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# A comparative radiographic study of bone density changes around titanium implants in the posterior mandible, preoperative, and postoperative

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**Background:** Implant success and the state of the surrounding bone require multiple measures, especially in humans, and this study aimed to identify the development of the state of the latter by means of radiographic examination performed during the period of osseointegration as well as investigate the changes in bone density that occur after implant installation and 2 months after functional loading. Implant success rates are affected by bone density at the implant site. Therefore, understanding changes in bone density after dental implant placement is essential, as it correlates with subsequent implant success.

**Materials and methods:** Digital radiographs of 28 implants were taken and evaluated at four intervals: preoperatively, 1 and 3 months postoperatively, and 2 months following placement of the permanent prosthesis. Gray values were measured in different areas around the implants through analyzing X-ray images and measuring bone density around the implants using EzDent – 2D software. The aim of this study was to investigate changes in bone density around implants in three regions: apex, neck, and body, as well as to record average density values during the observation period by measuring digital image gray levels (the gray values of the digital radiographs). This was conducted to determine local bone densities in dental implant recipient sites and to study changes in local bone densities at different intervals, preoperatively and postoperatively and after placement of the prosthesis.

**Results:** A decrease was observed in gray values proportional to reference values 1-month after implant insertion, but these increased at 3 months after insertion and continued to rise 2 months after placement of the prosthesis in the apical, body, and neck regions of the implant.

**Conclusion:** Sensor-tuned radiography can be used as an effective method to support clinical follow-ups as well as measure changes in bone densities around implants in critical cases.

**Keywords:** bone quality, bone density, cone-beam computed tomography (CBCT), gray values, sensor-tuned radiography, titanium implant

## Introduction

The clinical application of osseointegration, introduced in the mid-1960s, has shown predictable long-term success[1]. Nowadays, it is a common practice to use dental implants to replace missing teeth[2,3]. The most important factor in primary stability is quality and quantity of local bone, and primary implant stability is one of the main factors influencing implant survival rates[3,4]. Several studies have shown a high success rate for dental implants and an improvement in bone formation around implants[5,6], with the one for treatment with dental titanium implants ranging between 81 and 93%. Success of the treatment depends on a complex interaction of several factors. Specifically, bone density and implant stability are the two most important elements for achieving osseointegration.

Implant stability is a combination of mechanical and biological stability. Mechanical stability occurs due to pressure exerted by

### HIGHLIGHTS

- Digital radiographs of 28 implants were taken, and the images of 28 single implants were evaluated at four intervals: preoperatively, 1 and 3 months postoperatively, and 2 months following placement of the permanent prosthesis.
- Gray values were measured in different areas around the implants through analyzing X-ray images and measuring bone density around implants using EZ Dent – 2D software.
- To investigate changes in bone density around implants in three regions: apex, neck, and body, as well as to record the average density value during the observation period by measuring digital image gray levels (the gray values of the digital radiographs).
- This was conducted to determine local bone densities in dental implant recipient sites and to study changes in local bone densities at different intervals, preoperatively and postoperatively and after placement of the prosthesis.

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bone tissues during implant insertion into the bone, which is called 'primary implant stability,' while biological stability is the result of new formation of bone cells created at the implant surface during osseointegration – 'secondary implant stability'[6].

Higher failure rates appear to be associated with implants in which the surgeon finds a poor degree of bone mineralization or limited bone resistance with tactile assessment while drilling. Hence, the surgeon's assessment and knowledge of the amount of bone density in the areas receiving implants is quite essential[7,8]. However, regardless of the protocol applied in implant insertion, osseointegration development, as defined by Brånemark[9] is a major factor in clinical success after placement of dental implants.

Several studies have examined alveolar bone reaction and bone healing around dental implants, but were based, to a large extent, on animal histological experiments and studies[10].

The lack of histological investigations of the human body has undermined a proper understanding of the healing process that takes place in the bone around implants. Because the mechanical behavior and density of bone is a vital factor in achieving osseointegration, several systems and procedures have been proposed to classify bone density and quality[10,11].

The most common method for evaluating bone density was developed by Lekholm and Zarb, who introduced a scale of one to four, based on both radiographic assessment and resistance detected by the surgeon when preparing the implant site[12,13]. However, this classification was the result of a subjective experiment and, therefore, has been considered objectively compromised[14].

