T.C.
YEDITEPE UNIVERSITY
INSTITUTE OF HEALTH SCIENCES
DEPARTMENT OF ORAL AND MAXILLOFACIAL SURGERY

COMPARISON OF THE EFFECT OF CONVENTIONAL AND OSSEODENSIFICATION DRILLING TECHNIQUES ON PRIMARY STABILITY, IN INSERTION OF SHORT DENTAL IMPLANTS INTO D4 BONE WITH INSERTION / REMOVAL TORQUES AND RESONANCE FREQUENCY ANALYSIS

PhD Thesis

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APPROVAL

This thesis has been deemed by the jury in accordance with the relevant articles of Yeditepe University Graduate Education and Examinations Regulation and has been approved by Administrative Board of Institute with decision dated .... and numbered ....

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DECLARATION

I hereby declare and solemnly confirm that I wrote this study presented as doctoral thesis without resorting to a path or assistance against scientific ethics and traditions, the studies I used as reference are the ones stated in the references section, and I used quotations whenever I used these studies. Without being bound by a certain time by the Institute, I declare that I will bear all the moral and legal consequences that will arise in the event of a situation about my thesis which is contrary to this declaration.

30 / 06 / 2022
Fikri Can AYIK

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

ATH:	Acceleration Time History
BIC:	Bone to Implant Contact
BMD:	Bone Mineral Density
BV:	Bone Volume
Ca:	Calcium
Co:	Cobalt
Cr:	Chromium
CT:	Computed Tomography
Et Al:	And others
HA:	Hydroxyapatite
HCL:	Hidrocloric Acid
H_2SO_4 :	Sulfuric Acid
IAN:	Inferior Alveolar Nerve
ISQ:	Implant Stability Quotient
MAO:	Micro Arc Oxidation
mm:	Millimeter
Mo:	Molybdenum
Ncm:	Newton Centimeter
OD:	Osseodensification
P:	Phosphate
RBM:	Resorbable Blasting Media
RFA:	Resonance Frequency Analysis
SD:	Standard Deviation
SLA:	Sandblasted and Acid Etched Surfaces
TCP:	Tricalcium Phosphate
Ti:	Titanium

ABSTRACT

Ayık F.C. (2022). Comparison of the Effect of Conventional and Osseodensification Drilling Techniques on Primary Stability, in Insertion of Short Dental Implants into D4 Bone with Insertion / Removal Torques and Resonance Frequency Analysis. Yeditepe University, Faculty of Health Sciences, Department of Oral and Maxillofacial Surgery, Ph.D. Thesis. Istanbul.

Bone density is a determining factor in short dental implant treatments and the survival rates of short dental implants applied in the maxilla are lower. Implant losses were experienced in areas with low bone density due to peri-implant forcing and tensions. For this reason, short dental implants inserted in low-density D3-D4 bone types such as posterior maxilla by conventional drilling technique are less successful than high-density D1-D2 bone types such as mandible. The aim of this study is to compare the primary stability of 5 mm short dental implants placed in artificial bone blocks mimicking the structure of D4 posterior maxilla, using conventional and osseodensification (OD) drilling techniques with resonance frequency analysis (RFA), insertion and removal torque tests. A total of 42 short dental implants, 4.8 mm in diameter and 5 mm in length were applied to the same polyurethane bone block, which imitates the structure of D4 type posterior maxilla with different conventional and osseodensification osteotomy techniques. The result of this study showed that insertion torque values and removal torque values were statistically greater when the short dental implants were placed with the osseodensification drilling technique, ($p<0.001$). Similarly, Implant Stability Quotient (ISQ) values were statistically greater when the short dental implants were placed with the osseodensification drilling technique compared to the conventional drilling technique ($p<0.001$). As a result, the short dental implant placed with the osseodensification drilling technique in the low-density bone (D4) type is more successful than the implant placed with the conventional drilling technique. These findings are in line with the literature that is related to the standard implant diameters and length. Short dental implants placed with osseodensification drilling technique can be used as an alternative to augmentation techniques when dental implants are placed within D4 bone type. Further research is needed for different sizes for aggressive implant types.

Key Words: Primary Stability, Osseodensification, Insertion and Removal Torque

ÖZET

Ayık F.C. (2022). Kısa Dental Implantların D4 Kemik Tipine Yerleştirilmesinde, Konvansiyonel ve Osseodensifikasyon Frezleme Tekniklerinin Primer Stabiliteye Etkisinin, Yerleştirme/Çıkarma Torkları ve Rezonans Frekans Analizi ile Karşılaştırılması. Yeditepe Üniversitesi, Sağlık Bilimleri Enstitüsü, Ağız Diş ve Çene Cerrahisi Anabilim Dalı Doktora Tezi. İstanbul.

Kısa dental implant tedavilerinde kemik yoğunluğu belirleyici bir faktördür ve maksillaya uygulanan kısa dental implantların sağ-kalım oranları daha düşüktür. Düşük kemik yoğunluğu olan bölgelerde peri-implant zorlanma ve gerilmeleri sebebi ile, implant kayıplarının yaşandığı bildirilmiştir. Bu sebeple özellikle konvansiyonel frezleme tekniğiyle posterior maksilla gibi düşük yoğunluklu D3-D4 kemik tipine yerleştirilen kısa dental implantların, mandibula gibi yüksek yoğunluklu D1-D2 kemik tiplerine göre daha az başarılı oldukları bildirilmiştir. Bu çalışmanın amacı, konvansiyonel ve osseodensifikasyon (OD) frezleme teknikleri kullanılarak posterior maksillayi taklit eden D4 tipi kemiğe yerleştirilen 5 mm boyundaki kısa dental implantların primer stabilitesinin Rezonans Frekans Analizi (RFA), yerleştirme ve çıkarma tork testleri ile karşılaştırılmasıdır. Aynı poliüretan kemik blokları üzerine farklı osteotomi teknikleriyle, 4.8 mm çapında ve 5 mm boyunda 42 dental implant uygulanmıştır. Bu çalışmanın sonuçları, kısa dental implantların osseodensifikasyon frezleme tekniği ile yerleştirildiğinde yerleştirme ve çıkarma tork değerlerinin istatistiksel olarak daha yüksek olduğunu göstermiştir ($p<0,001$). Benzer şekilde, kısa dental implantlar osseodensifikasyon frezleme tekniği ile yerleştirildiğinde ISQ değerleri konvansiyonel frezleme tekniğine göre istatistiksel olarak daha yüksek gözlenmiştir ($p<0,001$). Sonuç olarak düşük yoğunluklu D4 kemik tipinde osseodensifikasyon frezleme tekniği ile yerleştirilen kısa dental implantlar, konvansiyonel frezleme tekniği ile yerleştirilen implanta göre daha başarılıdır. Bu bulgular, standart implant çapları ve uzunlukları ile ilgili literatür ile uyumludur. Osseodensifikasyon frezleme tekniği ile yerleştirilen kısa dental implantlar, D4 kemik tipine yerleştirildiğinde ogmentasyon tekniklerine alternatif olarak kullanılabilir. Farklı boylardaki agresif implant tipleri için de daha fazla araştırmaya ihtiyaç vardır.

Anahtar Kelime: Primer Stabilite, Osseodensifikasyon, Yerleştirme ve Çıkarma Tork

1. INTRODUCTION AND PURPOSE

In recent years, implant treatment has been widely used in dental deficiencies and it has been shown in the literature that implants have achieved high success in cases where vertical and horizontal dimensions of alveolar bone are sufficient. Especially in edentulous cases, implant treatment has an important role as an alternative to conventional prosthetic approaches to eliminate the patient's aesthetic concerns and restore function. However, in cases where the vertical size of the alveolar bone is not sufficient, it is not appropriate to place standard implants, and advanced surgical treatments such as elevating the sinus floor, inferior alveolar nerve (IAN) repositioning, or bone augmentations are commonly applied. Although very successful reports about such surgical operations have been published, the risks of complications in these operations are quite high (1,2).

Short dental implant may be a better treatment method as being less aggresive application and therefore in resulting patient satisfaction (3). Bone density is a determining factor in short dental implant application and the survival rates in the maxilla are lower. It has been reported that implant losses were experienced in areas with low bone density due to peri-implant forcing and tensions. For this reason, short dental implants inserted in low-density D3-D4 bone types such as posterior maxilla by conventional drilling technique are less successful than high-density D1-D2 bone types such as mandible (3).

For preparation of dental implant site, a variety of osteotomy systems has been suggested in the literary works. In low-density alveolar ridges, osseodensification is a drilling method which was recommended for increasing implant durability and local bone quality. By improving the neighboring bone’s density, this approach decides the growth of the implant site (4).

Primary stability, defined as the interface of the implant facial with the surrounding bone, is a predictor of the implant's capacity to maintain its health over time, and hence the therapy's effectiveness (5). Analysis of resonance frequency (RFA) is one of the primary ways for assessing osteointegration, and it gives essential clinical objective information regarding implant durability (6).

Moreover, one of the most prominent clinical indicators of primary stability of dental implants is insertion torque (IT) (7,8,9,10,11). During device placement, this quantity is connected to the mechanical frictional interactions between the surrounding and the bone implant fixture (7,10).

The torsional power necessary for the removal of an implant is called “the value of removal torque (RTV)”, and it has been extensively utilized by a variety of scholars to determine the interaction between the surrounding bone of the implant and the implant’s surface (12,13,14,15,16). The force required for the removal of the implant rises in proportion to the torsional resilience of the bone-implant contact, and thus the implant's anchoring capacity (15,17,18).

The aim of this study is to compare the primary stability of 5 mm long-short dental implants placed in D4 bone mimicking the posterior maxilla using conventional and osseodensification (OD) drilling techniques with resonance frequency analysis (RFA), insertion and removal torque tests.

2. LITERATURE REVIEW

2.1. Dental implants

In the past centuries, many methods have been tried to be developed for the replacement of the lost teeth to gain functionality and aesthetics. Implant treatment is one of these methods. Implants are substances that are inserted in living tissues in the body to fulfill their function. Structures that are planned to serve the role of the tooth in the mucosa, on the bone or in the bone are called dental implants (Figure 2.1) (19). The objective of these treatments is the reintegration of phonetic, aesthetic, functional and psycho-social integrity (20).

At the end of the surgical procedures, it was determined that there was integration at different rates between the implant surface and the bone. It was stated that remnants of bone and normal bone tissue are at this interface together with the hematoma formed during the implant construction phase.

This introduced the idea of posseointegration between the bone in implants and titanium (Ti) surface. This concept will be explained in the following sections of the thesis (21).

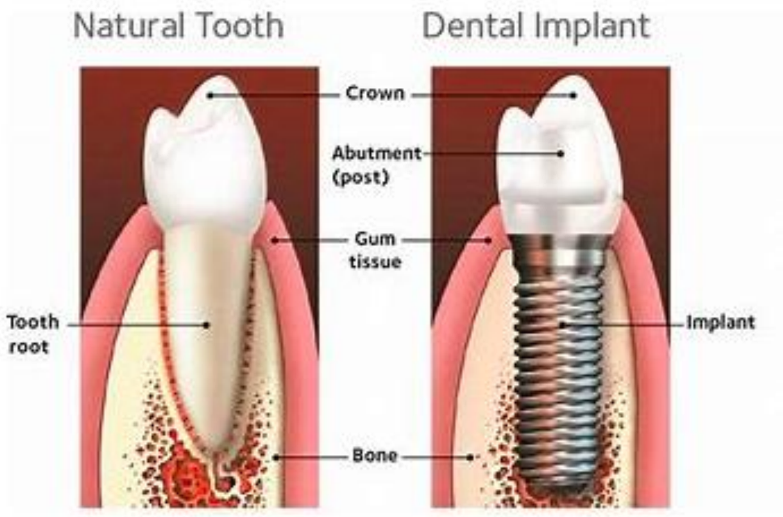


Figure 2.1. Dental implant

2.2. History of oral implantology

It was observed that instead of tooth sockets, sea shells were placed on the mandible, which were found in archaeological excavations before the discovery of America (22,23). In addition, ivory teeth found in ancient Egypt are among the oldest examples in implantology (24).

In the 16^{th} century, Ambroise Pare focused on transplantation and many attempts were made in the subsequent centuries (25).

For instance, Mr. Dupont removed the nerves of extracted teeth and replaced the teeth to their sockets in the 17^{th} century.

In the 18^{th} and 19^{th} centuries, teeth from poor people were extracted and inserted to rick people in British and American colonies. However, it has been observed that every study has resulted in ankylosis or root resorption. Thus, it was thought that the missing teeth should be replaced with other materials (26).

Maggiolo (1809) replaced the newly extracted tooth with a gold implant, but later observed pain and inflammation in the area. Over the years, many materials that can be used as dental implants have been tried.

Lambotte provided the production of silver, aluminum, magnesium, gold, nickel, red copper-plated mild steel implants in the early 1900s (27).

In 1938, Strock placed an endosseous implant consisting of a chromium-cobalt molybdenum screw and designed as a conical for cementation. Until patient's death in 1955 implant didn't show any problem. The implant remained stable and asymptomatic. Thus, for the first time success of a metallic implant in humans was proven (28).

Per-Ingvar Branemark was the first to develop root-shaped, threaded, and two-stage implants in North America in 1978. He conducted research with bunnies and found that the titanium discs he inserted in their femurs were osseointegrated (29).

In the following years, Branemark et al. portrayed a major function in the improvement of implant systems (30).

2.3. Implant materials

2.3.1. Metals and alloys

Titanium and titanium 6-aluminum – 4 vanadium

Cobalt – chrome – molybdenum

Iron – chromium – nickel

Titanium is the most commonly used metal. One of the reasons for this is its resistance to liquid attacks in the organism. Other reasons are the suitability of titanium for dental implant design, its resistance to loads, its good resistance corrosion, and its biocompatibility to bone structure. Titanium is self-passivated in the organism and on its surface a titanium oxide layer development is observed. By coating hydroxylapatites on pure titanium, the foreign body reaction was reduced and an effective recovery was observed (1).

