.11% of clinical cases (66 cases), and on the mandible in 38.89% of clinical cases (42 cases). All implants had shown 100% success due to the ICOI criteria of success.

Peri-implant bone changes among all patients were measured with the use of two methods: evaluation by CBCT sagittal slice and evaluation by original superimposition algorithm. First method helped to establish average vertical bone loss based on parameters registered from mesial and distal part of implant. Such values for the maxillary distal implants were 1.121 mm, maxillary frontal implants – 0.971 mm, mandibular distal implants – 0.896 mm, mandibular frontal implants – 0.902. Due to results of Bland and Altman plot analysis it was found that the bias between medial and distal values was 0.041 with value of standard deviation equal to 0.105. Agreement limits between average bone loss values and separate mesial and distal were next: lower agreement limit - 0.327, upper agreement limit 0.292, lower agreement limit-95%CL -0.261, lower agreement limit+95%CL -0.215, upper agreement limit-95%CL 0.201, lower agreement limit+95%CL 0.212.

Second method helped to establish volumetric parameter of circular bone reduction around dental implants. Such average values for the maxillary distal implants were 3.547 mm3, maxillary frontal implants – 3.118 mm3, mandibular distal implants – 2.614 mm3, mandibular frontal implants – 2.456 mm3.

Correlation values between averages of vertical bone loss parameters and volumetric bone loss parameters riches r=0.954. Among all patients the highest peri-implant bone reduction rates were observed in the distal and frontal areas of the maxilla, even though statistical difference among such parameters of implants installed at the areas of mandible and maxilla was not significant ($p > 0.05$). Such observation was established during the analysis of results obtained both by digital sagittal cross section from CBCT results and by superimposition method.

No significant association (either linear or curvilinear) was found between bone loss and age during use of digital sagittal cross section from CBCT results for evaluation of the peri-impant bone loss after one year of implant functioning (Table 1). The same situation was found when superimposition principle was used (Table 1), because in all cases $p > 0.05$.

Table 1. Regressions between bone loss and age parameters.

Method of peri-implant bone changes evaluation/age group	Mean (mm)	Linear	Quadratic
Digital sagittal cross section from CBCT results			
35-44 years	1.263		
45-54 years	1.187	p > 0.05	p > 0.05
55-64 years	1.224		
More than 65 years	1.325		
Superimposition			
35-44 years	2.957		
45-54 years	2.891	p > 0.05	p > 0.05
55-64 years	3.273		
More than 65 years	3.645		

No statistical dependency was also found between bone loss and such design of prosthetic rehabilitation as single crowns supported by dental implant and removable dentures supported by dental implants (Table 2). But, some linear and quadratic regression found to be significant between bone loss and non-removable bridges supported by dental implants, if the first parameter was evaluated by digital sagittal cross section from CBCT results. During the use of superimposition principle for peri-implant bone changes registration no statistical association was found for all three kinds of prosthetic designs (Table 2).

Table 2. Regressions between bone loss and prosthetic designs.

Method of peri-implant bone changes evaluation/prosthetic design	Mean (mm)	Linear	Quadratic
Digital sagittal cross section from CBCT results			
Single crowns supported by dental implant	0.987	p > 0.05	p > 0.05
Removable dentures supported by dental implants	1.116	p > 0.05	p > 0.05
Non-removable bridges supported by dental implants	1.227	p < 0.05	p <0.05
Superimposition			
	Mean (mm^3)	**Linear**	**Quadratic**
Single crowns supported by dental implant	3.074	p > 0.05	p > 0.05
Removable dentures supported by dental implants	3.206	p > 0.05	p > 0.05
Non-removable bridges supported by dental implants	3.571	p > 0.05	p > 0.05

Discussion

Radiographical methods remains the most widely used in the different modification to evaluate peri-implant bone level changes [13,14,16]. In the course of this study, it was found that the level of bone resorption after one year of implant functioning could be established according to the data obtained from digital sagittal cross section of CBCT results, because this method by its methodology of evaluation does not different from those one with the use of periapical X-ray images. Different techniques of use CBCT data results were described previously as efficient to register peri-implant bone changes [14,17,18]. Some authors found out that CBCT method is comparable to intra-oral radiography by the accuracy of visualizing peri-implant bone, but both of these methods differs compare to the objective results that could be obtained by histological evaluation [12]. Even though CBCT provides possibility to evaluate volumetric bone changes around dental implants.