Furthermore, Johansson and Strid described a technique for grading bone quality as an indicator of bone density and hardness based on torque forces required during implant insertion. They assumed that the energy used to excavate the site, prior to or during implant placement, is a combination of the force needed and the friction created as the remainder of the implant enters the implant site[4,15].

Despite the fact that these methods provide good information about bone density, they are not considered highly reliable because they are subject to personal evaluation[14–16].

Another method used is Periotest, which measures the degree of concrescence between periodontal tissues and teeth, and the extent of hardening of the bone – implant interface[17].

Periotest values include a narrow range of information, and thus present relatively fewer sensitive data about implant stability. Therefore, its usefulness in detecting osseointegration is a matter of debate.

Another method – resonance frequency analysis using the Osstell instrument – was introduced by Meredith and colleagues and has been since used in clinical studies[18]. Several studies have shown that measurement of implant stability with the latter is reliable, noninvasive, and usable any time after implant insertion[19].

In practice, the implant surgeon often has difficulty assessing the quality of cancellous bone before surgery, and many studies have proven that there is a relation between poor bone quality and increased implant failure rate.

Radiological bone quality evaluation should be an important element of presurgical implant planning, as it is an available and relatively nonsurgical method to evaluate bone quality of the jaws. Hounsfield units are used in dentistry to measure the value of bone densities at the site of implant placement, thus enabling the surgeon to more accurately diagnose the success of the osseointegration process.

Cone-beam computed tomography (CBCT) has thus been considered the most reliable and objective alternative. This method provides morphological and qualitative analysis of the bone[4], and has been applied in many clinical studies and research projects. It is one of the most important ways to monitor and evaluate changes in bone density, but two of the related challenges that researchers may face are the patient's exposure to high radiation and the relatively high cost[20,21].

In this study, bone density was measured based on gray levels obtained with tuned radiographs using Korea Vatech EZ-Sensor and its holder and a portable Dental X-Ray Bemems Vatech-Korea camera, which has a function for measuring bone density. The figure was adopted based on the change in gray levels around implants during observation. Vatech was contacted to verify the validity of these values, and it was advised that changes in gray levels around implants were indicative of density value fluctuation.

The use of sensor-tuned radiography reduces patient exposure to high radiation doses, which was the main factor in limiting the use of computed tomography to monitor changes in bone density around inserted dental implants.

The aim of this study was to monitor changes in bone densities around implants before applying the prosthetic in order to identify the implant's own impact on the surrounding bone using the sensor-tuned radiographic technique. It also aims to propose this as a potential method to evaluate and monitor density changes in the alveolar bone before and after implant installation.

## Materials and methods

The study population consisted of patients who presented to dental clinics between 2019 and 2020. The study was conducted after securing the approval of the Ethical Committee of Dentistry Faculty's Research Center (Approval 1312; Session 15 April 2020. The study complies with the STROCSS 2021 criteria[22], and was registered with the Research Registry under unique identifying number researchregistry9631 (https://www.researchregistry.com/browse-the-registry#home/(.

The sample size was indicated with software G*Power (G*Power v3.1.4; Heine-University Dusseldorf). Data on sex, age, implant positioning, appropriate commercial implant lengths and diameters, and follow-up intervals were collected. The authors of this cohort radiographic clinical study conducted a clinical trial on 28 implants in fourteen adult patients who had a single tooth missing in the posterior mandible. The area was rehabilitated by performing single titanium dental implants at the site of the loss. It was A cohort radiographic clinical study.

The eligibility criteria for this study included participants between the ages of 20 and 50; an adequate interocclusal space between the alveolar crest and the inferior alveolar canal in the area of tooth loss to accommodate dental implants of at least 10 mm long; and good oral health.

On the other hand, the exclusion criteria were an insufficient interocclusal space; nonfunctional habits, such as bruxism; uncontrollable systemic diseases, such as uncontrolled diabetes and osteoporosis; radiotherapy or chemotherapy; and heavy smoking.

All patients underwent a clinical examination before surgery, and the following patient data were collected: name, sex, age, and medical history. Oral mucosa and teeth were also examined.