An ideal implant material;

- Should not be carcinogenic or cytotoxic.
- Should not cause an allergy.
- Should be biocompatible.
- Should be resistant to pressures and should not undergo physical changes.
- Should be bio-adhesive.
- Should be economical.
- Should be sterilizable.
- Should be wear resistant.
- Should have the ability to be shaped (1).

2.3.2. Titanium in biocompatibility:

After a particular application, biocompatibility refers to a material's capacity to demonstrate an acceptable host reaction (31).

The most important reason why titanium and its alloys have been chosen is their biological compatibility. The biocompatibility of titanium and its alloys is due to its superior corrosion resistance. This corrosion resistance occurs when the oxide coating formed on the exterior of material protects the material against electromagnetic attacks. The excellent osseointegration of titanium with bone and allowing the construction of a calcium phosphate-redundant layer similar to hydroxyapatite (HA) on its exterior are other criteria that determine the biological compatibility (32,33).

Another criterion that determines the biological compatibility is the excellent osseointegration of titanium with the bone under normal conditions and allowing formation of a calcium-rich phosphate layer similar to hydroxyapatite on it. Biocompatibility studies conducted on titanium, a biomaterial, range from a wide variety of in vitro testing to animal trials and in vivo examinations. It has been reported in the literature that corrosion debris of titanium utilized as an osseointegration accumulate in body tissues and local lymph nodes which caused galvanic adverse effects. However, some researchers reported cases of allergic reaction to titanium (34,35,36,37).

In the late 20th century and early 21th century, biocompatibility term was generally defined with low toxicity. The implant's response in the spongy tissue of the location where it is inserted is to establish a relatively acellular foreign body capsule, and titanium, with its limited ion release, fully matches this criteria (36,37).

In their in vivo research, Urban et al. proved that corrosive products can be widely distributed in the body on patients with hip/knee prosthesis, however, they do not cause toxic effects (35). In vitro studies show that titanium doesn't have other toxic effects and mutagenic.

Surface features such as protein binding and metal release capacity influence the metallic implants biocompatibility. In a research comparing titanium and chromium-cobalt (Co-Cr-Mo) implants, it was shown that chromium release was higher than titanium, and it was reported that conformation and protein binding processes differed between the two surfaces (38). Depending on the nature of metal in addition to its alloy, the composition of biofilm and metal ion release define the implant alloys bioreactivity. Titanium metal's superior biocompatibility is owing to its protein conformation and minimal release of ion that occurs on its surface when it comes into contact with body fluids.

The materials characteristics of implant surface portrayed a major function in the biological reaction to these materials. The nature of the implant-tissue interaction is the key current challenge with implants. Wettability, roughness, heterogeneity, crystallization, and chemical properties are all factors that influence surface qualities. Every parameter has a significant impact on the biological response. Processes including ion implantation, plasma and laser application, and hydroxyapatite coating are used to improve the surface properties of titanium implants (39).

2.4. Classification of dental implants:

1) Subperiosteal implants

2) Intramucosal inserts

3) Endosseous (endosteal) implants

4) Transosseous (transmandibular) implants

2.4.1. Subperiosteal implants:

These implants are used in cases where there is too much resorbed crest and bone with insufficient vertical extent. Dentures, both full and partial, can be worn without sinking into the mucosal surface. It was emphasized that the high performance of these implants, which were applied in the 1940s, was 93 percent within a 5-year period. Certain changes have been made in order to spread the incoming forces more evenly over time. In this change, the implant body is extended through the retromolar area and lateral to the ramus. In addition, the implant is coated with hydroxyapatite for a more ideal fit in-between the implant and the bone. The bone is raised with an autogenous bones grafting onto the patrophic bone, and sufficient bone is provided for the implants, also a 3D simulation is generated via CT (computerized tomography) and the implant is applied on this simulation, thus performing the surgical procedure with a single attempt (Figure 2.2) (1).

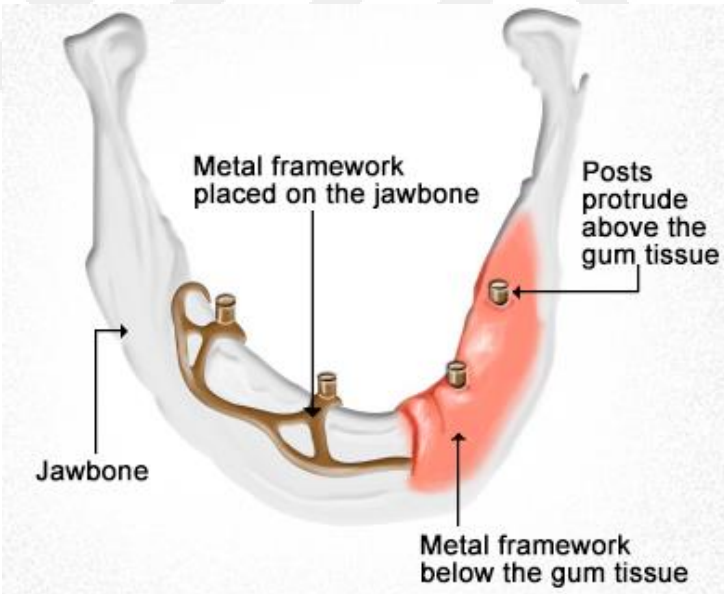


Figure 2.2. Subperiostal implant

2.4.2. Intramucosal inserts:

Gustau Dahi was the first to discuss these structures in 1943. These are titanium formations in the shape of mushrooms that are utilized mostly in maxillary prosthesis. Those structures are preferred in case the labial extensions of the prosthesis to be applied are desired to be short or if the palatal section is not desired in the prosthesis and retention is required because of the atrophic maxilla. Nevertheless, it is not suggested very often nowadays (1).

2.4.3. Endoosseous (endosteal) implants:

They are structures which are immediately osseointegrated into the bone after being implanted. Any connective tissue or space is not left between the implant and the bone.

Nowadays, endoosseous implants are emphasized and they are introduced by various companies every day. Nowadays, there are many different brands of endosseous implants in the world. The most preferred ones are root-shaped implants, which are mostly in the form of screws and cylinders. Success rates of these implants are far higher when compared to other implants.

Osseointegration is provided in the screw-shaped implant by the production of novel bone between the threads by osteoblasts. When compared to other implant types, this implant type has greater primary stability and can be inserted earlier. In addition, it is ensured that the incoming loads are transmitted to the bone more evenly. In cylindrical implants, however, the main durability is directly influenced by the retention of implant surface and the dimension discrepancy among the implant width and the implant hole. Cylindrical implants can also be prepared with perforations to encourage bone growth toward the implant and to improve implant-bone integration. (Figure 2.3) (1).

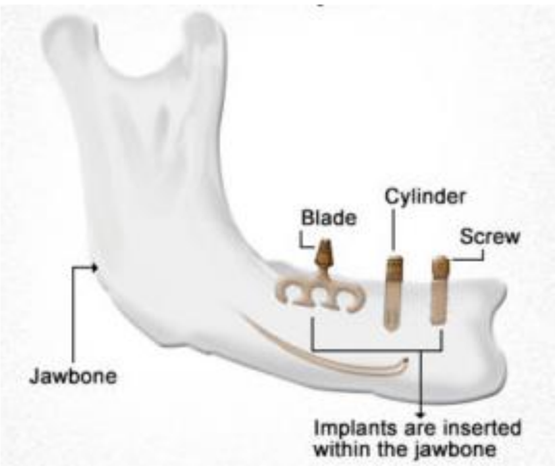


Figure 2.3. Endoosseous implant

2.4.4. Transosseous implants:

This implant system, which was created in 1973, is designed for toothless mandibles subject to extreme atrophy. This used in individuals who had an accident or patients who had severe defects as a result of surgical operation due to tumor or cyst structures in the mandible. Although most guidelines for subperiosteal implants are the same, they can be used if there is an alveolar bone thickness of at least 9 mm in the canine region (Figure 2.4.) (1).

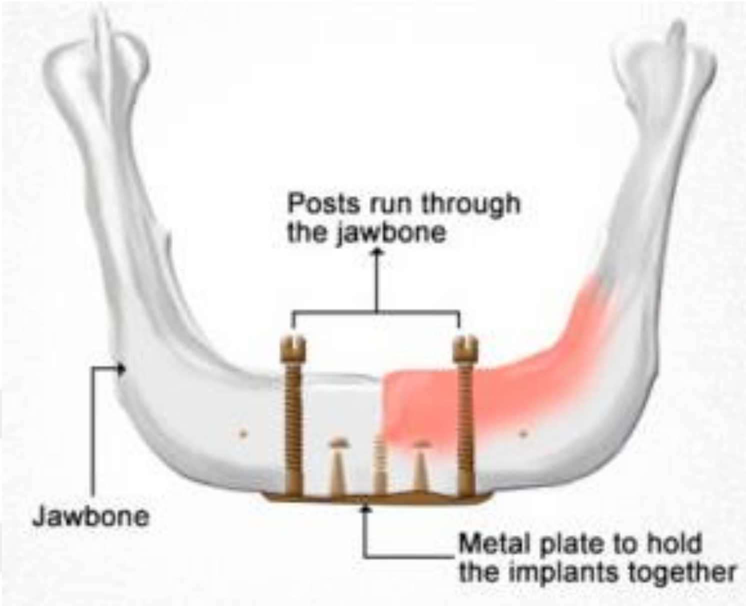


Figure 2.4. Transosseous Implant

2.5. Classification of implants according to surface properties:

a) Implants with unprocessed surfaces

b) Implants with processed surfaces

- Acid etched surfaces
- Sandblasted etched surfaces
- Polished surfaces
- Sandblasted and acid etched surfaces (SLA)
- Laser etched surfaces
- Implants with a porous surfaces
- Porous sintered surface

c) Coated surface implants

- Plasma spray coated surfaces
- Ceramic coated surfaces

1) Tricalciumphosphate coated (TCP)

2) Hydroxyapatite coated (HA)

d) Combined implants (40).

2.5.1. Implants with unprocessed surfaces:

The surface composition of the implants is directly derived from the milling device. The most prevalent discoveries in processed surface implants are circular parallel lines of 0.1nμ depth and width along the long axis of the implant.

2.5.2. Acid etched surfaces:

According to researches, the acid etching procedure enhances the quantity of bone generated on the implant's surface. Acid etching can be performed with hydrochloric acid/sulfuric acid (HCL/H2SO4) or a 2% hydrofluoric acid 10% nitric acid bath. It has been stated that the wearing rate in the acid etching technique relies on the concentration and acid type used (41).

According to experiments, acid etching at high temperatures causes a higher bone-implant contact and homogeneous micro-etched surface compared to TPS surfaces (42,43).

In addition to increasing the surface area, acid etching method also aids the healing of the bone-implant connection by removing the residues on the metal exterior (44,45).

In an investigation, clinicians inserted 3.25x4 mm implants roughened by acidification with polished Ti and HCL/H_2SO_4 (Osteotite) on rabbit femurs and subjected these to torque test. At the end of the two-month healing period, 20.5 newton centimeter (Ncm) and 4.95 Ncm values were determined for osteotite and polished Ti; it was revealed that the torque resistance of the acid etched surface, which is 4 times higher, is statistically significant, leading to the conclusion that etched surfaces promote bone attachment (46).

In a study Buser et al. have conducted in 1999, they have reported that a significantly higher torque should be applied in the removal of implants that have been etched and sandblasted. Also, Cochran et al. reported that there was a decrease in neck region bone resorption before and after insertion of implants where acid etching and sandblasting methods were applied (44).

Chemical treatments, on the other hand, can degrade titanium's mechanical characteristics. Acid etching, for example, can produce hydrogen hardness and microcracks on the surface, lowering implant fatigue resistance (47).

2.5.3. Sandblasted and acid etched (SLA) surfaces:

By applying a strong acid to a sandblasted surface with coarse particles, SLA is used to etch the surface. To achieve superior surface chemistry and topography, the SLA process has begun to be adopted as an alternative to TPS coatings. In order to generate micro-pits and macro-roughness, as well as to improve surface roughness and osseointegration, this method is used in a sequential combination of acid etching and grit-sandblasting (48,49). Greater values of reverse torque are reported in biomechanical tests and histomorphometric researches (50,51). SLA implants began to be employed for early loading in clinical investigations as soon as 6 weeks after implantation as a result of these experimental outcomes. Three-year clinical assessments of these implants revealed success rates of roughly 99 percent (52,53).

In 1997, Straumann introduced SLA implant surfaces as etched and sandblasted titanium surfaces. SLA surface is not a surface coating method. Macro-etching is created by blasting large grains of sand on the implant surface. By applying the acid to the surface, micro-pits of 2-4 µm depth are obtained. SLA implant surfaces are moderately rough surfaces. The roughness degree is the same across the surface of implant. In a research, it was shown that the activity of alkaline phosphatase in osteoblast-like cells was greater on SLA surfaces than on TPS surfaces (45).

2.5.4. Plasma spray coated surfaces:

A thick agglomeration layer, such as titanium (Ti) or hydroxyapatite (HA), is commonly used in the plasma spray process. Thermally melted materials are blasted onto the implant surface during the coating procedure. By enhancing the surface roughness of the implants, plasma spray effectively enhances their surface area (54).

The layers of calcium phosphate, primarily consisting of hydroxyapatite, are applied to metal implants. Calcium phosphate released into the peri-implant region improves bodily fluid saturation after insertion of the implant, resulting in the formation of biological apatite on the implant. The layer of biological apatite can be employed as a platform for osteogenic cell adhesion and development by including endogenous proteins. As a result, the organic apatite layer aids in the repair of the bone around the implant. The inclusion of a calcium phosphate coating speeds up the biological attachment of titanium implants to bone tissue. It is known that in the long term these coatings of calcium phosphate increase clinical success when it is compared to uncoated titanium implants (55,56).