In a previous study, the ability to determine the volumetric bone resorption parameter in the peri-implant region has already been demonstrated [19]. The researchers found that during the first year, the vertical bone loss in the peri-implant region was 0.2±0.4 mm, which corresponds to an average volumetric value of 7.2±6.1 mm3. The results obtained in our study are somewhat different, since the mean vertical loss of bone tissue was found to be 0.972 ± 0.21 mm evaluated by sagittal cross-section, and the average volumetric bone reduction value reaches only 3.547 mm3. The difference between the results obtained in our and Correia study [19] can be justified by several facts. First, in the Correia study [19], the vertical loss of bone tissue was determined by the peri-apical radiograph, and in our by the sagittal sections of CBCT results. Secondly, the parameters of the volume bone loss estimation are influenced by the initial parameters of the CBCT apparatus and algorithms used to provide superimposition process [14,16]. However, the authors of this article fully agree with Correia's findings [19] that improving the principles of graphical analysis and image quality will greatly support the accuracy of future research, and after appropriate optimization the proposed algorithm of bone loss volumetric evaluation by the superimposition principle can be easily used in the daily clinical practice of a dentist.

Higher bone reduction rates were noted around the implants installed at maxilla compared with implants on the mandible. Although there was no statistically significant difference between these parameters, but similar trend has been noted in a number of other studies, and may be explained by different potential of maxilla and mandible due to the bone remodeling processes [20-22]. Given the higher density of bone tissue in the mandible the processes of reactionary changes that occur in this region develops more slowly. But on the maxilla, taking into account its lower density and higher vascularization of bone, reduction in peri-implant area as an adaptation process of forming interface in the area of implant-bone contact resolves is faster.

The results of the study of bone loss in different age groups provided by both methods indicate that the level of bone reduction does not depend on age indicators, but apparently depends on the specificity of the individual mechanisms of bone tissue adaptation to the established dental implant. In previous studies, the relationship between age and bone loss was also not detected [23-25]. Even though some other studies found out correlation between age and peri-implant bone resorption parameters, but such were noted only at the age after 70 years and among individuals with compromised somatic status [26].

This study also found that higher bone resorption rates were noted around dental implants that supported non-removable bridges. Among patients that were rehabilitated with the use of single crowns and complete removable prosthetic dentures, bone loss parameters were somewhat lower, although this difference was not statistically significant. A similar effect can be caused by the specifics of the masticatory force distribution through different designs of prosthetic suprastructures in the area of the implant-bone connection. Such results were obtained in a number of studies conducted by other authors [27-29].

Even though we have proposed new adapted method for peri-implant bone changes evaluation, the issue of determining the exact physical loss of bone tissue around dental implants remains unresolved. Physical definition of volume is represent by the relation between mass and density. In this study, the concept of the bone density was not evaluated, but in the future research we will try to provide interpretation of it through the indexes of bone density by Hounsfield scale, even if diagnostic role of this densitometric parameter remains controversial [30,31]. Alternatively, we propose to determine the absolute physical loss of bone tissue by the formula $V_{ph} = V_{si} * HU$, where Vph – is objective physical volume of bone loss, Vsi – volume of bone loss evaluated by superimposition principle, HU – mean value of bone density represented in Hounsfield units. This way we can take into account both the loss of bone volume evaluated cubic millimeters by the superimposition principle and the specificity of bone density as an analogue of the individual density parameter. In the framework of comparative research in the conditions of standardized parameters of CBCT devices, this approach can be successfully used for the retrospective evaluation of the dental implants success rate by the criterion bone reduction in the peri-implant region.

Conclusion

Using the superimposition principle allows us to evaluate the individual indicator of volumetric bone loss at the peri-implant region. To implement the proposed approach in the dental practice, it is necessary to ensure the transformation of data among different digital formats, with further segmentation and graphical alignment. The possibility of taking into account the parameters of bone tissue volume reduction, instead of just geometrical parameter of bone height, allows to individualize the parameters of bone loss among patients of different prosthetic rehabilitation group. Correlation value between averages vertical bone loss parameters and volumetric bone loss parameters demonstrates strong statistical association, but in order to determine the further possibilities of implementation the superimposition method in implant clinical practice and to establish the reliability of the results obtained during its realization, additional research is needed.

