EGYPTIAN
DENTAL JOURNAL

Vol. 63, 739:746, January, 2017
I.S.S.N 0070-9484

Fixed Prosthodontics, Dental materials, Conservative Dentistry and Endodontics

www.eda-egypt.org • Codex : 07/1701

PREDICTABILITY OF PRIMARY IMPLANT STABILITY FROM CORTICAL BONE THICKNESS AND BONE DENSITY VALUES OF CONE BEAM COMPUTED TOMOGRAPHIC SCANS: A CROSS SECTIONAL STUDY

Iman AW Radi* *and* Nouran Abdel-Nabi**

ABSTRACT

Statement of Problem: Prediction of primary implant stability is important before surgery to determine the possibility of immediate loading.

Purpose: To evaluate the predictability of primary implant stability from cortical bone thickness and bone density values of cone bone beam computed tomography (CBCT).

Material and Methods: 10 completely and partially edentulous patients were scanned by CBCT, while wearing radiographic templates. Bone density and cortical bone thickness of the planned implant sites were measured for all patients. 23 implants were placed in the patients by computer aided design/ computer aided manufactured (CAD/CAM) surgical guides and their implant stability was measured using Ostell ISQ. The correlation of implant stability and many independent variables, including cortical bone thickness and bone density, was investigated using Pearson's correlation and multiple regression analysis.

Results: The regression model accounted for 61.5% of the variations in the implant stability with an insignificant impact (p value=014). Age was found to be the only variable that has a significant impact on implant stability with a coefficient correlation of – 0.47 and a p value of 0.03. **Conclusions:** Within the limitations of this study neither cortical bone thickness nor bone density obtained from a CBCT can predict primary implant stability. On the contrary, age seems to have a significant impact on the primary implant stability.

Clinical implications: CBCT does not seem to be a valuable tool for predicting the primary implant stability. Bone density and thickness readings should be interpreted with cautions.

KEYWORDS: Primary implant stability, bone thickness, bone density, age, correlation study

* Associate Professor of Prosthodontics, Member of the Evidence Based Committee, Faculty of Oral and Dental Medicine, Cairo University.

** Lecturer of Prosthodontics, Faculty of Oral and Dental Medicine, Cairo University.

INTRODUCTION

Primary implant stability is defined as the absence of implant mobility in bone bed.[1] It has long been determined as a key factor for enhancing osseointegration, especially in immediately loaded implants.[2] While the pool of patients, who seem to be indicated for immediate loading continues to expand, not all cases show satisfactory primary stability and are hence not good candidates for this treatment protocol. Prediction of primary implant stability could, therefore, save both the patients and the clinicians unrealistic expectations and unnecessary preparations of immediate restorations and hence lots of efforts, money, and time.

There are many methods to asses implant stability; invasive and non-invasive. The non-invasive methods that are commonly used are insertion torque (IT), Ostell, and Periotest. IT measures implant stability only during implant installation.[3] Ostell asseses implant stability as the Implant Stability Quotient (ISQ) which runs from a scale of 1 to a 100; the higher the ISQ the higher the stability. For the Periotest, stability assessment is through vibrational percussion of the implant, on a scale that runs from -8 to +50 Perio-Test Value (PTV); the lower the PTV the higher the stability. The last two methods offer the advantages of measuring primary and secondary stability, in addition to the possibility of measuring stability at different times, and having reproducible readings.[4] Ostell was claimed to be more accurate than Periotest. The device was also said to be highly reliable[5] and insensitive to direction of probe application.[6]

Primary stability of dental implants is affected by many factors, which could be classified into procedure and patient related factors.[7] Procedure related factors include implant stability measurement technique, surgical experience, surgical technique including undersized osteotomies and bone condensing, implant size and surface treatment.[1,8,9] Patient related factors, on the other hand, include bone quality,[3,10,11,12] and quantity of the receptor site, especially cortical bone thickness,[13,14,15] patient gender,[12,16] and age. Rather than age itself, diseases accompanying aging, such as osteoporosis or diabetes, and local bone quality and quantity at the implant site, which are mostly related to aging, have been reported to act as the real determinants for primary implant stability.[8,17,18]

Regarding the bone quality and quantity, computerized tomography (CT) has been considered as the best radiographic method for analyzing them.[19,20,21,22] It is also a valuable tool for evaluating the relative distribution of cortical and cancellous bone.[23] Recently, this method has been tremendously replaced in the field of dentistry by cone beam computed tomography (CBCT), since it allows the users to tailor the imaging protocol to the patient's individual needs, thereby achieving appropriate imaging at the lowest radiation dose.[24] Despite of the expanded use of this imaging modality, few studies have been addressed to correlating primary implant stability with the CBCT values. Hence, this cross sectional study was performed mainly to predict primary implant stability from cortical bone thickness and density as measured from CBCT.

