

The Influence of Bone Density on Primary Implant Stability, and Clinical and Radiographic Outcome of Narrow Diameter Implants Supporting Mandibular Overdentures

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Abstract: Bone density plays an important role in the determination of dental implant outcome. Low bone density values can be associated with poor implant stability and increased marginal bone loss. Bone density assessment prior to implant installation can provide useful information regarding implant planning. This study aimed at evaluating the effect of bone density on primary implant stability, and clinical and radiographic outcome of narrow diameter implants, supporting mandibular overdentures. A total of 32 narrow diameter (3x10mm) two piece implants were installed for the construction of implant-assisted mandibular overdentures for each of eight completely edentulous patients, each receiving 4 implants. Preoperative density values for each implant site were recorded using cone beam computed tomography (CBCT). Clinical and radiographic data including; implant stability using resonance frequency analysis (RFA) expressed by Implant stability quotient (ISQ), Peri-implant probing depth (PD), clinical attachment level (CAL) and marginal bone level changes were recorded at base line, 3 and 6 months after implant loading. Correlation between bone density and different studied parameters were performed using pearson coefficient. Mean Bone density and primary implant stability were $(782.7 \pm 253.5$ and $63.19 \pm 7.5)$ respectively. Significant correlations were recorded between bone density values and primary implant stability ($r=0.650$, $p=0.006$), and between bone density values and marginal bone loss after 6 months ($r = 0.516$, $p=0.041$). We conclude from this study that bone density values influences the clinical outcome of narrow diameter implants. Hence, preoperative density assessment represents an important prognostic factor in implant planning.

Key words: implant stability, narrow-diameter implant, implant-assisted overdenture, Bone density, implant outcome, ISQ.

Date of Submission: 05-12-2018

Date of acceptance: 21-12-2018

I. Introduction

Bone density plays an important role not only in primary implant stability but also in the predictability of dental implant outcome¹ A poor bone quantity and quality are considered as the main risk factors for implant failure. Impaired healing and increased marginal bone loss have been associated with low density bone³⁻⁵. Higher survival rates for dental implants were reported in the mandible than in the maxilla. This has generally been attributed to difference in bone quality⁴. Additionally, good implant stability and good surgical technique favors implant osseointegration⁵.

Because of the significant influence of bone density on implant therapy several classification systems and procedures were proposed to asses bone quality⁶⁻⁹. Lekholm and Zarb developed a classification method to pre-operatively asses bone density. The classification is based on both; the radiographic assessment, and the resistance at drilling when preparing the implant site⁹. However, this technique has been debated due to its poor objectivity and reproducibility^{10,11}.

Computerized tomography (CT) has long been used as a reliable method for analyzing bone quality and quantity for implant planning¹²⁻¹⁴. CT enables the evaluation of the proposed implant sites providing diagnostic information about both, bone quality and bone volume¹⁵. In the last years cone beam computed tomography (CBCT) has been increasingly replacing CT for head and neck imaging. CBCT offers potentially lower radiation dose, and reduced costs when compared to CT¹⁶. The density values obtained by CBCT were confirmed to correspond reasonably with those estimated using helical CT^{17,18}. Hence, bone density values obtained by CBCT can aid in implant planning with higher degree of predictability.

Mandibular implant-assisted overdentures are being widely used in dental practice. Beside the preservation of the peri-implant bone, they provide reduced prosthesis movement, better esthetics and improved

masticatory functions¹⁹. Inadequate residual bone volume may impede the placement of standard diameter implants to support overdentures. Various augmentation techniques are currently used to create sufficient bone width and height in cases of severely resorbed ridges²⁰.