VITRONEX Implant System, Italy was chosen due to the availability of logistical support from the company in terms of research work requirements. lengths of implants that used were – 3.7 and 4.2 mm; and 10, 11, and 12 mm, respectively. This was selected proportional to bone measurements available at loss sites, as evaluated radiographically before implant placement.

All patients underwent radiography by CBCT and sensor-tuned radiographic examination before the surgery to determine the size of the implants and their relationship to adjacent structures; to measure the bone height above the mandibular canal; and to assess the condition of the bone and measure its density.

Bone density values were measured preoperatively, 1-month and 3-month postoperatively and 2 months after placing the permanent prosthesis. Sensor measurements were taken at a 1 mm diameter away from the implant, and density was measured in three areas around the implant – apex, body, and neck as follows:

- Apex: pitch between the last two helices.
- Body: pitch between the fifth and sixth helices.
- Neck: pitch between the first and second helices.

The images were analyzed and the average bone density around titanium implants was recorded using EzDent - 2D software at three different points: apex, body, and neck. Arithmetic means for each area were then calculated, and bone density values at the given implant site were recorded (Fig. 1).

The sample required for the study was collected over a period of 6 months, and were taken from patients visiting dental clinics. Collection continued until the required sample size was reached. A total of 28 single implants in fourteen adult patients who had a single tooth missing in the posterior mandible were placed. Complete treatment was provided free of charge to patients but no monetary incentives were offered in return. Written informed consents were procured from the patients.

Patients were orally administered amoxicillin and clavulanic acid 2 mg antibiotic 1 h preoperatively as a part of the clinical guidelines, and the mouth was rinsed with chlorhexidine gluconate 0.12% for 30 s before the operation. The areas for implant placement were anesthetized by local anesthetic, using 2% lidocaine HCL, with 1:80 000 Epinephrin. A full-thickness flap was raised. Finally, the implant site was prepared through initial marking with 2.2 mm pilot drill. Recommended drilling speeds were applied, carefully excavating at 1 mm/5 s supply of copious amount of regular cold saline infusion at a rate of 50 ml/min.

Once the required preparation depth was achieved, the implant was driven to its final position using an appropriate wrench to deliver 25–30 N of force. Proper seating of the implant was ensured by close approximation of the crest module of the implant to the crestal bone and radiographic verification to confirm appropriate placement of the implants and their parallelism with adjacent teeth. Postoperative instructions regarding antibiotic and analgesic medication, maintenance of proper hygiene with 0.2% chlorhexidine gluconate, avoiding hot, spicy, or hard food during the healing period, and care for the surgical area were given to the participants. They were recalled at 7 days postoperatively for removal of sutures and for evaluation of surgical site healing.

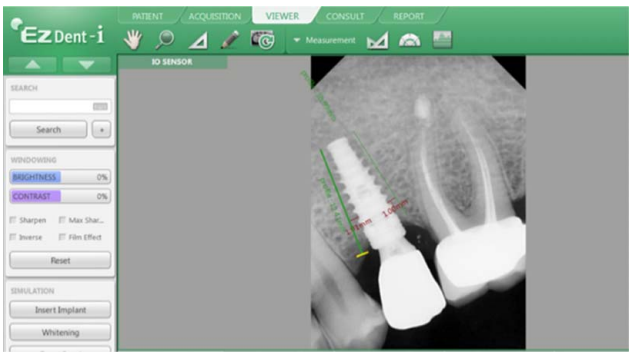


**Figure 1.** Bone density values around implants with EZ Dent – 2D software.

Radiographic images were taken using a sensor with special holders for distance and direction adjustment along with a portable camera. Average bone density was taken at a 1 mm diameter away from the implants preoperatively and 1 and 3 months after implant installation at three different points – apex, body, and neck. After that, the arithmetic mean for each part was calculated, and bone density values were recorded around the inserted implants with EzDent – 2D software.

- All complications received a grade one, according to Clavien–Dindo classification* with the exception of one implant, which was lost because of inflammation, thus receiving grade three under the same classification.