Even if the coating is properly adhered to the bone tissue, one of the primary problems with plasma blasting coating is the risk of delamination of the covering from the surface of titanium implant, resulting in failure. When the dimension of dental implants is not acceptable, coating delamination has been documented since efficiency of plasma blasting did not meet expectations. Coating loosening has also been observed, particularly with implants placed in dense bone (57,58,59).

2.5.5. Ceramic coated surfaces:

Micro-arc oxidation method (MAO)

This is a sophisticated electrochemical process developed for coating etched surfaces such as metal or ceramic using electrolyte solution under high voltage. MAO method is the coating of the surface by the regulation of the electrolyte concentration and composition of P and Ca ions (60,61). The importance of this process in terms of biomedical applications is that the presence of PO3 and Ca ions of electrolyte at the time of the MAO practice can boost the bioactivity of alloys like titanium by entering into the ceramic layer (62).

As a consequence of the anodization of the titanium by delivering a positive voltage to the Ti sample immersed in the electrolyte during the MAO process, an oxide layer forms on the surface. A micro-arc is detected when the deterioration of the oxide layer (depravity of the insulator) begins when the employed voltage is raised to a particular point. As soon as the insulator deterioration occurs, the electrolyte's Ti and OH ions begin to work in the opposite way, repairing the degraded oxide layer as quickly as possible. This freshly generated layer has a porous structure that is strongly adherent, which is very advantageous for bioactive surfaces (60,63).

Recently, the MAO technique has been described as one of the finest ways for surface modification in researches on enhancing the biological response to Ti implants (64).

2.6. Indications and contraindications of dental implants:

2.6.1. Indications:

- When the detachable prosthesis is unable to attain stability,
- When the retention of removable prostheses are inadequate,
- When the individual is rejecting the detachable prosthesis psychologically,
- When the individual is functionally uncomfortable while wearing a detachable prosthesis,
- When the number and distribution of the areas to be supported in the mouth are insufficient,
- When parafunctional behaviors that will jeopardize the prosthesis' stability are present,
- For anchoring in orthodontics,
- When the number of teeth available for use as a bridge leg in the construction of fixed prosthesis is inadequate,
- Congenital missing teeth,
- When only one tooth is gone and the neighboring teeth remain healthy,
- The patient's request for conservative treatment (65).

2.6.2. Contraindications:

- In case of an uncontrollable systemic disease,
- When the patient has a serious mental condition,
- When the patient has problems of drugs or alcohol addiction,
- When the patient is at the age of growth, at age of continuous bone development, or extremely old,
- When the patient has insufficient and poor bone quality,
- In cases where there is insufficient intra-occlusal space,
- Patients at risk (such as patients who have received radiotherapy, has severe bruxism, or osteoporosis) (65).

2.7. Short implants

Nowadays, the utilization of dental implants in missing teeth is quite common. In cases where there are sufficient horizontal and vertical lengths in the alveolar bones, the success rates of dental implant applications are high. In cases where anatomical structures and alveolar bone are not sufficient, it is impossible to place dental implants, and dental implants are commonly placed by providing adequate bone length with modern surgical methods such as bone augmentation, nerve reposition of inferior alveolar, and elevation of the sinus floor. Although many successful reports have been published for these techniques, it is generally accepted that it increases the complications risk and patient morbidity as well as lengthening the treatment time and expense (66).

Some researchers introduced short implants as implants shorter than 10 mm and shorter than 8 mm, which were originally offered as 7 mm implants with the Branemark system in 1979 (67,68,69,70,71). Telleman et al. defined implants with a vertical length of 8 mm or less than 8 mm in the bone as short implants, based on the reason that implants can be placed at various horizontal levels. There are additional studies that classify implants that are shorter than 7 mm as extra-short or short (72,73). According to research, the definition of short implants can range from 5 to 10 mm. (74). In reports, however, there has not been a common idea for the definition of short implants (75,76).

2.7.1. Surface properties on short implants:

Although there are numerous publications comparing short implants and standard implants, there is no agreement on these comparisons (77). It has been reported that failure rates are generally higher than standard implants due to less osseointegration and primary stability (68). Pommer et al. showed that failure rates in short implants were much greater than failure rates in long implants in a research that looked at the first year of functional loadings on the implant (78). Bahat, stated in their clinical research publications describing 7 mm implants as “short”, stated the ratio of failure as 9.5% for implants of this size while for longer implants, this ratio was 3.8% (79). It has been observed that the surface properties developed in short implants, together with the increasing number and depth of threads, support osseointegration between the bone and freshly manufactured implant systems (69).

It has been reported that macro-surface implants with machined surfaces constitute a risk in situations of inadequate density in these bone types. (80). Machined surfaces might be extracted using less torque compared to processed surfaces (81). In the near term, the porosity generated on the implant surface provides for a stronger link between the implant and the bone (70). Deporter et al. stated that implant surface alterations have a significant impact on the implant's survival rates and success, as well as its clinical function (82). It has been reported that the performance of short implants with an improved surface, which has the appropriate density and inserted with the appropriate surgical method, is positive (83). Malo stated that a functional success of 95% was achieved 1 year after the application of short implants with an anodic oxidized surface properties to the bone with a weak density, and reported that this success was directly related to the surface of the implant (84).

It has been stated that the reason why implants with a low success rate have this rate is linked to the surface properties of the implant rather than the implant length (85). Improved surface properties have shown that an interface that is more resistant to tensile forces of implants is formed (62). It has been stated that if short and long implants with machined surfaces were analyzed, the failure rates of short implants were 5-10% higher, while similar success rates were observed as a result of comparing short and long implants with etched surfaced (61,86). It has been stated that the implants prepared as machined surfaces should be at least 11-13 mm in length and at least 3.75 mm or 4 mm in diameter for a good prognosis (87). Gotfredsen and Karlsson compared machined surface prepared implants with implants of various sizes with TiO_2 etched surfaces and reported a higher bone level in the presence of TiO_2 etched implant surfaces (88). According to Atieh et al., the implant design and surface had no superiority over one another in terms of short implant survival rates (64).

2.7.2. Bone properties for short implants:

Bone densities are critical to the success of an implant (89). These are frequently used especially in the posterior regions of the jaws, atrophied and early loss of molar deficiencies (90). Some of the researchers suggested that short implants should not be used in the posterior maxillary region due to the D4 bone density (70,76). In studies conducted with short implants applied to this region, it has been stated that the findings are not clear because they are generally combined with long implants and restorations (84).

It has been reported that the success rates of short implants applied to the mandible are higher compared to those applied to the maxilla (91). Short implants in the mandible and maxilla were shown to have success rates of 100 percent and 87 percent, respectively, in a research (92). Whereas the clinical findings in the maxilla were found to be unclear, it was stressed that a three-year time should be considered in order to attain satisfactory outcomes in the mandible (93). There was no statistically significant difference among the maxilla and the mandible, according to a meta-analysis (72). Notwithstanding the several investigations and analysis, no consensus on the survival rates of short implants implanted in the maxilla and mandible has been obtained (Figure 2.5) (94).

Figure 2.5. Bicon brand short dental implants in 5mm and 6mm lengths

2.7.3. Indications of short implants:

Short implants are utilized in the maxillary and mandibular posterior areas wherein the vertical alveolar bone height is restricted especially by the mandibular canal and maxillary sinus and where bone width is adequate. These are an alternative to techniques of bone augmentation (70).

2.7.4. Advantages of short implants:

The placement of lengthy implants in individuals with insufficient bone elevations poses a risk to IAN and the maxillary sinus. Despite the fact that bone grafts are utilized to lessen these risks, individuals may reject them owing to the extended recovery duration and high cost. For this reason, patients who are undergoing implant treatment prefer shorter implants, and offer an easy, permanent and predictable treatment opportunity. Thanks to short implants, patients with bones that do not have sufficient vertical sizes can avoid the risks, costs and increased costs, as well as long recovery times, thought to be associated with graft procedures.

Therefore, with the use of short implants:

- It is a simple and easily applied surgical procedure.
- It is considered more acceptable by patients.
- Possibility of comfortable implant positioning is ensured.

- Bone graft procedures are kept to a minimum.
- Anatomical structures thought to be vital can be avoided.
- Minimizes the indication of sinus lifting operation (95,96).

2.7.5. Certain criteria to avoid complications that may occur when inserting short implants:

- The use of short implants which are processed should be prevented (70,75,97).
- Short implants shall be properly recommended when bone quality is good (70,75).
- In the case of short implants, cantilever should not be employed (96,98).
- In certain individuals with parafunctional habits, short implants should not be utilized (75).
- It is best to avoid surfaces that guide lateral motions (96,98).
- Surgeons must have a considerable amount of clinical experience (96,98).

2.8. Implant osteotomy

These are osteotomies made in the bone where the implants will be placed.

2.8.1 Classification of implant osteotomy techniques

1) Conventional drilling technique
2) Osseodensification drilling technique
3) Osteotome technique
4) Piezoelectric surgery technique

2.8.1.1. Conventional drilling technique

The implant is inserted to the bone by preparing the alveolar bone bed with plenty of irrigation using surgical burs under a certain rotational speed and torque. Osteotomy preparation is usually performed with a simplified osteotomy protocol that uses an sequential bur set that operates by extracting bone (Figure 2.6) (99).

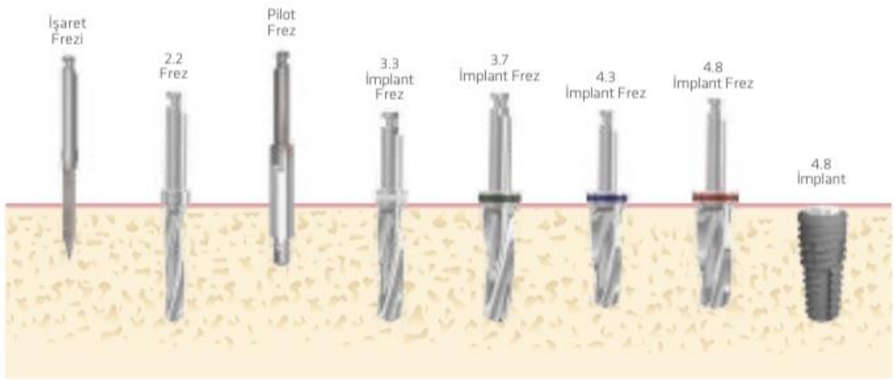


Figure 2.6. Conventional drilling technique (www.implance.com)

2.8.1.2. Osseodensification drilling technique

Osseodensification (OD) is a technique for preparing biomechanical bone for dental implant insertion. It is mainly the low plastic deformation of the bone which is generated by rolling and sliding contact with a densifying bur to densify the bone with little heat increase throughout the operation. Huwais invented OD, which uses specifically engineered burs to help densify the bone while preparing an osteotomy without removing bone at the implant site (100,101).

By compaction autografting during osteotomy preparation, the counter-clockwise operating burs of osseodensification allows for the densification and preservation of bone, resulting in increased bone density surrounding the implant (Figure 2.7) (102).

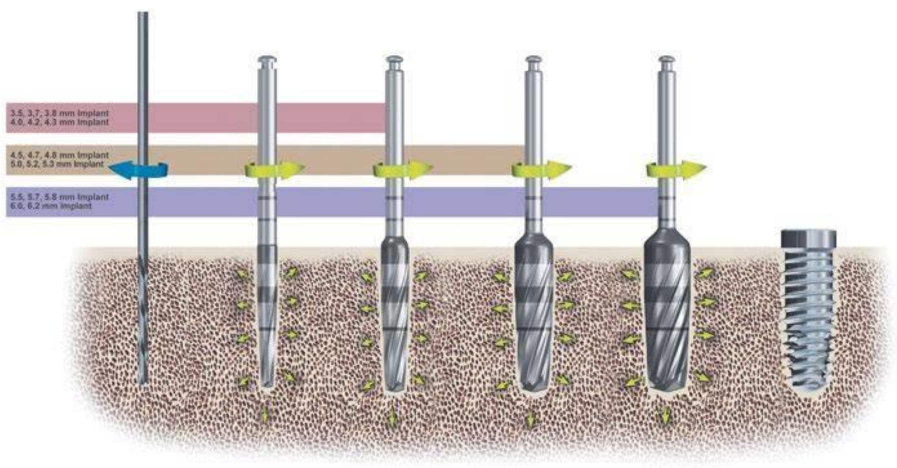


Figure 2.7. Osseodensification drilling technique (www.Versah.com)

2.8.1.3. Osteotome technique

A manual osteotome is used to compress the bone tissue apically and laterally after initially producing a tiny prototype implant slot. The objective of this procedure is to put the implant where there is a lot of bone contact while avoiding the extraction of more bone, which is thought to enhance bone repair in the long run. Summers invented the osteotome method, which appears to be beneficial for usage in the posterior maxilla (103,104).

By densifying the existing low-density bone, it improves the implant's adherence to the bone. It also extends the maxilla, raises the sinus floor, and reduces the amount of heat generated during surgery (Figure 2.8) (105,106).

Figure 2.8. Osteotomes

2.8.1.4. Piezoelectric surgery technique

Piezoelectric surgery looks to offer a viable alternative to traditional implant site preparation. These devices vibrate the cutting tips with ultrasonic frequency and generate electrical potential in reaction to mechanical force, allowing the implant bed to be created with little bone damage (107,108,109,110).

While the advantages of this technique are accepted due to the advantages that it has less traumatic with soft tissue protection, and better bone healing, precise, safe potential, it is a disadvantage that the implant osteotomy duration is long and it is dependent on continuous cooling since it creates high temperatures (Figure 2.9) (109,111,112,113).

Figure 2.9. Piezosurgery

2.9. Osseointegration concept:

Osseointegration was introduced by Branemark et al. to describe the functional and structural relationship between the implant and live bone tissue (Figure 2.10) (114).