MATERIAL AND METHODS

Sample size calculation

In this cross sectional study factors that might affect implant stability, especially cortical bone thickness and bone density, were investigated. A previous study[25] indicated that the standard deviation of the cortical bone thickness was 0.6 and the standard deviation of the regression errors was 0.6. If the true slope of the line obtained by correlating the implant stability with the bone thickness is 0.679, 22 implants will be needed to be able to reject the null hypothesis that this slope equals zero with probability (power) 0.85 and α error 0.05. The sample size required for this study was calculated using the PS software (PS program, Power and Sample size calculation version 3.0.43).

To study the variables that might be involved in predicting the implant stability, multiple regression analysis was also planned. The required sample size for this analysis was based on www.real-statistics.com which dictates a minimum sample size of 20 and value of 0.64 for r^2 necessary for a significant fit of a multiple regression model (with a power of at least 0.80) based on a number of 10 independent variables and a value of 0.05 for α. Accordingly, a total of 23 implants were included in this cross sectional study.

Data collection

The implants were placed by PhD candidates, Faculty of Oral and Dental Medicine, Cairo University, using computer aided design computer aided manufactured (CAD/CAM) surgical guides, in 10 patients, 4 males and 6 females. CAD/CAM guides made osteotomy sites identical to the planned ones. The guides were 3D printed using a biocompatible resin (Surgical guides 3D Diagnostix). The included patients were systemically healthy and had an age range from 26-62 years with an average age of 45.8 years. 4 of the selected patients were partially and 6 were completely edentulous. The distribution, size, and site of the placed implants are shown in table 1.

All participants were scanned by cone beam computed tomography (CBCT) (Planmeca Promax 3D imaging), while wearing radiographic stents, which were duplicates of dentures or diagnostic wax ups previously tried in intra-orally and agreed upon by the patient and the prosthodontist. The stents were constructed of radio-opaque resin (Jet XR self cure radio-opaque resin, Lang). Identical settings were applied for all patients: 120 kV, 90 mAs, 0.4 mm voxel size, 1 mm slice thickness and 0.3mm slice increment. The Dicom files were analyzed using Blue Sky Plan software (Blue Sky Plan, version 3.29.18, 64 bit, www.blueskybio.com). From the implant library of the software, an implant of the proper diameter and length was selected, so that its long axis was in one line with the radiopaque tooth of the stent. This ensured the best prosthetic results. Patients, for whom CBCT revealed a possible need for bone grafting, or expansion procedures, were not included in the study. Using the ruler of the software the cortical bone thickness at the most coronal implant thread was measured in three sections, buccal and lingual to the selected implant model. The measured lines were drawn perpendicular to the long axis of the implant as shown in figure 1. The average of the three sections was then calculated for both, lingual and buccal cortical plates of bone. This was done by the two authors and their average values were recorded to decrease the interexaminer's errors. The bone density was also measured using the density

TABLE (1) Implant distribution among patients based on their site, jaw, size, type, and dentulous status of the patient

Site and Jaw							Size				Implant type		Dentulous status of the patient	
Mandible				Maxilla			Length (mm)		Diameter (mm)					
Incisor	Canine	Premolar	T	Canine	Premolar	T	10	11.5	3.7	4.1	O	D	C (6)	P (4)
6	6	6	18	1	4	5	17	6	22	1	7	16	17	6

T= total, O= osteseal, D= Dentis, C (6) = 6 completely edentulous patients, P (4)= 4 partially edentulous patients

measuring tool of the software at three areas of each implant, coronal, mid, and apical (Fig. 2). This was done in three sections and the average of the nine readings was then recorded.