Nowadays narrow diameter implants have been recommended to avoid surgical intervention, cost, and longtime of bone grafting procedures in cases of insufficient bone volume^{21,22}. The use of narrow diameter implants is a predictable treatment option, since they afford clinical results comparable to those obtained by implants of standard diameter²²⁻²⁴. On the other hand, several potential biomechanical risk factors have been identified for narrow diameter implants. It has been reported that stress values at the implant-bone interface increases significantly by reducing the implant diameter. Inadequate overloading could then lead to peri-implant crestal bone resorption.²⁵ Also, narrow diameter implants can be more prone to fatigue fracture due to reduced diameter²⁶. Studies evaluating the performance of narrow diameter implants in different situations are therefore required. Since bone density is a crucial factor in determining primary implant stability and hence implant success. This study aimed at evaluating the influence of bone density measured by CBCT on primary implant stability and clinical outcome of narrow diameter implants supporting mandibular overdentures.

II. Material And Methods

This prospective study was performed in the period from 2017-2018. Patients were selected from the outpatient clinic of the Prosthetic department, Faculty of dentistry, Alexandria University, Egypt. A total of 32 narrow diameter two piece implants (3x10mm) (DIO, Korea) were used in the construction of implant-assisted mandibular overdentures for each of eight completely edentulous patients, each receiving 4 implants. All patients were thoroughly informed about the procedure and signed a written consent. The study was approved by the ethical committee at Faculty of Dentistry, Alexandria University (IRBNO:00010556-IORG0008839).

Inclusion criteria

- 1- All patients were completely edentulous.
- 2- Age of patients ranged from 50 to 70 years.
- 3- All patients were non-smokers.
- 4- All patients well motivated, cooperative and with adequate manual dexterity necessary to place and remove removable implant prosthesis to allow adequate oral hygiene around the implants.
- 5- The anterior mandibular alveolar ridges were being of adequate height and width.
- 6- Patients having sufficient inter-ridge space.
- 7- Patients were included if they were in a good health, free from any systemic diseases that might have an effect on the osseointegration of dental implants and of severely resorbed mandibular alveolar ridge but have adequate height and width anteriorly.

Exclusive criteria

- 1- Extremely senile patients as they were have poor healing capacity which may affect the surgical phase and osseointegration.
- 2- Habitual eccentric movements etc. which would compromise the results.
- 3- Uncooperative patients.
- 4- Patients were subjected to chemo-or radiotherapy.

Patient assessment

Prior to any treatment approach, every patient was thoroughly assessed regarding both dental and medical status. Thorough medical and dental history, intraoral and extraoral clinical examinations were performed.

Pre-operative bone density evaluation

A preoperative CBCT scan (Soredex SCANORA[®] 3D, Tuusula, Finland) was used to evaluate bone density for each patient. A standardized protocol was used for all patients using the same machine with the following exposure parameters: 120 Kvp, 5 mA with a field of view (FOV) of 16 x 8 cm for the mandible and 26.9 seconds at 0.25 resolution. Data from CBCT scans was exported in Digital Imaging and Communications in Medicine (DICOM) format into the OnDemand 3D[™] software (Cybermed Inc.) to reconstruct 3D volumes. The interforaminal area of the mandible was selected to receive the dental implants. The radiographs were taken with the patient wearing a clear acrylic radiographic/surgical mandibular template including gutta-percha radiopaque indicators. Three cross-sectional cuts 1mm apart at the middle of each previously designated implant area were selected. Trabecular bone density was obtained using the region of interest measuring tool (ROI) for a triangular area in each cut and their mean was calculated. Cross-sectional slice thickness and measured area size was standardized in all cases. (Figure 1)

Construction of conventional complete denture

Complete maxillary and mandibular dentures were fabricated for every patient according to standardized conventional technique. All subjects were adapted to their dentures for a period of time minimum two months to obtain adequate retention and stability.

Surgical procedure

Standard two-stage surgical technique was utilized to prepare the surgical sites for implant installation. Full-thickness mucoperiosteal flaps were raised while the patients were under local anesthesia. Buccal releasing incisions were made in the molar area, to identify both mental foramina. When indicated, a flattening of the alveolar crest was performed with a bur assembled on a straight low- speed handpiece, under irrigation with sterile saline, to obtain an adequate extension of a flat bony base. Osteotomy sites were prepared and four narrow diameter implants (two pieces) were screwed in position using a torque wrench.