Working on microcirculation, he developed titanium zones that provide strong and direct attachment to the bone. In his in vivo studies conducted on animal models, he observed that bone can be directly connected to titanium without soft connective tissue. With this invention he has made, he has ensured the continuous connection of prostheses to living tissues in reconstructive surgery (115,116).

Branemark has been a pioneer in the development of osseointegrated implant systems. While some studies argue that fibrous tissue should be formed around the implant, Branemark stated that this would compromise the implant's success and that a tight ankylosis between the implant and the bone without fibrous tissue is preferable. He called this osseointegration (117).

The Branemark system was approved by ADA (American Dental Association) in 1986, and this form of treatment began to become widespread (118).

The structure of the bone to which the implant will be put, the compatibility of the implant's material with the tissue, the implant's design, adequate surgical technique, and the implant's surface qualities all play a role in osseointegration. The reaction of the bone was affected by changes in the surface qualities of the implant utilized (50). The optimum implant surface should not obstruct the bone's natural healing process. It has been said that regardless of anatomical areas, bone amount, or quality, the implant surface should have an impact that promotes healthy recovery. (50,119).

To summarize briefly, it has been emphasized that for a good osseointegration;

- Applying a correct and atraumatic surgical method,
- Using a biocompatible substance like titanium,
- Ensuring the implant's primary stability,
- Without load transfer, a recovery period of 3-4 months in the mandible and 4-6 months in the maxilla is required. (120,121).

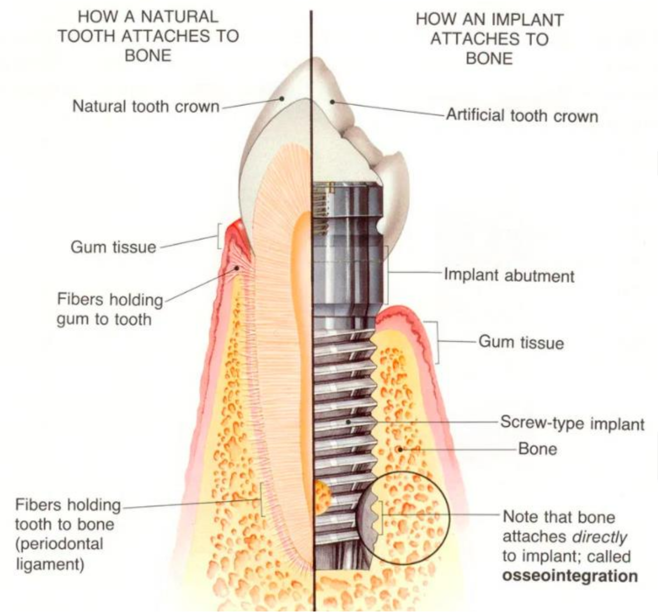


Figure 2.10. Osseointegrasyonun scheme

2.9.1. Biological phases of osseointegration:

Bone healing around the applied implant takes place in 3 stages;

- Osteophilic phase
- Osteoconductive phase

- Osteoadaptive phase (Figure 2.11) (122).

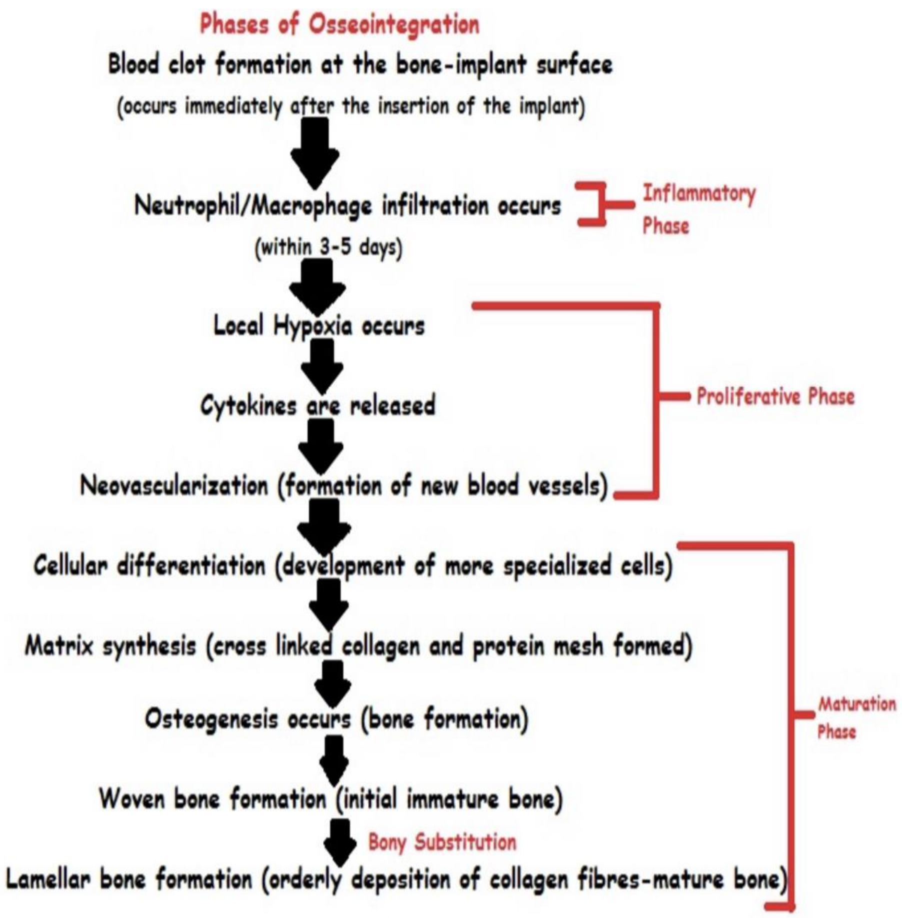


Figure 2.11. Osseointegration phases

2.9.1.1. Osteophilic phase:

After the etched surfaced implant is placed on the cancellous bone, blood fills between the bone and the implant, and clot forms. Contact of the implant with the bone is very low. The remaining components are extracellular fluid and cells. Collagen synthesis and molecule formation are controlled during this period. To produce these restrictions, cytokine is released. Cytokines also have a role in regulating bone metabolism and influencing cell proliferation.

At the conclusion of the first week, inflammatory cells develop. These cells arise in response to antigens from outside the body. Vascular development in important tissues begins on the third day. 3 weeks after the implant is inserted, there is a better vascular development. Cellular activation, proliferation, and differentiations begin.

Osteoblastic migration is observed with the onset of ossification in the first week. Duration of the osteophilic phase is 1 month (24,122).

2.9.1.2. Osteoconductive phase:

The bone cells extend outwards the implant's metal surface when they expand to the implant surface. The bone cells, which at originally comprised the juvenile connective tissue matrix, are referred to as "woven" bone as the accumulating bone becomes a thin layer.

The fibrocartilogenesis callus turns into bone at this phase. This change happens in the third month. More bone is deposited on the implant's surface during this procedure. At the 4th month following the insertion of the implant, the maximum amount of bone covers the implant surface (24,122).

2.9.1.3. Osteoadaptive phase:

It is the final phase and begins in the 4th month. In this phase, remodeling begins and there is no bone gain or loss around the implant. Woven bone thickens and turns into lamellar bone in this phase (24,122).

The final stage of osseointegration is remodeling. This is crucial for implant lifespan since it persists throughout life (123).

Primary stability and osseointegration are crucial for the success of an implant (124). The absence of movement of the inserted implant is referred to as the primary stability, and it is required for osseoingression to occur (30,125,126,127).

2.10. Primary implant stability

A crucial factor for successful implant treatment is the stability of the implant during insertion. Primary stability relies on the amount and the bone quality in which the implant will be inserted, length, diameter and type of the implant to be applied, and the surgical approach to be used for the insertion of the implant. Micromovements in the implants occur if primary stability is not attained, and healing is impaired. With the onset of implant movement, clinical failure is unavoidable (6,128,129,130).

Primary stability is determined by the degree of connection between the implant and the bone, as well as the compression forces that exist between the implant and the bone. Implants placed in thick cortical bone are more stable than those placed in trabecular bone, according to many studies. Before placing the implant, the cavity can be made using a bur that is smaller than the diameter of the implant, and the implant is placed in this cavity. As a result, the implant is more securely embedded in the bone. Although this improves primary stability, it also increases the risk of ischemia or bone necrosis (6,131).

According to Gapski et al., mechanical pressures against implants with poor initial stability enhance early failure percentages. In early loading methods, primary stability is also crucial. If the stability is good enough, functional loading can be done right away. Because the implants implanted in the spongiform bone have low initial stability, adequate healing time should be provided and loading performed subsequently.

2.10.1. Implant stability measurement methods:

The achievement of primary stability is a need for osseointegration (132). Furthermore, primary stability can provide details about the osseointegration process (6,132). The following are the ways for determining stability:

1. Insertion torque test
2. Removal torque test
3. Implatest
4. Periotest

   Percussion test

6. Resonance Frequency Analysis (RFA)
7. Dynamic model testing (133).

2.10.1.1. Insertion torque test:

Johansson, Strid and Colomina stated that using an electronic motor, the calculated torque amounts during the insertion of the implants into the bone can provide offer data on implant bone quality and stability (134,135). The torque force exerted when placing the implant into the previously constructed slot is the test, which is still used reliably today. It has become a frequently used method for immediate loading (131,136). In 2006, Türkyılmaz et al. and Ottoni stated that the amount of torque is high in implants placed in patients with high bone quality and that these implants have high implant stability quotient (ISQ) values (120,136). Friberg et al., on the other hand, claimed that there is no link between insertion torque and ISQ (137). Sullvian et al. evaluated insertion torques according to bone quality, finding no statistically significant difference between type 2 and type 3 bone, but considerable decreases in type 4 bone (138). Ottoni et al. stated that implants with a placement torque higher than 32 Ncm can be loaded immediately while those with less than 20 Ncm may be more likely to fail (136). The insertion torque test is described as a reliable and straightforward approach for determining implant stability (135).

2.10.1.2. Removal torque test:

Albrektsson and Johansson examined implants on rabbit bones in 1987 and used the removal torque test to determine their stability. This test has been described as loosening the placed implant with reverse moving torque and breaking it from the bone connection (139). The only tests that can explain bone development and maturation at the implant site, according to the researchers, are torque tests. This test can be used to determine the maximum shear force that can be sustained on the surface between the bone and the implant, as previously stated. Aside from implant shape, the quality of the implant's interaction with the surrounding tissues has a significant impact on the levels attained in these measures (140).

Torque testing is still used today, however, it is difficult to utilize in vivo investigations and, for ethical reasons, cannot be used in human studies. These are the most significant drawbacks of these exams (139).

2.10.1.3. Implatest:

It was created in 2002 by Dario et al. It's a computerized display showing the implant's stability. In aircraft, impulse testing, a structural analysis commonly utilized in engineering domains, is frequently employed. The accelerometer, which is put in the flexible membrane inside its own body, is located at the tip of the recording device in Implatest. The accelerometer gets a warning from the device's activation mechanism during recording, and this warning is sent to the implant. The acceleration time history (ATH) data obtained when the tip of the device comes into contact with the implant is recorded. Data obtained at the beginning when the implant and the tip of the device are in contact are not taken into account. Remaining data is included in the evaluation. After the data is analyzed, a graph is projected onto the device’s display and the stability of the implant is evaluated according to this graph. The curve creating the graph appears flat if the osseointegration is better. Insufficient osseointegration is indicated by an indented curve (133).

2.10.1.4. Periotest:

Periotest device was first developed by Siemens in 1980s at Tubingen University, and it is manufactured by Gulden Medizintechnik (Bensheim, Germany) today (141,142). Its purpose is to measure the reduction of support in the periodontal tissues surrounding the tooth with numerical values and to evaluate it in terms of tooth mobility (131,143). Today, there are 3 variants as follows: Periotest classic (Figure 2.12), Periotest S and the newly released wireless Periostest M (Figure 2.13). The data collected by Periotest S can be saved. Periotest is a noninvasive diagnostic procedure that determines the stability of the bone to the implant surface (144,145,146). Periotest is an electromechanical application. It operates and monitored with electricity. With percussive movement, the instrument's moving point hits the implant or tooth 16 times, and the full measurement takes 4 seconds. The contact time to the implant or tooth is measured by this component of the pressure-sensitive movable tip. The longer the contact time, the higher the periotest value will be. This shows that the stability of the implant or tooth is low. The shorter the contact time and the lower the periotest value, the better the stability of the tooth or implant.

Measurement value ranges between -8 and +50 in Periotest (Table 1). According to these values (139,147,148);

Table 2.1. Periotest measurement values

Periotest measurement value range	**Significance**
-8 to 0	Sufficient osseointegration, implant can be loaded
+1 to +4	Clinical examination is necessary, in a lot of cases the implants are not ready to be loaded
+10 to +50	Insufficient osseointegration, implant.should not be loaded

Periotest values may vary depending on instrument angulation, recording position, and physician use. In addition, after the abutment is inserted and the crown is made, there may be changes in the periotest values due to the change in the dynamic properties of the implant. Therefore, periotest is not considered a healthy method for the evaluation of osseointegration by some researchers (6,132,146,149).

Figure 2.12. Periotest Classic

Figure 2.13. Periotest M

2.10.1.5. Percussion test:

It is considered a subjective method. It is a simple procedure and it is done by evaluating the sound produced by hitting the implant with the back of manual tools such as mirrors and probes. The lack of mobility and stability of the implant is evaluated by the blunt sound after hitting the implant. If there is a weak sound, fibrous tissue capsulation presence is thought instead of osseointegration (139).