References

1. Kwon T, Bain PA, Levin L. Systematic review of short- (5–10 years) and long-term (10 years or more) survival and success of full-arch fixed dental hybrid prostheses and supporting implants. J Dent 2014; 42(10):1228-41. doi: 10.1016/j.jdent.2014.05.016.

2. Rossi F, Botticelli D, Cesaretti G, De Santis E, Storelli S, Lang NP. Use of short implants (6 mm) in a single-tooth replacement: A 5-year follow-up prospective randomized controlled multicenter clinical study. Clin Oral Implants Res 2016; 27(4):458-64. doi: 10.1111/clr.12564.

3. Jimbo R, Albrektsson T. Long-term clinical success of minimally and moderately rough oral implants: A review of 71 studies with 5 years or more of follow-up. Implant Dent 2015; 24(1):62-9. doi: 10.1097/ID.0000000000000205.
4. Wittneben JG, Buser D, Salvi GE, Bürgin W, Hicklin S, Brägger U. Complication and failure rates with implant-supported fixed dental prostheses and single crowns: A 10-year retrospective study. Clin Implant Dent Relat Res 2014; 16(3):356-64. doi: 10.1111/cid.12066.
5. Moraschini V, Poubel LDC, Ferreira VF, dos SP Barboza E. Evaluation of survival and success rates of dental implants reported in longitudinal studies with a follow-up period of at least 10 years: A systematic review. Int J Oral Maxillofac Surg 2015; 44(3):377-88. doi: 10.1016/j.ijom.2014.10.023.
6. Albrektsson T, Zarb GA, Worthington P. The long term efficacy of currently used dental implants: A review and proposed criteria of success. Int J Oral Maxillofac Impl 1986; 1(1):11-25.
7. Misch CE, Misch-Dietsh F, Silc J, Barboza E, Cianciola LJ, Kazor C. Posterior implant single-tooth replacement and status of adjacent teeth during a 10-year period: A retrospective report. J Periodontol 2008; 79(12):2378-82. doi: 10.1902/jop.2008.080188.
8. Buser D, Janner SF, Wittneben JG, Brägger U, Ramseier CA, Salvi GE. 10-year survival and success rates of 511 titanium implants with a sandblasted and acid-etched surface: A retrospective study in 303 partially edentulous patients. Clin Implant Dent Relat Res 2012; 14(6):839-51. doi: 10.1111/j.1708-8208.2012.00456.x
9. Misch CE, Perel ML, Wang HL, Sammartino G, Galindo-Moreno P, Trisi P, Schwartz-Arad D. Implant success, survival, and failure: The International Congress of Oral Implantologists (ICOI) pisa consensus conference. Implant Dent 2008; 17(1):5-15. doi: 10.1097/ID.0b013e3181676059.
10. Papaspyridakos P, Chen CJ, Singh M, Weber HP, Gallucci GO. Success criteria in implant dentistry: A systematic review. J Dent Res 2012; 91(3):242-8. doi: 10.1177/0022034511431252.
11. Galindo-Moreno P, León-Cano A, Ortega-Oller I, Monje A, Catena A. Marginal bone loss as success criterion in implant dentistry: Beyond 2 mm. Clin Oral Implants Res 2015; 26(4):e28-34. doi: 10.1111/clr.12324.
12. Ritter L, Elger MC, Rothamel D, Fienitz T, Zinser M, Schwarz F, Zöller JE. Accuracy of peri-implant bone evaluation using cone beam CT, digital intra-oral radiographs and histology. Dentomaxillofac Radiol 2012; 43(6):20130088. doi: 10.1259/dmfr.20130088.
13. De Bruyn H, Vandeweghe S, Ruyffelaert C, Cosyn J, Sennerby L. Radiographic evaluation of modern oral implants with emphasis on crestal bone level and relevance to peri-implant health. Periodontol 2000 2013; 62(1):256-70. doi: 10.1111/prd.12004.
14. Rusyn V, Goncharuk-Khomyn M. Alternative approach for the registration of peri-implant bone level changes at the remote rehabilitation period. Morphologia 2016; 10(2):77-84.
15. Giavarina D. Understanding bland altman analysis. Biochem Med 2015; 25(2):141-51. doi: 10.11613/BM.2015.015.
16. Dave M, Davies J, Wilson R, Palmer R. A comparison of cone beam computed tomography and conventional periapical radiography at detecting peri-implant bone defects. Clin Oral Implants Res 2012; 24(6):671-8. doi: 10.1111/j.1600-0501.2012.02473.x.
17. Huang Y, Van Dessel J, Depypere M, EzEldeen M, Iliescu AA, Dos Santos E, Jacobs R. Validating cone-beam computed tomography for peri-implant bone morphometric analysis. Bone Res 2014; 2:14010. doi: 10.1038/boneres.2014.10.
18. Gupta J, Ali SP. Cone beam computed tomography in oral implants. Natl J Maxillofac Surg 2013; 4(1):2-6. doi: 10.4103/0975-5950.117811.
19. Correia A, Villarinho E, Vigo A, Ramos NV, Vaz M, Shinkai R. Volumetric bone changes around dental implants, the use of 3D image superimposition. Clin Oral Implants Res 2017; 28(Suppl.14):245. doi: 10.1111/clr.244_13042.
20. Ajanović M, Hamzić A, Redžepagić S, Kamber-Ćesir A, Kazazić L, Tosum S. Radiographic evaluation of crestal bone loss around dental implants in maxilla and mandible: One year prospective clinical study. Acta Stomatol Croat 2015; 49(2):128-36. doi: 10.15644/asc49/2/6.
21. Babbush CA, Tallarico M. Twelve-year clinical and radiological results of maxillary and mandibular implant-retained bar overdentures carried out on oxidized (TiUnite) replace select implants: A clinical case. J Oral Implantol 2012; 39(6):737-42. doi: 10.1563/AAID-JOI-D-12-00311.
22. Anitua E, Orive G. Short implants in maxillae and mandibles: A retrospective study with 1 to 8 years of follow-up. J Periodontol 2010; 81(6):819-26. doi: 10.1902/jop.2010.090637.

