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Evaluation of the effect of osseodensification on implant stability and bone density in low-density bone: A clinical study

A thesis

Submitted to the council of the College of Dentistry at the University of Baghdad, in partial fulfillment of requirements for the Degree of Master of Science in Oral and Maxillofacial Surgery

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Dedication

*To the memory of **my father** who I miss everyday*

*To **my mother** for raising me to believe that anything is possible*

*To **my Family** for their love and endless support*

*To my wonderful husband **Ali** and lovely daughters **Sama** and **Haya***

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Abstract

Background: Osseodensification, a nonextraction technique, developed by Huwais in 2013 made it possible with specially designed burs to increase bone density as they expand an osteotomy. It allows bone preservation and condensation through compaction autografting during osteotomy preparation, increasing the peri-implant bone density and the implant mechanical stability.

Aims of the study: To assess the effect of implant site preparation in low-density bone using osseodensification method on implant stability changes during the osseous healing period, to assess the effect of osseodensification on bone density apical to the implant using cone beam computed tomography and to determine the effect of some predictor variables (age, gender, jaw, insertion torque and implant dimensions) on dental implant stability and on bone density apical to the implant.

Materials and Methods: This prospective observational clinical study included 24 patients, 7 males and 17 females who received 46 dental implants that were installed in low-density bone using the osseodensification method. Cone beam computed tomography was used to measure the bone density using On demand software preoperatively and within 7 days postoperatively and implant stability was measured using Periotest® immediately after implant insertion and then after 6 and 12 weeks postoperatively. The data were analyzed using paired t-test, unpaired t-test, one-way analysis of variance, Tukey's multiple comparisons test and Pearson correlation coefficient. Probability values <0.05 were considered statistically significant.

Results: Of the 46 implants, 43 were osseointegrated making the early survival of the implants 93.5%. There was a significant increase in bone density postoperatively; 337.6 ±182.9 compared to 265.3 ±173.9 Hounsfield units preoperatively. The primary implant stability was -2.7 ± 2.13 Periotest values, at the 6th week it decreased significantly ($p < 0.0001$) to become 0.7 (± 4) Periotest values, and at the 12th week (secondary stability) it increased significantly ($p < 0.0001$) to become -2.1 (± 2.8) Periotest values. The difference between primary and secondary stability was statistically non-significant ($p=0.0814$).

Conclusion: Osseodensification resulted in high primary stability and increased bone mineral density apical to the implant but it did not prevent the implant stability drop during the first 6 weeks after insertion of implants.

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List of abbreviations

Abbreviations	Representative words
3D	Three dimensions
ANOVA	Analysis of variance
BIC	Bone implant contact
BMD	Bone mineral density
BV	Bone volume
CBCT	Cone beam computed tomography
cc	Cubic centimeter
ccw	Counter-clockwise
Co.	Company
CP-Ti	Commercially pure-titanium
CT	Computed tomography
cw	Clockwise
D	Density
DI	Dental implant
DXA	Dual energy X-ray absorptiometry
etc.	et cetera
Fig.	Figure
FIZs	Functional implant zones
FOV	Field of view
g.	Gram
HU	Hounsfield unit
ISQ	Implant stability quotient
ITI	International Team for Implantology
kHZ	Kilohertz
Kv	Kilovolt
LLC	Limted liability company
Ltd	Limited
m/s	meter/second
mA	Milliampere
mCT	Micro-computed tomography
mg	Milligram
mm	Millimeter
MRI	Magnetic resonance imaging
n.	Sample number
N/cm	Newton/centimeter
NS	Non-significant

Ø	Diameter
OD	Osseodensification
OPG	Orthopantomography
P	Probability
PTVs	Periotest® values
qCT	Quantitative-computerized tomography
R	Correlation
RF	Resonance Frequency
Rpm	Revolutions per minute
sec	Second
S	Significant
SAC	Simple-Advanced-Complex
SD	Standard deviation
SSOI	Swiss Society of Oral Implantology
USA	United States of America
vs	Versus

Introduction

Introduction

Primary implant stability is one of the most important factors for osseointegration of dental implants; it is achieved by the mechanical engagement of the external implant surface to the walls of the recipient osteotomy site. Bone density, surgical protocol and implant design are involved in enhancing primary implant stability **(Tirsi *et al*., 2016)**.

Lekholm and Zarb in **1985** proposed a classification for the bone quality based on plain radiographs and the assessment of tactile sensation during drilling of bone but assessment of bone quality with this approach is subjective, therefore, quantitative assessment of bone mineral density using computerized tomography (CT) scan constitutes an important indicator for bone quality, this, however, may increase the radiation burden on the patient **(Todisco and Trisi, 2005)**. To overcome the problem of radiation related to CT scans many studies suggested that cone beam computed tomography (CBCT) is an optimum option to assess bone mineral density and hence bone quality **(Aranyarachkul *et al*., 2005; Razi *et al*., 2014)** although other studies found that CBCT could not demonstrate the true bone density compared with histologic analysis and micro-CT **(Suttapreyasri *et al*., 2018)**.

Improving primary stability in areas of low bone density is desirable but challenging, traditionally this has been achieved through underpreparation of the implant site **(Lahens *et al*., 2019)**, and in an in vitro study, a 10% underpreparation of the implant site was considered sufficient to improve primary stability in poor bone quality **(Degidi *et al*., 2015)**. Another approach to increase primary implant stability in poor bone quality is by using osteotomes to condense and compress bone apically and laterally creating a layer of compact bone at the implant interface **(Tretto *et al*., 2019)**.

The conventional implant site preparation techniques are subtractive in nature that use successively increasing-diameter drills rotating in a clockwise direction under copious irrigation to excavate bone and prepare the implant bed **(Witek *et al*., 2019)**, while recently a new non-subtractive drilling technique, osseodensification (OD), was introduced where a specially designed drills rotate in a counterclockwise direction compacting bone at the osteotomy walls allowing more intimate engagement of the implant with the osteotomy site and increasing the primary stability **(Huwais and Meyer, 2017; Tian *et al*., 2019)**.

Compared with conventional drilling, OD was reported to result in higher insertion and removal torque, increased primary and secondary stability, higher bone-to-implant contact (BIC) and higher bone volume (BV) around implants **(Tretto *et al*., 2019)**, this favorable outcome is possible because of the drills that have many lands with large negative rake angles which work as a noncutting edges to expand the implant site and increase the density of the bone **(Huwais and Meyer, 2017)**.

After implant installation and during the osseous healing period there is a physiological drop in implant stability which accompanies the transition from primary mechanical stability to the secondary biological stability, this drop is the result of the resorption of the bone tissue immediately lateral to the implant which takes place during the initial 1-4 weeks of the healing period **(Berglundh *et al*., 2003)**.

Despite the fact that many studies conducted on animal models have demonstrated a favorable outcome of OD over conventional drilling techniques **(Lahens *et a*l., 2016; Huwais and Meyer, 2017; Oliveira *et al*., 2018; Alifarag *et al*., 2018; Witek *et al*., 2019; Lahens *et al*., 2019)**, but its clinical effect on implant stability during the osseous healing period of dental implants installed in low-density bone is not clear.

Aims of the study

1. To assess the effect of implant site preparation in low-density bone using OD method on implant stability changes during the osseous healing period.
2. To assess the effect of OD on bone density apical to the implant using CBCT.
3. To determine the effect of some predictor variables (age, gender, jaw, insertion torque and implant dimensions) on dental implants stability and on bone density apical to the implant.

Chapter One

Review of literature

Review of literature

1.1 Rationale for dental implant

A dental implant is an alloplastic biomaterial that is surgically inserted into the jawbone to solve functional and/or esthetic problems. Most dental implants today are made from commercially pure titanium (CP-Ti grade 4) or from titanium alloy with well-established properties of biocompatibility and corrosion resistance of those materials that are attributed to the native surface oxide **(Shemtov-Yona and Rittel, 2015)**.

Over the past 30 years, dental implant placement has evolved towards a predictable and routine treatment option for the restoration of missing teeth and various edentulous cases, with reported success rates exceeding 95%. There are many variables and clinical conditions reported to have some potential influence on implant success, including local and systematic disease condition, smoking habits, intravenous medications interacting with bone metabolism and radiotherapy. Considering that all these variables and conditions may directly or indirectly affect bone conditions, attention should be paid to the local bone quantity and quality during the pre-surgical planning phase **(Pauwels *et al.*, 2015)**.

The evolution of surgical techniques, awareness about tissue biology and improving quality of implants over time have enabled immediate and early loading protocols to be efficient and reliable if reasonable guidelines are followed **(Bilhan *et al.*, 2010)**.

1.2 Bone quantity and quality

Bone quantity can be defined as the amount of bone (height and the width) of the alveolar bone at an edentulous site. The term “atrophy” is used to denote the amount of loss of normal alveolar bone secondary to the loss of a tooth.

The term "bone quality", however, is not so simple to define. There is no clear consensus on the definition of bone quality, but, in general, it encompasses multiple aspects of bone physiology, the degree of mineralization, the morphology and type of trabecular pattern. Bone quality has been suggested as one of the main factors influencing implant therapy success **(Pauwels *et al.*, 2015)**.

Bone quality is often referred to as the amount (and their topographic relationship) of cortical and cancellous bone in which the recipient site is drilled. A poor bone quantity and quality have been indicated as the main risk factors for implant failure as it may be associated with excessive bone resorption and impairment in the healing process **(Patil and Bharadwaj, 2016)**.

Lindh *et al*., 2004 emphasized that bone mineral density (BMD) and bone quality are not synonymous. BMD is the amount of bone tissue in a certain volume of bone while bone quality encompasses factors other than bone density such as skeletal size, the architecture and 3- dimensional orientation of the trabeculae and matrix properties. The success rate obtained with dental implants depends to a great extent on the volume and quality of the surrounding bone. Therefore, it is important to know the bone quantity and quality of the jaws when planning implant treatment **(Gulsahi, 2011).**

1.2.1 Bone quality and quantity classification

Lekholm and Zarb, 1985 classified bone according to the quality using panoramic radiograph and the resistance to drilling into four types**, Fig. (1-1):**

- Type 1 = large homogenous cortical bone.
- Type 2 = thick cortical layer surrounding a dense medullar bone.
- Type 3 = thin cortical layer surrounding a dense medullar bone.
- Type 4 = thin cortical layer surrounding a sparse medullar bone.

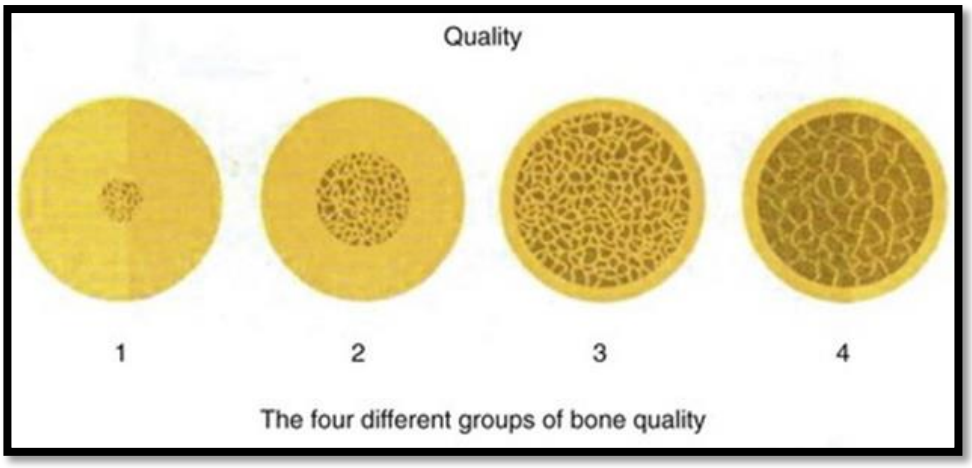

Figure (1-1): Bone density scheme according to **Lekholm and Zarb, 1985**.

Bone quantity of jawbone is classified into five groups (from minimal to severe, A–E), based on residual jaw shape and different rates of bone resorption following tooth extraction, **Fig. (1-2) (Lekholm and Zarb, 1985; Ribeiro and Rotta, 2010)**.

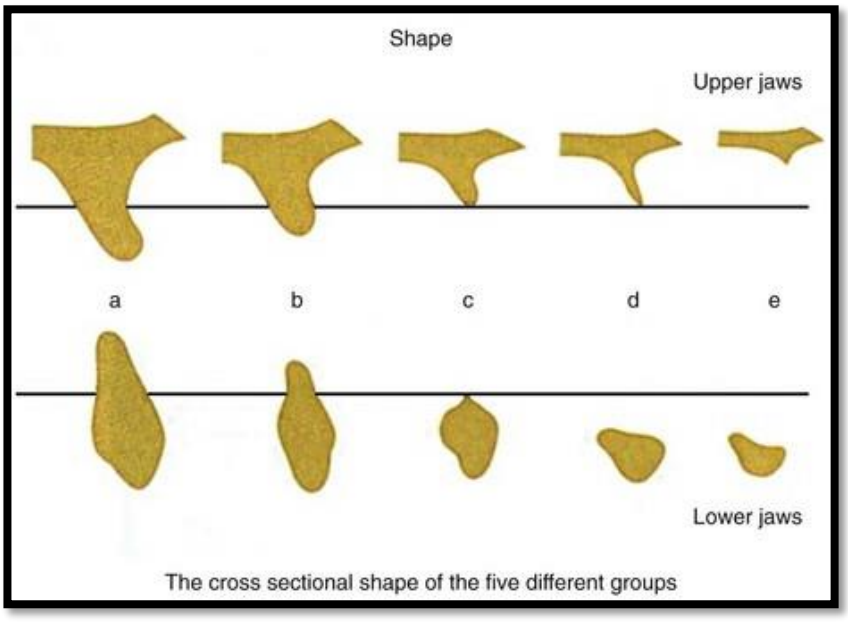

Figure (1-2): Bone quantity scheme according to **Lekholm and Zarb, 1985**.

1.2.2 Bone density classification

Misch classified the bone density into five groups based on number of Hounsfield units (HU). D1 corresponds to values greater than 1250 HU, D2 has 850–1250 HU, D3 refers to density within 350–850 HU, D4 has 150–350 HU and D5 less than 150 HU **(Juodzbalys and Kubilius, 2013)**.

D1 bone is dense cortical bone, D2 bone is thick dense-to-porous cortical bone that wraps a coarse trabecular bone, D3 bone is thin porous cortical bone that wraps a fine trabecular bone, D4 is fine trabecular bone within the ridge and minimal or no cortical bone on the crest, whereas D5 is immature, non-mineralized bone **(Misch, 2008; David *et al.*, 2014)**.

- **D1 bone:** is more often found in anterior mandibles with moderate to severe resorption. The percentages of light microscopic contact of bone at the implant interface is greatest in D1 bone and greater than 80%. This bone density exhibits greater strength than any other density. The strongest bone also benefits from the greatest BIC. Less stresses are transmitted to the apical third of the implants than other bone densities. D1 bone has fewer blood vessels than the other three densities, and therefore it is more dependent on the periosteum for its nutrition. The cortical bone receives the outer one third of all its arterial and venous supply from the periosteum. This bone density is almost all cortical and the capacity of regeneration is impaired because of the poor blood circulation. In addition, greater heat is often generated at the apical portion of the D1 bone **(Misch, 2008; Gulsahi, 2011)**.
- **D2 bone:** is a combination of dense-to-porous cortical bone on the crest and coarse trabecular bone on the inside. The D2 bone trabeculae are 40% to 60% stronger than D3 trabeculae. It occurs most frequently in the anterior mandible, followed by the posterior mandible. Sometimes, it is observed in the anterior maxilla, especially for a single missing tooth. D2 bone provides excellent implant interface healing, and osseointegration is very predictable **(Misch, 2008; Gulsahi, 2011)**.

- **D3 bone:** is composed of thinner porous cortical bone on the crest and fine trabecular bone within the ridge. The trabeculae are approximately 40% to 60% weaker than those in D2 bone. It is found most often in the anterior maxilla and posterior regions of the mouth in either arch. The D3 anterior maxilla is usually of less width than its mandibular D3 counterpart. The D3 bone is not only 50% weaker than D2 bone, BIC is also less favorable in D3 bone. The additive factors can increase the risk of implant failure **(Misch, 2008; Gulsahi, 2011)**.
- **D4 bone:** has very little density and little or no cortical crestal bone. It is the opposite spectrum of D1 (dense cortical bone). The most common locations for D4 are the posterior region of the maxilla. It is rarely observed in mandible. The bone trabeculae may be up to 10 times weaker than the cortical bone of D1. After initial loading, BIC is often less than 25%. Bone trabeculae are sparse and, as a result, initial fixation of any implant design presents a surgical challenge **(Misch, 2008; Gulsahi, 2011)**.

1.2.3 Methods of assessment of bone density

1. **Histological and morphometrical measurement**

It has been considered the golden standard for bone density measurements of the jawbone. Small trephine biopsies taken preoperatively can be used for histomorphometric evaluation to allow a calculation of the percentage of bony trabeculae over the total biopsy area **(Molly, 2006)**. This procedure is certainly reliable and safe but does not seem practical in a routine clinical situation **(Alsaadi *et al*., 2008)**.

2. **Micro-computed tomography (mCT)**

It is used to obtain a 3D-morphometric data which can give more specified information on trabecular thickness and trabecular separation but it is more time consuming and is not possible on in vivo subjects **(Molly, 2006)**.

3. **Quantitative-computerized tomography (qCT)**

This procedure was developed for the measurement of bone mineral density using HU, which could be used for the assessment of osteoporosis, and was applied to lumbar vertebrae. However, Q-CT could not be applied to dental implantology because the region of interest (ROI) for implant installation was too small for the procedure **(Barunawaty, 2011)**.

4. **Dual energy X-ray absorptiometry (DXA) scan**

The DXA technique is applied for the assessment of the bone density of the jawbone, and other bones, it has advantages including low cost, low radiation doses, and high accuracy but DXA does not provide the cross-sectional image and determination of the positioning is difficult; hence, it is not appropriate for implant placement **(Jeong *et al.*, 2013)**.

5. **Magnetic resonance imaging (MRI)**

Thin slice high-resolution MRI was used for bone density and quantity assessment to allow proper implant planning in mandibles and maxillae **(Gray *et al.*, 1996)**. This technique can be used in patients where the use of ionizing radiation is contraindicated.

6. **Torque-measuring micromotor**

Recently, a torque-measuring micromotor has been introduced that enables quantitative intra-operative and site-specific bone density measurement during implant-site preparation. The micromotor allows measuring bone density at an intermediate step of implant site preparation by means of a dedicated probe; such density measurement is based on the principle that cutting resistance at threading is a good estimator of bone quality at the placement site. When used in human subjects, the torque-measuring micromotor was shown to provide operator-independent bone density measurements and correctly discriminate between the anterior and posterior areas of both arches **(Di Stefano *et al.*, 2019**).

7. Cone beam computed tomography

Among imaging modalities used for bone density assessment, CBCT has advantages over conventional CT due to lower radiation dose, shorter acquisition times, reasonable price and submillimeter resolution and an advantage over micro-CT, since it is being used clinically and not only for in vitro experiments **(Razi *et al*., 2014; Alkhader *et al*., 2017)** although other studies found that CBCT could not demonstrate the true bone density compared with histologic analysis and micro-CT **(Suttapreyasri *et al*., 2018)**.

1.3 Dental implant stability

One of the prerequisites for clinical success of the implant treatment is the stability of the implant.

The stability of the implant can be classified as:

1. Mechanical stability (primary stability) between implant and bone.
2. Biological stability (secondary stability) that occurs as a result of osseointegration **(Lahens *et al.*, 2019)**.

Primary stability is a crucial factor to achieve implant osseointegration. It is obtained as the threads of the implant interlocking with the bone upon insertion, holding the implant in place. Primary stability is vital to the healing process, as it prevents the implants' micro-movements during the initial bone remodeling process **(Trisi *et al.*, 2016; Lahens *et al*., 2019)**.

1.3.1 Factors affecting primary stability

They include: **(Lahens *et al*., 2019)**

- The bone quality, quantity and density surrounding the implant.
- The macro and micro-geometric parameters of the implant, which uniquely interlock with the surrounding bone.
- The surgical protocol.

1.3.2 Methods of measurement of dental implant stability

Measuring implant stability supports making good decisions about when to load, allows advantageous protocol choice on a patient-to-patient basis, indicates situations in which it is best to unload, supports good communication and increased trust and provides better case documentation **(Mistry *et al*., 2014)**.

There are different methods to assess implant stability. They can be grouped as invasive/destructive methods and noninvasive/ nondestructive methods **(Swami *et al*., 2016)** as follows:

- **Invasive/Destructive methods**: These methods are invasive methods and are not suitable of the clinical assessment. They include:

1. **Histomorphometric analysis**

Histomorphometric method, quantitatively assesses the bone contact and bone area within threads. Ultrastructural studies are mostly performed on the decalcified specimens sectioned for transmission electron microscopy. But due to the invasive and destructive nature of this techniques, its use is only limited to non-clinical and experimental studies **(Park *et al*., 2012; Sachdeva *et al*., 2016)**.

2. **Tensional test**

The interfacial tensile strength was originally measured by detaching the implant plate from the supporting bone. Later on it was modified by applying the lateral load to the cylindrical implant fixture. However, there were difficulties in translating the test results to any area- independent mechanical properties **(Chang *et al*., 2010; Sachdeva *et al*., 2016)**.

3. **Push-out/Pull-out test**

In a typical pushout or pull-out test, a cylinder type implant is placed transcortically or intramedullarly in bone and then removed by applying a force parallel to the interface. However, the push-out and pullout tests are only applicable for non-threaded cylinder type implants, whereas most of clinically available fixtures are of threaded design, and their interfacial failures are solely

dependent on shear stress without any consideration for either tensile or compressive stresses **(Sachdeva *et al*., 2016)**.

4. Removal torque analysis (Reverse torque)

In this technique, osseointegration is tested at the second stage surgery. During the test, a counter-clockwise (reverse) torque is applied to implant up to level of 20 N/cm as removal torque value of clinically osseointegrated implant ranged from 45 to 48 N/cm **(Atsumi *et al*., 2007)**. Osseointegrated implants resist this torque, while failed implants unscrew. However, torque load can result in plastic deformation, even at low levels of torque, and implant surface in the process of osseointegration may fracture under the applied torque stress **(Chang *et al*., 2010)**. This test is considered one of the most crude test as it gives little information about implant bone interface and provides result only by all or none rule i.e. ossteointegrated or failed, thereby not able to discriminate the degree of bone healing or bone formation around implant **(Sachdeva *et al*., 2016)**.

Reverse torque assessment; pull-out and push-out techniques are generally used only in preclinical applications and may be of value as research techniques. The clinical usage of destructive tests is limited due to ethical concerns associated with invasive nature of these methodologies **(Swami *et al*., 2016)**.

❖ **Non- invasive/Non- destructive methods**: These methods are non-invasive methods and can be used in clinical assessment. They include:

1. Clinical perception

The clinical perception of primary implant stability is frequently based on the mobility detected by blunt ended instruments. It is a very unreliable and nonobjective method. It can also be checked by the cutting resistance of the implant during its insertion. The feeling of "good" stability may be accentuated if there is the sense of an abrupt stop at the seating of the implant. Root forms of tapered implants often have a geometry that will provide a firm stop and perhaps a false perception of high stability **(Mistry, *et al.*, 2014)**. In addition, one's

personal perception is difficult to communicate to others. However, most importantly, this type of measurement can only be made when the implant is inserted, it cannot be used later, for example, before loading the implant **(Swami, *et al*., 2016)**.

2. Cutting resistance analysis/ insertion torque measurement

The cutting resistance refers to the energy required in cutting of a unit volume of bone, and the energy has been shown to significantly correlate with bone density. The major limitation is that it does not give any information on bone quality until osteotomy site is prepared. Furthermore, it has been highlighted that longitudinal data cannot be collected to assess bone quality changes after implant placement **(Atsumi *et al*., 2007)**.