2.10.1.6. Resonance frequency analysis (RFA):

Meredith et al. were the ones who came up with it. It's an electrical technique for determining implant stability. It's non-intrusive and unbiased. This technology allows for in-vivo numerical measurement of osseointegration (6,131,132,150). It has been thought that conventional techniques are insufficient in implant systems that are constantly changing as design, and therefore a device that will measure implant stability noninvasively and objectively should be developed. The device that makes this measurement was called Osstell TM (112) (Figure 2.14). Later, certain changes and developments were made on the device, and it was made more practical and released under the name Osstell Beacon (Figure 2.15). Over time, other brands that produce devices that measure implant stability have emerged, and Penguin RFA is one of them (Figure 2.16). As a result of research, the advantages of these devices are stated as follows:

1. Ostell or Penguin RFA allows measuring the stability and bone quality of the implant and obtaining information about the loading duration of the implant.

2. The implant's changes and healing are measured, and the best time for restoration is selected. It is possible to discover potential problems in advance, which aids in taking appropriate action. Clinical failure is therefore avoided.

3. The clinical effectiveness of the implant can be assessed. This permits you to choose from a variety of implants.

4. These gadgets allow dentists to maintain measurements and patient information together. This aids the physician in patient follow-up as well as legal processes (6,131,151).

Figure 2.14. Osstell TM

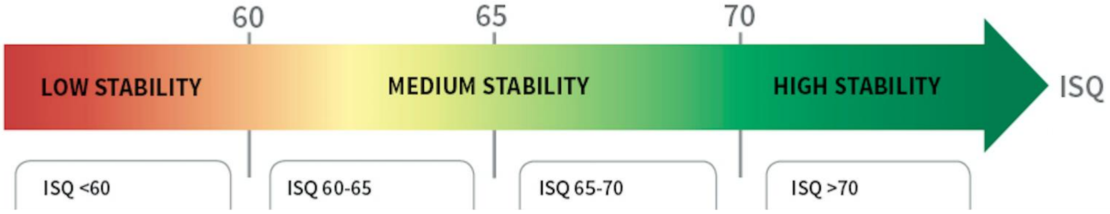
Figure 2.15. Osstell Beacon

Figure 2.16. Penguin RFA

ISQ values, which range from 1 to 100, are used to determine the main stability of the implants implanted, as seen in the graph below (Table 2.2).

Ostell ISQ scale

Table 2.2. Ostell ISQ scale



Under normal conditions, clinical ISQ values range from 55 to 80. It has been reported that the values measured in the mandible are higher than the maxilla. High stabilization is described as ISQ >70, moderate stabilization is shown between ISQ 60-69 values, and low stabilization is reported when ISQ is <60.

Implant values with ISQ <60 are considered to be risky and no loading should be placed on them in the short term. It has been emphasized that traditional loading can be performed for implants with ISQ values between the range 60-69 while immediate loading can be comfortable for implants with ISQ values >70 (140,152). However, these reference values may change in low-density bone types such as D4, and it has been stated that implants with ISQ values >40 do not have unsuccessful implant stability (153).

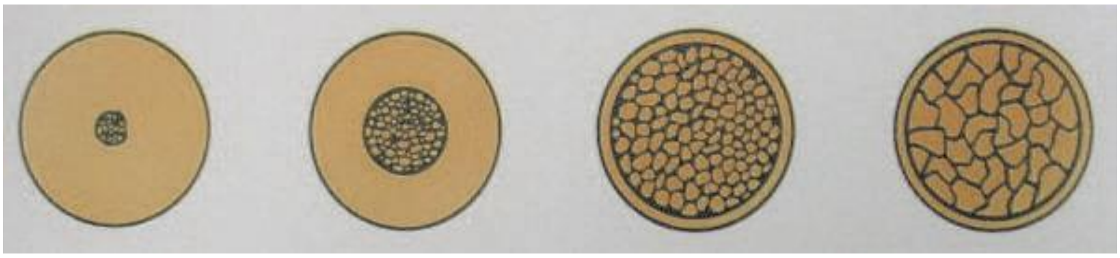
Primary stability measurement values (ISQ) are directly related to the type of bone inserted as well as how the implant is inserted. There are 4 types of bones in the human mouth. According to Lekholm and Zarb, bone classification was made as follows.

D1: It consists of a small amount of spongiform and thick compact bone. It is mostly seen in anterior region of toothless mandible.

D2: It consists of thick spongiform and thick compact bone. It is seen on the posterior and anterior region of the mandible and palatial region of the maxilla.

D3: It is a narrow spongiform and thin compact bone formation. It is seen on posterior and anterior regions of the maxilla.

D4: A class consisting of densely spaced spongiform and thin bone which is mostly seen on posterior region of the maxilla (Figure 2.17) (154).



D1 D2 D3 D4

Figure 2.17. Bone types (Lekholm and Zarp, 1985)

2.10.1.7. Dynamic Model Test:

Elias et al. developed it in 1996. In this technique, which uses a circular hammer similar to a clock pendulum, the hammer strikes the implant and creates vibration. The hammer, which has a piezoelectric crystal on its tip, creates a voltage signal according to the incoming force. Depending on the resulting values, a graph indicating the force and time is obtained. The area under the force timeline on the graph gives the thrust force. The data varies according to the magnitude of the force and the direction in which it is applied. It has been explained that this measurement is quite difficult in implants with poor stability (147).

2.11. Techniques applied to increase the primary stability of an implant in low-density bone

Many surgical methods have been developed in recent years in order to improve the main stability of an implant inserted in a low-density bone (155).

2.11.1. Bone tapping technique:

It is recommended to skip the bone tapping stages due to invasiveness, especially in low-density bone cases (155,156).

2.11.2. Bicortical anchorage:

Bicortical anchorage has been reported to significantly increase primary implant stability (157). On the other hand, Ivanoff et al., in a retrospective research in 2000, for bicortical implants recorded a 3-times higher fracture rate compared to monocortical implants (158). Higher stress and bending forces as a result of prosthesis mismatch or high occlusal tables might be the cause, according to the studies (157, 158).

2.11.3. Preparation of implant bed with a small diameter bur:

In this technique, a smaller size than the selected implant diameter is obtained by using the bur diameter as the final bur. A 10% reduction in implant bed preparation is adequate in case of poor bone quality in order to enhance primary stability, but further reduction has no effect (159,160,161). Studies on gradual osteotomy of the implant bed, another variation of the preparation method with a low-diameter bur, have reported higher implant stability regarding insertion torque in soft bone compared to conventional osteotomy (155,161).

2.11.4. Bone condensation and condensation technique:

Summers described the use of osteotomes to manually densify bone in low bone density cases in 1994 (103). Bone densification surrounding the implant bed works on the idea of placing the implant in a high-density bone matrix. The osteotome technique employs manually controlled instruments to compress the surrounding bone before gradually expanding it, resulting in increased insertion torque values, which practitioners take to be a sign of enhanced primary stability. The bone densification approach has been suggested in several research as a way to improve an implant's main stability. Stavropoulos et al., 2008, used the bone densification method to report satisfactory primary implant durability (162). Recently, a new implant bed preparation technique has been improved based on the concept of osseodensification drilling (100,155).

2.11.5 Osseodensification:

Salah Huwais developed this method in 2013. It is a new, biomechanical osteotomy preparation technique that does not extract bones. In order to achieve it, Huwais developed densifying burs that are specially designed and named as Densah® burs (Figure 2.18).

The benefits of osteotomes are combined with the speed and tactile control of burs during osteotomy using bone densifying burs (156).

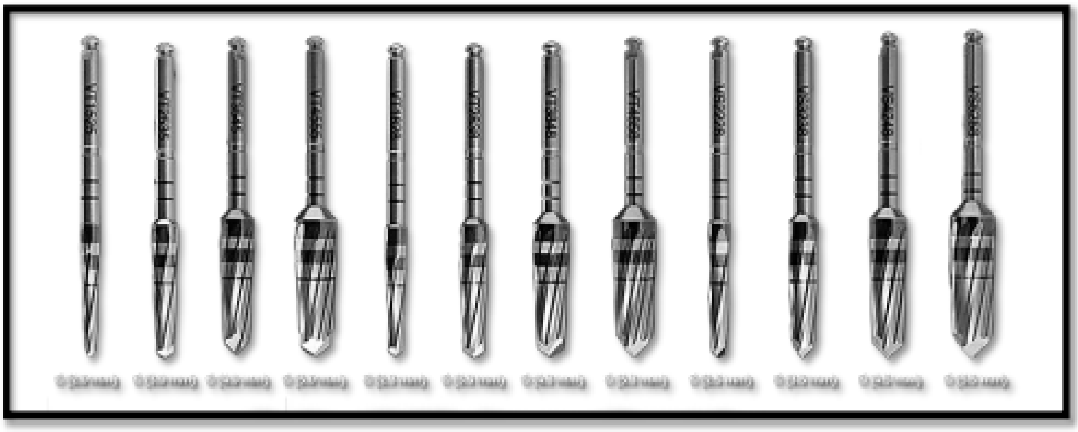


Figure 2.18. Osseodensification surgery kit (www.Versah.com)

2.11.5.1. Logic of osseodensification

The theory behind OD is that compressed autologous bone in direct contact with an endosteal device not only provides greater primary stability owing to physical interlocking between device and bone, however aids in osseointegration, as well, by osteoblasts nucleating on the instrumented bone around the implant (156,163).

This is done to create a dense autograft around the implant, which makes it useful in clinical situations when anatomical bone insufficiency exists (156). In contrast to conventional drilling protocols (bone subtraction drilling), OD improves primary stability because of the centrifugal densification of the milled osteotomy site walls by non-reducing drilling (4).

Gaspar et al. stated that bone extension capacity for predictable ridge widening of ID is confirmed with increased insertion torque and primary stability values. This may be clinically relevant in minimizing detachments from peri-implant bone detachments or fenestration openings in bone. OD can also be utilized for crestal sinus lift to reduce morbidity in a predictable, safe and simple way (164).

2.11.5.2. Advantages of osseodensification

- It's a one-of-a-kind, highly controlled, quick, and effective bone preservation osteotomy preparation approach that leads to improved primary stability, BMD, and bone percentage on the implant surface, resulting in faster wound healing and osseointegration (165,166,4).

- Owing to the autografted and preserved bone matrix, cells, and biochemicals throughout the osteotomy surface area, the healing course can be accelerated (4).
- Without bone fenestration or separation, larger implant diameters may be placed on narrow ridges with the OD technique (157).
- Insertion and removal torque values which increase with dental implants inserted on osseodensified osteotomies are reported (4,156,157).
- Because the bur may be used in both cutting and non-cutting directions, the doctor may be able to autograft the maxillary sinus and expand any ridge on the mandible and maxilla (166).
- Huwais showed that OD aids crest growth while retaining alveolar crest integrity, permitting autogenous bone implant implantation. OD assisted preserving of bone mass and shortened the waiting duration until the restorative phase (165,167).

2.11.5.3. Disadvantages of osseodensification

- Case selection for using osseodensification burs in the counter-clockwise mode is important as the procedure is not recommended in dense bone (D1, D2) and is more suitable for soft bone (168). This is due to the fact that soft bone trabeculae between the spaces of marrow one larger compared to compact bone, allowing compression of bone. Lateral compression of bone beyond the viscoelastic limit of dense and thick trabeculae causes continued damage and results in aweaker implant-bone interface (169).
- Bone is vulnerable to a micro damage threshold during bone compression and implant loading under high torque. If the bone microdamage threshold is breached, the bone remodeling cycle may take three months or more to restore the affected regions (170). This is especially essential in the case of OD, because severe compression might result in bone necrosis inadvertently (171).

2.11.5.4. Contraindications of osseodensification

- This method does not function with cortical bone since it is a non-plastic, non-dynamic tissue.
- Densification of xenografts ought to be prevented since they only give mass with no viscoelasticity, have just inorganic substance, and biomechanically act not the same as bone tissue (161).

3. MATERIAL AND METHOD

All studies were carried out in Marmara University, Faculty of Technology, Department of Mechanical Engineering, in Göztepe. The overall sample size was found to be n=42 using the G-POWER tool with an effect size of 0.9, a power of 80 percent, and a 0.05 margin of error based on the percentage measurement values of the techniques to be evaluated in the literature study. A total of 42 (4.8x5 mm) implants were used to be inserted by different osteotomy techniques on the polyurethane blocks (#1522-03: Sawbones, Malmö, Sweden) that mimic the bone structure of D4 (PCF05) (Figure 3.1). For human cancellous bone, solid hard polyurethane foam is employed as an alternate test medium. It does not have the same structure as human bone, but it does have consistent qualities in the cancellous bone spectrum. Torque of stripping, insertion, and screw pullout are all regularly tested with this closed cell polyurethane foam.