Resonance frequency analysis (RFA)

Resonance frequency measurements were recorded using Osstell™ mentor (Integration Diagnostics, Go™teborg, Sweden). The SmartPegs™ were mounted on the implants and tightened by hand with a screw. Each implant was measured twice from two different angles, around 90 degrees and parallel to the crestal line. RF values were represented by a quantitative unit called the implant stability quotient (ISQ) on a scale from 1 to 100. The results were expressed in ISQ and averaged for each implant. After analyzing the primary stability of each implant, the Smartpeg™ was then removed and the flap was sutured.

Post operative management

Post operative medications included; Antibiotics 1 gm tablet (Augmentin, GlaxoSmith Kline, UK) (Amoxicillin 875mg clavulanic acid 125mg), once every 12 hours for 5 days postoperatively; Non-steroidal anti-inflammatory drugs Diclofenac potassium 50 mg tablets (Cataflam 50mg), (Novartis, Swiss multinational pharmaceutical company, Novartis, New Jersey) every 8 hours for 5 days, chlorhexidine HCL (0,12%) mouth wash (Hexitol, the Arab Drug Company, Cairo, ARE) three times daily for 2 weeks. Sutures were removed two weeks post operatively.

Overdenture fabrication

After 3 months healing period, implants were uncovered using a tissue punch. The cover screws were removed. Then the ball abutments were screwed on the implants. Protective disks were placed over the ball, then the stainless steel housings caps were placed on the attachments. The denture was seated into the patient's mouth to determine the location of the metal housings relative to the tissue bearing surface of the prosthesis by marking the metal housings with indelible pencil. The areas over the housings were relieved with an acrylic bur until the denture fully seated passively in the patient's mouth without contacting the metal housings. On the prosthesis, the implant sites were filled with mix of autopolymerized acrylic resin and inserted into the patient's mouth. The prosthesis were removed and verified that of positions of the attachment were correct. The protected disks were removed. The excess resins were trimmed away carefully. The completed prosthesis were seated and stabilized in the mouth. Finally, the patients were instructed about the care of the denture and the oral hygiene procedures. (Figure 2)

Follow-up and evaluation

Participants were evaluated clinically at one month after implant installation (base line) then after 3 and 6 months after loading. The following clinical and radiographic parameters were assessed :

1. Peri-Implant Probing depth.
2. Clinical attachment level.^{27,28}
3. Radiographic evaluation of marginal bone level changes using CBCT, were the mean of the facial and proximal measurements was recorded for each implant.
4. Implant Mobility assessed by resonance frequency analysis and expressed by ISQ, measured at the time of implant placement, 3 and 6 months after loading.

Statistical analysis

Statistical analysis were performed using IBM SPSS software package version 20.0. (Armonk, NY: IBM Corp). Mean and standard deviation was calculated for all studied parameters at different follow up periods. Spearman coefficient was used to correlate between quantitative variables.

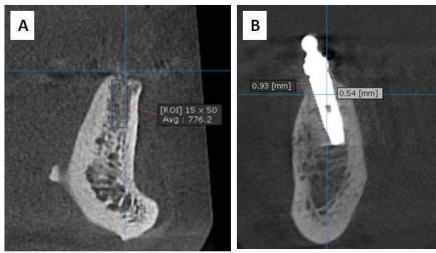


Figure 1: A) Preoperative radiographic assessment of density value using CBCT. B) marginal bone level assessment around narrow diameter implant.

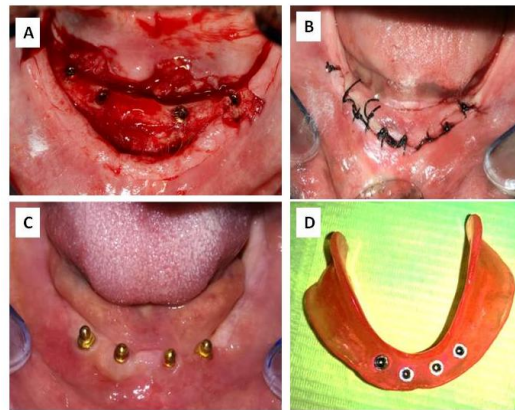


Figure 2: A) clinical photograph showing surgical procedure of implant placement. B) flap suturing C) ball abutments screwed to the implants D) implant assisted mandibular overdenture with metal housing.