Insertional torque is measured during the fixture tightening procedure. Both these measurements consider the lateral compression force and friction at the interface during implant insertion and are mainly influenced by the tolerance of the fixture thread design. Insertion torque values have been used to measure the bone quality in various parts of the jaw during implant placement **(O'Sullivan *et al*., 2004)**. The technique is non-invasive, since it involves measurement of torque created while cutting a thread in a hole in bone. However, it cannot assess the secondary stability by new bone formation and remodeling around the implant. So it cannot collect longitudinal data to assess implant stability change after placement **(Park *et al*., 2012; Sachdeva *et al*., 2016)**.

3. Percussion test

A percussion test is one of the simplest methods that can be used to estimate the level of osseointegration. This test is based upon vibrational-acoustic science and impact response theory. The clinical judgment on osseointegration is based on the sound heard upon percussion with a metallic instrument. A clearly ringing “crystal” sound indicates successful osseointegration, whereas a “dull” sound may indicate no osseointegration. However, this method heavily relies on the

clinician's experience level and subjective belief. Therefore, it cannot be used experimentally as a standardized testing method **(Bayarchimeg *et al.*, 2013)**.

4. Resonanace frequency analysis (RFA)

It was suggested by Meredith in 1998. It measures the stability by applying a bending load, which mimics the clinical load and direction and provides information about the stiffness of the implant-bone junction. It evaluates the micro-mobility or displacement of the implant in bone under a lateral load, applying microscopic lateral forces to the implant with a vibrating transducer that is vibrating by a sinusoidal signal (5–15 kHz) **(Swami *et al.*, 2016)**. The results are given as implant stability quotients (ISQs), **(Sennerby and Meredith, 2008),** which are affected by three main factor:

1. The stiffness of the implant fixture.

2. The interface with surrounding tissue.

3. The design of the transducer and the total effective implant length above bone level.

The stiffer the interface between the bone and implant, the higher the frequency and higher the frequency, higher is the ISQ level. The ISQ unit is based on the underlying RF and ranges from 1 (lowest stability) to 100 (highest stability). Research indicates that implants yielding high ISQ values during follow-up appear to maintain stability. Low or decreasing ISQ values may be indicative of developing instability **(Patil and Bharadwaj, 2016)**, **Table (1-1)** summarizes the main advantages and disadvantages of RFA.

Table (1-1): Advantages and disadvantages of RFA **(Sachdeva *et al.*, 2016)**.

Advantages	Disadvantages
• Non invasive. • Can be used clinically. • Quantitative method. • Fair amount of predictability. • Can be used repeatedly.	• Expensive equipment. • No critical value to suggest implant success or/ failure.

5. Periotest® M

Periotest® is an electronic instrument that uses an electro-magnetically driven and electronically controlled tapping metallic rod in a handpiece. Response to a striking is measured by a small accelerometer incorporated into the head **(Swami, *et al*., 2016)**.

In periotest®, the electronically controlled rod weighting 8 g taps implant 4 times/sec at a constant speed for 4 sec at a velocity of 0.2 m/sec. The rod is decelerated when it touches the implant. The greater the implant solidity, the higher the deceleration and thus higher the damping effect of the surrounding tissues. After tapping the spot, rod recoils, a faster recoil indicates increased damping. Periotest® can measure all surfaces such as the abutment or prosthesis, but the rod must make contact at a correct angle and distance **(Sachdeva *et al*., 2016)**.

The contact time between the tapping rod and the implant is calculated into a value called the Periotest value (PTV), which ranges, with decreasing stability of the tooth or implant, from −8 to +50 PTV units **(Choi *et al*., 2014)**.

❖ **Factors related to Periotest® M values**

Meredith in **1998** demonstrated that a number of important variables, including angulation, striking point and abutment length, may influence the accuracy of Periotest®. If the perpendicular contact angle is larger than 20 degrees, or if the parallel contact angle is larger than 4 degrees, the measured value is invalid. Also, the rod and the test surface must maintain 0.6-2.0 mm distance and if the distance is over 5 mm, the measured value may be insignificant.

As the outcome of Periotest® measurements is influenced by the distance from the striking point to the first bone contact, it is evident that placement of the implant in the vertical dimension, abutment height, the level of marginal bone loss and the striking position on the abutment/implant are critical factors for accuracy and/or reproducibility. Single readings of Periotest® determinations are of limited

clinical value and have not been demonstrated to reflect the nature of the BIC. By performing repeated measurements of the same implant over time, implant stability may be confirmed **(Patil and Bharadwaj, 2016)**.

In vitro evaluations revealed that no statistically significant difference existed in measuring Periotest values from the operator to operator, as well as high level of repeatability between different Periotest units. Successfully integrated dental implants have yielded a wide range of stability readings with the Periotest® as **Table (1-2)** summarizes. This range in values is believed to reflect bone density at the implant interface, which is related to implant location **(Mistry *et al*., 2014)**.

Table (1-2): Interpretation of Periotest® M value range **(Periotest® M operating instructions)**

Readings	Interpretation
-8.0 to 0.0	Good osseointegration, implant can be loaded.
+0.1 to +9.9	Examination is required; implant loading is not possible in many cases.
+10.0 or higher	Osseointegration is not complete, implant cannot be loaded.

The lowest PTVs were characteristic for very dense bone (Type I: Lekholm and Zarb 1985) and significantly lower PTVs in mandibular than in maxillary bone. Also, a relationship between the number of engaged cortical layers (no cortical bone, mono and bicortical anchorage) and PTVs was established, for bicortical screws lower PTVs were observed than for other implants **(Salonen *et al*., 1997)**. While, in another study there was no correlation **(Mericske-Stern *et al*., 1995).**

Time elapsed since implant installation appears to influence implant stability measured by Periotest® M. This is rationalized by the fact that lower PTVs are usually encountered with increasing time of follow-up **(Naert *et al*.,**

2004). **Table (1-3)** summarizes the main advantages and disadvantages of Periotest® M.

Table (1-3): Advantages and disadvantages of Periotest® M **(Sachdeva et al., 2016)**.

Advantages	Disadvantages
• Non invasive. • Can be used clinically. • Quantitative method. • Can be used repeatedly.	• Poor sensitivity (as compared to RFA). • Lack of resolution (as compared to RFA). • Susceptibility to being influenced by the operator.

1.4 Osseointegration

Osseointegration is defined as a direct structural and functional connection between ordered, living bone and the surface of a load carrying implant. Osseointegration is crucial for implant stability, which determines the long-term success of dental implants **(Kanathila and Pangi, 2018)**.

The process of osseointegration leads to bone formation on the implant surface and contributes to implant secondary stability between bone and dental implant. Osseointegration is the basis of a successful endosseous implant. The process itself is quite complex and there are many factors that influence the formation and maintenance of bone at the implant surface **(Pai *et al*., 2018)**.

1.4.1 Factors affecting osseointegration

In **1981, Albrektsson *et al***. demonstrated the six major parameters of osseointegration, mainly: the implant material, the implant surface, the implant design, the condition of the bone at the host bed, the surgical technique and the loading conditions. However, as research revealed more on the role of these factors, it is more useful to categorize them by their determinants into the following factors:

1. **Implant related factors**: The biocompatibility of the material, the topography, the composition, the coating of the surface, the shape, the design of the implant and the dimensions of the fixture.
2. **Host bed factors**: The bone volume, density and vascularity.
3. **Surgical factors:** Achieving primary stability, mechanical trauma, thermal trauma or infection.
4. **Biomechanical factors:** Loading conditions.
5. **Patient related factors:** Systemic disease, systemic medication, radiotherapy and parafunctional habits **(Podaropoulos, 2017)**.

Primary stability of the implant is, however, of utmost importance as it is related to the parameters of all five categories. It is influenced by the shape and design of the implant, the quality and quantity of the bone, the surgical technique and skills of the surgeon, whilst its maintenance is depended on the loading conditions, the presence of parafunctional habits and the healing capacity of the host. The absence of movement immediately after implant insertion is one of the most important factors affecting implant osseointegration **(Di Stefano *et al.*, 2019)**.

Different surgeons have different preparation protocols, depending on the patient bone densities. Among the surgical factors that influence osseointegration, implant bed preparation is of critical importance. Drilling the implant bed not only causes mechanical damage to the bone but also increases the temperature of the bone directly, adjacent to the implant surface **(Parithimarkalaignan and Padmanabhan, 2013)**. Mechanical and thermal damage to the tissue surrounding the implant during drilling can have a destructive effect on the initial state of the cavity housing the implant **(Patil and Bharadwaj, 2016)**.

1.4.2 Bone remodeling around dental implants

Shortly after dental implant placement, a sequence of immuno-inflammatory responses, followed by angiogenic and osteogenic events, takes place. This sequence is primarily influenced by the implant surface characteristics, including surface topography, chemistry and material composition, which either facilitate or prevent the adsorption of proteins onto the implant surface **(Pikos, 2019)**.

- Within the first 5 days, thrombin and fibrinogen adsorb to the implant surface and play a key role in the early homeostasis as the release of cytokines and growth factors stimulates future collagen matrix deposition around the titanium oxide layer of the implant, leading to **newly formed woven bone**.
- In about 8 to 12 weeks, **lamellar bone** initiates the biological stability, namely osseointegration.
- Twelve weeks afterwards, as with natural dentition, implants are subject to soft- and hard-tissue remodeling where the average biologic width around dental implants has been reported at approximately 3.5 mm **(Tomasi *et al.*, 2014; Pikos, 2019)**.

Clinical bone response to surgically placed dental implants at the time of or soon after insertion (pre-osseointegration) relates to biomechanical factors. This would include surgical insertion technique, such as drilling and non-drilling approaches, bone quality factors, including bone density, and use of adjacent graft material and device capabilities related to implant force generation upon placement. Each of these three aspects is strategically applied to obtain initial primary stability, which must persist through the demineralization phase of bone injury, permitting implants depending on the surface topography to remain passive long enough for bone modeling to progress to a unifying callus and then onto load responsive (maintenance) osseointegration **(Hao *et al.*, 2014; Jensen, 2017)**.

The stiffness of the surrounding tissue is determined by the ratio of cancellous to cortical bone and the density of the bone with which an implant engages. Stiffness found at the bone-to-implant interface changes over time; thus, primary stability decreases with time. During this period of transition between primary and secondary stability, the implant faces the greatest risk of micromotion and consequent failure. It is estimated that this period in humans occurs roughly 2-3 weeks after implant placement when osteoclastic activity decreases the initial mechanical stability of the implant but not enough new bone has been produced to provide an equivalent or greater amount of compensatory biological stability **(Norton, 2013)**. This is related to the biologic reaction of the bone to surgical trauma during the initial bone remodeling phase; bone and necrotic materials resorbed by osteoclastic activity. This process is followed by new bone apposition initiated by osteoblastic activity, therefore leading to adaptive bone remodeling around the implant **(Barikani *et al*., 2013; Patil and Bharadwaj, 2018)**.

Hypothetically, if the level of primary stability can be increased and the rate of osseointegration at the same time can be accelerated, the dip in total stability can be reduced and the implant is made less susceptible to micromovement and potential failure. The goal must be the rapid onset of secondary stability, with minimal critical pressure to the poorly vascularized cortical bone so that unfavorable resorptive responses and delayed healing are avoided **(Degidi *et al*., 2010; Patil and Bharadwaj, 2018)**.

The process of osseointegration continues to increase the bone mineral density close to the implant body for up to 2 years. A steady state of osseointegration is achieved where there is nearly equal gain and loss of minerals, without substantial change in volumetric bone mass **(Jensen, 2017)**.

1.5 Increasing the primary stability of an implant in low-density bone

During the past decades, many surgical techniques have been developed to increase the primary stability of an implant placed in low-density bone (**Podaropoulos, 2017**).

- **Bone tapping**: it was suggested that the stage of bone tapping should be omitted due to invasiveness, especially in cases of low-density bone **(Lahens *et al*., 2016; Podaropoulos, 2017)**.
- **Bicortical anchorage:** It was reported that bicortical anchorage significantly increases primary implant stability **(Trisi *et al*., 2016)**. On the contrary, **Ivanoff *et al*. in 2000**, in a retrospective study, record 3 times higher fracture rate in bicortical implants than monocortical ones. According to the authors, possible explanation for this could be increased stress and bending forces as a result of prosthetic misfit or high occlusal tables.
- **Underpreparation of the implant bed:** which is achieved by using a one or more size smaller as the last drill than selected implant diameter. In the presence of poor bone quality, 10% undersized implant bed preparation is sufficient to enhance primary stability whereas, additional decrease does not improve primary stability values **(Alghamdi *et al*., 2011; Degidi *et al*., 2015; Kanathila and Pangi, 2018)**. Studies on stepped osteotomy of implant bed, which is another variant of the under preparation method, have reported greater implant stability in terms of insertion torque than conventional osteotomy in soft bone **(Podaropoulos, 2017; Kanathila and Pangi, 2018)**.
- **Bone condensation: Summers** in **1994** described the use of osteotomes to condense bone manually in case of low bone density. The principle behind the bone condensation at the periphery of implant bed is to insert implant in a high-density bone matrix. The osteotome technique, uses hand driven devices and compresses the surrounding bone by gradual expansion leading to enhanced

insertion torque values that is considered by the practitioners as an indication of improved primary stability. Many studies recommend the bone condensing technique as another method to increase the primary stability of an implant. **Stavropoulos *et al*., 2008** reported good primary stability of implants using bone condensation technique. Recently a new technique of preparation the implant bed has been developed based on OD drilling concept **(Huwais, 2013; Podaropoulos, 2017)**.

1.6 Osseodensification

It is a novel, biomechanical, non-excavation osteotomy preparation technique developed by Salah Huwais in 2013. For this purpose, Huwais invented specially designed densifying burs called Densah® burs (by Versah-The osseodensification company, LLC., USA), **Fig. (1-3)**.

The densifying burs combine the advantages of osteotomes with the speed and tactile control of the drills during osteotomy **(Lahens *et al*., 2016)**.

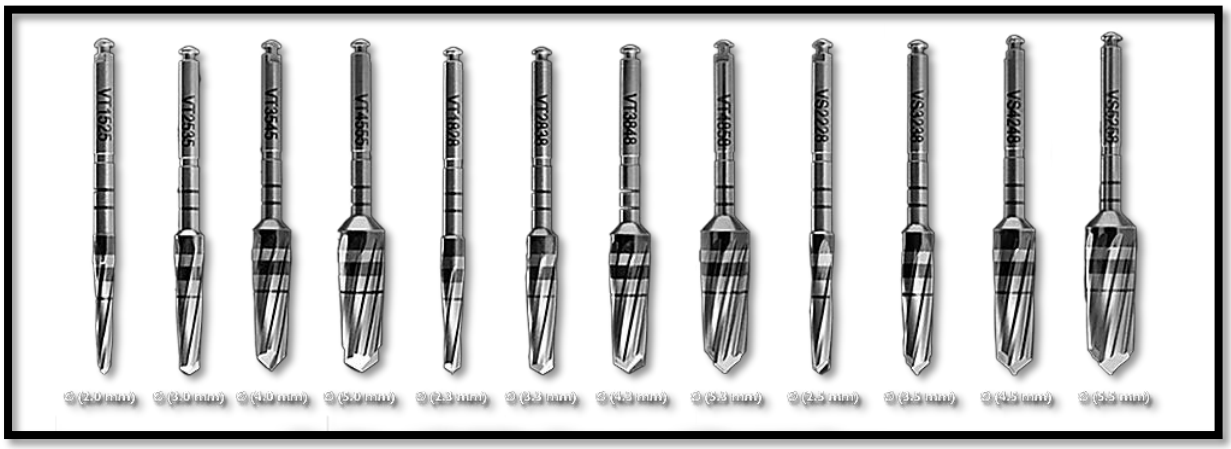

Figure (1-3): Osseodensification surgical kit (www.Versah.com).

1.6.1 Rationale of osseodensification

The rationale of OD is that compacted, autologous bone immediately in contact with an endosteal device will not only have higher degrees of primary stability due to physical interlocking between the bone and the device, but also

facilitate osseointegration due to osteoblasts nucleating on instrumented bone in close proximity to the implant **(Lahens *et al*., 2016; Lopez *et al*., 2017)**.

This is performed in an attempt to develop a condensed autograft surrounding the implant, making it valuable in clinical settings where there is an anatomic paucity of bone **(Lahens *et al*., 2016)**. Unlike traditional drilling protocols (subtractive drilling), OD increases primary stability due to densification of the drilled osteotomy site walls centrifugally by means of non-subtractive drilling **(Huwais and Meyer, 2017)**.

Gaspar *et al*. stated that the bone expansion capacity of OD for predictable ridge expansion has been validated with enhanced primary stability and higher insertion torque values. This may be clinically relevant in minimizing implant dehiscences or fenestrations. OD can also be used for crestal sinus lift in a simple, safe and predictable way with reduced morbidity **(Gaspar *et al*., 2018)**.

1.6.2 Characteristics of osseodensification drills

- A conically tapered body with a maximum diameter adjacent the shank and minimum diameter adjacent the apical end. This taper design controls the expansion process, as the bur enters deeper into the osteotomy, **Fig. (1-4 a)**.
- The apical end includes at least one lip to grind bone when rotated in the counter-clockwise/non-cutting/burnishing direction and cut bone when rotated in the clockwise/cutting/drilling direction, **Fig. (1-4 b)**.

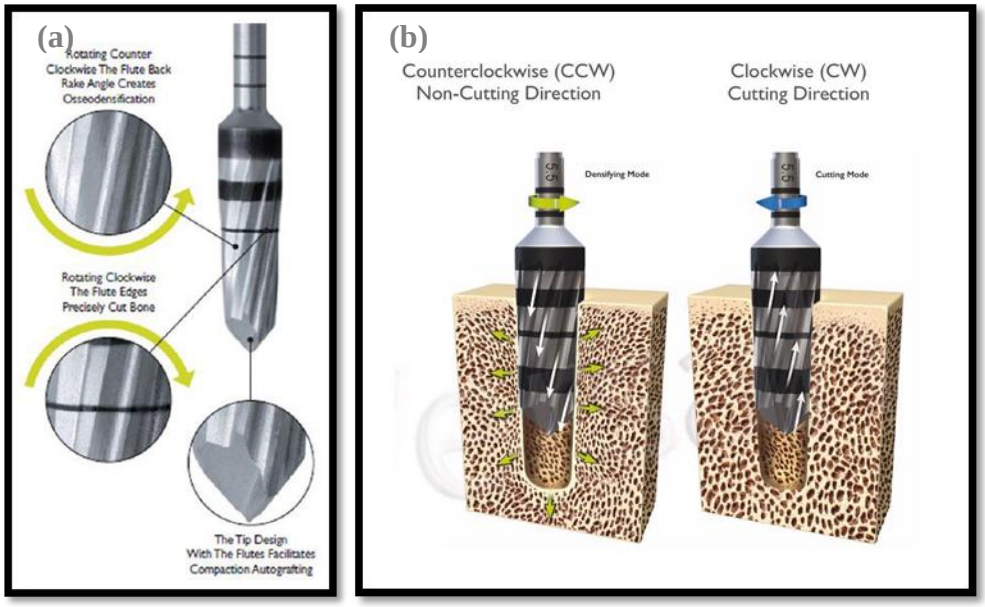

Figure (1-4): (a) Densification drills **(Pai *et al*., 2018)**. **(b)** Dual use capability of densifying bur **(Gayathri, 2018)**.

- Helical flutes and interposed lands are disposed about the body. Each flute has a burnishing face and an opposing cutting face. The burnishing face burnishes bone when rotated in the burnishing direction and the cutting face cuts bone when turned in the cutting direction.
- At least one of the lip and the lands are configured to generate an opposing axial reaction force when continuously rotated in a burnishing direction and concurrently forcibly advanced into an osteotomy. This results in a push-back phenomenon, which provides the user enhanced control over the expansion procedure **(Gayathri, 2018)**.

1.6.3 Osseodensification and bone density

The process of osseointegration leads to bone formation on the implant surface and contributes to implant secondary stability between bone and dental implant.

In areas of low bone density, such as maxillary posterior region, the insufficient bone available could affect the histomorphometric parameters such as

BIC and BV negatively, thereby affecting primary and secondary implant stability. A layer of increased bone mineral density has been shown by imaging around the periphery of osteotomies using OD, **Fig. (1-5)**. The increase in bone density achieved by OD has been shown to have a potentiating effect on secondary stability **(Pai *et al*., 2018)**.

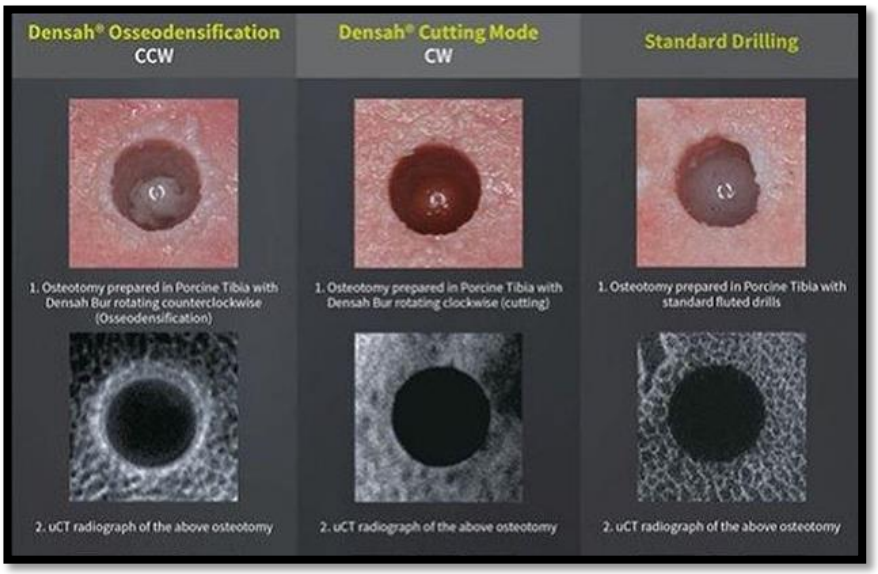

Figure (1-5): (1) Surface view of 5.8 mm counter-clockwise (ccw) osseodensification, clockwise cutting (cw) mode and standard drilling (2) Microcomputed tomography midsections **(Huwais and Meyer, 2017)**.

1.6.4 Advantages of osseodensification

- It is a unique, highly controllable, fast and efficient bone preservation osteotomy preparation technique which results in increased primary stability, BMD and percentage of bone at the implant surface leading to faster wound healing and enhanced osseointegration **(Huwais, 2015; Hofbauer and Huwais, 2015; Huwais and Meyer, 2017).**
- Healing process can be accelerated due to bone matrix, cells and biochemicals maintained and autografted along the osteotomy surface site **(Huwais and Meyer, 2017)**.

- By OD technique, wider implant diameter can be inserted in narrow ridges without creating bone dehiscence or fenestration **(Trisi *et al*., 2016)**.
- Increased insertion **(Trisi *et al*., 2016; Lahens *et al*., 2016)** and removal torque values **(Huwais and Meyer, 2017)** have been reported with dental implants placed into osseodensified osteotomies.
- The dual use capability of densifying bur in both cutting and noncutting direction may enable the clinician to autograft the maxillary sinus and expands any ridge in maxilla and mandible **(Hufbauer and Huwais, 2015**).
- Huwais demonstrated that OD helped ridge expansion while maintaining alveolar ridge integrity, thereby allowing implant placement in autogenous bone. OD helped in preserving bone bulk and shortened the waiting period to restorative phase **(Huwais, 2015; Pai *et al*., 2018)**.

1.6.5 Disadvantages of osseodensification

Case selection for using OD burs in counterclockwise mode is important as the procedure is not recommended in dense bone (D1, D2) and more suitable for soft bone **(Pikos, 2019)**.