Figure 3.1. Sawbones, PCF05(D4) polyurethane bone (#1522-03: Malmo, Sweden)

Implants were uniform with the 4.8 mm diameter and 5 mm length. Slots that were created on the blocks, were done via computer by the CNC Milling Machine (Johnford

VMC-850 model CNC Milling machine, Taichung City, Taiwan) (Figure 3.2) with digital drawings and commands (Figure 3.3). In this way, the margin of error that may occur in implant slots due to angular forces between different osteotomies was reduced to negligable. In the conventional technique the drills rotate clockwise and gradually increase in diameter, and the final bur diameter is considered to be 4.8mm (Figure 3.4), whereas in osseodensification technique except pilot drill remaining drill rotate counter-clockwise and the diameters increase proportionally. The final drill is considered to be 4.3mm in diameter due to the bone type drill procedure (Figure 3.5). Implant slots were prepared on the CNC milling machine at equal distances and intervals in the bone block (Figure 3.6). A gap of 3 cm from the top of the bone block and 2 cm from the left and right side, and a gap of 1 cm was left between each slot. A total of 42 (4.8x5mm) implants were inserted on the same D4 bone block: 21 with conventional drilling technique and 21 with osseodensification drilling technique (Figure 3.7)

Figure 3.2. Johnford VMC-850 model CNC Milling machine (Taichung City, Taiwan)

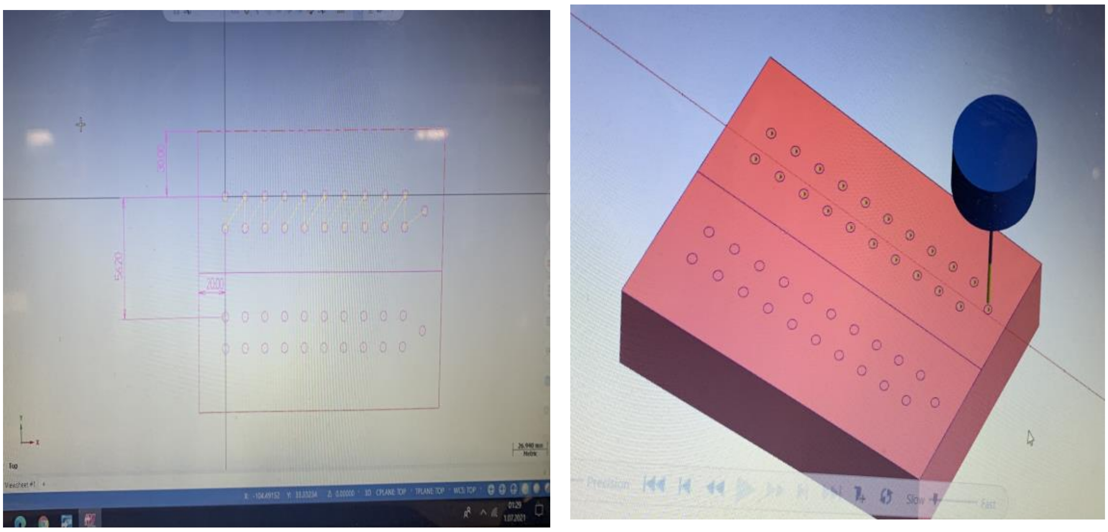


Figure 3.3. Digital drawings made on the computer connected to the CNC Milling machine

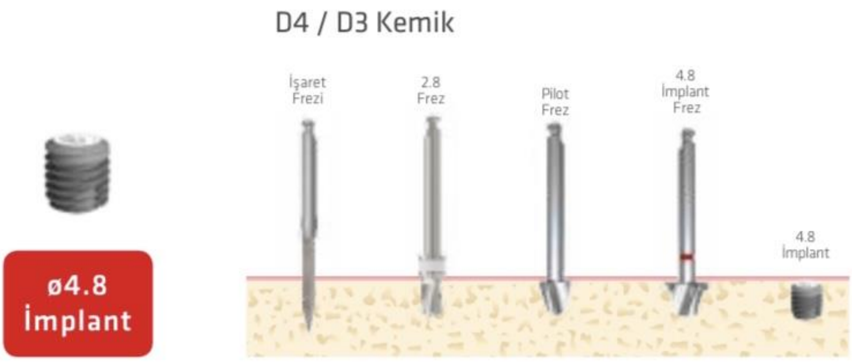


Figure 3.4. Conventional drilling technique (www.implance.com)

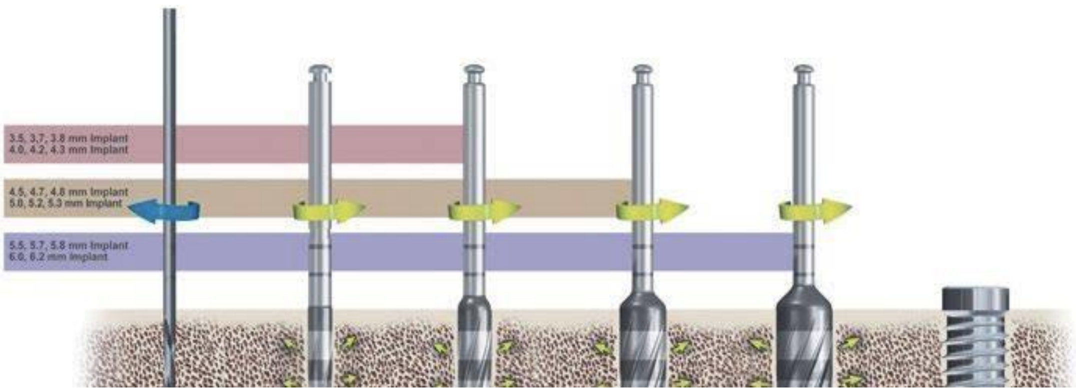


Figure 3.5. Osseodensification drilling technique (www.Versah.com)

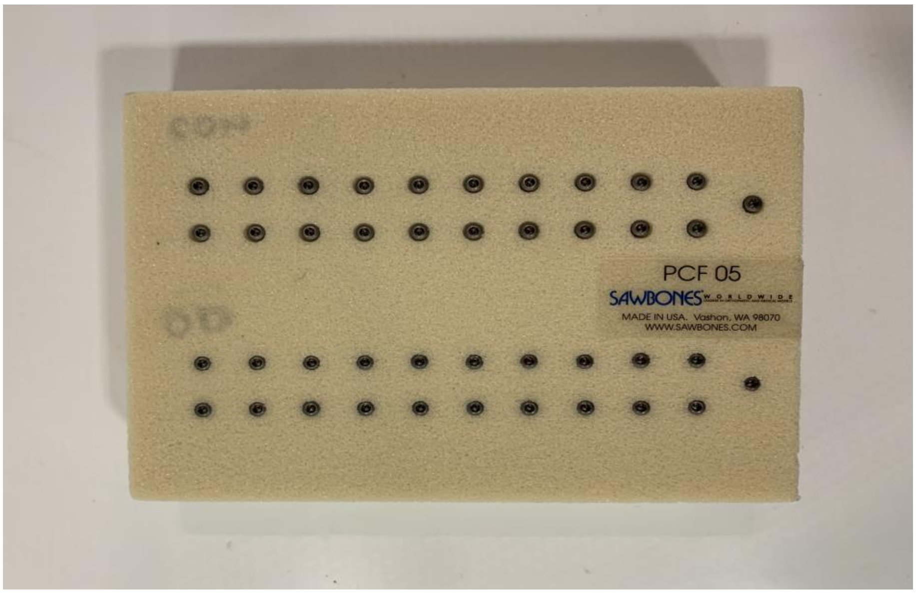


Figure 3.6. Implant slots opened at equal distances and intervals in the bone block

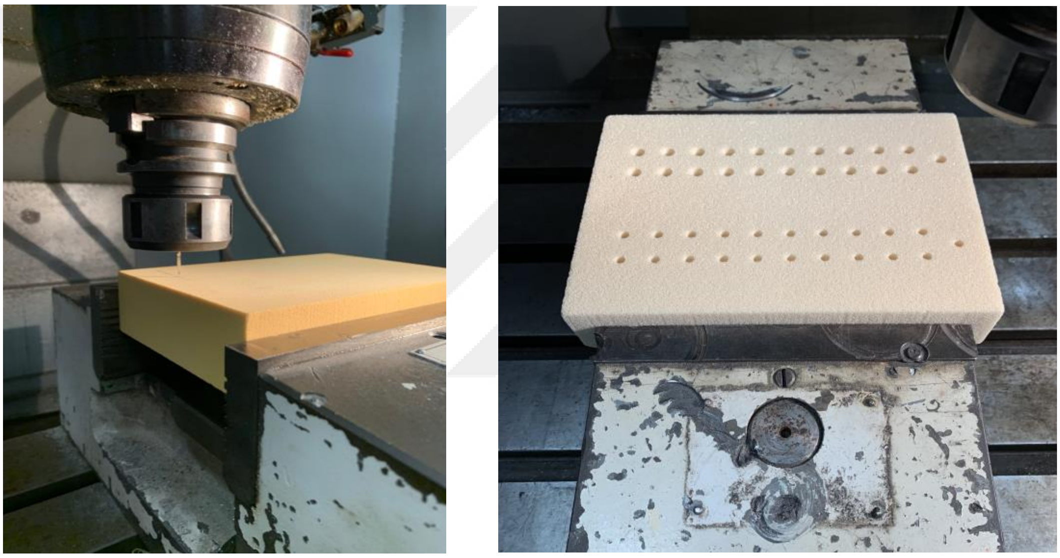


Figure 3.7. 42 implant slots opened to PCF05 bone type with different osteotomy techniques

Short implants placed on the artificial bone blocks were obtained from IMPLANCE (AGS Medical Products, Trabzon, Turkey) (Figure 3.8) company, and the implant sockets were created with the Implance conventional surgical set (Figure 3.9) and Densah osseodensification surgery set (Figure 3.10). The implanted IMPLANCE brand implants have a total internal connection of 2.25 mm. 1.75 mm of this is conical and 1.35 mm is hexagonal connection. The purpose is to prevent screw breaks and cement leakages during prosthesis cementation. The implants placed have a resorbable blasting media (RBM) surface. While the lowest thread depth of the implants with aggressive thread structure is 0.5 mm, the outer body of the implant is designed as an cylindrical so that the outer body of the implant distributes the stress equally to the entire implant.

Figure 3.8. IMPLANCE 4,8x5mm dental implant (Trabzon, Turkey)

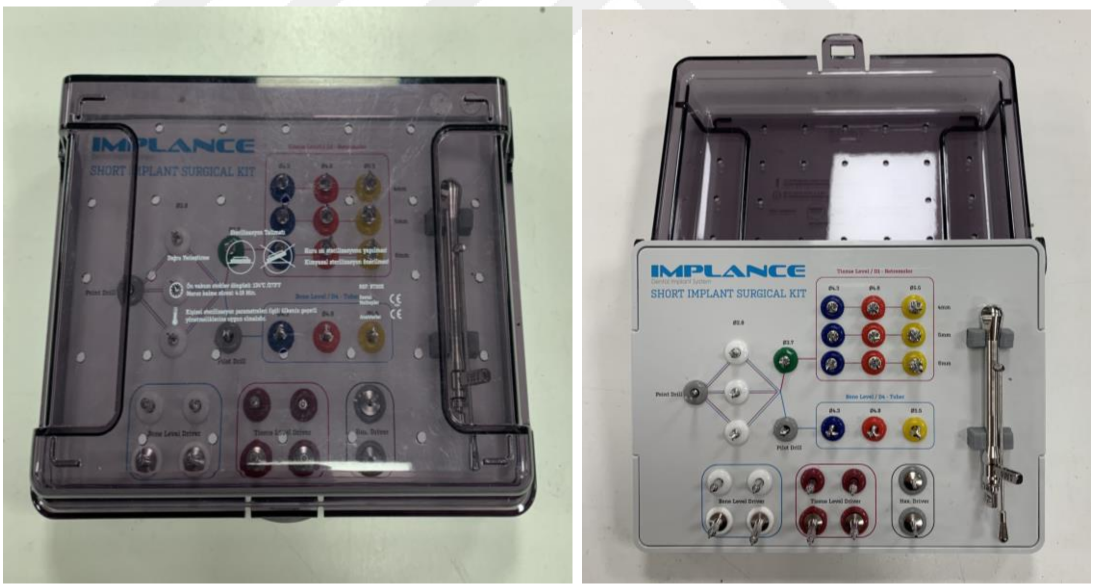


Figure 3.9. IMPLANCE conventional surgical kit (Trabzon, Turkey)

Figure 3.10. DENSAH® osseodensification surgical kit (Versah Co., LLC., USA)

In the study, insertion torques, removal torques and ISQ values of a total of 42 implants were recorded. All of the implant slots drilled on the artificial bone were opened with a speed of 1200 rpm, and placed in the bone block at a speed of 40 rpm. The measurement of the insertion and removal torque values of the implants were made with Woodpecker physio dispenser (Guilin, China) brand physio-dispenser (Figure 3.11).

Figure 3.11. Woodpecker physio dispenser (Guilin, China)

Torque values at each turn were observed while inserting and extracting the implants, and all values were averaged from the beginning to the end. Calculation of the insertion torque values ended when each implant reached the bone level. The values obtained from the physio dispenser were compared with the values obtained from the calibrated Geratech Digital Torque Wrench (Germany) brand torque tool (Figure 3.12), obtained from Marmara University Faculty of Technology, and the verification was made.

Figure 3.12. Geratech Digital Torque Wrench torque tool (Germany)

The resonance frequency analysis of the implants was performed with the smartpeg (type 57; Gothenburg, Sweden) (Figure 3.13) placed on them.

Figure 3.13. Type 57 smartpeg; Gothenburg, Sweden

Resonance frequency analysis measurement was performed by Penguin RFA device (Integration Diagnostics Sweden AB, Gothenburg, Sweden) (Figure 3.14) held approximately 1 cm from the smartpeg placed on the implants. The values observed are in ISQ (implant stability quotient) units. For each implant, three measurements were taken. The peak, left, and right points of the implants were measured and averaged. The studies have been carried out very attentively; especially with the same operator and the same measuring devices, in the same ambient conditions, with the same method.