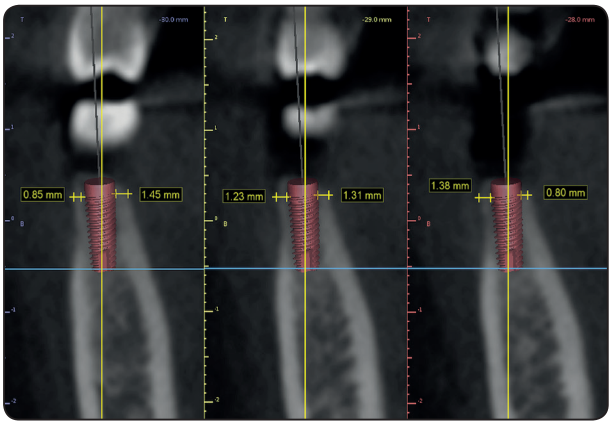

Fig. (1) Cortical bone thickness at coronal thread of virtual implant, measured by Blue Sky Plan software in three successive sections.

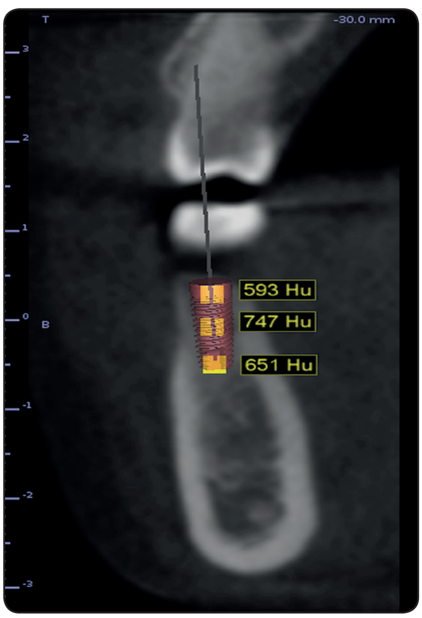

Fig. (2) Bone density measured in coronal, mid and apical parts of virtual implant in one of the cross sections by Blue Sky plan software.

At time of surgery, all implants were placed monocortically. After implant placement, the stability of each implant was tested with a resonance frequency analyzer (Osstel ISQ; Integration Diagnostics). The unit for the implant stability is ISQ (implant stability quotient). ISQ is recorded as a number between 1 and 100, 100 representing the highest degree of stability. The resonance frequency was observed as a peak in the amplitude-frequency plot of the response of the transducer beam. The method involves the use of a small transducer that is attached to the implant. The device was applied perpendicular to the implant long axis from the buccal, lingual, mesial, and distal aspects to the measure the respective implant stability from all implant sides. The average of all readings was recorded to represent the stability of each implant.

Statistical methods

Data were collected, tabulated, and were copied to an excel sheet (Microsoft office 2010) and to Statistical Package for the Social Sciences software (SPSS, version 21, IBM) to study the correlation of all independent variables collectively and separately, respectively. Using excel, multiple regression analysis was performed to investigate the correlation between primary stability and implant length, age, sex, dentulous status of the patient, jaw (maxilla versus mandible), region (premolar versus anterior), buccal, lingual and their average cortical bone thicknesses, and density collectively. Implant diameter was not included in the model because all implants had a diameter of 3.7 mm except one (4.1 mm). The multiple regression model was analyzed using ANCOVA to detect the significant impact of all independent variables of the model on implant stability. Using the simple regression function of the Excel, the co-linearity of the density with the following factors was tested; age, sex, region, and jaw. Co-linearity of average thickness with age, sex, jaw, and region was also tested. The correlation between each independent variable and implant stability was investigated individually using SPSS. For quantitative variables, this was done using the Pearson correlation test, while nominal variables called for student's t test. For all tests, a P-value ≤ 0.05 was considered significant. Finally, the interexaminer reliability and agreement between the authors for the linear measurements of the CBCT was tested using the kappa analysis.

RESULTS

All data were normally distributed. The multiple regression model has shown that the tested independent variables: buccal, lingual and their average cortical bone thicknesses, bone density, patient's age, sex, dentulous state, implant site, length, and jaw, explain 61.5 % of the variations in implant stability. However, the regression model does not have a significant effect on ISQ values, since the p value of the F-test was 0.14. This was confirmed by the p values of the regression coefficients of the tested variables, which were all > 0.05, except for the patient's age as shown in table 2. The latter showed a significant coefficient and can, therefore, significantly predict the implant stability by a coefficient of -0.65 at a y intercept of 91.5. This means that for each unit increase in age, the implant stability will be decreased by 0.65 at the calculated y intercept.