This can be explained by the fact that soft bone has wider marrow spaces between the bone trabeculae, allowing for bone compaction, rather than the compact bone, leading to lateral compression that exceeds the viscoelastic limit of the thick and dense bone trabeculae, with subsequent damage and a weaker bone implant interface **(Almutairi *et al*., 2019)**. During bone compaction and implant loading under high torque, bone is subject to a micro-damage threshold. If the bone's micro-damage threshold is exceeded, the bone remodeling cycle may require an additional 3 months or more to repair these damaged areas **(Frost *et al*., 1998)**.This is particularly important in relation to OD since over-compression may also unintentionally cause bone necrosis **(Wang *et al*., 2017)**.

1.6.6 Osseodensification versus conventional osteotomy

Osseodensification technique is a bone preservation method, whereas traditional drilling method involves cutting and excavation of bone tissue. It has been demonstrated that densifying drills increase the percentage of BV and the percentage of BIC area for implants placed in low-density bone compared to traditional osteotomies, which may enhance osseointegration **(Trisi *et al*., 2016)**.

Drilled osteotomies may sometimes become elongated and elliptical due to chatter of the conventional drills while OD drills produce a precise circumferential osteotomy due to their geometric configurations, **Fig. (1-6)**. Lack of precise osteotomy may lead to reduced insertion torque, leading to poor implant stability **(Gayathri, 2018)**.

Figure (1-6): (a) Regular drill **(b)** Versah drill, illustrating the geometric configurations **(Alifarag *et al*., 2018)**.

Heat generation during rotary cutting is one of the crucial factors influencing the development of osseointegration **(Mishra and Chowdhary, 2014)**. During drilling, temperature rises due to the plastic deformation and shear failure of bone and friction at the machining face, which may affect the viability as well as the structure and mechanical properties. These circumstances may reduce the implant insertion torque, leading to poor primary stability and potential lack of integration to bone **(Huwais, 2015)**.

External irrigation with copious amount of saline along with a bouncing motion of bur used in OD technique seems beneficial in reducing the heat generated during the osteotomy preparation in the same manner as the conventional drilling **(Huwais and Meyer, 2017)**.

The diameter on an osteotomy prepared by OD is found to be smaller than conventional osteotomies prepared with the same burs. The percentage of BIC is reported to be increased by approximately three times for implants placed with OD compared with standard drilling by creating a crust of increased bone mineral density around the osteotomy site **(Huwais and Meyer, 2017)**.

Many authors reported a significant increase in insertion torque and concomitant reduction in micromotion by bone compaction techniques with that of standard drilling (**Trisi *et al*., 2009; Lahens *et al*., 2016; Huwais and Meyer, 2017)**. High insertion torque can significantly increase the initial BIC percentage and is found to be directly related to implant primary stability and host bone density. High insertion torque is also important for achieving a good clinical outcome with early or immediate loading **(Trisi *et al*., 2009; Capparé *et al*., 2015)**.

Higher removal torque values are noted with implants placed by OD compared to drilling. This may be due to the reverse compression applied to the implant by the compressed bone in osteotomy prepared by OD **(Trisi *et al*., 2016; Huwais and Meyer, 2017; Lopez *et al*., 2017)**.

1.6.7 Contraindications of osseodensification

- It does not work with cortical bone, as cortical bone is a non-dynamic tissue that lacks plasticity.
- Densification of xenografts should be avoided because they behave biomechanically different from the bone tissue, as they have only inorganic content and they just provide the bulk without any viscoelasticity **(Kanathila and Pangi, 2018)**.

1.7 Diagnostic imaging of dental implant

One of the most important factors in determining implant success is proper treatment planning. Diagnostic imaging is an integral part of dental implant therapy for preoperative planning, intraoperative and postoperative assessment by use of variety of techniques **(Gulsahi, 2011)**.

1.7.1 Objectives and characteristics of ideal diagnostic imaging for dental implant

The objectives of diagnostic imaging depend on a number of factors, including the amount and type of information required and the period of the treatment rendered. The decision to image the patient is based on the patient's clinical needs. After a decision has been made to obtain images, the imaging modality is used that yields the necessary diagnostic information related to the patient's clinical needs and results in the least radiologic risk **(Gulsahi, 2011)**.

According to **Benson and Shetty** in **2009**, the ideal imaging technique for dental implant care should have several essential characteristics, including:

- The ability to visualize the implant site in the mesiodistal, buccolingual and superioinferior dimensions.
- The ability to allow reliable and accurate measurements.
- A capacity to evaluate trabecular bone density and cortical thickness.
- Reasonable access and cost to the patient.
- Minimal radiation risk.

If images are required of all of the maxilla and mandible to evaluate possible implant sites, cross-sectional images are useful assist for the clinician. CBCT is the best modality for the ease of acquisition and relatively low radiation risk even for single implants **(Gulsahi, 2011)**.

1.7.2 Cone beam computed tomography

The introduction of CBCT has allowed clinicians to view the maxillofacial structures in three dimensions at a relatively high spatial resolution، which has led to a more widespread use of 3D imaging in dentistry in recent years **(Pauwels *et al.*, 2015)**.

CBCT is considered essential for optimal implant placement, especially in the case of complex reconstructions **(Chan *et al.*, 2010)**. In implant dentistry, CBCT is frequently used for planning purposes or guided surgery**.** The CBCT effective dose varies substantially depending on the device, field of view (FOV) and selected technique factors. Effective dose detriment of CBCT is higher than conventional panoramic radiographs and lower than conventional CT **(Raes *et al.*, 2011)**.

1.7.3 Main indications of CBCT in implant dentistry

Yepes and Al-Sabbagh, 2015 identified the main indications of CBCT as follows:

- Evaluation of the density, quality, height and width of available bone.
- Three-dimensional assessment of alveolar ridge topography.
- Identification of vital anatomic structures.
- Identification of potential problems.
- Fabrication of CBCT-derived surgical guides.
- Postoperative assessment (Integration, marginal peri-implant bone height, bone-implant interface, bone augmentation in sinus lift procedure, postoperative complications, altered sensation, infection or postoperative integration failure, implant mobility and rhinosinusitis).
- Patient education.

1.7.4 CBCT and bone density

The bone density is considered to be directly proportional to the load-bearing capacity of the bone and implant failure has been linked to low bone density. Thus, accurate estimation of the alveolar bone density in the implant site would be of great benefit. However, density estimates provided by the various CBCT systems demonstrate great variation and inconsistency. This is mainly due to the high level of noise in the acquired images and in-homogeneities in the detection system of CBCT scanners. In addition, the provided estimates are gray scale values (brightness values) and not true X-ray attenuation values, HU, such as provided by medical CT scanners. Attempts have been made to link the grey level values provided by CBCT to HU **(Angelopoulos and Agaloo, 2011)**.

Katsumata *et al*., 2007 found that calculated HU on a CBCT scan varied widely from a range of -1500 to over +3000 for different types of materials. However, after a correction has been applied to grey levels with the CBCT, the HU values are much similar to those one would expect in a medical CT device than to the original grey levels obtained from the CBCT scanners **(Nomura *et al*., 2010)**.

Although high levels of radiation scatter and artifacts in CBCT have been reported as the disadvantages of CBCT in the estimation of bone density, a large number of studies have shown a linear relationship between HU in CT scan and gray scale in CBCT and suggested that voxel value in CBCT can be used for estimation of bone density **(Parsa *et al*., 2012; Razi *et al*., 2014)**.

1.7.5 Advantages of CBCT

- Lower radiation dose to the patient, shorter acquisition times, submillimeter resolution and reasonable price compared to CT **(Razi *et al*., 2014)**.
- Helpful in multiple reconstruction, bone grafting assessment, computer-aided surgery **(Yepes and Al-Sabbagh, 2015)**.

1.7.6 Limitations of CBCT

- Radiation exposure higher than that associated with traditional radiographs (intraoral or panoramic radiographs).
- Limited soft tissue visualization.
- Artifacts created by metal objects.
- Cost and liability **(Yepes and Al-Sabbagh, 2015)**.

1.8 Dental implant success, survival and failure

1.8.1 Criteria of implant success

Misch *et al.*, 2008 approved four clinical categories that contain conditions of implant success, survival and failure:

1. Success (optimum health): (No pain or tenderness upon function, no mobility, < 2 mm radiographic bone loss from initial surgery, no exudates history).
2. Satisfactory survival: (No pain on function, no mobility, 2–4 mm radiographic bone loss, no exudates history).
3. Compromised survival: (May have sensitivity on function, no mobility ، radiographic bone loss > 4 mm (less than 1/2 of implant body), may have exudates history).
4. Failure: (Pain on function, mobility, radiographic bone loss 1/2 length of implant, uncontrolled exudate, no longer in mouth).

1.8.2 Classification of dental implant failures

Dental implant failures can be classified according to the time when failure occurs into: **early failures** or failures during the osseointegration period (usually within the first year after an implant insertion, during the healing period, and initial loading); and **late failures** or failures after the osseointegration period (usually about a year after implant insertion, when an osseointegration process is complete and implant function is established) **(Tolstunov, 2006)**.

1.8.3 Factors affecting failure of dental implant

Tolstunov, 2006 summarized factors affecting dental implant failures as follows:

1. Poor quality (type 4 bone, posterior maxillary bone and irradiated bone) and quantity of bone (severe alveolar bone resorption). Poor quality of soft tissue (lack of keratinized gingiva) **(Albrektsson, 1989; Degidi and Piattelli, 2005).**

2. Patient medical condition that affects normal bone healing: immunocompromised condition (uncontrolled diabetes, acquired immunodeficiency syndrome), advanced osteoporosis, steroid therapy, metastatic bone disease in the jaw, metabolic and endocrine conditions, malnutrition and malabsorption syndromes, drugs that affect bone metabolism (bisphosphonates, others), collagen disorders, psychotic syndromes, lack of compliance and other conditions **(Ruggiero *et al*., 2004)**.

3. Unfavorable patient habits: bruxism, heavy long-term smoking, poor oral hygiene, plaque accumulation and others **(Kourtis *et al*., 2004)**.

4. Inadequate surgical analysis and technique: suboptimal insertion technique, lack of primary implant stability and poor 3D implant position **(Ashley *et al*., 2003)**. Poor primary stability is considered the major cause of implant failure; greater primary stability enables uninhibited healing and osseointegration because of little micromotion between implants and bone **(Tozum *et al*., 2006)**.

5. Inadequate prosthetic analysis and technique: improper choice of the prosthesis, suboptimal prosthetic design and an occlusal scheme of the prosthesis, excessive load and inadequate laboratory work **(Kitamura *et al*., 2004)**.

6. Suboptimal implant design and surface characteristics (**Steigenda *et al*., 2003)**.

1.9 SAC Classification

The Swiss Society of Oral Implantology (SSOI) and the International Team for Implantology (ITI) have adapted the SAC classification (S = Straightforward, A = Advanced and C = Complex) for identification and categorization of treatment complexity in implant dentistry in an attempt to help dental teams in treatment planning, **Table (1-4)** summarizes SAC classification **(Dawson *et al.*, 2009)**.

Table (1-4): SAC surgical recommendations in implant dentistry **(Beagle, 2013)**.

Straightforward	Advanced	Complex
-Simple surgical intervention. -No anatomical risk. -No surgical risk. -Low complications. -Sufficient bone quantity. -Sufficient vertical/horizontal dimensions.	-Challenging surgical intervention. -Anatomical risk. -Little surgical risk. -Possible complications. -Single tooth esthetic gap in maxilla. -Osteotome sinus lift. -Simultaneous membrane technique.	-Complicated surgical intervention. -Anatomical risk. -High surgical demands. -Expected complications. -Edentulous maxilla. -Bilateral sinus grafting. -Vertical augmentation. -Graft harvesting. -Complex soft tissue grafting. -High esthetic demands. -Immediate implant placement/loading.

1.10 Complications in dental implant surgery

Dental implant surgery has become routine treatment in dentistry and is generally considered a safe surgical procedure with a high success rate. However, complications should be taken into consideration because they can follow dental implant surgery as with any other surgical procedure. Many of the complications can be resolved without severe problems; however, in some cases, they can cause dental implant failure or even life-threatening circumstances. Avoiding complications begins with careful treatment planning based on accurate preoperative anatomic evaluations and an understanding of all potential problems **(Kim, 2011)**. According to **Park and Wang, 2005, intraoperative** surgical-related complications include:

- Nerve injury.
- Hemorrhage during drilling.
- Fracture of mandible.
- Penetration of nasal/sinus floor.
- Lack of primary stability.
- Significant bleeding.
- Devitalization of adjacent teeth.

Annibali *et al*., 2009 stated that **early complications** appear in the immediate postoperative period and interfere with healing، and **late complications** arise during the process of osseointegration, **Table (1-5)**.

Table (1-5): Complications of dental implant **(Annibali *et al*., 2009)**.

Early complications	Late complications
• Infection. • Edema. • Ecchymoses and haematomas. • Emphysema. • Bleeding. • Flap dehiscence. • Sensory disorders.	• Perforation of the mucoperiosteum. • Maxillary sinusitis. • Mandibular fractures. • Failed osseointegration. • Bony defects. • Periapical implant lesion.

Chapter Two

Materials and Methods

Materials and Methods

2.1 Materials

2.1.1 Study sample

The study sample included patients who attended the Department of Oral and Maxillofacial Surgery / College of Dentistry /University Of Baghdad for the purpose of implant placement to replace single or multiple missing teeth.

A total of (24) patients, (7) males and (17) females, aged from 20 to 66 years old, who fulfilled the eligibility criteria participated in this study; and they received (46) dental implants. This clinical study was conducted from December 2018 to August 2019.

2.1.2 Inclusion criteria

1. Patient's age is ≥ 18 years old including both genders.

2. Healed short or long span edentulous area (single or multiple missing teeth) in the maxillary and mandibular arches for at least 6 months after extraction (delayed implant placement protocol).

3. Patients who have an alveolar ridge with sufficient vertical and horizontal dimensions, which considered as straightforward cases according to SAC classification **(Beagle, 2013)**.

4. Jaw regions with low bone density (D3-D5 bone density according to Misch bone classification) based on CBCT findings **(Juodzbalys and Kubilius, 2013)**.

5. Patients who were well motivated for the dental implant therapy and were available for the follow-up visits and maintained good oral hygiene.

2.1.3 Exclusion criteria

1. The presence of acute or chronic infection or local pathological condition at the proposed implant zone.

2. Jaw regions with high bone density (D1 and D2 bone density according to Misch bone classification) depending on CBCT findings.

3. Patients with parafunctional habits such as severe bruxism and clenching.

4. Any local limitation that interfere with implant placement like inadequate inter-ridge distance or insufficient vertical height.

5. Any drug that compromise the healing of bone like corticosteroids or hormone replacement or Bisphosphonates.

6. Patients with history of any uncontrolled systemic disease or local condition that compromises the bone healing potential such as heavy smoking, Diabetes Mellitus, immunocompromised patient, hyperparathyroidism, fibrous dysplasia, uncontrolled bleeding disorder, current pregnancy at the time of the surgical procedure and history of radiotherapy to the head and neck region or chemotherapy over the past 5 years.

2.1.4 Case sheet

All the required informations about the patient and detailed previous medical and dental history were taken from each patient by a special case sheet designed for this study **(Appendix I)** in addition to the case sheet used in the dental implant unit **(Appendix II)**.

2.1.5 Armamentarium (Instruments, Materials)

1. Surgical set

It included Dental mirror, Explorer, Tweezers, Dental syringe, Dental needle,, Scalpel handle No.3, Scalpel Blade No.15, Periosteal elevators, Flap retractor, Toothed tissue forceps, Curette, Cumine scaler, Needle holder, Black braded silk suture (3/0), Scissors, Sterile gauze, Disposable suction tip, Normal saline 0.9 % and Disposable syringes 20 mm/cc, as shown in **Fig. (2-1)**.

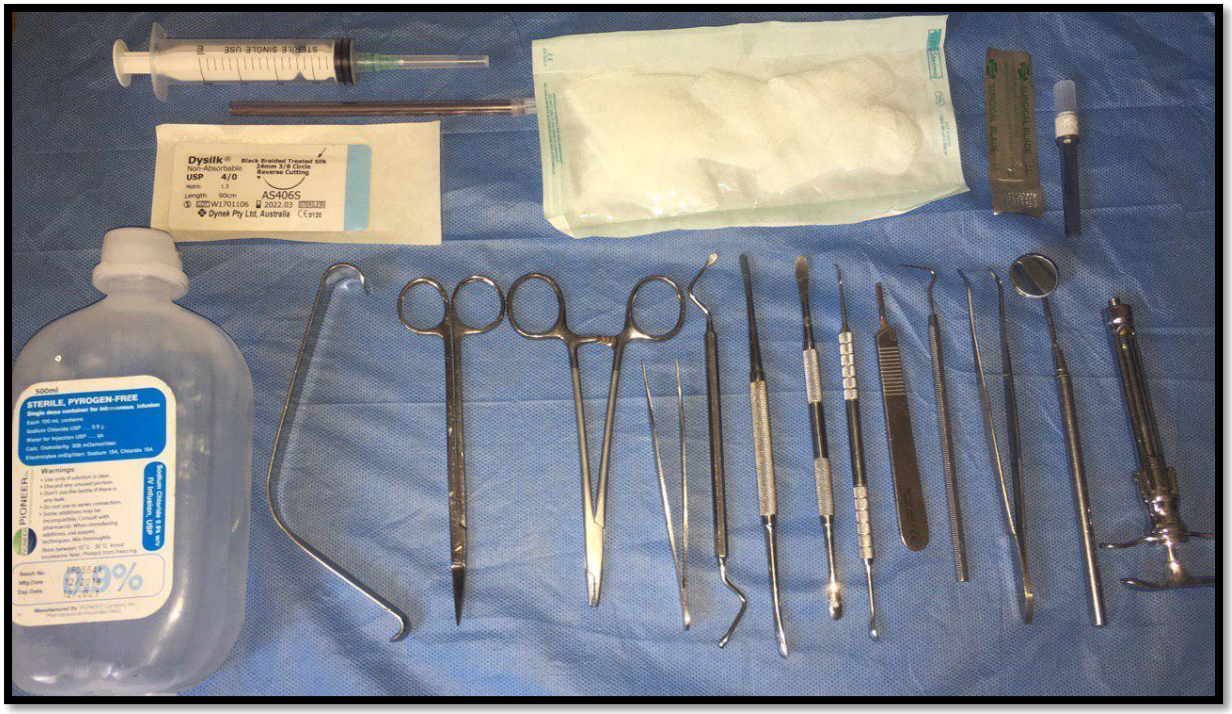

Figure (2-1): The surgical set.

2. Osseodensification surgical kit

Universal Densah® osseodensification bur kit (Versah Co., LLC., USA) for implant site preparation, **Fig. (2-2)**.

Figure (2-2): Densah® osseodensification surgical kit (Versah Co., LLC., USA).

3. Dental implant system

- Endosseous dental implants (NucleOSS™ T_6, Izmir, Turkey) sizes 3.5 and 4.1 mm diameter and 08, 10 and 12 mm in length and healing abutments used in the second stage surgery, **Fig. (2-3 a and b)**.
- Implant placement surgical kit (NucleOSS™ T_6, Izmir, Turkey), **Fig. (2-4)**.

Figure (2-3): Dental implant (NucleOSS™ T_6, Izmir, Turkey) **(a)** Dental implant package. **(b)** Healing abutment.

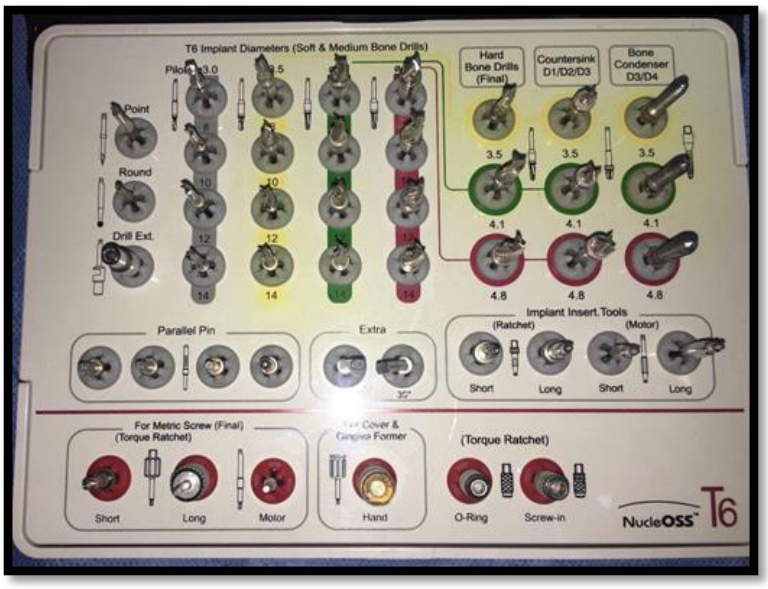

Figure (2-4): Surgical kit (NucleOSS™ T_6, Izmir, Turkey).

4. Dental implant micromotor engine

Dental implant engine (Dentium, Korea) set at 800 revolution per minute (rpm) speed and torque equal 35 N/cm coupled with external irrigation system, as displayed in **Fig. (2-5)**.

Figure (2-5): Dental implant engine (Dentium, Korea).

5. Vernier caliper

A digital stainless steel Caliper (Stainless hardened steel, China) was used for preoperative assessments for space analysis (length of the edentulous alveolar ridge span, inter-arch distance and patient mouth opening) and measuring the height of bone presented on orthopantomography (OPG), **Fig. (2-6)**.

Figure (2-6): Digital Caliper (Stainless hardened steel, China).

6. Periotest® M device:

Periotest® M (Gulden-Medizintechnik, Germany**)** for measuring primary and secondary implant stability, **Fig. (2-7)**.

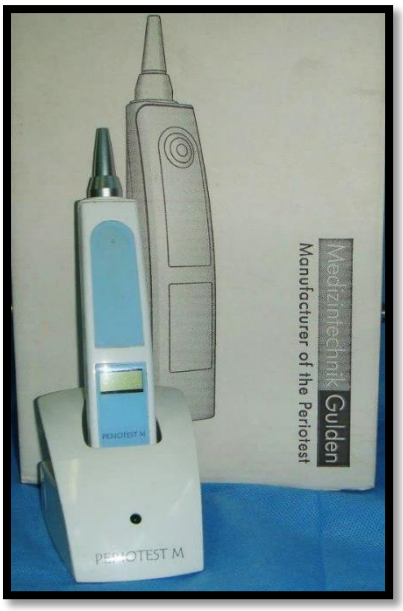

Figure (2-7): Periotest® M (Gulden-Medizintechnik, Germany).

7. CBCT device: Cone beam 3D system (Kavo OP 3D PRO, Germany) for pre and postoperative imaging (using On demand software), set at 90 Kv, 9.2 mA and 8.1 s with (13 × Ø15) c FOV and 0.5 mm slice thickness , **Fig. (2-8)**.

Figure (2-8): Cone beam 3D system (Kavo OP 3D PRO, Germany).

8. Autoclave (W& H sterilization, Italy), **Fig. (2-9 a)** and **Sterilization pouches** (ADS, Australia), as shown in **Fig. (2-9 b)**.