23. Peñarrocha M, Palomar M, Sanchis JM, Guarinos J, Balaguer J. Radiologic study of marginal bone loss around 108 dental implants and its relationship to smoking, implant location, and morphology. Int J Oral Maxillofac Implants 2004; 19(6):861-7.
24. Chung DM, Oh TJ, Lee J, Misch CE, Wang HL. Factors affecting late implant bone loss: A retrospective analysis. Int J Oral Maxillofac Implants 2007; 22(1):117-26.
25. Bryant SR, Zarb GA. Crestal bone loss proximal to oral implants in older and younger adults. J Prosthet Dent 2003; 89(6):589-97. doi: 10.1016/S0022391303001999.
26. Lee HJ, Kim YK, Park JY, Kim SG, Kim MJ, Yun PY. Short-term clinical retrospective study of implants in geriatric patients older than 70 years. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010; 110(4):442-6. doi: 10.1016/j.tripleo.2010.02.019.
27. Çehreli MC, Karasoy D, Kökat AM, Akca K, Eckert S. A systematic review of marginal bone loss around implants retaining or supporting overdentures. Int J Oral Maxillofac Implants 2010; 25(2):266-77. doi: 10.1016/S0022-3913(10)60181-3.
28. Mumcu E, Bilhan H, Cekici A. Marginal bone loss around implants supporting fixed restorations. J Oral Implantol 2011; 37(5):549-58. doi: 10.1563/AAID-JOI-D-10-00018.
29. Bilhan H, Mumcu E, Arat S. The comparison of marginal bone loss around mandibular overdenture-supporting implants with two different attachment types in a loading period of 36 months. Gerodontology 2011; 28(1):49-57. doi: 10.1111/j.1741-2358.2009.00334.x.
30. Lee S, Chung CK, Oh SH, Park SB. Correlation between bone mineral density measured by dual-energy X-ray absorptiometry and Hounsfield units measured by diagnostic CT in lumbar spine. J Korean Neurosurg Soc 2013; 54(5):384-9. doi: 10.3340/jkns.2013.54.5.384.
31. Mah P, Reeves TE, McDavid WD. Deriving Hounsfield units using grey levels in cone beam computed tomography. Dentomaxillofac Radiol 2010; 39(6):323-35. doi: 10.1259/dmfr/19603304.