The co-linearity of the independant variables was non-significant except for that between density and region, density and jaw, thickness and jaw with a p value of 0.0073, 0.041, and 0.036 respectively.

Regarding the individual impact of each independent variable on the implant stability, it was found that neither the quantitative nor the nominal variables had a significant impact on the stability except for the age, which again showed a negative correlation coefficient of – 0.47 with a p value of 0.03 (table 3,4) (Fig. 3). The degree of agreement between the two examiners for the linear measurements was found to be 0.57.

TABLE (2) The correlation coefficient of all independent variables in the multiple regression model (ANCOVA)

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	91.59	9.83	9.31	7.68 E-07	70.16	113.02
Average Bone thickness	1.52	4.26	0.35	0.72	-7.76	10.81
Buccal bone thickness	-5.86	4.33	-1.35	0.20	-15.30	3.58
Lingual bone thickness	-0.41	3.54	-0.11	0.90	-8.14	7.31
Bone density	0.00	0.00	0.50	0.62	-0.01	0.017
Age	-0.65	0.19	-3.29	0.01*	-1.08	-0.22
State	-6.88	4.01	-1.71	0.11	-15.62	1.85
Sex	2.26	3.04	0.74	0.47	-4.37	8.90
Region	4.18	3.03	1.37	0.19	-2.42	10.79
Jaw	10.27	6.48	1.58	0.13	-3.84	24.39
implant length	3.11	4.28	0.72	0.48	-6.21	12.44

Significant at p ≤ 0.05

TABLE (3) Correlation between tested quantitative variables and primary implant stability.

Independent varible	N	Correlation	p value
Average cortical bone thickness	23	-0.08	0.72
Lingual cortical bone thickness (mm)	23	-0.09	0.68
Buccal cortical bone thickness (mm)	23	-0.05	0.82
Bone density	23	-0.11	0.63
Age	23	-0.47	0.03*

Significant at p ≤ 0.05

TABLE (4) Impact of nominal variables on mean of primary implant stability

Independent variable	Mean	SD	P value
Implant length			
- 10 mm	69.5	7.3	0.79
- 11.5 mm	70.4	4	
Implant type			
- Dentis	68.8	6.9	0.30
- Osteoseal	71.9	5.5	
Jaw			
- Maxilla	69.1	7.2	0.35
- Mandible	72.2	2	
Region			
- Anterior	67.9	6.4	0.12
- Premolar	72.2	6.3	
Dentulous status of the patient			
- Completely edentulous	68.33	6.57	0.057
- Partially edentulous	73.5	4	
Sex			
- Females	70.25	1.75	0.21
- Males	71.33	6.8	

Significant at p ≤ 0.05

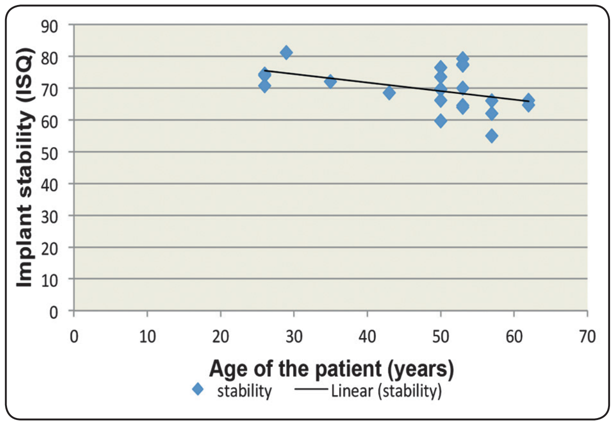

Fig. (3) Correlation between patient's age and implant stability (Pearson's correlation coefficient $r^2 = -0.47$, p value=0. 03)