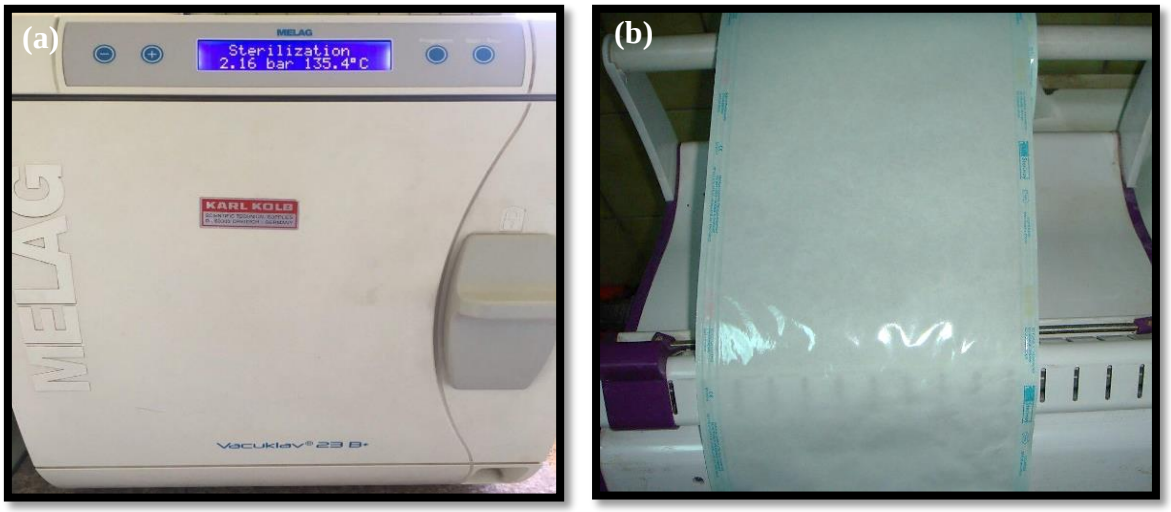

Figure (2-9): (a) Autoclave (W& H sterilization, Italy). **(b)** Sterilization pouches (ADS, Australia).

2.1.6 Local anesthesia and medications

- Lidocaine hydrochloride 2% with epinephrine 1:80,000 (Huons Co., Ltd., Korea), **Fig. (2-10)**.

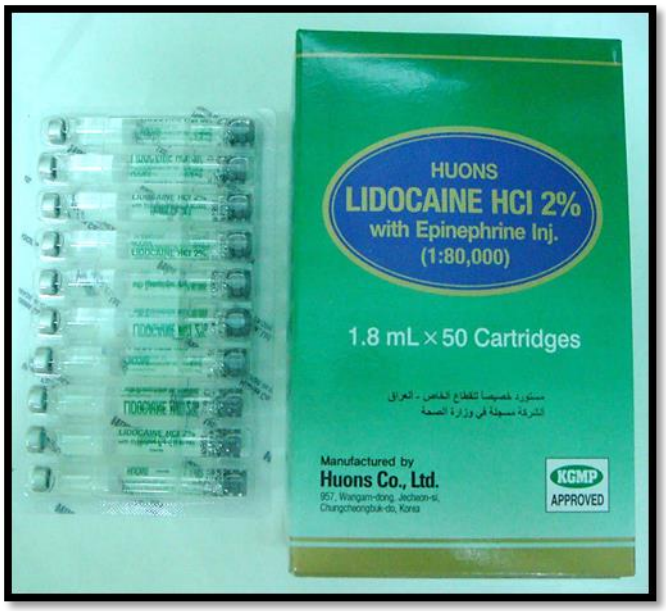

Figure (2-10): Local anesthetic solution (Huons Co., Ltd., Korea).

- 0.12% Chlorhexidine mouth wash (Kin, Spain).
- Amoxicillin capsules 500 mg or Azithromycin tablets 500 mg (in cases of Penicillin allergic patients).
- Metronidazole tablets 250 mg.
- Paracetamol tablets 500 mg.

2.2 Methods

2.2.1 Study design

This study was designed as a prospective observational clinical study.

2.2.2 Ethical approval

The Research Ethics Committee at the College of Dentistry, University of Baghdad approved the protocol of this study (protocol reference number 042118) **(Appendix III)**.

2.2.3 Preoperative assessment, clinical and radiographic examination

2.2.3.1. History

A detailed medical, dental and social history was taken from each patient; this usually included any systemic disease that may adversely affect the healing potential of the bone, as shown in **(Appendix I)** and **(Appendix II)**.

2.2.3.2 Clinical examination

Extra oral examination: This included examination of facial symmetry, smile line, color of skin, sclera and conjunctiva, cervical regional lymph nodes and temporomandibular joint condition.

Intra oral examination: It included inspection of oral mucosa, examination of teeth for the presence of caries, abnormal mobility of adjacent teeth, presence of retained roots, any signs of pathological condition and any signs of parafunctional habits, A space analysis of the site where dental implant to be installed was performed; it involved the followings:

- The inter-coronal (mesiodistal) distance was measured using Vernier caliper to verify the number of dental implants that could be placed (when multiple dental implants were needed). For single tooth replacement, it was useful to make sure that enough space was available for implant placement without jeopardizing adjacent roots and also for future prosthesis, **Fig. (2-11 a and b)**.

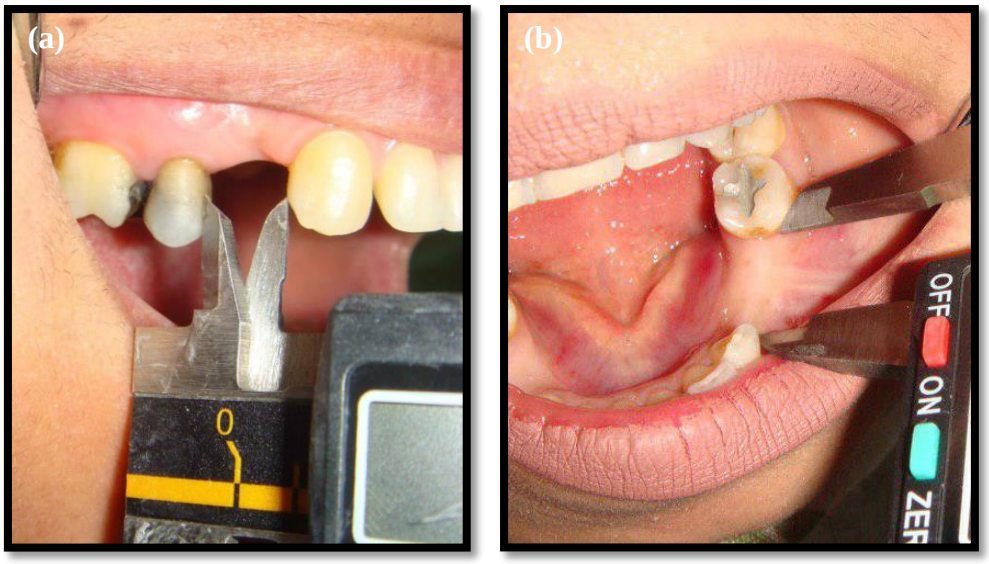

Figure (2-11): Inter-coronal distance measurement **(a)** for single tooth site #5. **(b)** For multiple teeth sites #20 and #21.

- Inter-arch (inter-ridge) distance during occlusion was measured using Vernier caliper to have an initial idea about the length of clinical crown and if there is any need for osteoplasty to increase inter-ridge distance in case of the presence of sufficient alveolar bone height, **Fig. (2-12 a)**. Inter-incisal distance at maximum mouth opening was also measured, as shown in **Fig. (2-12 b)**.

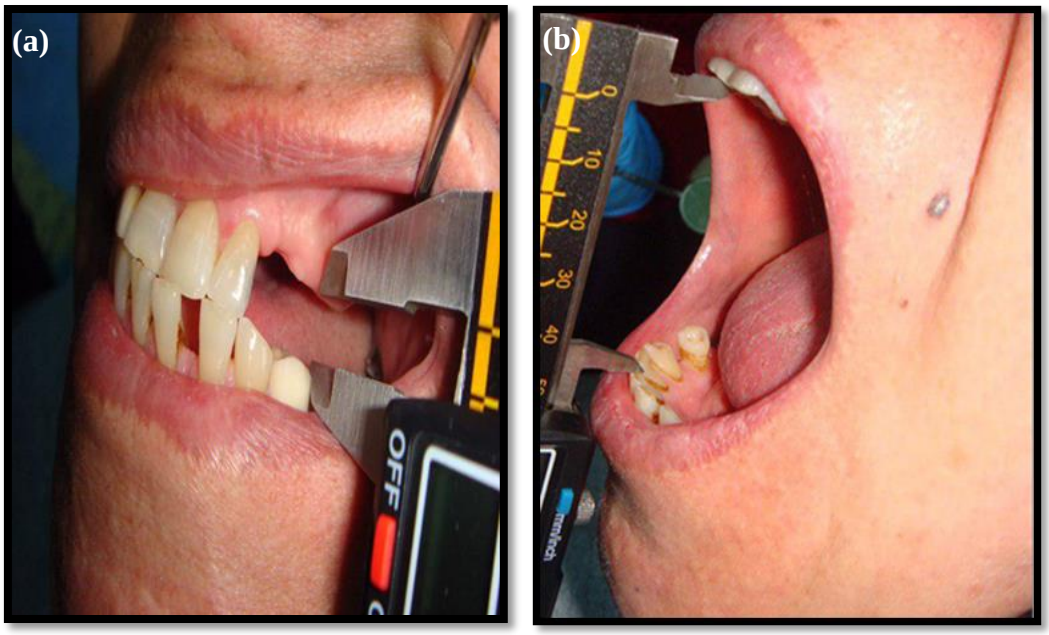

Figure (2-12): Space analysis **(a)** Inter-arch distance measurement for missing tooth site #13. **(b)** Inter-incisal distance measurement at maximum opening.

2.2.3.3 Radiographic evaluation

Preoperative OPG was taken for the patients; it provided a general evaluation for jaws and dentition, presence of any pathological lesion and proximity to the vital structures like the floor and the anterior wall of the maxillary sinus, inferior alveolar canal, mental foramen and nasal floor and also to estimate the available bone height for proper selection of implant length. Evaluation also included the condition of the bone planned to receive dental implant and the divergence of the root adjacent to the operative area for proper implant angulation .**Fig (2-13)**.

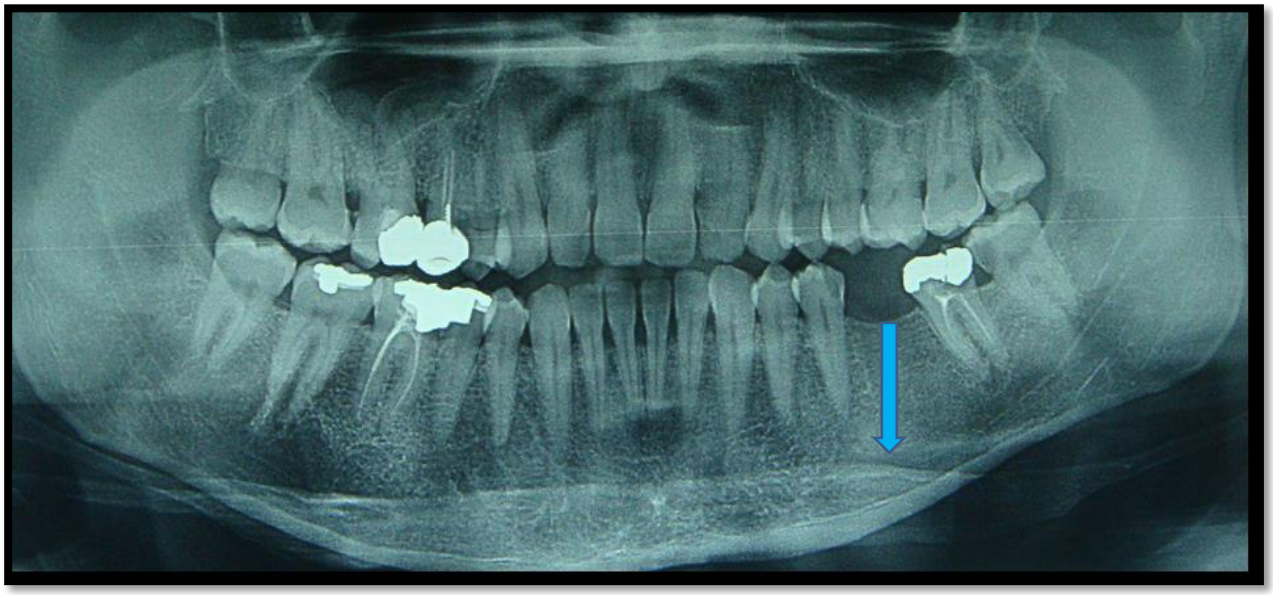

Figure (2-13): Available bone height at site of missing tooth # 19 on preoperative OPG.

CBCT was taken for all patients preoperatively to assess the bone density of the planned implant site to ensure that the bone is of low-density (D3 –D5 bone densities) depending on **Misch**, **2008** scale for density estimation as follows : D1>1250 HU, D2= 850-1250 HU, D3= 350- 850 HU, D4 =150-350 HU, and D5 <150 HU, **Fig. (2-14 b)**.

A preoperative measurement of the bone density was recorded from the coronal view with ROI of 1.5 mm of the entire cancellous bone of the apical area of the planned implant site (baseline), **Fig. (2-14 c)**.

Also further detailed measurements were made to determine the exact bone height and width of alveolar ridge at proposed implant site to ensure that the case is considered straightforward according to SAC classification **(Beagle, 2013)** and also to determine the dimensions of the implant to be installed so that the implant apex is to be at least 2 mm above mandibular canal and 2 mm away from mental foramen, 1 mm below nasal cavity and 1 mm below the floor and the anterior wall of maxillary sinus, **Fig. (2-14 d)**.

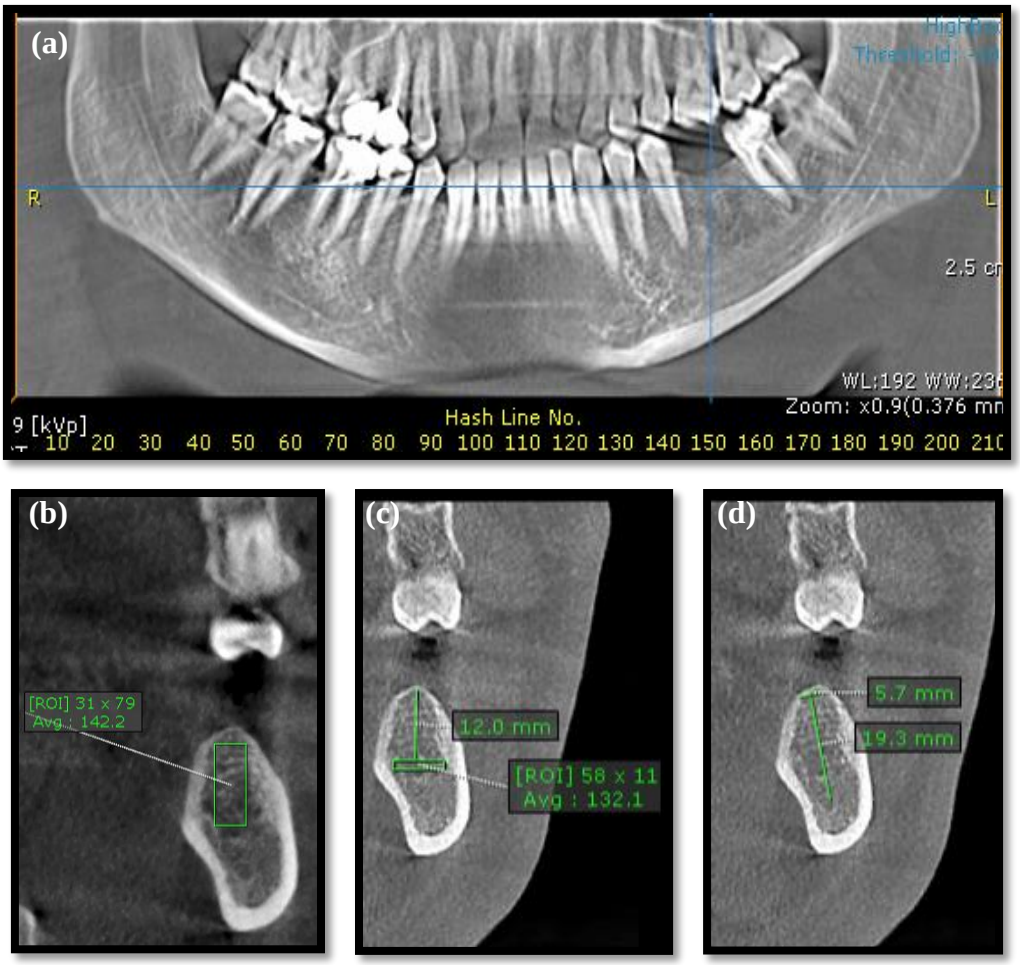

Figure (2-14): Preoperative CBCT **(a)** Panoramic view of missing tooth #19. **(b)** Coronal view showing the average bone density (D5) of the entire area of planned dental implant site. **(c)** Coronal view showing the average bone density (D5) of the apical area of planned dental implant site. **(d)** Measurement of available bone height and width of the planned dental implant site in coronal view.

2.2.4 Patient's preparation

The patients were informed about the nature of the procedures and the possible complications that may arise, and they signed an informed consent regarding the steps of the treatment and the free use of patient's data for the scientific or academic research purposes (**Appendix IV**).

Before the surgery, the patients were asked to gargle with chlorhexidine 0.12% mouthwash for about 1 minute, this was followed by circumoral scrubbing by gauze soaked in Povidone-Iodine solution and draping with sterile surgical drapes.

2.2.5 Anesthesia and flap design

- All the procedures were performed under local anesthesia using local infiltration into labial/buccal and lingual/palatal mucosa of the planned surgical field using lidocaine hydrochloride 2% with epinephrine (1:80,000).
- A mucoperiosteal flap was reflected (conserved or extensive flap design was made depending on the case demand), **Fig (2-15)**.

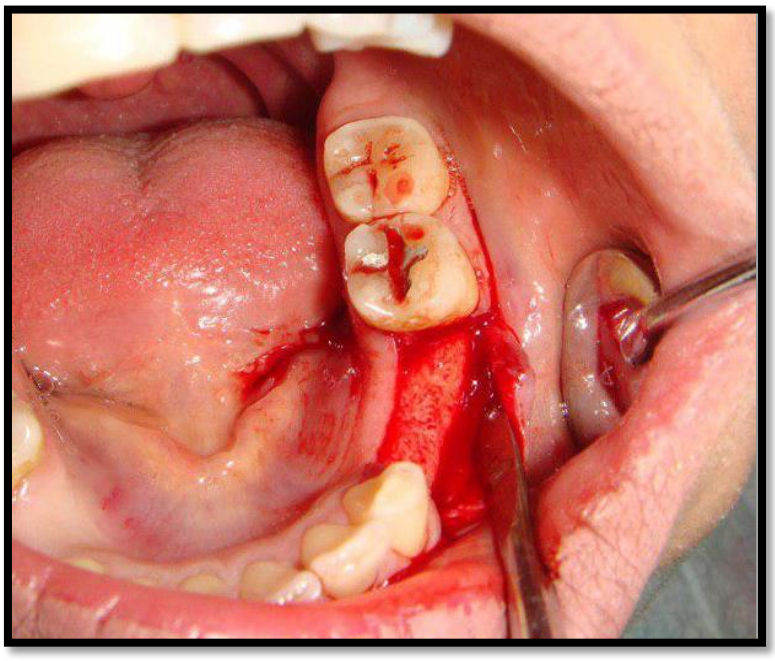

Figure (2-15): Extensive flap design at missing teeth sites #20 and #21.

2.2.6 Implant bed preparation

- Pilot drill of Densah® Burs (1.7 mm) was inserted to the desired depth (Clockwise drill speed 800 rpm with copious irrigation), **Fig. (2-16)**.

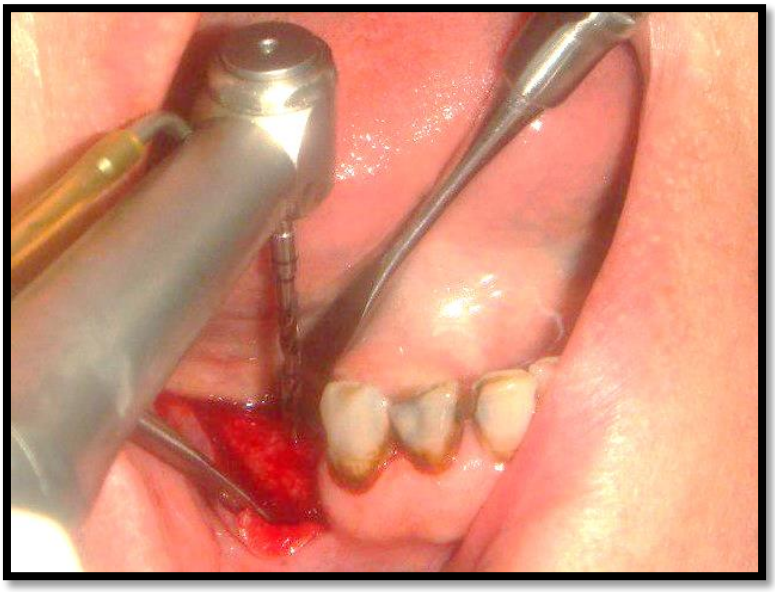

Figure (2-16): Pilot drill (1.7 mm) of Densah® burs rotated in clockwise direction in missing tooth site #28.

- Parallel pins were used to assess the correct position and alignment of planned dental implants, **Fig. (2-17)**.

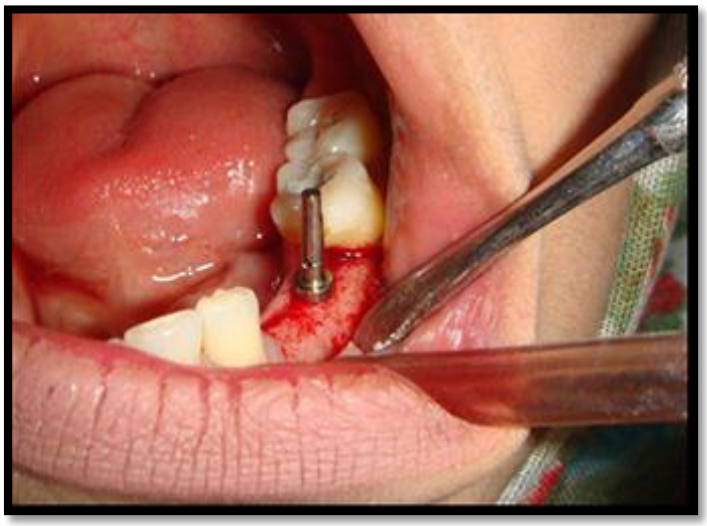

Figure (2-17): A parallel pin in missing tooth site #20 to check alignment with adjacent teeth.

- Depending upon the implant diameter selected for the site, preparation proceeded in densification mode through the sequential stepped drilling with the Densah® Burs (counter-clockwise drill speed 800 rpm) with copious irrigation. The diameter of the final drill inserted was 0.5 or 0.6 mm smaller than the implant diameter (undersized drilling) according to manufacturer instructions, **Fig. (2-18 a and b)**.

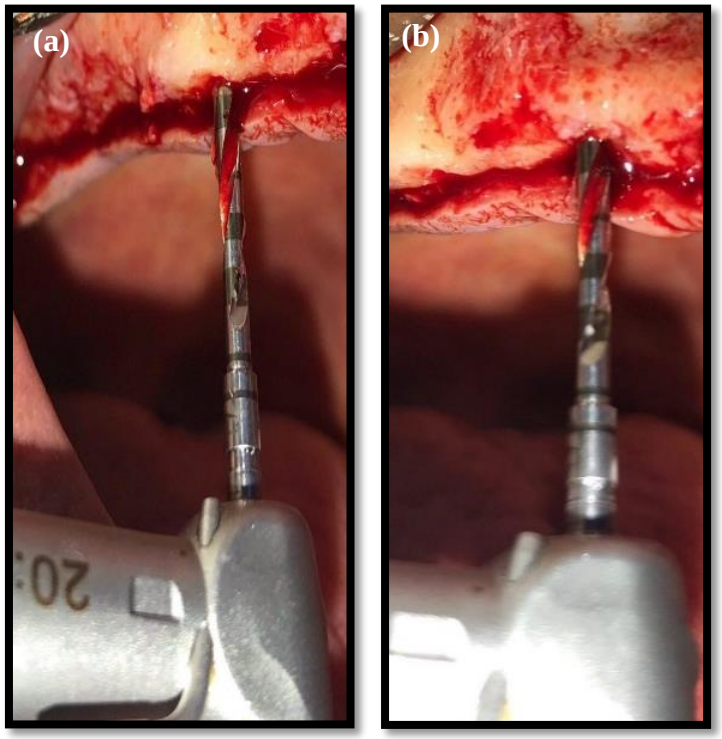

Figure (2-18): Sequential drilling with Densah® burs of missing tooth site #5 for placement of dental implant of 3.5 mm diameter. **(a)** VT1525 (2.0 mm) drill with counter-clockwise rotation. **(b)** VT2535 (3.0 mm) drill with counter-clockwise rotation.