## Results

### *Study sample*

The study sample included 28 implants distributed among fourteen patients who had lost of one posterior tooth on each side. Two single implants were inserted for each patient in the posterior region of the lower jaw, bilaterally. Bone densities around the neck, apex, and body of implants were measured preoperatively, 1 and 3 months postoperatively, and after the placement of the prosthetic.

At the first follow-up 7 days after the surgery, none of the patients exhibited any signs of infection or flap dehiscence. In all cases, healing progressed normally without scarring, bleeding, edema, or other side effects. Additionally, no patient reported experiencing postoperative pain.

### *Statistical methods used*

To achieve the objectives of the research, the researchers used the Statistical Package for Social Sciences (SPSS version 20) to carry out the analysis and achieve the goals of this research study. A 5% significance – generally deemed acceptable in social sciences – was used, with a 95% confidence to interpret the results of the study conducted by the author. The following statistical methods were used:

- Kolmogorov–Smirnov normality test.
- Arithmetic means, SD, and CIs.
- One-way ANOVA.

### *Normal distribution testing with Kolmogorov–Smirnov*

The researchers used Kolmogorov–Smirnov (K-S) normality test to identify the nature of the distribution of the results of the research sample tests. When alpha value was greater than 5%, this would indicate that data had a normal distribution.

**Table 1**

**Descriptive statistics of bone density results around the implant's apex.**

| Interval | *mean* ± *sd* | Min. | Max. | 95% CI |
|---|---|---|---|---|
| Preinsertion | 148.17 ± 24.82 | 111 | 179 | [132.40 – 163.94] |
| After 1-month | 139.33 ± 30.02 | 92 | 182 | [120.26 – 158.41] |
| After 3 months | 149.25 ± 24.70 | 101 | 180 | [133.56 – 164.94] |
| Postprosthetic | 152.83 ± 24.25 | 109 | 191 | [137.42 – 168.24] |

One may notice a *P*-value $>0.05$ for all measurements; therefore, distribution was normal, and use of normal tests (parametric tests) would entail.

### First – Bone density around the implant at the apex

1. Descriptive statistics
   Table 1 shows the descriptive statistics of bone density results around the implant's apex:
   It demonstrates a decrease in average bone density after a month from before the surgery, compared with an increase 3 months afterward and following placement of the prosthetic. This is demonstrated in Figure 2.
2. Statistical comparison

For statistical comparison, one-way ANOVA was used.

We notice that *P*-value $=0.631>0.05$, and, therefore, there were no significant statistical differences in mean bone density at the apex between follow-up intervals. The following observations could be highlighted:

1. Average bone density underwent an insignificant decrease (5.96%) at 1-month interval compared with presurgery.
2. Average bone density insignificantly increased from preinsertion by 0.73 and 7.12% at 3-month and 1-month intervals, respectively.
3. Average postprosthetic bone density increased in a nonsignificant manner by 3.15% from preinsertion and 9.69% and 2.40% from the figures at 1-month and 3-month intervals, respectively.

### *Second – Bone density around the implant's body*

1. Descriptive statistics
   Table 2 summarizes descriptive statistics of data on bone density around the implant's body.
   A decrease in average bone density could be seen after a month from before the surgery, compared with an increase 3 months afterward and following placement of the prosthetic. This is illustrated in Figure 3.

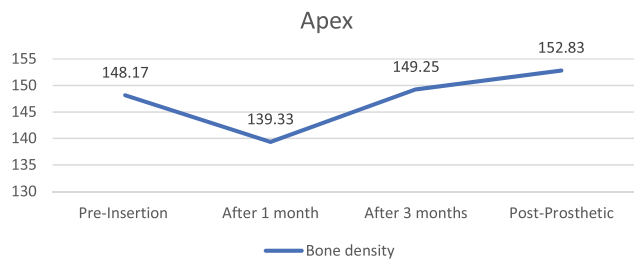


**Figure 2.** Average bone density in the apical region during follow-ups.

**Table 2**

**Descriptive statistics of bone density around implant's body.**

| Interval | *mean* ± *sd* | Min. | Max. | 95% CI |
|---|---|---|---|---|
| Preinsertion | 143.50 ± 23.65 | 110 | 174 | [128.47 – 158.53] |
| After 1-month | 134.67 ± 32.17 | 70 | 183 | [114.23 – 155.11] |
| After 3 months | 145.17 ± 23.03 | 120 | 175 | [130.53 – 159.80] |
| Postprosthetic | 153.75 ± 23.25 | 110 | 183 | [138.98 – 168.52] |