III. Result

Table (1) shows the descriptive data of all studied parameters at different follow up periods. Mean preoperative bone density for different implant sites was (782.7 ± 253.5) ranging from (463–1258). Mean ISQ at implant placement representing primary stability was (63.19 ± 7.5) . It decreased to reach (62 ± 7.69) at 3 months of implant loading, and increased again to a value of (64 ± 7.89) at 6 months of implant loading. CAL and PD showed low values throughout the different follow up periods, with the maximum mean CAL and PD at 6 months follow up being (0.25 ± 0.2) and (1.22 ± 0.36) respectively. Mean bone level measured from the shoulder of the implant was recorded to be (0.09 ± 0.08) , (0.37 ± 0.13) and (0.71 ± 0.14) at baseline, 3 and 6 months respectively.

Table (1): Descriptive analysis of studied cases according to different parameters

	Median (Min. – Max.)	Mean \pm SD
Bone density	745.5(463 – 1258)	782.7 \pm 253.5
ISQ		
Baseline	66 (50 – 70)	63.19 \pm 7.5
3 months	65.5(49 – 72)	62 \pm 7.69
6 months	67(49 – 72)	64 \pm 7.89
CAL		
Baseline	0(0 – 0.5)	0.13 \pm 0.18
3 months	0(0 – 0.75)	0.19 \pm 0.28
6 months	0(0 – 0.75)	0.25 \pm 0.2
PD		
Baseline	0.25(0 – 0.75)	0.25 \pm 0.24
3 months	1(0.5 – 1.75)	0.97 \pm 0.34
6 months	1(1 – 2)	1.22 \pm 0.36
Bone level		
Baseline	0.06(0 – 0.25)	0.09 \pm 0.08
3 months	0.35(0.20 – 0.64)	0.37 \pm 0.13
6 months	0.68(0.45 – 0.99)	0.71 \pm 0.14

Table (2) shows correlation between preoperative bone density and different studied parameters. Significant positive correlation was found between bone density and both; primary implant stability at the time of implant placement, and secondary stability after 6 months of loading ($r=0.650$, $p=0.006$ and $r=0.588$, $p=0.017$) respectively.

Inverse correlation was found between bone density values and maximum CAL and PD reached after 6 months of loading, indicating that more dense bone showed lower CAL and PD around dental implants. However, this correlation was not statistically significant ($p<0.05$). Correlation was also assessed between bone density and total change from base line to 6 months for both CAL and PD. Insignificant inverse correlation was found for CAL but not for PD.

Regarding marginal bone level, Significant inverse correlation was found between bone density and maximum bone level change at 6 months after loading, indicating that dense bone showed more stable bone margins. However, an insignificant inverse correlation was found regarding the total change from baseline to 6 months.

Table (2): Correlation between bone density and different parameters

	Bone density	
	r	p
ISQ		
Baseline	0.650*	0.006*
6 months	0.588*	0.017*
CAL		
6 months	-0.276	0.301
Total change	-0.380	0.147
PD		
6 months	-0.119	0.660
Total change	0.066	0.809
Mean Bone level		
6 months	-0.516*	0.041*
Total change	-0.180	0.504

r: Pearson coefficient

*: Statistically significant at $p \leq 0.05$

IV. Discussion

Different oral implant systems have been developed and promoted for the treatment of partially or completely edentulous patients. Continuous evaluation of these implants is necessary to determine their long term success. Narrow diameter implants have been proposed as a treatment option for inadequate bone volume that impedes the installation of standard diameter implants. They have been successfully used to support mandibular overdentures^{23,24}.