The sequence of surgical drills used in preparing implant sites for the different implant diameters used in this study is illustrated in **Fig. (2-19 a and b)**.

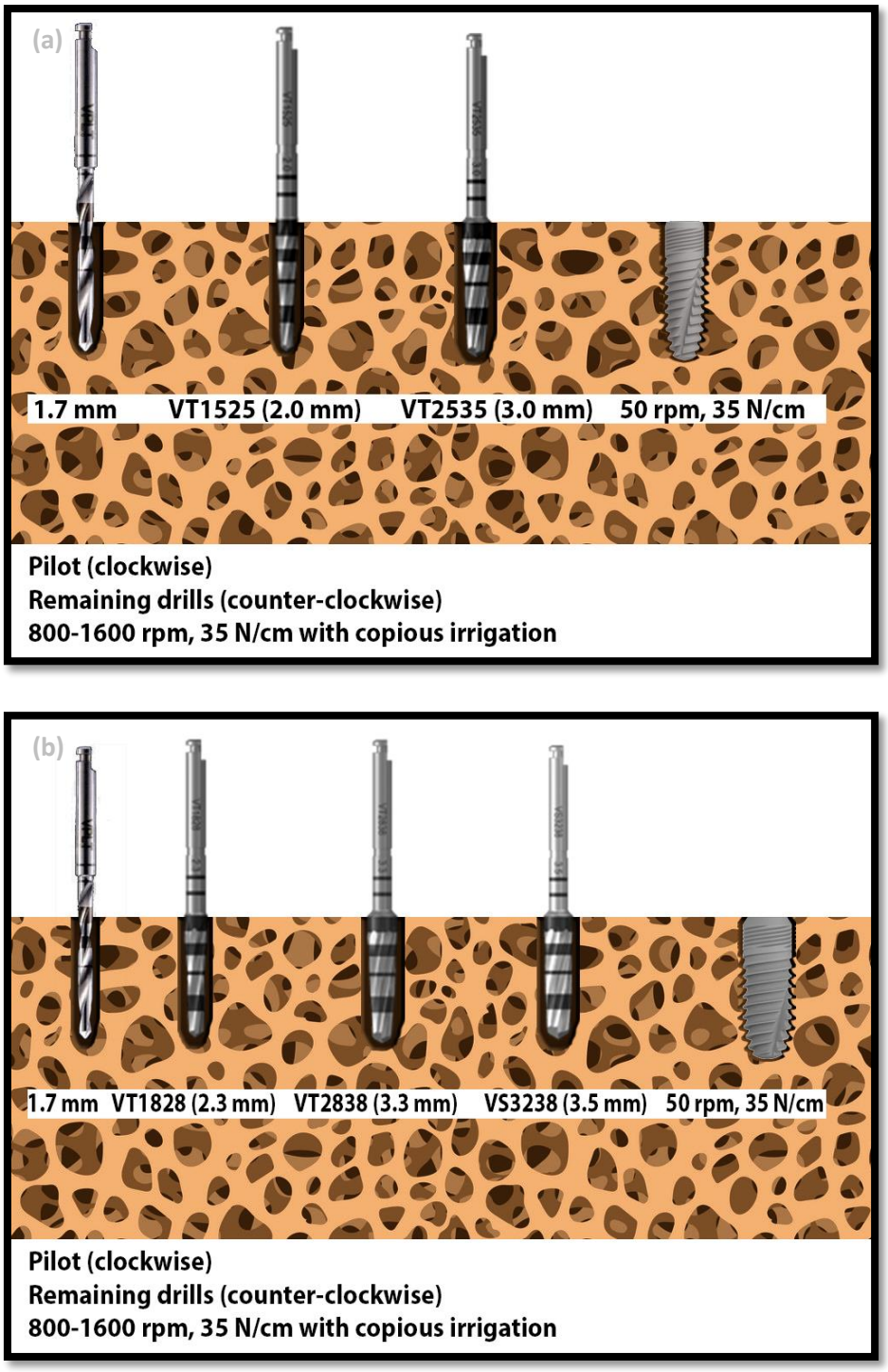

Figure (2-19): Sequential drilling steps during implants bed preparation according to the recommended OD protocol for tapered implant in soft bone. **(a)** For 3.5 mm, implant diameter. **(b)** For 4.1 mm, implant diameter.

2.2.7 Implant insertion

The implant was installed into the osteotomy site using the motorized method with the engine set at 50 rpm and 35 N/cm torque, **Fig (2-20 a)**.

A ratchet was used to place the implant to the desired depth when the insertion torque was more than 35 N/cm, **Fig (2-20 b)**.

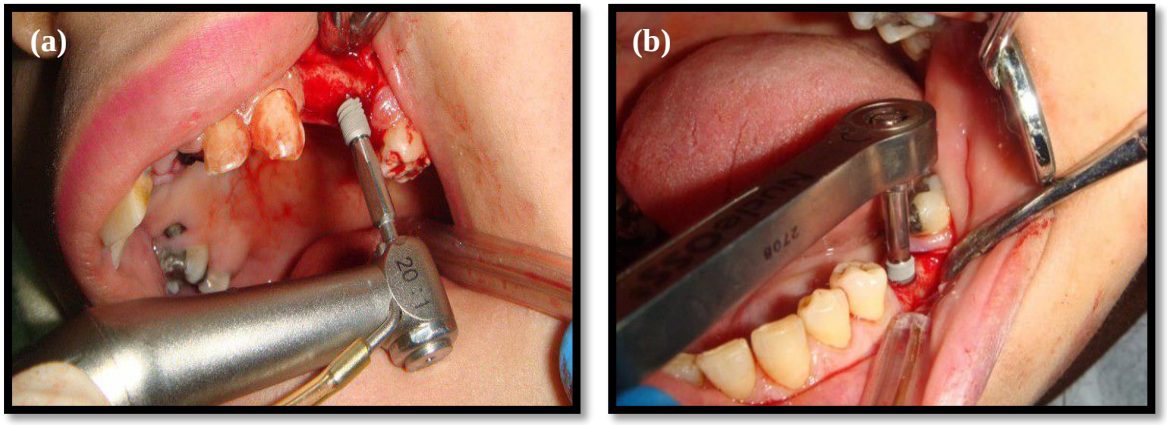

Figure (2-20): (a) Motorized implant insertion of implant at missing tooth site #13. **(b)** Manual implant insertion using ratchet for implant at missing tooth site #19.

2.2.8 Primary stability measurement (baseline)

Immediately after insertion of dental implant, healing abutment was placed and the implant stability was measured using Periotest® M device held in a right angle to the center toward the implant to be examined, the maximum deviation angle from the orthoradial direction of percussion is 45 degree. In addition, the rod and the test surface must maintain 0.6-2.5 mm distance according the Periotest® M operating instructions, **Fig. (2-21)**.

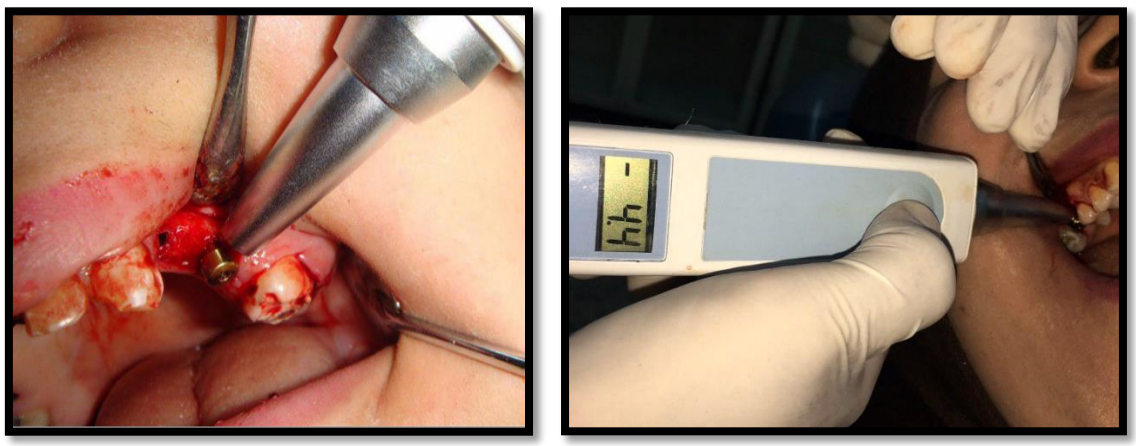

Figure (2-21): Primary stability measurement using Periotest® M.

Two repeated measurements were obtained for each implant and the mean of these two readings was taken. An audible sound will be emitted and the damping capacity was measured as a Periotest® M value (PTV), this value can range from -8 to +50, the lower values represent more rigidity.

The measurement was recorded as (primary stability) then a cover screw was placed after removing the healing abutment, **Fig. (2-22)**.

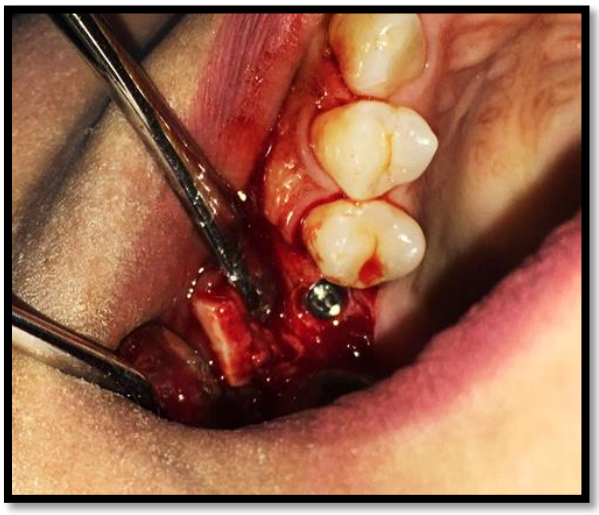

Figure (2-22): Cover screw in position for implant replacing missing tooth #3.

2.2.9 Surgical flap repositioning and suturing

After toilet of the operated area, the flap was repositioned and stabilized with 3/0 black silk interrupted suture, as shown in **Fig. (2-23)**.

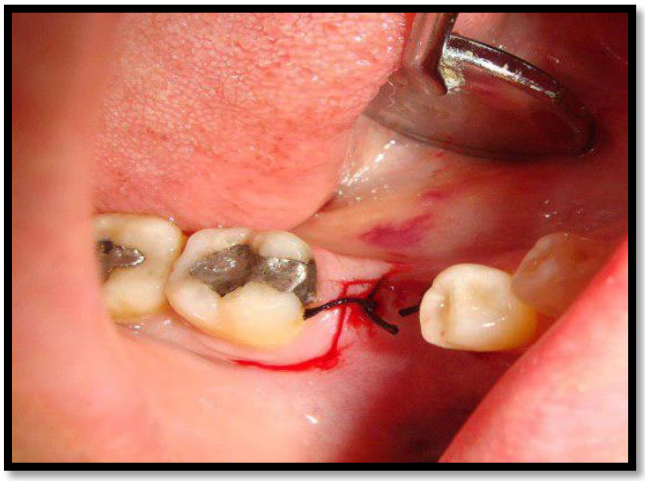

Figure (2-23): Flap repositioning and suturing for implant site #30.

2.2.10 Instructions and postoperative care

Patients were instructed to:

- Maintain pressure over the gauze pack applied over the operated area for about 30 minutes.

- Apply ice packs on the operated area in an alternate manner with 15 minutes on and 15 minutes off for about 3 hours in order to reduce postoperative edema and the patients were instructed to rest and avoid any heavy exercise for the first two days after surgery.

- Avoid gargling and spitting for the first 24 hours, gentle rinse for 30 seconds after meals and at bedtime with chlorhexidine mouth wash 0.12% for 5 days and gentle brushing of teeth especially close to the surgical site starting in the second day postoperatively.

- Avoid eating for 2 hours after surgery and maintain soft diet thereafter for the first 24 hours.

- Use the prescribed antibiotics and analgesics, which included (for all patients): Amoxicillin capsules 500 mg every 8 hours or Azithromycin tablet 500 mg once daily (in case of Penicillin allergic patients), Metronidazole tablets 250 mg every 8 hours, Paracetamol tablets 500 mg as required for 5 days after surgery.

- Attend for the first follow up visit 7-10 days postoperatively for sutures removal.

2.2.11 Follow up and data collection

A postoperative CBCT was taken within 7 days to estimate bone density apical to the implant within the same coronal view and dimensions of ROI used preoperatively (1.5 mm height and width of the entire cancellous bone apical to the implant), **Fig. (2-24)**.

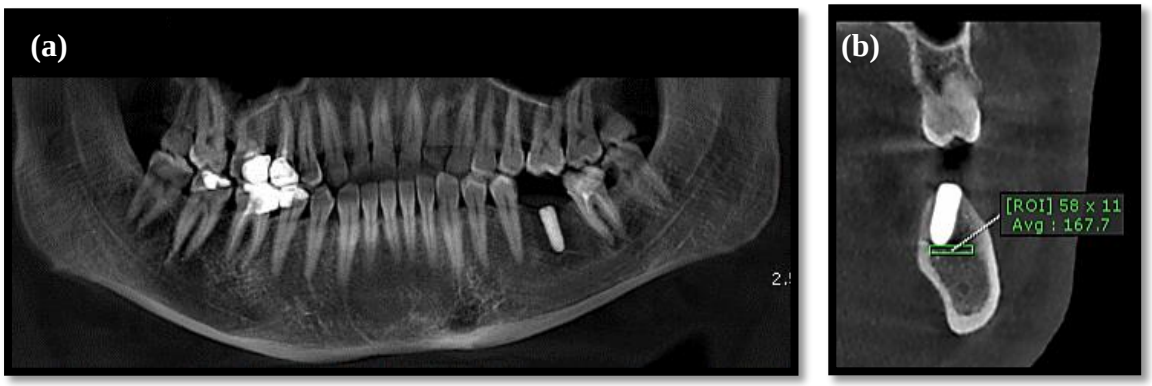

Figure (2-24): Postoperative CBCT **(a)** Panoramic view of the implant in missing tooth site #19. **(b)** Coronal view showing the average bone-density (D4) of the apical area of dental implant postoperatively.

Patients were instructed for follow up visit at 6 and 12 weeks postoperatively. During the follow up visits, any complications such as paresthesia, pain, edema, infection and pus/exudate discharge were recorded and managed accordingly.

At the 6th week follow up visit, the patient was given local anesthesia by infiltration and implant was uncovered using No.15 surgical blade with removal of the cover screw and placement of healing abutment. The implant stability was measured using Periotest® M in the same manner described in primary stability measurement.

At the 12th week follow up visit, implant stability was measured and recorded as secondary stability and all patients were referred to prosthodontics department for completing of their prosthesis.

2.3 Study variables

❖ **The predictor variables (independent variables)** in this study were:

- Implant site preparation using the OD technique.
- The bone density at the apical area of the proposed implant site measured preoperatively using CBCT within 1.5 mm ROI of the entire cancellous bone.
- Other predictor variables included gender, age, jaw, insertion torque and implant dimensions (diameter and length).

❖ **The outcome variables (dependent variables)** in this study included:

- Implant stability measurement immediately after insertion of implant (primary stability), at the 6^{th} and 12^{th} weeks postoperatively (secondary stability).
- The bone density apical to the implant postoperatively as measured by CBCT within the same ROI used preoperatively within 7 days after insertion of the implant.
- Implants success and failure rate according to **Misch** criteria in **2008**. Success was defined as implants that were clinically stable, pain free with no exudates after 12 weeks postoperatively.
- The correlation of certain predictor variables (age, gender, jaw, insertion torque and implant dimensions) with implant stability and bone density.

2.4 Statistical analysis

The statistical analysis was performed using GraphPad Prism version 6 for Windows (GraphPad Software, La Jolla, CA, USA). Descriptive statistical analysis included calculation of percentages and mean ± (SD) and inferential analysis included using paired t-test, unpaired t-test, one-way ANOVA, Tukey's multiple comparisons test and Pearson correlation coefficient**.** Probability values <0.05 were considered statistically significant.

2.5 Case presentation

A 42 year old female patient attended to the Implantology Unit in December 2018, she presented with missing tooth #19, on clinical examination and space analysis, the mesiodistal distance and inter-arch distance were sufficient for conventional dental implant placement. The patient was referred for taking CBCT that revealed the low-density of the bone (with an average bone density of 114.3 HU which classified as D5 depending on **Misch** scale (**2008**) for density estimation) which made the case a good candidate for OD technique; the stages of treatment and the final result are illustrated in figures **(2-25)** through **(2-36)**.

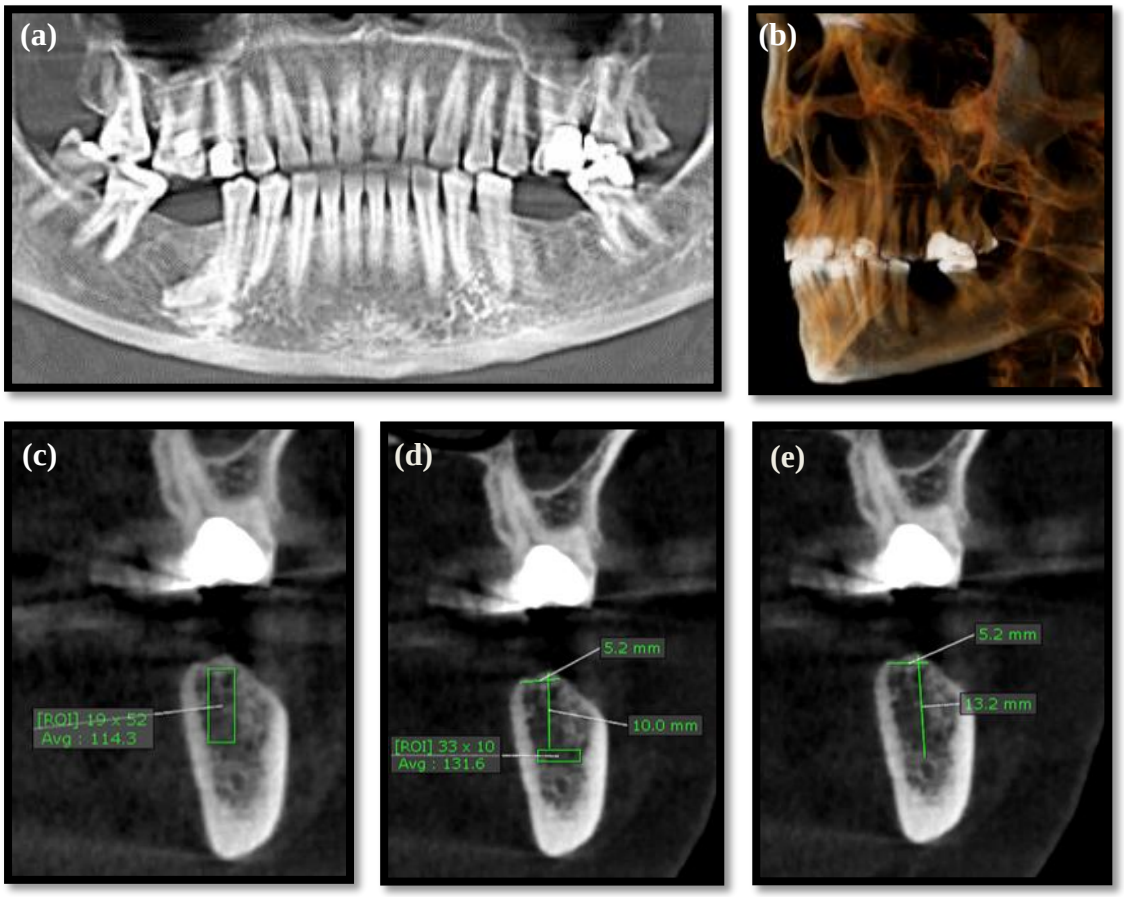

Figure (2-25): Preoperative CBCT of missing tooth site #19 **(a)** Panoramic view of missing tooth #19. **(b)** 3D view. **(c)** Coronal view showing the average bone density (D5) of the entire planned dental implant site. **(d)** Coronal view showing the average bone density (D5) of the apical area of the planned dental implant site. **(e)** Measurement of available bone height and width of the planned dental implant site in the coronal view.

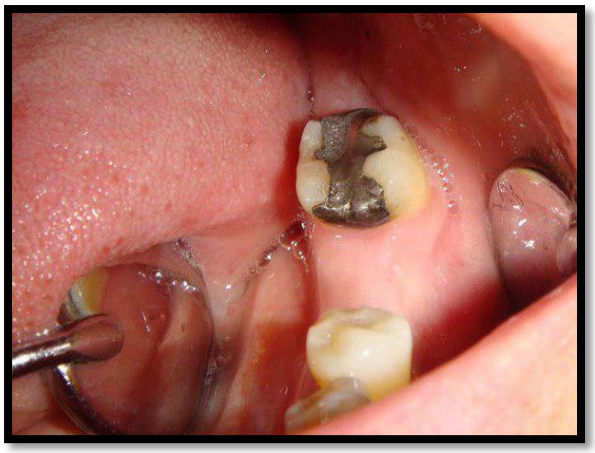

Figure (2-26): Initial preoperative clinical view.

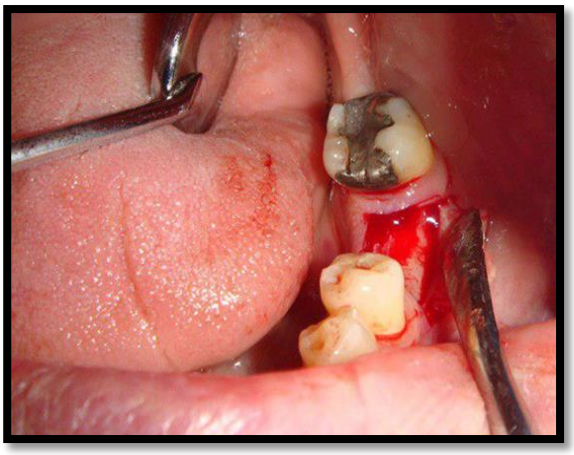

Figure (2-27): Conserved flap design.

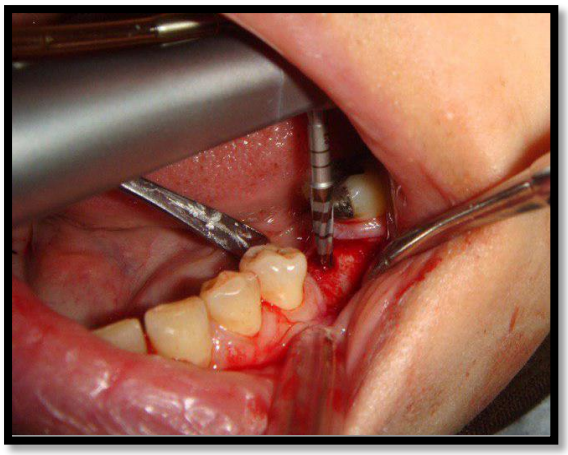

Figure (2-28): Sequential drilling with Densah® burs.