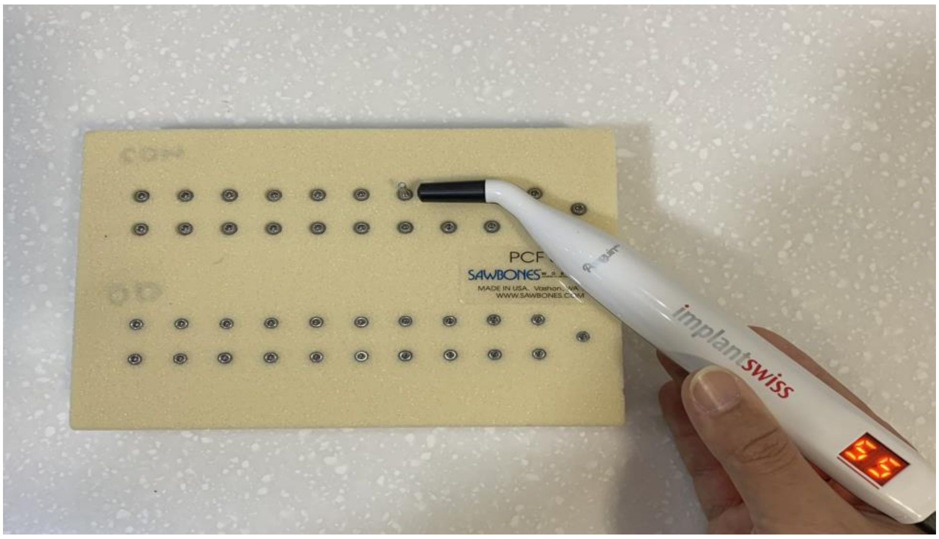


Figure 3.14. Penguin RFA (Integration Diagnostics Sweden AB, Gothenburg, Sweden)

Statistical Analysis

For statistical analyses, NCSS (Number Cruncher Statistical System) 2007 (Kaysville, Utah, USA) software was used. When evaluating the study data, descriptive statistical methods (Mean, Standard Deviation (SD), Median, Frequency, Ratio, Minimum, Maximum) were used and the distribution of the data were evaluated with the Shapiro-Wilk Test. Mann-Whitney U Test was used to compare the quantitative data between two groups that did not show normal distribution. Significance was evaluated at $p<0.05$ levels.

4. RESULTS

In this study, it was aimed to compare the primary stability, together with the insertion and removal torques of short dental implants with a length of 5 mm placed in the D4 type bone that mimics the posterior maxilla using conventional and osseodensification drilling techniques.

4.1. Comparison of measurements by groups:

4.1.1. Insertion torque value:

Comparison of the insertion torque values according to the groups were evaluated with the Mann Whitney U test and a statistically significant difference was found ($p<0,05$). The insertion torque value in the conventional technique (3.19 ± 0.75N/cm) was found to be statistically lower than the insertion torque value of the osseodensification technique (4,76 ± 0,62 N/cm) (Table 4.1) (Figure 4.1).

Table 4.1. Comparison of insertion torque value by groups

		n	Mean ± SD	Min-Max (Median)	p
Insertion Torque Value	**Conventional Technique**	21	3.19 ± 0,75	2 - 4 (3)	**0,05***
	Osseodensification Technique	21	4.76 ± 0,62	4 - 6 (5)	

Mann Whitney U Test *p<0.05

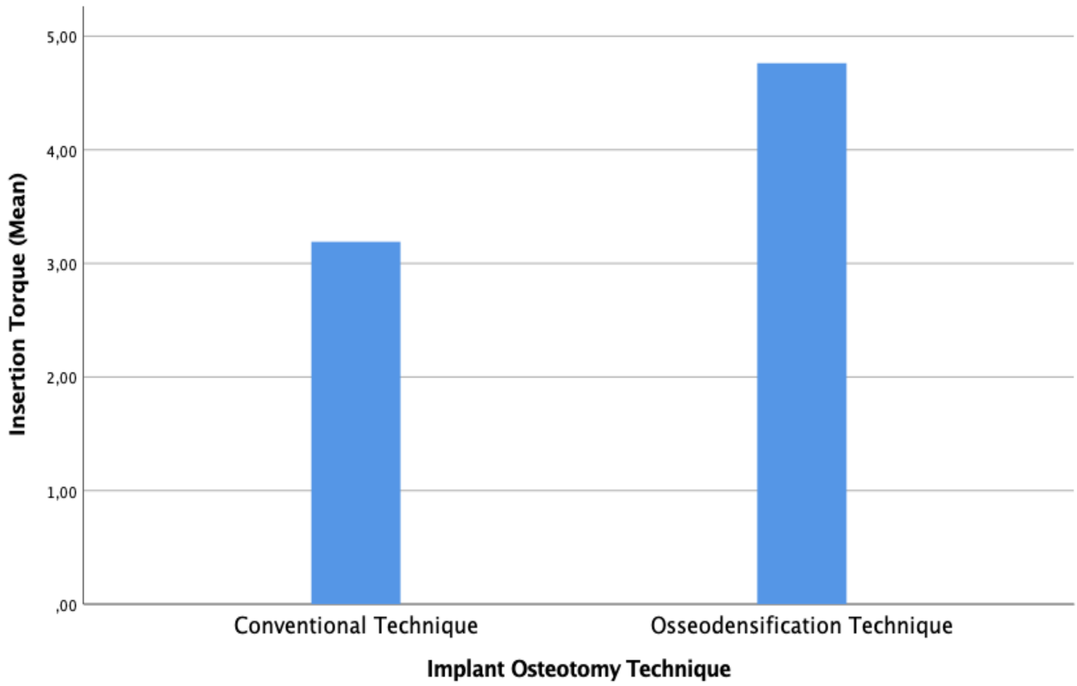


Figure 4.1. Comparison of insertion torque value by groups

4.1.2. Implant stability quotient (ISQ) value:

Comparison of the ISQ values according to the groups was evaluated with the Mann Whitney U test and a statistically significant difference was found (p<0,001). The ISQ value in the conventional technique (51,68 ± 3,25N/cm) was found to be statistically lower than the ISQ value of the osseodensification technique (56,28 ± 1,41N/cm) (Table 4.2) (Figure 4.2).

Table 4.2. Comparison of ISQ value by groups

		n	Mean ± SD	Min-Max (Median)	p
ISQ Value	**Conventional Technique**	21	51,68 ± 3,25	44,33 - 55 (52,66)	**0,001***
	Osseodensification Technique	21	56,28 ± 1,41	54,66 - 60,33 (56)	

Mann Whitney U Testi   *p<0,001

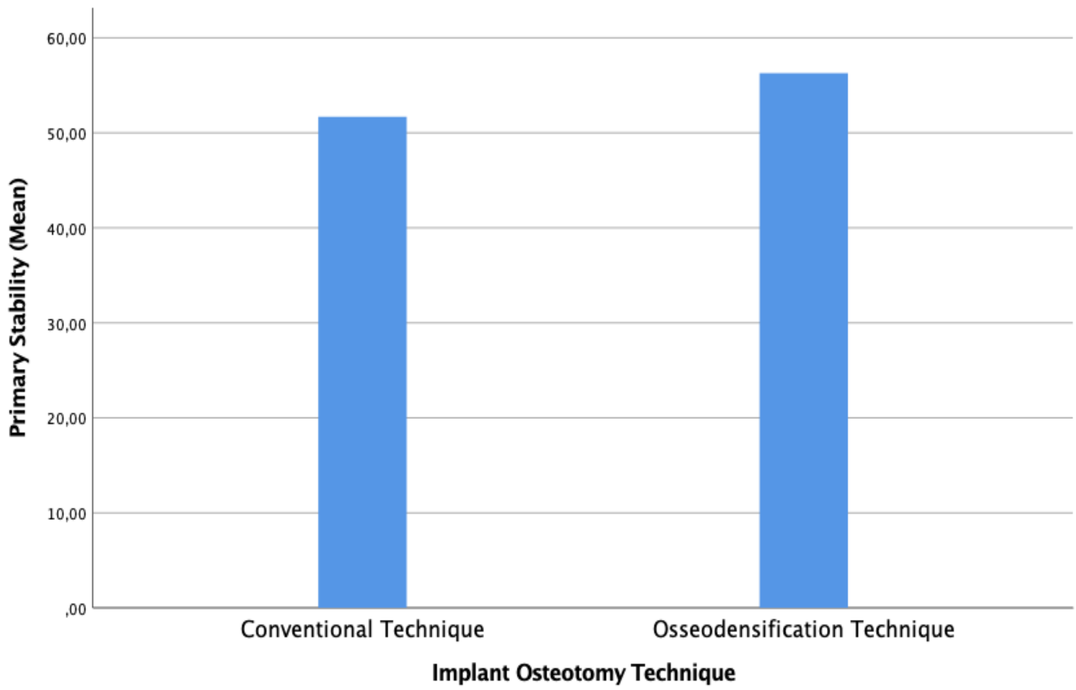


Figure 4.2. Comparison of ISQ value by groups

4.1.3. Removal torque value:

Comparison of the removal torque values according to the groups were evaluated with the Mann Whitney U test and a statistically significant difference was found ($p<0.05$). The removal torque value in the conventional technique (1.57 ± 0.6 N/cm) was found to be statistically lower than the removal torque value of the osseodensification technique (2.57 ± 0.6 N/cm) (Table 4.3) (Figure 4.3).

Table 4.3. Comparison of the removal torque value by groups

		n	**Mean ± SD**	**Min-Max (Median)**	**p**
Removal Torque Value	**Conventional Technique**	21	1.57 ± 0.6	1 - 3 (2)	**0.05***
	Osseodensification Technique	21	2.57 ± 0.6	2 - 4 (3)	

Mann Whitney U Testi *p<0.05

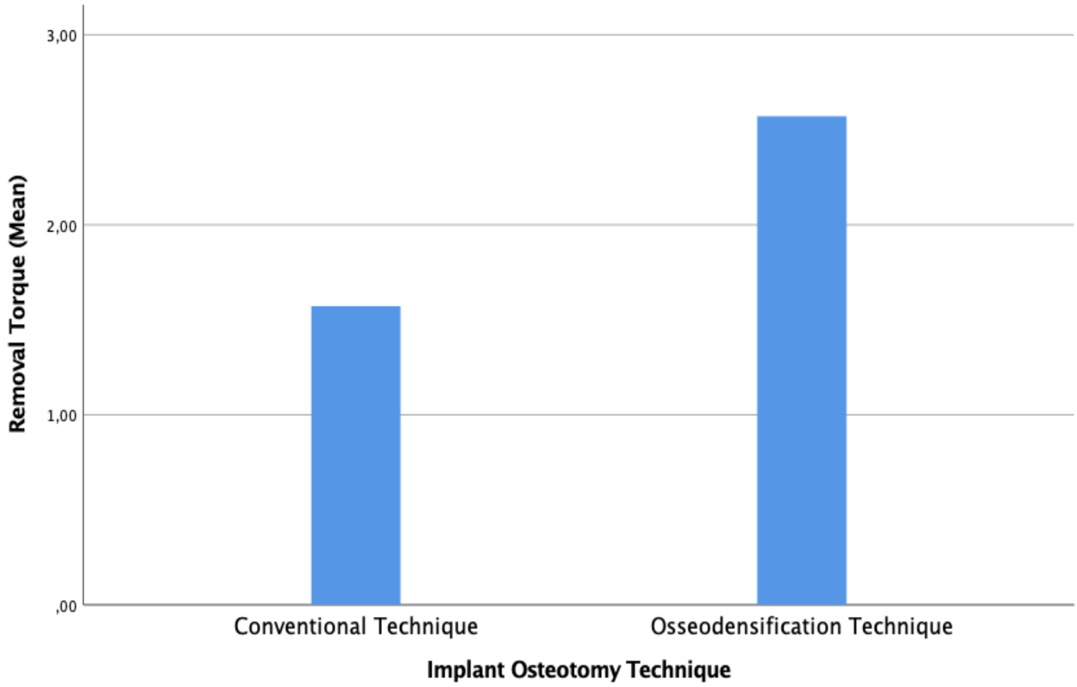


Figure 4.3. Comparison of the removal torque value by groups

5. DISCUSSION

In this study, it was aimed to compare the primary stability together with the insertion and removal torques of short dental implants with a length of 5 mm placed into D4 type bone that mimics the posterior maxilla using conventional and osseodensification drilling techniques.

Inferior alveolar nerve (IAN) nerve lateralization, sinus lifting, and advanced surgical methods such as bone augmentation procedures may cause various complications during and after the operation. Therefore, it has been stated by the researchers that the application of short dental implants may be an alternative treatment method in terms of being a less invasive surgical procedure resulting in patient satisfaction.

Survival rates of implants vary depending on many factors such as surface properties of implants, patient habits, prosthetic factors, and bone density. The research showed that the failure rate of short dental implants with machined surfaces reaches up to 29%. In addition, it has been reported that larger diameter implants create better contact areas with the bone surrounding the implant, and play an important role in better osseointegration with higher primary stability. However, in this study, short dental implants with RBM surface were preferred instead of machined surfaces, since their insertion, removal torque, and ISQ values are higher. In addition, an implant with high primary stability was chosen due to its aggressive thread structure (3).

Bone density is also one of the most determining factors in short dental implant treatments. The literature showed that implant losses were more experienced in areas with low bone density due to peri-implant forcing and tensions. For this reason, it has been reported that short dental implants inserted in low-density D3-D4 bone types such as posterior maxilla by conventional drilling techniques are less successful than in high-density D1-D2 bone types such as mandible (3). In this study, the success criteria of the osseodensification drilling system, which is a new technique, in D4 type bone blocks that mimic the bone density in the posterior maxilla, where the survival rate of short dental implants is low, has been investigated.

Misch et al. stated that 2837 short implants applied to the posterior regions between 1991-and 2003 were successful at a rate of 85.3% (98). Das Neves et al. and Esposito et al. stated that as an alternative to sophisticated augmentation methods, brief dental implant applications are a viable option (97,172). Van Assche et al. stated that there is not enough research, however, considering the studies conducted, short dental implants can be used as an alternative to augmentation techniques in D3 and D4 bones in atrophic jaws. On the other hand, Neha Jain et al., in their study in which they associated dental implant selections with bone density and quality, stated that bone quality is the primary factor for the success of short dental implants and reported that failure rates were higher, especially in D3 and D4 bone types. They also stated that when the length of short dental implants and low bone quality is considered as a whole, this reduces the primary stability of dental implants and adversely affects healing (173).