DISCUSSION

In this study we aimed to identify the factors that could predict primary implant stability and hence, foretell the possibility of immediate implant loading. Results of the multiple regression analysis has shown that buccal, lingual and their average cortical bone thicknesses, bone density, patient's age, sex, dentulous state, implant site, length, and jaw, explain 61.5 % of the variations in implant stability. Age was the only factor that showed a significant negative correlation with the ISQ value (r^2= -65%, 95% CI [-108, -22], p=0.006). This means that an increase in the age by one unit is accompanied by a decrease in the primary stability by 65% at the y intercept of 91.5. The width of the confidence interval reflects too much uncertainty in the coefficient value. However, impact of age on implant stability is still statistically significant, which is in agreement with Turkyilmaz et al[16] and Turkyilmaz et al[19]. Many studies[8,17,18] reported that it is not the age itself that could affect the implant stability, it is rather the conditions that are associated with aging like bone quantity (thickness and height) and quality (density) that act as real determinants for primary implant stability. Surprisingly, in this study these factors, density and thickness, showed non-significant effect on stability. They are also non-significantly correlated to age and sex. This could be attributed to the inaccuracy of the CBCT in measuring bone density and thickness. Limited contrast resolution impairs detectability in CBCT images. Several factors contribute to this low contrast resolution including increased x-ray scatter in CBCT acquisition, lower detector quantum efficiency of CBCT compared with multidetector helical of CT, and limited contrast range of amorphous silicon flat panel detectors.[26] This is confirmed by the inter-examiner reliability results of 0.57 for the linear measurements of the CBCT. Hence, all radiographic variables seem to be inefficient in predicting clinical variables, including the region and the jaw. Therefore, despite of the significant correlation between jaw and density, region and density, and jaw and thickness an insignificant impact of region and jaw on primary stability was found in this study. This is in contrast with many studies which showed that primary stability is affected by cortical bone thickness and bone density.[8,11,17,18] However, in these studies computerized tomography was the imaging tool used for evaluating density and thickness, which might explain the difference in the findings between these studies and the current one.

Further predictors that were evaluated in this study are implant length and dentulous status. Both showed an insignificant correlation with implant stability. Dentulous status was investigated to see if the presence of teeth might affect the stability readings due to a change in osstel probe angulation. The lack of significant correlation may be explained by the fact that probe angulation has no significant impact on the stability readings as proved by Ohta et al.[6]

Regarding implant length, considering that only two very close lengths were investigated in this study, namely 10 and 11.5 mm, the extra 1.5 mm seems to have an insignificant impact on the stability readings. Stability record has been also proved to be affected by the implant length only when the bone density was low (D3), where longer implants were utilized to enhance the primary stability.[9]

CONCLUSION

Within the limitations of this study, it seems that cortical thickness and bone density values obtained from a CBCT are not accurate predictors of primary implant stability. On the contrary, age seems to have a significant impact on the primary implant stability.

REFERENCES

1. Javed F, Romanos, GE. The role of primary stability for successful immediate loading of dental implants. A literature review. Journal of Dentistry 2010; 38:612-20.
2. Meredith, N. Assessment of implant stability as a prognostic determinant. International Journal of Prosthodontics 1998;11:491-501.
3. Pagliani L, Mortoni A, Nappo A, Sennerby L. Short Communication: use of diagnostic software to predict bone density and implant stability in pre-operative CTS. Clinical Implant Dentistry and Related Research 2012;14:553-7.
4. Cehreli MC, Kokat AM, Comert A, Akkocaoglu M, Tekdemir I, Akca K. Implant stability and bone density: assessment of correlation in fresh cadavers using conventional and ostetome implant sockets. Clinical oral Implants Research 2009;137:37-79.
5. Herrero-Climent M, Santos-García R, Jaramillo-Santos R, Romero-Ruiz MM, Fernández-Palacin A, Lázaro-Calvo P, Bullón P, Ríos-Santo JV. Assessment of Osstell ISQ's reliability for implant stability measurement: a cross-sectional clinical study. Med Oral Patol Oral Cir Bucal 2013;18:877-82.
6. Ohta K, Takechi M, Minami M, Shigeishi H, Hiraoka M, Nishimura M, Kamata N. Influence of factors related to implant stability detected by wireless resonance frequency analysis device. Journal of Oral Rehabilitation 2010; 37:131–7.
7. Beer A, Gahleitner A, Holm A, Tschabitscher M, Homolka P. Correlation of insertion torques with bone mineral density from dental quantitative CT in the mandible. Clin Oral Implants Res 2003;14:616–20.
8. Javed F, Ahmed HB, Crespi R, Romanos GE. Role of primary stability for successful osseointegration of dental implants: factors of influence and evaluation. Interventional Medicine & Applied Science 2013;5:162–7.