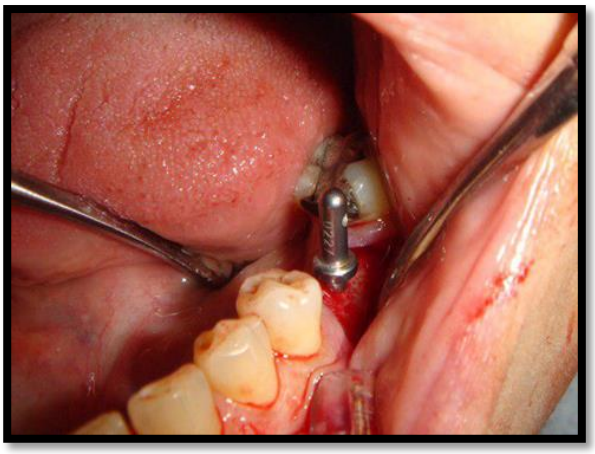

Figure (2-29): Parallel pin in intial hole verifying proposed implant angulation.

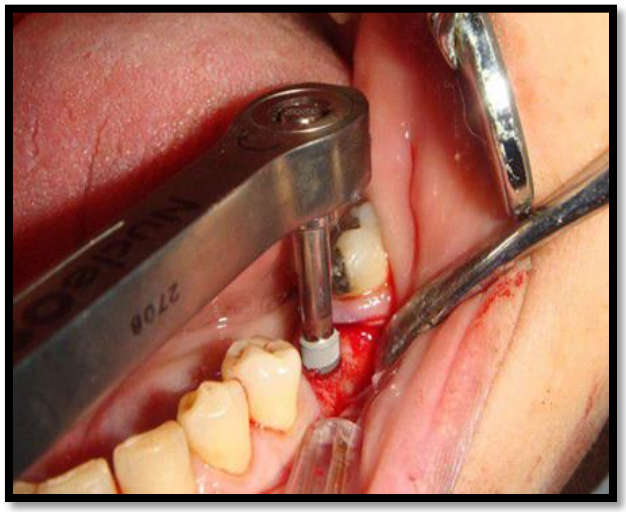

Figure (2-30): Manual implant installation after the insertion torque had exceeded 35 N/cm.

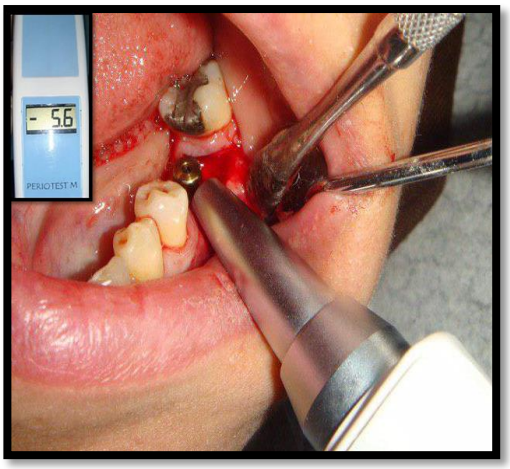

Figure (2-31): Placement of healing abutment and primary stability measurement using Periotest® M.

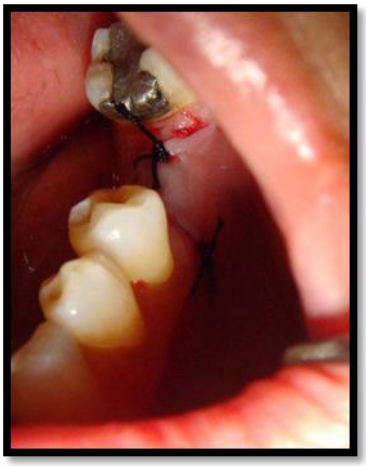

Figure (2-32): Flap repositioning and suturing.

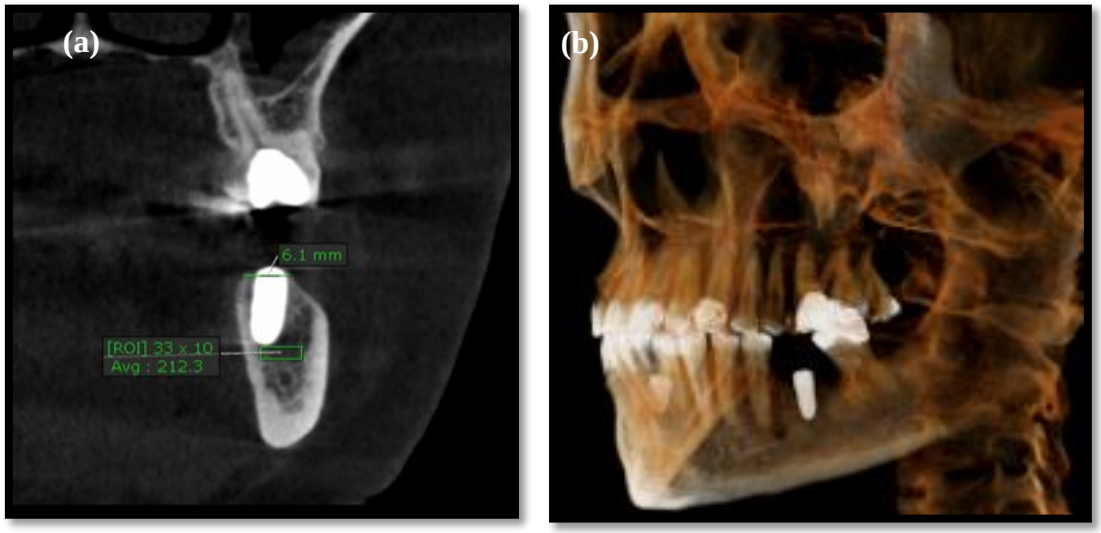

Figure (2-33): Postoperative CBCT of dental implant at missing tooth site #19 **(a)** Coronal view showing the average bone density (D4) of the apical area to the dental implant. **(b)** 3D view.

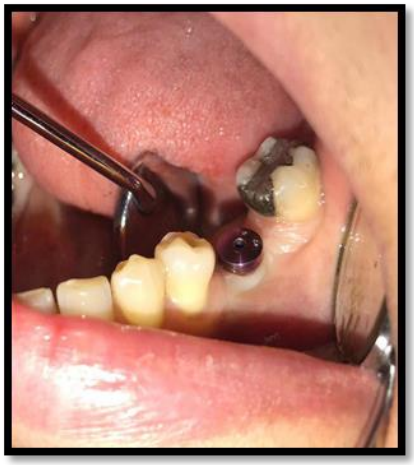

Figure (2-34): Second stage surgery (Placement of healing abutment) 6 weeks postoperatively.

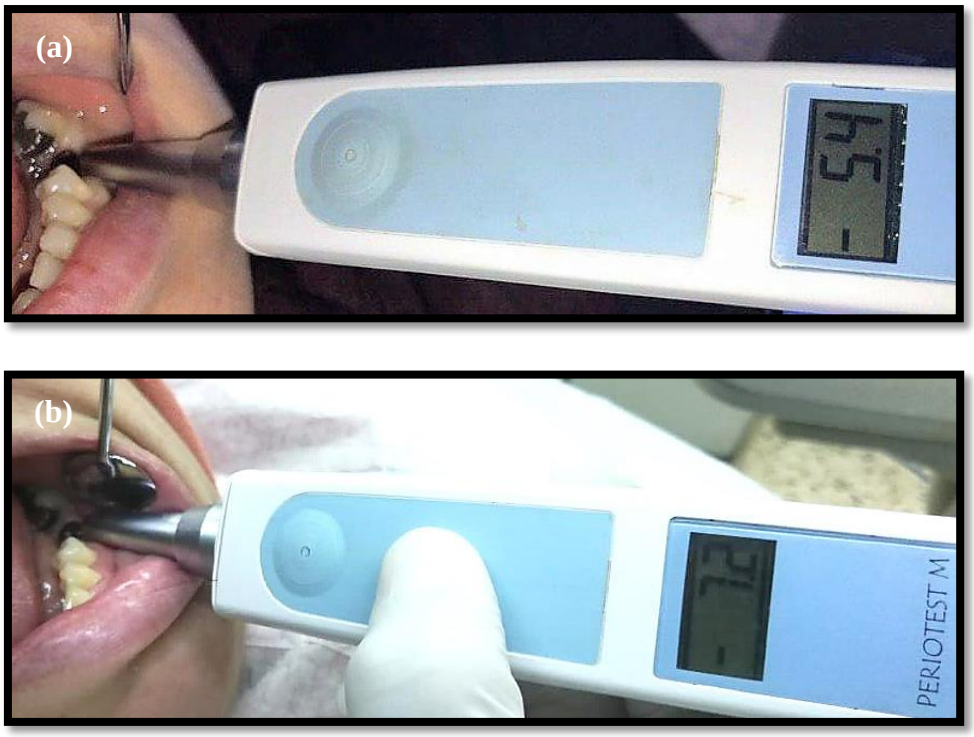

Figure (2-35): Implant stability measurement. **(a)** 6-weeks after surgery. **(b)** 12-weeks after surgery (Secondary stability).

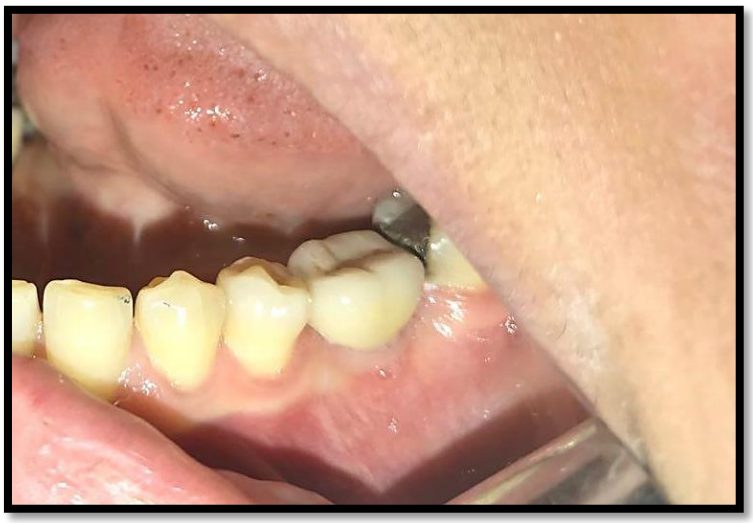

Figure (2-36): Final prosthesis.

Chapter Three

Results

Results

3.1 Demographic characteristics of the study sample

Twenty-four patients, 17 females (70.8%) received 32 implants and 7 males (29.2%) received 14 implants with an age range of 20-66 and a mean age (± SD) 43 (±15) years participated in this study, the distribution of patients according to age groups is illustrated in **Fig. (3-1)**. The patients received 46 implants, at the end of this study 43 implants were osseointegrated making the early survival of the implants 93.5%.

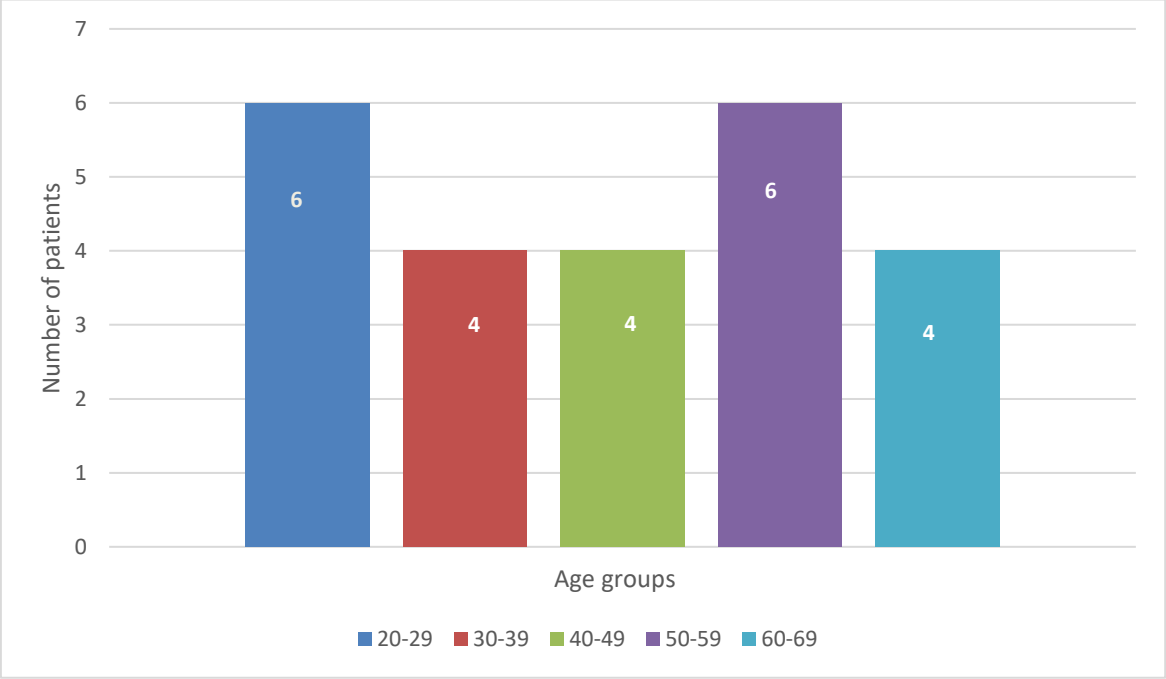

Figure (3-1): Bar chart showing the distribution of patients according to age groups.

3.2 Distribution of dental implants in relation to the functional implant zones

The number of implants inserted in the mandible were 23 (50%) and the maxilla received 23 (50%) implants. The distribution of implants according to functional implant zones (**Tolstunov, 2007)** is summarized in **Table (3-1)**.

Table (3-1): Dental implants distribution in relation to functional implant zones.

Functional implant zone	Number of implants (%)
Traumatic	12 (26.1%)
Ischemic	21 (45.6%)
Sinus	11 (23.9%)
Interforaminal	2 (4.4%)
Total	46 (100%)

3.3 Distribution of dental implants according to the implant dimensions

Implants with 4.1 mm diameter were the most commonly used in this study (n=26, 56.2%). With respect to length, implants with 10 mm length were the most frequently used. The distribution of implants according to implant dimensions is displayed in **Table (3-2)**.

Table (3-2): Dental implants distribution according to implant dimensions.

Implant dimensions (mm)		Number of implants (%)
Width	**3.5**	20 (43.8%)
	4.1	26 (56.2%)
Length	**8**	6 (13.1%)
	10	21 (45.6%)
	12	19 (41.3)
Total		46 (100%)

3.4 Distribution of dental implants according to the bone density

The highest percentage of the implants were inserted in D4 bone density and the lowest percentage of the implants were inserted in D3 bone density **(Misch, 2008)**, as shown in **Table (3-3)**.

Table (3-3): Dental implants distribution according to bone density.

Bone density categories	No. of dental implants (%)
D3	13 (28.26%)
D4	18 (39.13%)
D5	15 (32.61%)
Total	46 (100 %)

3.5 Distribution of dental implants according to the insertion torque

Most of the dental implants (n=35, 76.1%) were inserted with an insertion torque greater than 35 N/cm (23 in the mandible and 12 in the maxilla), while the remaining 11 dental implants (23.9%) were installed with 35 N/cm insertion torque (2 in the mandible and 9 in the maxilla), as demonstrated in **Table (3-4)**.

Table (3-4): Distribution of dental implants according to the insertion torque

Insertion torque (N/cm)	Number of implants (%)
35	11 (23.9 %)
>35	35 (76.1 %)
Total	46 (100%)

3.6 The pattern of implant stability changes during the follow up period

Of the 46 dental implants, 3 implants were lost during the early healing phase so they were excluded from statistical analysis, the remaining 43 implants were available for follow up. Data in **Table (3-5)** demonstrate that the mean (± SD) PTV increased (stability decreased) significantly at 6 weeks in comparison to that measured immediately after surgery (primary stability), whereas at the end of the follow up period (at 12 weeks), the mean of PTVs decreased significantly compared to that at 6 weeks. The difference between the mean PTV immediately after surgery and at 12 weeks was statistically non-significant.

Table (3-5): The mean PTV at surgery and after 6 and 12 weeks following surgery.

Implant stability	Mean PTV	SD	Mean difference	*p*-Value
Primary stability	-2.7	2.13		
At 6 weeks	0.7	4		
Changes at 6 weeks compared to primary stability			-3.317	< 0.0001 a [S]
At 12 weeks	-2.1	2.81		
Changes at 12 weeks compared to 6 weeks			2.720	< 0.0001 a [S]
Changes at 12 weeks compared to primary stability			-0.5972	0.0814 a [NS]

PTV=Periotest value. SD= standard deviation. a=Paired t-test. S= Significant. NS= non-significant.

3.7 Assessment of the effect of osseodensification technique on bone density

As demonstrated in **Table (3-6)**, the mean of bone density measured at the area apical to the implant as described in the method section was higher postoperatively than preoperatively and the difference was statistically significant.

Table (3-6): Bone density mean preoperatively and postoperatively.

Bone density	Mean HU	SD	*p*- Value
Preoperative BD	265.32	173.93	0.0001 a [S]
Postoperative BD	337.62	182.89	

BD= Bone density. HU= Hounsfield unit. SD= Standard deviation. a= Paired t-test. S= Significant.

3.8 The effect of some variables on implant stability and bone density

3.8.1 The effect of gender

As demonstrated in **Table (3-7)**, the mean PTV in females was lower (higher implant stability) than that of males at the time of surgery and after 6 and 12 weeks following surgery but this was statistically non-significant.

Table (3-7): Gender difference in PTVs mean at surgery and after two successive time intervals following surgery.

Implant stability	Gender	Mean PTV	SD	*p*- value
Primary stability	**Female**	-2.79	2.12	0.3651 a [NS]
	Male	-2.2	2.32	
At 6 weeks	**Female**	0.52	3.96	0.7230 a [NS]
	Male	1	4.24	
At 12 weeks	**Female**	-2.4	2.69	0.2110 a [NS]
	Male	-1.2	3.01	

PTV= Periotest value. SD= standard deviation. a= Unpaired t-test. NS= non-significant.

The bone density was higher in males than in females preoperatively and postoperatively and the differences were statistically significant **(Table 3-8)**.

Table (3-8): Gender differences in bone density preoperatively and postoperatively.

Bone density	Gender	Mean HU	SD	*p*- value
Preoperative BD	**Female**	225.02	159.56	0.0191 a [S]
	Male	358.32	175.86	
Postoperative BD	**Female**	300.75	172.83	0.0432 a [S]
	Male	422.70	183.43	

BD= Bone density. HU= Hounsfield unit. SD= standard deviation. a= Unpaired t-test. S= Significant.

3.8.2 The effect of age

As demonstrated in **Table (3-9)**, there was statistically significant difference in primary implant stability among the age groups while there were statistically non-significant differences in implant stability among age groups at 6 and 12 weeks following surgery. The Tukey multiple comparison test demonstrated that the mean PTV immediately after surgery was statistically higher in 60-69 age group than the 20-29, 30-39, 40-49 and 50-59 age groups ($p< 0.0001$), in general there was a tendency for higher PTV score immediately after surgery with older ages and vice versa ($r =0.5205$, $p= 0.0003$).

Table (3-9): The differences in PTV in relation to age groups at surgery and after 6 and 12 weeks following surgery.

Implant stability	Age group	Mean PTV	SD	*p*- Value
Primary stability	**20-29**	-3.71	1.7	0.0045 a [S]
	30-39	-4	1.38	
	40-49	-3.4	1.63	
	50-59	-2.24	1.69	
	60-69	-0.7	2.47	
At 6 weeks	**20-29**	0.49	4.68	0.4207 a [NS]
	30-39	-1.59	2.51	
	40-49	-0.5	5.25	
	50-59	1.36	3.92	
	60-69	2.3	2.42	
At 12 weeks	**20-29**	-2.84	2.64	0.0791 a [NS]
	30-39	-3.99	2.21	
	40-49	-2.8	2.55	
	50-59	-1.43	2.43	
	60-69	-0.2	3.21	

PTV= Periotest value. SD= standard deviation. a= ANOVA. S= Significant. NS= non-significant.

Concerning the bone density, there was statistically non-significant difference in the bone density among age groups preoperatively and postoperatively **(Table 3-10)**.

Table (3-10): The differences in preoperative and postoperative bone density in relation to age groups.

Bone density	Age group	Mean HU	SD	*p*-Value
Preoperative BD	**20-29**	207.37	121.55	0.3792 a [NS]
	30-39	338.17	232.08	
	40-49	278.42	229.51	
	50-59	213.21	118.29	
	60-69	333.4	175.31	
Postoperative BD	**20-29**	285.91	134.51	0.3639 a [NS]
	30-39	424.37	254.71	
	40-49	337.64	217.99	
	50-59	279.96	127.86	
	60-69	411.61	196.71	

BD= Bone density. HU= Hounsfield unit. SD= standard deviation. a= ANOVA. NS= non-significant.

3.8.3 The effect of the recipient jaw

The implants that were inserted in the mandible showed significantly lower mean PTV compared to those inserted in the maxilla at the time of surgery and after 6 and 12 weeks following surgery, **(Table 3-11)** and **(Fig. 3-2)**.

Table (3-11): The differences in PTV in relation to the recipient jaw at surgery and after 6 and 12 weeks following surgery.

Implant stability	Jaw	Mean PTV	SD	*p*-Value
Primary stability	**Maxilla**	-1.45	1.91	<0.0001 a [S]
	Mandible	-4	1.53	
At 6 weeks	**Maxilla**	1.98	3.33	0.0236 a [S]
	Mandible	-0.8	4.26	
At 12 weeks	**Maxilla**	-0.62	2.58	0.0003 a [S]
	Mandible	-3.6	2.23	

PTV= Periotest value. SD= standard deviation. a= Unpaired t-test. S= Significant.

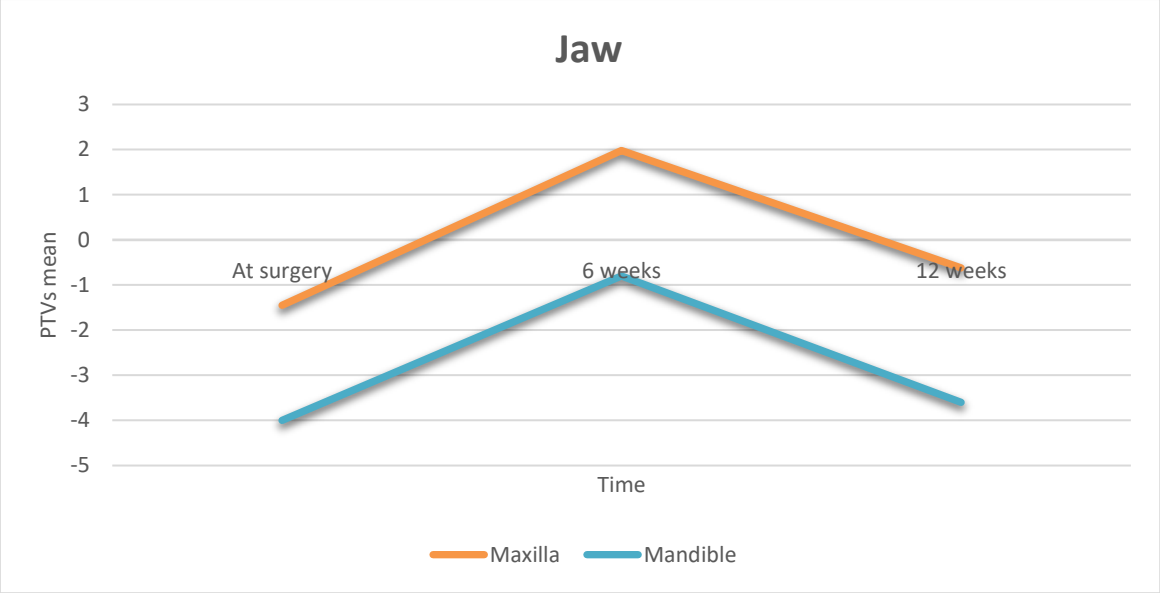

Figure (3-2): Linear chart demonstrating the difference in mean PTVs at surgery, 6 and 12 weeks following surgery in relation to the recipient jaws.