The current study was performed to evaluate the influence of bone density on the clinical and radiographic outcome of narrow diameter implants supporting mandibular overdentures. Mean preoperative bone density obtained in the current study was 782.7, in accordance to Farre´-Page´s et al who reported a mean density value of 776 in the anterior mandibular region using helical CT²⁹. Higher values of 970 and 994.9 were reported in other studies for the same region^{30,31}. In comparison to other regions of the jaw bone, the anterior mandible mostly presents the highest density values.^{30,31}

Regarding implant stability, mean ISQ for the evaluated implants at the time of implant installation was (63.19 ± 7.5) indicating good primary stability. The resonance frequency analysis technique has been successfully used for assessing the primary implant stability^{29,31}. The stiffness of the implant-tissue interface is calculated as a reaction to oscillations exerted onto the implant/ bone system. The normal range of ISQ values that has been generally reported for implants achieving primary stability is between 50 and 70^{32,33}. In the current study significant correlation was found between preoperative bone density and ISQ values at the time of the implant installation ($r=0.650$, $p=0.006$). This suggest a high correlation between the density values obtained by CBCT and primary implant stability. In accordance to the obtained results, Song et al. and Salimov et al found significant correlation between CBCT density values and implant stability parameters including insertion torque, and ISQ values^{34,35}. Implant stability parameters were also evaluated on 18 fresh femoral heads of swine, and positive correlation to CBCT bone density was also obtained³⁶. These results suggest that the assessment of the quality of the bone before the surgery is a key factor in the success of the surgery and the stability of the implant after the operation. ISQ values for the evaluated implants in the present study showed decreased values after 3 months, followed by and increase after 6 months of loading. Similarly Simunek et al. reported a decrease in the ISQ values by 3 units during the healing process to reach the lowest level in the third week. After that, ISQ has increased constantly up until week 12³⁷. Primary stability is associated with the mechanical engagement of an implant with the surrounding bone, whereas secondary stability depends on the bone regeneration and remodelling which occurs during the healing process^{38,39}. The current study also revealed a significant positive correlation between preoperative bone density and secondary stability measured six months after loading. Considering the direct correlation between bone density and bone strength, it can be concluded that the bone density is a key factor for the long-term and secure stability of the implant inside the bone.

Significant correlations was also obtained between bone density values and marginal bone loss after 6 months ($r = 0.516$, $p=0.041$) i.e increased bone density showed decreased bone level changes. These results suggest a strong influence of bone density on marginal bone stability. Marginal bone loss after 6 months was 0.71 ± 0.14 similar to the mean bone loss (0.78 ± 0.48 mm) reported in a systematic review for narrow implants of diameter ranging from (3- 3.25 mm). The same review reported a survival rate of 93.8% to 100% for these implants⁴⁰. After 6 months of implant loading, mean PD and CAL were (1.22 ± 0.36 and 0.14 ± 0.2) respectively. Highest mean reported measurement for the current study was 1.75mm suggesting successful outcome for the used implants. Salvi et al⁴¹ and Neiva et al⁴² have indicated that successful implants allow probe penetration of approximately 3 mm probing depths. Inverse correlation was also found between bone density, and CAL and PD at 6 months however, it was not statistically significant.

In light of the obtained results bone density seems to have a strong influence on implant primary stability and the clinical and radiographic outcome of the narrow diameter implants supporting mandibular overdentures. Preoperative density measurement could aid in formulating a proper protocol for implant installation that would result in better treatment outcome.

V. Conclusion

We conclude from this study that bone density influences the clinical outcome of narrow diameter implants supporting mandibular overdentures. Hence, preoperative density assessment represents an important prognostic factor in implant planning.

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Rania A Fahmy. “The Influence of Bone Density on Primary Implant Stability, and Clinical and Radiographic Outcome of Narrow Diameter Implants Supporting Mandibular Overdentures”. ” *IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)*, vol. 17, no. 12, 2018, pp 17-23.