2. Statistical comparison

For statistical comparison, one-way ANOVA was used. It could be noticed that *P*-value $=0.359>0.05$, and, therefore, there were no significant statistical differences in mean bone density in the midsection between follow-up intervals. The following observations could be highlighted:

1. Average bone density underwent an insignificant decrease (6.16%) at 1-month interval compared with presurgery.
2. Average bone density insignificantly increased from preinsertion by 1.16 and 7.80% at 3-month and 1-month intervals, respectively.
3. Average postprosthetic bone density increased in a nonsignificant manner by 7.14% from preinsertion and 14.17 and 5.91% from the figures at 3-month and 1-month intervals, respectively.

### *Third – Bone density around the implant's neck*

1. Descriptive statistics
   Table 3 summarizes descriptive statistics of data on bone density around the implant's neck.
   It shows a decrease in average bone density after a month from before the surgery; a slight increase 3 months afterward; and an increase following placement of the prosthetic compared with the preinsertion. This is illustrated in Figure 4.
2. Statistical comparison

For statistical comparison, one-way ANOVA was used.

We notice that *P*-value $=0.151>0.05$, and, therefore, there were no significant statistical differences in mean bone density in the neck between follow-up intervals. The following observations could be underscored:

1. Average bone density underwent an insignificant decrease (12.64%) at 1-month interval compared with presurgery.

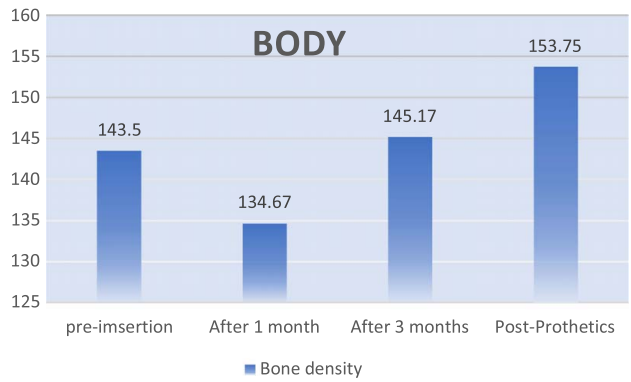


**Figure 3.** Average bone density in the body during the follow-ups.

**Table 3**

**Descriptive statistics of bone density around implant's neck.**

| Interval | *mean* ± *sd* | Min. | Max. | 95% CI |
|---|---|---|---|---|
| Preinsertion | 124.58 ± 22.81 | 80 | 160 | [110.09 – 139.07] |
| After 1-month | 108.83 ± 20.83 | 77 | 142 | [95.60 – 122.07] |
| After 3 months | 122.08 ± 20.85 | 87 | 162 | [108.83 – 135.33] |
| Postprosthetic | 128.83 ± 23.15 | 89 | 167 | [114.12 – 143.54] |

2. Average bone density insignificantly increased from preinsertion but remained 2.0% lower than its value before the surgery and 12.17 higher than the figure at 1-month interval.
3. Average postprosthetic bone density increased in a nonsignificant manner by 3.41% from preinsertion and 18.38% and 5.53% from the figures at 1-month and 3 months intervals, respectively.

## Discussion

In this study, the limitations included the prospective study design, the size of the sample population, the use of two-dimensional digital radiographs, the follow-up period preoperative and postoperative and after functional loading, Lack of prior research studies on the topic, and the absence of intraoral occlusion data to confirm the existence of overloading, which was reported as a potential risk factor for implant failure. The data integrity could be strengthened by increasing the sample size and extending the follow-up period, as well as conducting more future clinical trials on this topic.