Bone density was higher in the mandible preoperatively and postoperatively compared to that of the maxilla but the difference was statistically non-significant **(Table 3-12)**.

Table (3-12): The differences in bone density preoperatively and postoperatively in relation to the recipient jaw.

Bone density	Jaw	Mean HU	SD	*p*-value
Preoperative BD	**Maxilla**	220.34	144.42	0.0825 a [NS]
	Mandible	312.45	192.56	
Postoperative BD	**Maxilla**	290.46	161.96	0.0636 a [NS]
	Mandible	387.04	194.17	

BD=Bone density. HU= Hounsfield unit. SD= standard deviation. a= Unpaired t-test. NS= non-significant.

3.8.4 The effect of insertion torque

The implants that were inserted with 35 N/cm insertion torque showed significantly higher mean PTV compared to those inserted with more than 35 N/cm at the time of surgery but after 6 and 12 weeks following surgery, the difference was statistically non-significant **(Table 3-13)**.

Table (3-13): The differences in PTV in relation to the insertion torque at surgery and after 6 and 12 weeks following surgery.

Implant stability	Insertion torque N/cm	Mean PTV	SD	*p*-Value
Primary stability	**35**	-1.1	2.3	<0.0032 a [S]
	>35	-3.2	1.8	
At 6 weeks	**35**	0.98	2.6	0.7603 a [NS]
	>35	0.6	4.43	
At 12 weeks	**35**	-1.2	2.2	0.2338 a [NS]
	>35	-2.4	2.96	

PTV= Periotest value. SD= standard deviation. a= Unpaired t-test. S= Significant. NS= non-significant.

There was statistically non-significant difference in bone density preoperatively and postoperatively in relation to insertion torque **(Table 3-14)**.

Table (3-14): The differences in bone density preoperatively and postoperatively in relation to the insertion torque.

Bone density	Insertion torque N/cm	Mean HU	SD	*p*- Value
Preoperative BD	**35**	280.6	175.5	0.7394 a [NS]
	>35	260	175.9	
Postoperative BD	**35**	366.5	201.6	0.5497 a [NS]
	>35	327.7	178.3	

BD=Bone density. HU= Hounsfield unit. SD= standard deviation. a= Unpaired t-test. NS= non-significant.

3.8.5 The effect of dental implant diameter

The data presented in **Table (3-15)** and **Fig. (3-3)** revealed that at surgery, 6 and at 12 weeks after surgery, dental implants with 3.5 mm diameter demonstrated the highest mean PTV and implants of 4.1 mm diameter had the lowest mean PTV and there was a statistically significant effect of implant diameter on primary implant stability and on implant stability at 12 weeks (secondary stability).

Table (3-15): The differences in PTV in relation to implant diameter at surgery and after 6 and 12 weeks following surgery.

Implant stability	Implant diameter mm	Mean PTV	SD	*p*-Value
Primary stability	**3.5**	-1.36	1.84	<0.0001 a [S]
	4.1	-3.7	1.76	
At 6 weeks	**3.5**	1.19	3.05	0.4711 a [NS]
	4.1	0.3	4.62	
At 12 weeks	**3.5**	-0.79	2.56	0.0067 a [S]
	4.1	-3.1	2.62	

PTV= Periotest value. SD= standard deviation. a= Unpaired t-test. S= Significant. NS= non-significant.

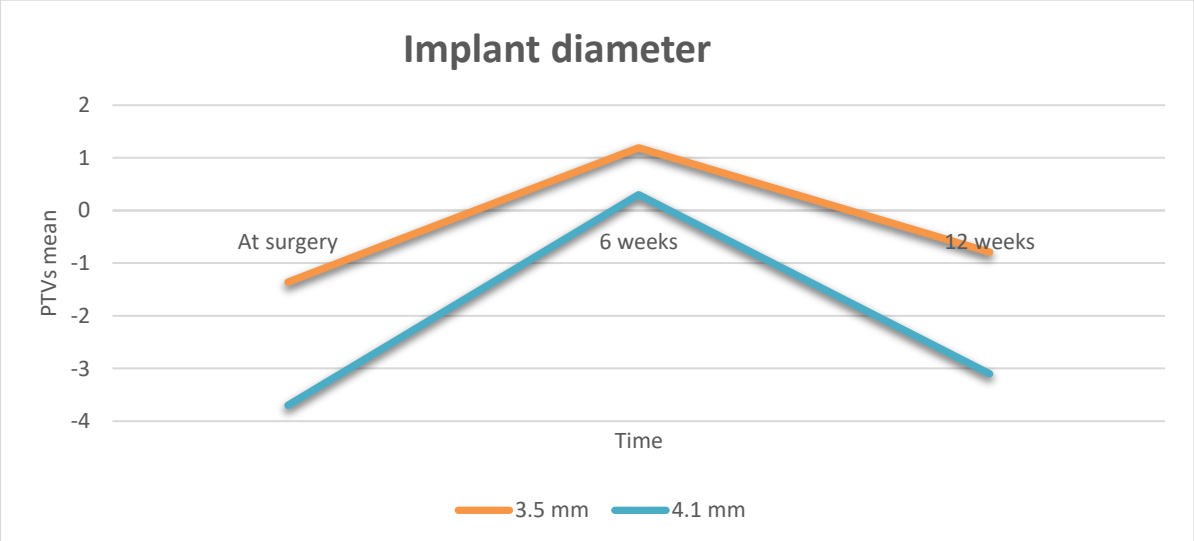

Figure (3-3): Linear chart showing the differences in PTV in relation to implant diameter at surgery and after 6 and 12 weeks following surgery.

There was statistically non-significant difference in bone density preoperatively and postoperatively in relation to implant diameter **(Table 3-16)**.

Table (3-16): Correlation between implant diameter and the difference between preoperative and postoperative bone density.

Implant diameter mm	Mean HU	SD	*P*-value
3.5	72.36	32.35	0.9899 a [NS]
4.1	72.25	25.27	

HU= Hounsfield unit. SD= standard deviation. NS= non-significant. a=Unpaired t-test.

3.8.6 The effect of dental implant length

In general there was a statistically non-significant effect of implant length on the PTV throughout the study period, **(Table 3-17)** and **Fig. (3-4)**.

Table (3-17): The differences in PTV in relation to implant length at surgery and after 6 and 12 weeks following surgery.

Implant stability	Implant length mm	Mean PTV	SD	*P*-Value
Primary stability	**8**	-2.7	1.27	0.9784 a [NS]
	10	-2.6	1.93	
	12	-2.8	2.62	
At 6 weeks	**8**	0.68	4.73	0.8929 a [NS]
	10	1.17	3.91	
	12	0.34	4.07	
At 12 weeks	**8**	-2.87	1.70	0.7524 a [NS]
	10	-1.88	2.91	
	12	-1.98	3.07	

PTV= Periotest value. SD= standard deviation. a= ANOVA. NS= non-significant.

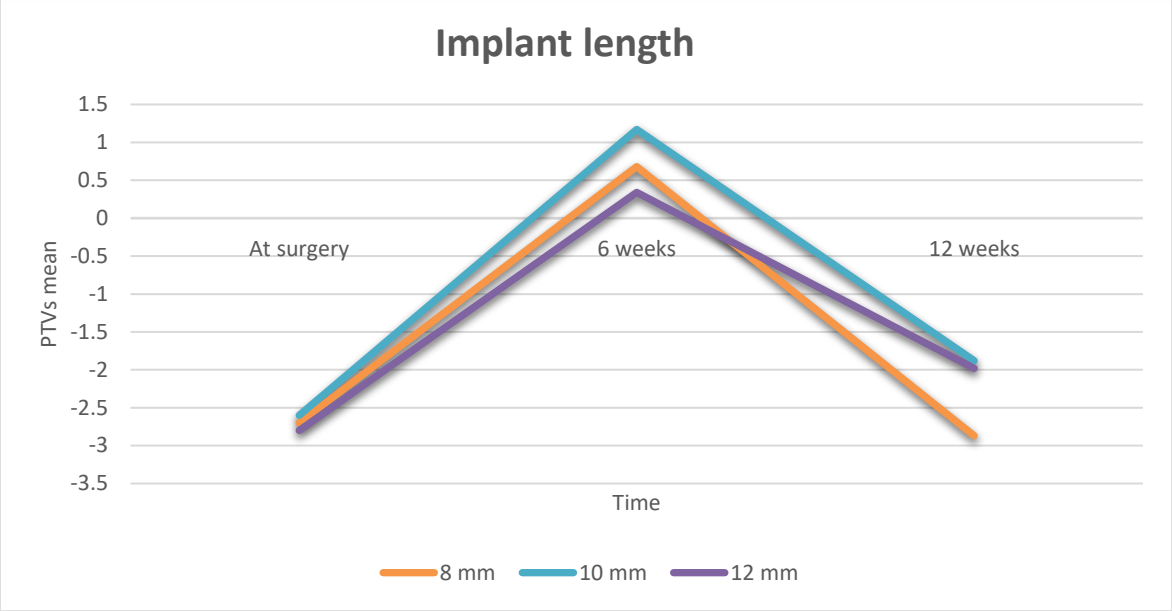

Figure (3-4): Linear chart showing the differences in PTV in relation to implant length at surgery and after 6 and 12 weeks following surgery.

Regarding the effect of implant length on bone density, the correlation between the implant length and the difference between the preoperative and postoperative bone density was statistically non-significant **(Table 3-18)**.

Table (3-18): Correlation between implant length and the difference between preoperative and postoperative bone density.

Implant length mm	Mean HU	SD	*P*-value
8	61.87	31.91	0.3799 a [NS]
10	78.65	31.51	
12	69.07	23.60	

HU= Hounsfield unit. a= One-way ANOVA. SD=standard deviation NS= non-significant.

3.9 Correlation of primary stability with 6 and 12 weeks implant stability

There was a moderate positive correlation between primary stability and secondary stability in that higher PTV values in primary stability resulted in higher PTV values in secondary stability. With respect to the correlation between primary stability and that of 6 weeks there was a weak positive correlation, as illustrated in **Table (3-19)**.

Table (3-19): Correlation of primary stability with implant stability at 6 and 12 weeks postoperatively.

	Primary stability vs. 6 weeks	Primary stability vs. 12 weeks
R	0.3937	0.6046
R square	0.1550	0.3656
***P*-value (two-tailed)**	0.0099	< 0.0001

R=Person correlation.

3.10 Survival rate of dental implants and complications in relation to different factors

At the end of the healing period of 12 weeks, 43 implants were stable and successfully osseointegrated and fulfilled the criteria of success producing survival rate of 93.5% as shown in **Table (3-20)**. Early postoperative complications were manifested as infection that occurred in two patients for three implants (6.5%), these were treated by antibiotics. Early implant failure (late complication) occurred during the first follow-up period in 3 implants (6.5%), **Table (3-21)** summarizes all the factors that were related to the early and late postoperative complications of dental implants in this study.

Table (3-20): Survival and failure rate of dental implants

Survived DIs (%)	Failed DIs (%)	Total (%)
43 (93.5)	**3 (6.5)**	**46 (100)**

Table (3-21): Early and late postoperative complications in relation to different factors.

Factors		Early complications (Infection)	Late complications (Early implant failure)
Gender	**Male**	0	**1**
	Female	**3**	**2**
Age	**20-29**	**2**	0
	30-39	0	0
	40-49	0	0
	50-59	**1**	**2**
	60-69	0	**1**
Functional implant zone	**Traumatic zone**	**1**	**1**
	Sinus zone	**1**	0
	Interforaminal zone	0	0
	Ischemic zone	**1**	**2**
Bone density	**D3**	0	0
	D4	0	**2**
	D5	**3**	**1**
Implant diameter	**3.5 mm**	**1**	**1**
	4.1 mm	**2**	**2**
Implant length	**8 mm**	0	0
	10 mm	**2**	**2**
	12 mm	**1**	**1**

Chapter Four

Discussion

Discussion

Osseodensification, a nonextraction technique, developed by Huwais in 2013 made it possible with specially designed burs to increase bone density as they expand an osteotomy. It allows bone preservation and condensation through compaction autografting during osteotomy preparation increasing the peri-implant bone density and the implant mechanical stability **(Huwais and Meyer, 2017)**. The aim of this study was to investigate the effect of OD on implant stability changes throughout the healing period and to demonstrate the densification effect on bone density measured by CBCT in the early postoperative period.

4.1 General characteristics of the sample

The majority of patients (70.8%) who received dental implants in this study were females who constitute a higher percentage of implant treatment seekers **(Wakimoto *et al*., 2011; Jeong *et al*., 2015)**. The female predominance in this study can also be attributed to the fact that the low bone density was an essential inclusion criterion and many studies have demonstrated that the density of the jaw bones is lower in females than in males **(Turkyilmaz and McGlumphy, 2008; Aksoy *et al*., 2009; Barunawaty, 2011)** which may be related to the hormonal characteristics in females and higher bone mass in males **(Ikumi and Tsutsumi, 2005; Turkyilmaz and McGlumphy, 2008)**.

According to functional implant zones proposed by **Tolstunov** in **2007**, the ischemic functional implant zone (posterior mandible) was the most frequent zone that received dental implants (45.6%) followed by the traumatic functional implant zone (anterior maxilla) that received 26.1% of the implants in this study. **Jeong *et al***. in **2015** in a retrospective clinical study using Periotest® also reported that the posterior mandible received the highest number of implants (52 out of 88 dental implants).

An implant treatment in the posterior mandible area can be potentially challenging because of low-density of the bone due to medullary pattern of bone atrophy and poor wound healing which may indicate OD technique as a treatment option **(Tolstunov, 2007)**.

Loss of anterior teeth has a major effect on esthetics, function and phonation, in addition to that, a poorly constructed prosthesis in the anterior maxillary region is readily observable, which make patients seek restoration of missing maxillary anterior teeth more often and this finding is supported by other studies (**Tang *et al*., 2015**).

Some studies reported no significant differences between the posterior mandible and maxilla in bone density, even though slightly higher mean density values were found in the posterior mandible than the posterior maxilla **(Shapurian *et al*. 2006)**. Other studies, on the other hand, showed that the posterior mandible region presents lower bone density than the anterior mandible, followed by the anterior maxilla then the posterior maxilla **(Norton and Gamble, 2001; Turkyilamaz and McGlumphy, 2008; Farré-Pagès *et al*., 2011)**.

Concerning the implant dimensions, 4.1 mm diameter implants were the most frequently used in this study (56.2%) since the alveolar ridge width was sufficient for placement of the widest implant diameter possible with respect to the rule of leaving at least 1 mm of circumferential bone around the implant **(Jenson *et al*., 2017)**. This is mainly because the cases were straightforward cases according to SAC classification **(Beagle, 2013)** as one of the inclusion criteria. **Bilhann *et al*.** in **2010** and **Barikani *et al*.** in **2013** maintained that if the bone volume is suitable, the use of wide diameter implants in cancellous bone seems to be a valuable aid in obtaining better primary stability.

Regarding the implant length, 10 mm length implants were the most frequently used (45.6%) in this study, the selection of the implant length was based on measurement of the available bone height by CBCT after considering the safety distance from any vital structures, which is keeping with **(Barikani *et***

***al.*, 2013; Gaviria *et al.*, 2014)**.

With respect to the insertion torque, the majority of implants (76.1%) were inserted with more than 35 N/cm insertion torque which is in agreement with **Lopez *et al.*** in **2017** who demonstrated**,** in their animal study, that implants installed after preparation with OD required significantly higher levels of insertion torque (approximately 65 N/cm) as compared with the regular drilling group (approximately 35 N/cm).

A similar observation was also made by another study that found implants inserted in low-density bone via OD presented higher insertion torque values regardless of implant surface treatment **(Oliveira *et al.*, 2018)**.

4.2 The pattern of implant stability changes during the follow up period

It is noteworthy to mention that there are no published clinical studies that assess the implant stability changes during the osseous healing period or the survival rate of dental implants inserted after preparation by OD in low-density bone, which represent a limitation in comparing the results of this study with other similar studies.

Clinically, the dental implant primary stability can be evaluated using several techniques, such as the amount of torque needed during insertion, or after insertion using the resonance frequency analysis technology implemented in the Osstell device, or the mechanical percussion principle used in the Periotest® **(Javed *et al.*, 2013)**.

Studies have emphasized that it is important to consider several readings of Osstell or Periotest® over a long period of time in order to be able to evaluate the implant stability and approved the use of Periotest® once the clinicians consider its limitations and the difficulty in results interpretation **(Andresen *et al.*, 2003; Aparicio *et al.*, 2006)**.

Oh *et al.* in **2012** found that the Periotest® was comparable and as reliable as the Osstell, while **Javed *et al.*** in **2013** demonstrated that the Periotest® readings are less sensitive.

The PTV is inversely proportional to implant stability, i.e., low PTVs indicate high stability while high values indicate low implant stability **(Teerlinck *et al.*, 1991)**. Positive values should alert the clinicians to take additional precautions such as unloading until implant stability is regained or check for trauma or infection **(Bilhan *et al.*, 2015)**. In the case of successful implants, PTVs are within the range from -5 to +5 **(Meredith, 1998)**.

Satisfactory primary stability in low-density bone is difficult to achieve because of the poor BV around the implant surface and higher rates of implant failure are usually observed in those cases **(Bilhan *et al.*, 2010; Isoda *et al.*, 2011; Trisi *et al.*, 2016; Podaropoulos, 2017**).

Merheb *et al.* in **2017** demonstrated that a direct relationship exists between implant primary stability and bone density as derived from a reading of HUs of bone at the implant site. On the contrary, other studies reported no correlation between bone quality and primary stability **(Beer *et al.*, 2003)**; **Youssef *et al.*** in **2015** also demonstrated no correlation between bone density and implant stability throughout the follow up period.

The mean primary stability (PTV) achieved in this study was (-2.7) which is considered relatively high compared to that obtained by other studies for conventional drilling in low-density areas **(Alsaadi *et al.*, 2007; Oh and Kim, 2012; Jeong *et al.*, 2015)**.

Lahens *et al.* in **2016** in an animal model found that OD drilling recorded superior primary stability as measured by insertion torque and demonstrated no impairment to osseointegration when compared to regular drilling, irrespective of implant macrogeometry.

On the other hand, different findings were made by other studies, **Almutairi *et al.* in 2019** showed that there was no statistically significant

difference between the OD and the regular drilling techniques, nor between the different thread designs used based on the PTVs recorded for the implant primary stability, and the authors concluded that OD is not necessary in situations where there is bone of good quality and quantity. Similar findings were also demonstrated by **Wang *et al.*** in **2017** who observed that condensation can increase the density of peri-implant bone; but it did not ensure greater BIC, nor did it improve implant stability.

Although dental implants inserted in osteotomy sites prepared by OD in this study demonstrated good primary stability, but it dropped significantly during the first 6 weeks of the healing period only to increase significantly at 12 weeks compared with the stability measured at 6 weeks. This pattern of implant stability change during the healing period is also evident after implant site preparation by conventional drilling **(Digidi *et al*., 2010; Jeong *et al*., 2015; Alattar and Bede, 2018)**.

The establishment of osseointegration is a dynamic process that involves bone tissue modeling and remodeling and this physiologic drop of implant stability during the early osseous healing period is associated with resorption of bone in contact with the implant surface which is evident during the first weeks of healing, the resorbed bone is replaced with newly formed viable bone which represents the transition of the implant stability from mechanical anchorage responsible for primary stability to biological attachment responsible for secondary stability **(Berglundh *et al*., 2003)**, therefore measuring implant stability during the healing period can provide an objective assessment of stability changes that is essential in decision making regarding implant loading.

This drop in stability was not observed in some studies where implant stability remained constant or increased slightly during the first 4–6 weeks and then increased more markedly **(Bischof *et al*., 2004)**, also **Rosen *et al.*** in **2010**, using enhanced implant surface exhibiting electro-wetting, reported ISQ values

during early healing periods of 2 and 4 weeks that were significantly higher than those measured at insertion.

In an animal study, **Trisi *et al.*** in **2016** found that OD was able to increase implant primary stability and maintain implant secondary stability.

The purpose of assessment of implant stability during the osseous healing period, in this clinical study, was to determine if OD can maintain high stability levels in the early weeks after implant insertion thereby facilitating early loading, but the significant drop in stability compared with that recorded immediately after insertion of implants indicates that OD is similar to conventional drilling in this aspect, although this finding needs to be considered cautiously due to the lack of a control group in order to better assess the effect of OD on implant stability.

4.3 The effect of osseodensification technique on bone density

Several approaches such as densitometric measurements, DXA scan, CT and dental CBCT have been used to measure jawbones density **(Gulsahi, 2011)**.

Among imaging modalities used for bone density assessment, CBCT has advantages over conventional CT due to lower radiation dose, shorter acquisition times, reasonable price and submillimeter resolution and an advantage over micro-CT, since it is being used clinically and not only for in vitro experiments **(Razi *et al.*, 2014; Alkhader *et al.*, 2017)** although other studies found that CBCT could not demonstrate the true bone density compared with histologic analysis and micro-CT **(Suttapreyasri *et al.*, 2018)**.

In this study, the assessment of the effect of OD on bone density was confined to the apical area since most of the studies found that the direction of bone condensation with OD was lateral and apical to the implant body (**Huwais and Meyer, 2017; Slete *et al.*, 2018)** but to overcome the effect of buccal/labial

and lingual/palatal cortices on the measurement of bone density of the cancellous bone only the apical area was measured which is in line with other studies **(Bergkvist *et al*., 2010; Merheb *et al*., 2010; Wakimoto *et al*., 2011)**.

The results of this study support the use of OD technique to increase the bone density in low-bone density areas, which is in keeping with **(Huwais and Meyer, 2017)** in their animal study that demonstrated that OD increases mineral bone density around the periphery of the osteotomy and produces a compaction autografted bone along the entire depth of the osteotomy, especially at the apical portion. The same findings were also obtained by **(Huwais *et al*., 2018)** in their 5-years retrospective clinical study that demonstrated that OD technique enhances bone density through compaction autografting and thus facilitates crestal sinus augmentation.

In an animal study conducted by **Lopez *et al*.** in **2017** to assess the biomechanical and histological effects of OD surgical instrumentation, it was concluded that this technique can potentially improve the safety and success rates of bony drilling at all sites of low bone density and limited BV. Another histomorphic study concluded that the trabecular bone quantity and integrity immediately surrounding the implant appeared visibly more intact, denser, and more consistent in distribution through OD preparation than the other methods tested (standard extraction drilling, Summers osteotomes) that was evident both laterally and apically to the implant body **(Slete *et al*., 2018)**.

On the other hand, **Trisi *et al*.** in **2016** observed that the increase of bone density in the OD site was evident in the most coronal implant site where the bone trabeculae were thickened because of incorporation of autogenous bone fragments during healing.

4.4 The effect of some predictor variables on the outcome variables

The correlation between predictor variables and dental implant stability and bone density was non-significant in most instances probably due to the small sample size of this study.

Gender did not affect implant stability throughout the study period, which is in line with other studies **(Fuster-Torres *et al*., 2011; Shiffler *et al*., 2016)** that made similar observations in dental implants inserted by conventional drilling. Other studies, on the other hand, reported different results where significant differences were observed in relation to gender, higher implant stability in females compared with males was reported by **(Mesa *et al*., 2008; Aksoy *et al*., 2009; Alghamdi *et al*., 2011)**; whearas **Park *et al.*** in **2012** demonstrated higher ISQ values in males compared to females.

Regarding the age, primary implant stability in the age group 30-39 was the highest whereas the 60-69 age group recorded the lowest primary stability, while the effect of age on implant stability during the 6^{th} and 12^{th} weeks was non-significant. Some studies **(Rokn *et al*., 2011; Wang *et al*., 2012; Shiffler *et al*., 2016)** reported that age did not seem to affect implant stability, while other studies noticed that when age increases the primary and secondary stability decreases probably due to the fact that with aging bone becomes less in both quality and quantity; these changes occur especially in cancellous compartment due to high oxidative stress with aging that affects the osteoclast activity positively within the bone trabeculae **(Manolagas, 2010; Negri *et al*., 2014)**.