9. Barikani H, Rashtak S, Akbari S, Badri S, Daneshparvar N, Rokn A. The effect of implant length and diameter on the primary stability in different bone types. Journal of Dentistry, Tehran University 2013;10:449-55.

10. Turkyilmaz I, McGlumphy, EA. Influence of bone mineral density on implant stability parameters and implant success. a retrospective clinical study. BMC Oral health 2008;8:32-9.

11. Marquezan M, Osorio A, Sant Anna E, Mria Souza M, Maia L. Does bone mineral density influence the primary stability of dental implants? a systematic review. Clinical Oral Implant Research 2011;23:767-77.

12. Aksoy U, Eratalay K, Tozum TF. The possible association among bone density, resonance frequency measurements, tactile sense, and histomorphometric evaluations of dental implants osteotomy sites: a preliminary study. Implant Dentistry 2009;18:316-25.

13. Bergkvist G, Koh,KJ, Sahlholm S, Klinstorm,E, Lindh C. Bone density at implant sites and its relationship to assessment of bone quality and treatment outcome. International Journal of Oral and Maxillofacial Implants 2010;25:321-8.

14. Merheb J, Van Assche N, Coucke W, Jacob R, Naret I, Quirynen M. Relationship between cortical bone thickness or computerized tomography derived bone density values and implant stability. Clinical Oral Implants Research 2010;21:612-7.

15. Miyamoto I, Tsuboi Y, Wada E, Suwa H, Iizuka T. Influence of cortical bone thickness and implant length on implant stability at the time of surgery: clinical, prospective, biomechanical, and imaging study. Bone 2005;37:776–80.

16. Turkyilmaz I, Tumer C, Ozbek EN, Tözüm TF. Relations between the bone density values from computerized tomography, and implant stability parameters: a clinical study of 230 regular platform implants. J Clin Periodontol 2007;34:716-22.

17. Mesa F, Munoz R, Noguerol B, de Dios Luna J, Galindo P, O'Valle F. Multivariate study of factors influencing primary dental implant stability. Clin Oral Implants Res 2008;19:196-200.

18. Ikebe K, Wada M, Kagawa R, Maeda Y. Is old age a risk factor for dental implants? Jpn Dent Sci Rev 2009; 45:59–64.

19. Turkyilmaz I, Tozum TF, Tumer C, Ozbek EN. Assessment of correlation between computerized tomography values of the bone, and maximum torque and resonance frequency values at dental implant placement. J Oral Rehabil 2006;33:881-8.

20. Lee S, Gantes B, Riggs M, Crigger M. Bone density assessments of dental implant sites: bone quality evaluation during osteotomy and implant placement. Int J Oral Maxillofac Implants 2007;22:208–12.

21. Al-Askar M, O'Neill R, Stark PC, Griffi T, Javed F, Al-Hezaimi K: Effect of single and contiguous teeth extractions on alveolar bone remodeling: a study in dogs. Clin Implant Dent Relat Res 2013;15:569-75.

22. Howashi M, Tsukiyama Y, Ayukawa Y, Isoda□Akizuki K, Kihara M, Imai Y, Sogo M, Koyano K. Relationship between the CT Value and cortical bone thickness at implant recipient sites and primary implant stability with comparison of different implant types. Clinical implant dentistry and related research 2016;18:107-16.

23. Shahlaie M, Gantes B, Schulz E, Riggs M, Crigger M. Bone density assessments of dental implant sites: quantitative computed tomography. Int J Oral Maxillofac Implants 2003;18:224–31.

24. Dawood A, Patel S, Brown J. Cone beam CT in dental practice. British Dental Journal 2009;207:23-8.

25. Bryant SR. The effects of age, jaw site, and bone condition on oral implant outcomes. Int J Prosthodont 2016; 11:470–90.

26. Fuster-Torres MA, Penarrocha-Diago M, Penarrocha-Oltra D, Penarrocha-Diago M. Relationships between bone density values from cone beam computed tomography, maximum inseryion torque and resonance frequency analysis at implant placement: a pilot study. J Oral Maxillofac Implants 2011;26:1051-6.