Implants may wear out eventually or without proper oral hygiene, not to mention that they are not suitable for everyone, as a few patients may not be eligible for tooth replacement due to their bone health since they usually require healthy bones that are dense. Strong bones in place are a parameter that support dental implants. When dental implants are installed in low-quality bone, the initial stability would be poor and might lead to implant failure. Various classifications have been bone proposed to rank bone quality[23], and one of the most determining factors behind implant success is the size and quality of bone available in the areas receiving it. Clinical studies have shown a higher survival rate for lower jaw dental implants[24] and a higher failure rate for those placed on the upper jaw[5].

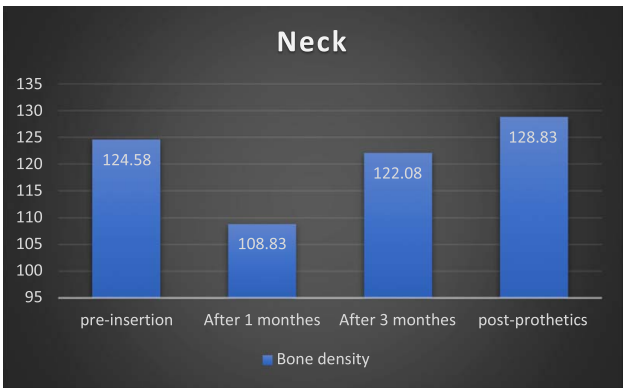


**Figure 4.** Average bone density in the neck during the follow-ups.

Researchers have indicated that the difference in survival rates for implants in the upper or lower jaw is due to the discrepancy in bone quality between the two. Within the limits of this study, the bone density values obtained at the particular implant site decreased after 1-month from implant installation, which could be considered normal during recovery and bone regeneration around implants.

The researchers' findings revealed an increase in postoperative bone density measurements at the three levels around dental implants, suggesting that bone is compressed around dental implants after placement, which is good for implant stability, especially in areas with low bone density, like the posterior maxilla[25].

Within the limits of this study, bone density values recorded around implants increased after 3 months from implant installation until after the placement of the prosthetic. When osteointegration is developing, bone density increase occurs around the implants as well as at bone-to-implant contacts (BIC). These results correlate with the studies conducted by Reddy[14,26].

A previous clinical study conducted by Turkyilmaz *et al.* for 158 implant sites from 85 patients indicated significant correlations between bone density values and stability parameters[27].

So, understanding changes in bone density after dental implant placement is essential, as it correlates with subsequent implant success. Another challenge this study tried to circumvent is high radiation exposure for the patient and high cost when CBCT in utilized. Instead, for measuring bone density based on gray levels, the authors of this study applied tuned radiographs using Korea Vatech EZ-Sensor and its holder and a portable dental radiograph.

## Conclusion

Bone density around dental implants was evaluated using EzDent – 2D; periapical radiographs with a Vatech sensor; and imaging with a portable X-ray machine, equipped with holders to adjust dimensions, direction of rays and perpendicular positioning onto the implant. Three implant areas – apex, body, and neck – were measured during follow-ups. In the limits of this study, measurements showed that there was a decrease in density values in the first month of surgery, which could considered normal during recovery and bone regeneration around implants. This was followed with a gradual increase from the second month until after placement of the prosthetic. Tables 2 and 3 show neck and body density values upon implant insertion. Similarly, in the limits of this study, measurements showed that there was a fall in density values in the first month of surgery, which could considered normal during recovery and bone regeneration around implants. This was followed with a gradual increase from the second month until after placement of the prosthetic.

## Ethical approval

The approval of the ethics committee for research was obtained. The protocol of the study had been approved by the ethics committee of the collage of Dentistry Research Centre at the university under approval (1312) during session (15).

## Consent

Informed consent was obtained from patients and it is available from the corresponding author upon reasonable request.


## Sources of funding

No funding was obtained for this study.


## Author contribution

All authors have approved the final draft of the manuscript.

## Conflict of interest disclosures

The authors declare no conflict of interest, whether financial or otherwise.

## Research registration unique identifying number (UIN)

https://www.researchregistry.com/browse-theregistry#home/registrationdetails/6428913beafb2d0028aaff89/Researchregistry9631

## Guarantor

The Guarantors are Dr. Nazih Issa and Dr. Batoul Sleman.

## Data availability statement

All data and material collected during this study are available from the corresponding author upon reasonable request.

## Provenance and peer review

Not commissioned, externally peer-reviewed.

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