The quantity and quality of bone at the implant site determine primary implant stability. It is critical to have adequate primary stability in regions having D3 and D4 bone, such as the posterior maxilla (174,175). In computer tomography (CT), bone density may be measured using Hounsfield units (HU), which are CT attenuation values reported on a linear density scale (176). The Hounsfield scale is used to assess bone for implant placement, and the results are quantitative, objective, and site-specific. The density of the tissue represented by the voxel bone density classification, which is classified as follows, is connected to the HU value: D4, 150–350 HU; D3, 350–850 HU; D2, 850–1250 HU; D1, >1250 HU (177). Fuster-Torres et al. reported a mean bone density of 464 HU for 25 implant sites in the posterior maxillary area, whereas Norton et al. reported a mean bone density of 417 HU for 27 maxillary implant sites. Similar investigations were conducted by Shapurian et al. and Türkyılmaz et al., with findings of 403 HU for 70 implant sites and 333 HU for 54 implant sites, respectively (176,178,179,180). Kim, Ji-Hyun, et al. obtained similar results to those reported by Türkyılmaz et al. (180,181). In addition, Türkyılmaz et al. and Isoda et al. found statistically significant relationships between HU and the parameters of RFA, insertion torque, and main stability (180,182,183).

To evaluate the state of implant stability, continuous objective and quantitative monitoring is required. Microscopic or histologic investigation was once the gold standard approach for determining the degree of osseointegration. Nevertheless, because of the method's invasiveness and associated ethical concerns, numerous additional ways of analysis have been offered such as torque of cutting resistance, insertion torque, removal torque and RFA (133).

The insertion torque test is the torque force applied when inserting the implant in the previously prepared slot. It has become a frequently used method for immediate loading (131,136). In 2006, Türkyılmaz et al. and Ottoni stated that the amount of torque is high in implants placed in patients with high bone quality and that these implants have high implant stability quotient (ISQ) values (120,136). However, Friberg et al. argued that there is no connection between the insertion torque and the ISQ (137).

Sullivan et al. compared the insertion torques according to bone quality, and stated that there was no statistically clear difference in D2 and D3 bone, however, the values decreased significantly in D4 bone (138).

Ottoni et al. stated that implants with a placement torque higher than 32 Ncm can be loaded immediately while those with less than 20 Ncm may be more likely to fail (136). It is stated that the insertion torque test is a reliable and simple method for implant stability (135).

Trisi et al. discovered a statistically significant connection between insertion torque, peri-implant bone density, and micro-movement in an in vivo investigation. A substantial increase in insertion torque and a corresponding decrease in the micro-movement has been seen when bone density levels rise (184). In a review, Li et al. and Berardini et al. reported no significant difference in crestal bone resorption or implant failure rate when implants were placed with low or high insertion torque values (185,186). They also showed that the osseodensification method drills can improve the percentage of bone volume (BV) and percentage of bone-implant contact (BIC) for dental implants put in the low-density bone as compared to those inserted in standard osteotomies, indicating that this could aid osseointegration (156,157).

Oliveira et al., found in their research that implants inserted in low-density bone by osseodensification (OD) technique offered higher insertion torque values compared to those inserted with conventional technique and independent of implant surface properties (187).

Ottoni et al. stated in their study that the insertion torque test is a reliable and simple method for implant stability (188). Similar studies observing that the correlation between primary implant stability values and insertion torque was statistically significant were conducted by Türkyılmaz et al. and Farré-Pagè et al. (183,189).

Huwais et al. inserted 72 implants into the tibias of 12 pigs to analyze the implant insertion torque of the implants they exerted with the conventional drilling technique and the osseodensification drilling technique (36 implants in each group) (84). They reported considerably greater values of implant insertion torque for the osseodensification drilling technique group compared to the conventional drilling technique group and concluded that this significantly increased the implant primary stability of the osseodensification drilling technique. Likewise, other studies have reported that the osseodensification technique increases implant primary stability when they are compared with the conventional method (156,187,190).

In the present study, it was indicated that the osseodensification drilling technique increased the insertion torques of implants compared to the conventional drilling technique. This also indicates that the primary biomechanical stability of the implants is increased. Similarly, in this study, we found that the short dental implants placed using the OD approach had a higher insertion torque (mean=4.76±0.62 N/cm) than short dental implants inserted using the conventional technique (mean=3.19±0.75 N/cm), and it was statistically significant.

The amount of torque required to unscrew an implant from bone is dictated by the overall degree of contact between the implant surface and the surrounding bone. The higher the removal torque levels, the more stable the implants are thought to be (48).

Researchers argued that torque tests are the only tests that can explain the bone formation and bone maturation at the implant surface. It has been explained that the maximum shear force that can be tolerated on the surface between the bone and the implant can be measured with this test. In addition to the implant geometry, the quality of the connection of the implant with the surrounding tissues also plays an important role in the levels obtained in these measurements (140).

The removal torque value (RTV) was later found to vary from 45 to 48 Ncm in 404 clinically osseointegrated implants in humans as an indirect evaluation of BIC or clinical osseointegration (119). Because none of the implants in their trial could be withdrawn during abutment connection at 20 Ncm, Sullivan et al postulated that any RTV more than 20 Ncm could be acceptable as a criteria for effective osseointegration. Furthermore, it was claimed that RTV is a valid diagnostic tool for osseointegration verification (138).

According to Ivanoff et al., larger torque rotation forces necessary to remove implants might be interpreted as an increase in bone-implant contact, resulting in better osseointegration strength (17). Sennerby et al. (1992) showed no change in removal torque values for screw-shaped implants implanted in rabbit tibiae for 6 weeks, 3 and 6 months; there was no difference in removal torque values for cancellous bone (femoral intra-articular implants) at 3 and 6 months (191). The findings of this study back up the theory that a changed design improves osseointegration and early implant loading. Other rabbit tibia removal torque investigations yielded comparable findings (153,192). There was no consistent ratio between the ISQ values and the removal torque values, according to Gehrke and Marin, although there were correlations when the averages were translated into percentages within each time period (193). As a result, ISQ values in the groups were generally connected with removal torque values; this is consistent with Cehreli's study, which found a statistically significant association between cutting torque or insertion torque and resonant frequency analysis (194). Surface alterations impacted removal torque values according to a prior study, thus implants with the same surface treatment were employed (195).

Higher values of removal torque have been recorded in implants inserted with OD drilling technique compared to conventional drilling technique. The reason for this might be due to the compressed bone in the osteotomy produced by OD applying reverse-compression on the implant (4,157,163). In our study, we also found that the removal torque of short dental implants placed with the OD approach (mean=2.57±0.6 N/cm) was significantly greater than that of short dental implants placed using the conventional technique (mean=1.57±0.6 N/cm).

Meredith proposed resonance frequency analysis in 1998 as a noninvasive diagnostic tool for measuring implant stability and bone density over time utilizing vibration and a structural analysis premise (110). RFA is considered to be the most important method for evaluating the primary stability of dental implants. Implant values with ISQ <60 are considered to be risky and no loading should be placed on them in the short term. While traditional loading can be done for implants with ISQ values between 60 and 69, it was reported that instantaneous loading may be done for implants with ISQ values more than 70 (140,152). However, these reference values may change in low-density bone types such as D4, and it has been stated that implants with ISQ values >40 do not have unsuccessful implant stability (153).

Primary implant stability is recognized to be dependent on implant design, bone density, and surgical procedures (6,159,196). It is critical to maintain low implant micro-movement, particularly during the early healing phase, to facilitate direct bone ingrowth to the implant surface (197). Previous research has revealed that the exposed implant height and the accompanying ISQ values have a linear relationship (198,199). Sim and Lang found a link between ISQ values and bone structure and implant length in their study (200). However, O'Sullivan et al found no link between implant form and implant primary stability (201). A comparison was made in this study between bone level implants and tissue level implants of identical size. When compared to tissue level implants, bone level implants had slightly higher but negligible ISQ and removal torque values. When the main stability of implants was examined in different bone qualities, the ISQ values for implants implanted in type II bone with 1 mm cortical bone were significantly greater. This finding is in line with that of Akca et al., who found that implant form had less of an impact than bone quality (202). The important factors impacting primary stability, according to Elias et al, are implant design, surgical technique, and substrate type (203).

In their study, Antonelli et al. looked at bone compaction and osseodensification procedures, as well as how cancellous bone compaction affects primary implant stability, and found no significant variations in ISQ between the two groups. For all groups, high values of ISQ and IT indicate good primary implant stability, implying a strong stiffness at the implant-bone contact (204).

Cáceres et al. assessed the effect of the osseodensification drilling technique on the insertion torque, the removal torque, and ISQ of conical implants. The values of the insertion torque, removal torque, and ISQ were found to be higher for the osseodensification drilling technique with a statistically significant value ($p < 0.001$) compared to the conventional drilling control group (205). Oliveira et al. studied the effects of osseodensification on implant primary stability and osseointegration progression with RFA in sheep's iliac crest. According to their findings, the osseodensification drilling approach greatly enhanced the main stability of the implant compared to the conventional drilling method, which favors early osseointegration (187). Similarly, in this study, the ISQ value of short dental implants inserted with the OD technique (mean=56,28±1.41 N/cm) was found to be higher than the ISQ value of short dental implants inserted with the conventional technique (avg=51,68±3.25N/cm), and it was statistically significant.

In a spine model animal research, Lopez et al. evaluated the histological and biomechanical consequences of the osseodensification drilling procedure (163). The fixation devices were put on the vertebral bodies of 12 sheep's spines. Because of its low-density bone structure, the sheep cervical spine model was chosen. The standard drilling technique was used to implant the devices on the left side, while the osseodensification drilling technique was used to implant the devices on the right side. Six of the twelve sheep were sacrificed three weeks following operation, while the other animals were killed six weeks later. They measured the structural adequacy of the equipment using the biomechanical test of removal force while Histomorphometry was used to evaluate the quality and amount of new bone production and remodeling. When comparing the osseodensification drilling group to the conventional drilling group, statistical analysis revealed that the osseodensification drilling group had substantially greater insertion torque levels (about 65 N cm) (approx. 35 N cm). Removal force showed the osseodensification group to provide superior anchorage with statistical significance compared with the conventional group. Despite the lack of stress on the implanted devices, the authors concluded that this method might enhance the safety and success rates of implant osteotomy in all locations with poor bone density and restricted bone volume.

In 2016, the first in vivo investigation of parallel-walled implants in low-density bone and early osseointegration of conical and the influence of osseodensification on primary stability was published (156). A total of 30 implants were implanted in the bilateral ilium of five male sheep. Each animal received 30 different implants, with bone areas created using three different techniques: counter-clockwise osseodensification drilling, clockwise osseodensification, and standard drilling. Densah Bur (Versah, Jackson, MI) was utilized in the osseodensification drilling method in the first two techniques, which were considered two test groups. Regardless of implant macro geometry, insertion torque as a function of implant type and drilling technique resulted in greater osseodensification values than traditional drilling. In comparison to traditional drilling, both osseodensification methods had a considerably higher BIC. Trisi et al. also conducted research to evaluate implants placed by osseodensification against implants inserted through traditional drilling on sheep. For each procedure, ten implants were implanted, the sheep were sacrificed, and biomechanical and histological investigations were conducted after two months of recovery. In the osseodensification group, the proportion of bone volume increased significantly (about 30 percent higher). In comparison to the conventional group, the test group had much-improved RTV and micro-movement under lateral pressures. Furthermore, osseodensification and traditional drilling methods prevented inevitable bone loss while also preventing trabeculae fracture, which was produced by the osteotome approach and resulted in a delay in bone development. The OD method also aids in bone growth, allowing bigger diameter implants to be placed in the narrow ridge without causing bony detachment or fenestration, according to their research (157).

To the contrary, different findings were obtained in other studies. Almutairi et al. in 2019 showed that between the osseodensification drilling technique and conventional drilling techniques, there was no statistically significant difference in terms of implant primary stability in quality and high-density bone (169). They also concluded that the osseodensification technique is not necessary for this type of bone. Wang et al. conducted a study with similar findings in 2017 where the peri-implant bone density observed the possibility of condensation increase, however, no higher implant primary stability is provided. Alghamdi studied distinct aspects, such as the influence of the drilling method, in his review of methods for improving the osseointegration of dental implants in poor quality bone, and reported that improvements with implant surface modifications appear to be more crucial in areas that do not have sufficient or quality bone to improve bone healing and osseointegration (206). In contrast, Toia et al., in recent research on the implant drilling protocol, indicated that a pre-surgical radiographic evaluation and perception of bone quality are required to determine the best drilling procedure and reduce surgical stress (207).

To the author’s knowledge, no study has been conducted to compare the primary stability of short dental implants placed in D4 bone using conventional and osseodensification (OD) drilling techniques with resonance frequency analysis (RFA), insertion and removal torque tests.

The results of the current study show that in D4 bone types, the osseodensification drilling technique instead of the conventional drilling technique can be a better alternative treatment method, especially if short dental implants are placed in the bone. This study confirms the hypothesis that the osseodensification technique will increase primary stability compared to the conventional technique.

As a result, in dental implant treatments, osseointegration is critical, and main stability of the implant, as well as insertion and removal torque levels, are of great importance for effective osseointegration. Short dental implant applications is provided as an efficient method in terms of advanced surgical techniques avoidance, patient cooperation and throughout the treatment with economic advantage.

6. CONCLUSION

- The insertion torque value in the conventional drilling technique was found to be statistically lower than the insertion torque value of the osseodensification drilling technique with the short dental implant of 4.8x5mm length inserted on PFC05 (D4) bone type mimicking low density

- The removal torque value in the conventional technique was found to be statistically lower than the removal torque value of the osseodensification technique with the short dental implant of 4.8x5mm length inserted on PFC05 (D4) bone type mimicking with low density

- The ISQ value in the conventional technique was found to be statistically lower than the ISQ value of the osseodensification technique with the short dental implant of 4.8x5mm length inserted on PFC05 (D4) bone type mimicking with low density

- As an alternative to augmentation, 4.8x5mm short dental implants might be utilized with osseodensification drilling technique for D4 bone types,

- Further studies are needed for the non-aggressive implant type and for different implant lengths.

7. REFERENCES

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