This study demonstrated that the implant stability was higher in the lower jaw than the upper jaw throughout the entire healing period which is in concordance with other studies that concluded that intraoral location is an important factor in implant stability, with implants placed in mandible being more stable than implants placed in maxilla both at placement and follow up due to the

higher proportion of lamellar bone to cancellous bone in the mandible **(Farré-Pagès *et al*., 2011; Jeong *et al*., 2015; Shiffler *et al*., 2016)**. On the contrary, a study by **Bischof *et al*.** in **2004** found that a higher ISQ was seen in the maxilla than in the mandible.

The primary stability was higher for implants that were inserted with >35 N/cm than those inserted with <35 N/cm which is in agreement with some studies **(Turkyilmaz *et al*., 2007; Farré-Pagè *et al*., 2011)** that observed that the correlation between primary implant stability values and insertion torque was statistically significant. **Trisi *et al*.** in **2011** also found that high insertion torque is an indicator of good primary stability and is necessary for early or immediate loading. On the other hand, **Friberg *et al*.** in **2003** and **Da Cunha *et al*.** in **2004** reported no relationship between insertion torque and implant stability probably due to the difference in the type of implants that were used. Other authors reported that the insertion torque and initial stability increased according to the increase in the bone density, resulting in a strong positive correlation **(Bayarchimeg *et al*., 2013)**.

With respect to implant dimensions, this study showed that implant diameter had significant effect on primary and secondary implant stability which is in concordance with other studies **(Turkyilmaz *et al*., 2008; Bilhan *et al*., 2010)** who found significant correlations between implant diameter and stability, this is attributed to the increased surface area of BIC and more bone deposition on implant surface **(Barikani *et al*., 2013)**. Other reports, on the other hand, found no relationship between implant diameter and stability **(Digidi *et al*., 2012; Shiffler *et al*., 2016)**.

The effect of implant length on implant stability in this study was non-significant, which is agreement with the findings of **Shiffler *et al*.** in **2016** who reported no significant effect of implant length on stability. Other authors reported that implant length (and not diameter) is significantly correlated to stability **(Aparicio, 1997; Horwitz *et al*., 2003)**, while **(Teerlink *et al*., 1991)** found that

neither length nor diameter of the implant correlated with implant stability.

Bone density was higher in males than female both preoperatively and postoperatively and the difference was statistically significant which is in agreement with the findings reported by **(Barunawaty, 2011)** when CT scan was used to evaluate the bone around the implants 2 months after implant installation. Some studies **(Turkyilmaz and McGlumphy, 2008; Aksoy *et al*., 2009)** also concluded that density values (HU) were higher in men than in women.

According to the results of this study, age did not affect the bone density significantly preoperatively and postoperatively, while other studies **(Farré-Pagès *et al*., 2011)** demonstrated that older patients show a decrease in the bone density. **Jang *et al*.** in **2011** maintained that as people get older, bone density decreases because the amount of bone resorption is greater than amount of bone production and, as the cortical bone becomes thinner, porosity increases in cancellous bone.

Bone density values were higher in the mandible preoperatively and postoperatively compared to that of the maxilla but the difference was statistically non-significant, while some studies reported significantly higher HU values in the mandible than maxilla **(Aksoy *et al*. 2009; Farré-Pagès *et al*., 2011)**.

There was no statistically significant difference in bone density preoperatively and postoperatively in relation to insertion torque. Some studies, however, observed that a significant increase in insertion torque and a concomitant reduction in micromotion was noted using OD with an increase in bone density values **(Trisi *et al*., 2015)**. In addition, **(Homolka *et al*., 2002)** found a significant correlation between bone mineral density measurements and the insertion torque measurements in cadaver mandibles.

4.5 The survival rate in relation to different factors

According to the results of this study, the survival rate obtained was 93.5% which is within the range reported in dental implants installed after conventional drilling (92-100%): **(Ivanoff *et al*., 1999; Alsaadi *et al*., 2008; Turkyilmaz *et al*., 2008; Alghamdi *et al*., 2011; Negri *et al*., 2014; Jeong *et al*., 2015)**.

There are various causes related to early implant failure such as overheating, contamination, trauma during surgery and poor bone quantity and/or quality **(Levin, 2008)**. Three implants (6.5 %) failed to osseointegrate during the follow up period, two of which were inserted in female patients within the ischemic functional implant zone supported by the findings of (**Tolstunov, 2007)** that reported that insufficiency of the arterial blood flow and related poor wound healing in this zone can contribute to failure of dental implants. Findings of this study were in concordance with that reported by other studies that found higher implant failures within the posterior mandible **(Raikar *et al*. 2017)**.

Alsaadi *et al*. in **2007** found significantly more failures in the posterior region of both jaws compared to the anterior mandibular region. Other clinical studies, however, revealed a higher survival rate for dental implants in the mandible **(Malo *et al*., 2003)**. However, in a prospective study by (**Alsaadi *et al*., 2008)**, the implant site was not a significant factor in implant failure.

All of the three failed implant were inserted in patients over 50 years old that is in line with other studies that demonstrated that when age increases, failure rate had a tendency of increment **(Raikar *et al*., 2017)**.

The failed implants within this study were placed in D4 and D5 bone density which is in agreement with findings of other studies that found that sites with moderate to poor bone quality (D3-D5) had 3.7 times greater implant loss versus sites with good bone quality (D1 or D2) **(Becker *et al*. 2000)**.

4.6 Limitations of the study

The main limitations of this study are:

- Its observational design and lack of a control group to compare the outcome variables between OD and conventional methods.
- Small sample size.
- Short follow up period that does not include a long-term assessment of the implant success or complications after the fabrication of the prosthesis and functional loading.

Chapter Five

Conclusions and Suggestions

Conclusions and Suggestions

5.1 Conclusions

Taking in consideration the limitations of this study, the following conclusions can be listed:

1. OD technique resulted in high primary stability and increased bone mineral density apical to the implant in low-density bone.
2. During the healing period, implant stability drops significantly in the first 6 weeks postoperatively, and then increases steadily in the following weeks to reach to a level close to that of primary stability after 12 weeks.
3. Implant stability during the healing period was not affected by age, gender and implant length.
4. Better implant stability was obtained in the mandible during the entire healing period.
5. Dental implants inserted with more than 35 N/cm using OD technique showed higher primary stability.
6. Wider implants resulted in higher primary and secondary implant stability.
7. Higher bone density was recorded in males both preoperatively and postoperatively.

5.2 Suggestions

1. Conducting similar study with larger sample size and longer follow up period to assess the effect of OD on crestal bone resorption, the success rate and the complications after functional loading.
2. Conducting a study that compares the outcome of OD technique with conventional implant site preparation.
3. Conducting a study in which the implant stability is assessed using resonance frequency analysis for implants inserted using OD technique.

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Appendices

Appendices

Appendix I

University of Baghdad - College of dentistry

Department of Oral & Maxillofacial Surgery

Study case sheet

No

Personal data

Name: Age:

Gender: Occupation:

Phone number: Date: / /

Medical history:……

Medications _____ Allergy_____

Social habits:

Smoking Alcohol Others

Parafunctional habits: Bruxism Clenching

Clinical examination:

Extraoral examination:

Facial symmetry TMJ Lymph nodes

Intraoral examination:

- Oral hygiene : Good Fair Poor
- Intercoronal distance of the recipient implant site
- Distance between alveolar crest and the opposing teeth or ridge
- Inter-ridge distance at maximum opening

Jaw treated: maxilla mandible both

The width of the bone at the implant site before preparation

Tooth (teeth No. site)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17

Radiographic examination: Preoperative bone density(CBCT)

Tooth No. site	Min.	Max.	Std.	Mean

Available bone height
Surgical procedure:
Flapped surgery **Conserved** **Extensive**

The width of the bone at the implant site after preparation

Insersion torque:

Type of dental implant placed **Number of DI placed**

Dental implant dimensions
Primary stability

Tooth No. site			**Mean**

2nd stage surgery
Follow up:
Radiographic examination: CBCT (Within 7 days postoperatively)

Postoperative bone density

Tooth No. site	**Min.**	**Max.**	**Std.**	**Mean**

Implant stability (6 weeks postoperatively)

Tooth No.site			**Mean**

Secondary stability (12 weeks postoperatively)

Tooth No.site			**Mean**

CBCT (bone density change) around the implant (Within 7 days)

Tooth No.site	**Min**	**Max.**	**Std.**	**Mean**

Appendix II

College of Dentistry – Baghdad University

Department of Oral & Maxillofacial Surgery

Dental Implantology

Name:

Age:

Gender:

Occupation:

Telephone N0.

Address:

General Health: BHP 1 2 3

Patient Interrogation: Obsessional neurosis Availability

Esthetic demands: (realistic high unrealistic)

Etiology of Eduntulism: caries trauma periodontal disease occlusal trauma

Extraoral Exam: Smile line → dental gingival

Intraoral Exam:

Missing teeth to be replaced by DI:

Hygiene: good moderate poor

Pathology: no yes

Depth of vestibule: good poor

Alveolar crest width: wide sharp

Vestibular concavity: no yes

Jaw opening: 3 fingers 2 fingers 1finger

Interarch distance at maximal opening: mm

Mesiodistal distance: mm

Height between alveolar crest and opposing teeth or ridge: mm

Vertical bone resorption: no yes

Gingiva: thick & fibrous fine

Papillae of adjacent teeth: flat scalloped

Periodontal evaluation: gingivitis treated periodontitis active periodontitis

Functional evaluation: bruxism – parafunction no

Radiographic Exam: OPG CT Periapical Others

Chronic lesions: close to implant zone distant from implant zone

Bone density: D1 (type I) D2 (II) D3 (III) D4 (IV)

Vertical bone resorption: no yes

Study models surgical template

Surgical (operative) data: Treatment protocol → I (delayed) II (intermediate) III (immediate) Jaw operated upon → maxilla mandible

DI system: N0 of DI

DI dimensions: Surgical approach →

Level of DI in relation to crest:

Bone expansion bone condensation: GBR→ barrier membrane space filler

Bone grafting

Sinus Lift

Surgical notes:

……
……

Length of healing phase: 2nd stage surgery: Uncoverage → tissue punch scalpel others Gingival former dimensions→

Follow-up and maintenance: Complications:

Appendix III

العدد: ٤٢
التاريخ: ٩/ ١/ ٢٠١٩
رمز البحث: ٠٤٢١١٨

م/ قبول بحث

إلى الزميلة الدكتورة **اسيل رعد هندي** المحترمة
والزميل الدكتور **سلوان يوسف** المحترم

نود اعلامكم بأن لجنة اخلاقيات البحوث في كلية طب الأسنان – جامعة بغداد اطلعت على مشروع البحث المقدم من قبلكم والموسوم:

The Assessment of dental implant stability after osteotomy site preparation by Osseodensification drilling system: A prospective clinical radiographic study.

ولا ترى اللجنة ما يمنع من القيام بالبحث من الجانب الاخلاقي.

مع التقدير.

د. أكرم فيصل الحويزي
رئيس لجنة اخلاقيات البحوث

Appendix IV

كلية طب الأسنان جامعة بغداد

إستمارة معلومات المريض

أنت مدعو(ة) للمشاركة في بحث علمي سوف يجري في .....قسم جراحه الفم والوجه والفكين / كلية طب الاسنان /جامعة بغداد..... الرجاء أن تأخذ(ي) الوقت الكافي لقراءة المعلومات التالية بتأن قبل أن تقرر(ي) إذا كنت تريد(ين) المشاركة أم لا. بإمكانك طلب إيضاحات أو معلومات إضافية عن أي شيء مذكور في هذه الاستمارة أو عن هذه الدراسة ككل من الباحث كما يمكنك مناقشتها مع أي شخص آخر.

في حال وافقت على المشاركة في هذه الدراسة، سيبقى اسمك طي الكتمان. لن يكون لأي شخص، ما لم ينص القانون على ذلك، حق الاطلاع على ملفك الطبي باستثناء الباحثين المسؤولين عن الدراسة.
تعتبر المشاركة في هذه الدراسة تطوعية تمامًا وأنت حر(ة) في رفض المشاركة أو الانسحاب من الدراسة في أي وقت

معلومات عن البحث (يجب أن تكتب من قبل الباحث بلغه بسيطه مجيبة عن الأسئله التاليه قدر الإمكان)

1. عنوان الدراسة؟ تقييم استقرارية زراعة الأسنان بعد التحضير في موقع العظم عن طريق نظام حفر التكثيف العظمي .
2. ما هو الغرض من هذه الدراسة ؟ تقييم كفاءة نظام الحفر الجديد (التكثيف العظمي) في الصفات العظمية المتوسطة والناعمة.
3. أين سوف تجرى الدراسه؟ في عياده طب الاسنان لقسم جراحه الفم والوجه والفكين في كليه طب الاسنان جامعه بغداد
4. ما هي الإجراءات التي يجب اتباعها وما الذي سيطلب مني القيام به في كل زيارة؟ سيطلب من المريض أخذ التصوير المقطعي المحوسب المخروطي لتحديد نوعية العظام في موقع الزرع المزمع. مباشرة بعد إدخال زرع الأسنان باستخدام نظام الحفر OD ، سيتم قياس استقرار الزرعه (الاستقرار الأولي). سيتم أخذ التصوير المقطعي المحوسب المخروطي الثاني في غضون أسبوعين بعد تركيب الغرسة. بعد 6 أسابيع ، سيتم كشف الغرسات ، وحساب استقراريه الزرعه، بعدها يوضع مكون اللثه . ثم بعد 12 أسبوعًا ، يتم إجراء قياس الاستقرار الزراعى (الاستقرار الثانوي) وسيتم إحالة المرضى لتصنيع الجزء التعويضي.
5. إلى متى ستستمر مشاركتي في الدراسة؟ ثلاثه اشهر .
6. إذا قررت المشاركة في الدراسة، هل سيختلف العلاج عن العلاج الذي سأحصل عليه بخلاف ذلك؟ كلا .
7. من يجب أن لا يدخل في الدراسة؟ المرضى الذين يعانون من أمراض جهازية غير مسيطر عليها - المرضى الذين تقل أعمارهم عن 18 سنة - المرضى الذين لديهم تاريخ العلاج الإشعاعي في الرأس والرقبة - الحاجة إلى تعزيز العظم في موقع الزرع المقصود - عدوى نشطة أو التهاب في منطقة الزرع.
8. ماذا ستكون فوائد الدراسة:

(أ) لطفلك او لك ؟ تحسين نوع العلاج
(ب) للباحث ؟ تقييم كفاءة نظام الحفر الجديد (التكثيف العظمي) في الصفات العظمية المتوسطة والناعمة.

9. ما هي المخاطر المحتملة للمشاركة؟ لا توجد
10. عندما اشعر بعدم راحة أو ألم أثناء الدراسة، هل سأتمكن من تناول اي دواء مهدئ؟ نعم تستطيع
11. هل ستتداخل مشاركتي في الدراسة مع أنشطتي اليومية؟ لا .
12. هل سأبلغ بنتائج الدراسة؟ نعم اذا احببت ان تبلغ بالنتائج.

دون الحاجة إلى إعطاء سبب ودون أن يؤثر هذا على الرعاية الطبية المستقبلية أو علاقتك مع الطاقم الطبي الذي يعتني بك.

نشكرك على قراءة ورقة المعلومات هذه والنظر في مشاركتك في هذه الدراسة

موافقة للإشتراك في بحث علمي

	الرجاء التأشير للموافقة
أؤكد بأني قد قرأت وفهمت المعلومات التي تخص البحث أعلاه وقد كان لدي الوقت الكافي لطرح الأسئلة المتعلقة بالموضوع وتمت الإجابة على أسئلتي جميعا.	
أتفهم أن مشاركتي في البحث تطوعية وأني حر(ة) في الإنسحاب من المشاركة في أي وقتبدون أن يؤثر ذلك على الرعاية الطبية المقدمة لي.	
أتفهم أن معلوماتي ذات الصلة بالبحث سوف يتم الإطلاع عليها من قبل الإشخاص المسؤولين عن البحث في كلية طب الأسنان – جامعة بغداد وأعطي الموافقة بذلك.	
أوافق على المشاركة في البحث المذكور أعلاه.	

فيما يتعلق بأي معلومات أو بيانات تأخذ خلال البحث، يرجى تحديد موافقتكم على نشرها حسب رغبتكم					
	بيانات شخصيه	أشعه	صور الوجه	صور الفم	أخرى
تبقى سريه					
لغرض الأستشارات					
لغرض التعليم					
في المؤتمرات					
لغرض النشر في المجلات العلميه					

	الإسم	**التوقيع**	**التأريخ**
المشترك			
الأب/الأم أو الوصي (عند الحاجه)			
الشخص المسؤول عن مليء الأستماره			

شخص يمكن الأتصال به:

الاسم:

رقم الهاتف:

البريد الإلكتروني:

College of Dentistry – University of Baghdad

Patient Information Sheet

Information about the research (to be written by the researcher in a simple language answering the following questions when applicable)

1. Study title . Assessment of dental implant stability after osteotomy site preparation by Osseodensification drilling system .

2. What is the purpose of this study? The aim of this study is to assess the effect of a new drilling system (Osseodensification) on implant stability in medium and soft bone qualities.

3. Where will the study be conducted? department of surgery in the teaching hospital of dentistry college /University of Baghdad/Iraq .

4. What are the procedures to be followed and what will you be asked to do at each visit? Patient will be asked to take cone beam CT to determine bone quality in the planned implant site. Immediately after insertion of dental implant using OD drilling system, the implant stability will be measured (primary stability) .A second CBCT will be taken within 2 weeks after implant installation .After 6 weeks, the implants will be exposed, their resonance frequency will be measured, and gingival former will placed. Then after 12 weeks implant stability measurement will be made (secondary stability) and the patients will be referred for fabrication of prosthesis.

5. How long will the participation in the study last? 3 months.
6. If you decided to taking part in the study, will the treatment be different from the treatment you would get otherwise? No.
7. Who should not enter the study? Patients with uncontrolled systemic diseases – patients under 18 years of age – Patients with history of radiotherapy to the head and neck - Need for bone augmentation at the intended implant site - Active infection or inflammation in the implant zone.

8. What will be the benefits of the study?
   a) To the participant? Improvement of treatment.
   b) To the investigator? Assessment of the effect of (Osseodensification) drilling system on implant stability in medium and soft bone qualities.
9. What are the possible risks of taking part? No risk.
10. If you feel severe discomfort or pain during the study, would you be able to take any relief medication? Yes.
11. Will your participation in the study interfere with your daily activities? No .
12. Will you be informed of the results of the study? Yes if you wish so .

You are invited to participate in a scientific research. Please take your time to read the following information carefully before you decide whether or not you wish to participate. You can ask for clarifications or any more information about the study from the researcher and you can discuss this with outsiders.

If you agree to participate in this study, we will ensure your confidentiality with no one except the study researchers have the right to access your dental (medical) notes.
Participation in this study is entirely voluntary and you are free to refuse to take part or to withdraw from the study at any time without having to give a reason and without this affecting your future medical care or your relationship with medical staff looking after you.

Thank you for reading this Information Sheet and considering your participation in this study

Consent Form

	Please tick to confirm
I confirm that I have read and understood the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.	
I understand that my participation is voluntary and that I am free to withdraw at any time without any medical/dental care affected.	
I understand that relevant sections of my medical notes and data collected during the study may be looked at by individuals from the College of Dentistry – University of Baghdad where it is relevant to my taking part in this research. I give permission to these individuals to have access to my records.	
I agree to take part in the above study.	

Regarding any information and records taken during the research please specify your acceptance to share them as you desire:					
	Personal Data	X-rays	Extra-oral Photographs	Intra-oral photographs	Others
Confidential					
For consultation					
For teaching					
For conferences					
For publication					

	Name	**Signature**	**Date**
Participant			
Parent/guardian (if appropriate)			
Person taking consent			

Person to contact:

Name:

Phone No.:

Email:

الخلاصه

الخلفية: التكثيف العظمي هي تقنية غير استخراجية وضعت من قبل هويس في عام 2013 وجعلت ممكنه من خلال الأزيز المصممة خصيصا لزيادة كثافة العظام لأنها توسع بضع العظم وتسمح بالحفاظ على العظام وتكثيفها من خلال ضغط التطعيم الذاتي أثناء تحضير فغر العظم، مما يزيد من كثافة العظام المحيطة بالزرعة، والاستقرار الميكانيكي للزرعة.

أهداف الدراسة: تقييم تأثير تحضير موقع الزرع في عظام منخفضة الكثافة باستخدام طريقة التكثيف العظمي على تغيرات استقرار الزرعة خلال فترة الشفاء العظمي، لتقييم تأثير التكثيف العظمي على كثافة العظام المحيطة بالزرعة باستخدام التصوير المقطعي المحوسب ذو الشعاع المخروطي ولتحديد تأثير بعض المتغيرات (العمر، الجنس، الفك، عزم الدوران عند الإدراج وأبعاد الزرعة) على ثبات زرعات الأسنان وعلى كثافة العظام المحيطة بالزرعة.

المواد والطرق: شملت هذه الدراسة السريرية المرتقبة 24 مريضا(17 انثى و7 ذكر) تلقوا 46 زرعه سنيه التي تم تثبيتها في العظام منخفضة الكثافة باستخدام طريقه التكثيف العظمي. تم استخدام جهاز التصوير المقطعي المحوسب ذو الشعاع المخروطي لقياس كثافة العظام قبل وبعد الجراحة وتم قياس ثباتيه الزرعات باستخدام جهاز قياس الثباتية (البريوتيست) مباشرة بعد إدخال الزرعات وبعد 6 أسابيع و12 أسبوعًا بعد العمل الجراحي. تم تحليل المعطيات باستخدام unpaired t-test , paired t-test، واختبار مقارنات ANOVA و Tukeyالمتعددة، ومعامل ارتباط Pearson .قيم الاحتمالات < 0.05 اعتبرت ذات دلالة إحصائية.

النتائج: من بين 46 زرعه،43 زرعه اندمجت عظميا مما جعل البقاء المبكر للزرعات 93.5٪. كانت هناك زيادة كبيرة في الكثافة العظمية بعد العمل الجراحي 337.6 ±182.9 مقارنة بـ 265.3±173.9 وحدات هونسفيلد قبل الجراحة. كان استقراريه الزرعة الأولية 2.7- (± 2.13) PTV باستخدام جهاز قياس الثباتيه (البريوتيست) ، في الأسبوع السادس انخفضت بشكل كبير لتصبح 0.7 (±4) PTV ، وفي الأسبوع الثاني عشر (الثباتيه الثانوية) زادت بشكل كبير لتصبح 2.1- (± 2.8) PTV كان الفرق بين الاستقراريه الأولية والثانوية غير مهم إحصائياً (p= 0.0814).

الخلاصة: أدى التكثيف العظمي إلى استقراريه اوليه عالية وزيادة كثافة العظام المحيطة بالزرعة لكنه لم يمنع هبوط ثباتيه الزرعة خلال الأسابيع 6 الأولى بعد إدخال الزرعة.

جمهورية العراق
وزارة التعليم العالي والبحث العلمي
جامعة بغداد
كلية طب الأسنان

تقييم تأثير التكثيف العظمي على ثباتية الزرعة والكثافة العظمية في العظام منخفضة الكثافة: دراسة سريرية

رسالة مقدمة الى مجلس كلية طب الاسنان في جامعة بغداد كجزء من متطلبات نيل شهادة الماجستير في جراحة الفم والوجه والفكين

قدمت من قبل
أسيل رعد هندي
بكالوريوس طب وجراحة الفم والأسنان

اشراف
أ. د. سلوان يوسف حنا
بكالوريوس طب وجراحة الفم والاسنان
زميل المجلس العراقي للاختصاصات الطبية
جراحه الفم الوجه والفكين

١٤٤١ هـ **٢٠٢٠ م**