T.C.
YEDİTEPE UNIVERSITY
GRADUATE SCHOOL OF HEALTH SCIENCES
DEPARTMENT OF ORAL AND MAXILLOFACIAL SURGERY

CALCULATION OF INSERTION AND EXTRACTION TORQUES OF DENTAL IMPLANTS WITH 5 MM AND 8 MM SIZES IN D2 AND D4 TYPES OF BONES, CONDUCTION OF RESONANCE FREQUENCY ANALYSES AND COMPARISON OF PRIMARY STABILITY VALUES

DOCTORAL THESIS

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ONAY

Bu tez Yeditepe Üniversitesi Lisansüstü Eğitim-Öğretim ve Sınav Yönetmeliğinin ilgili maddeleri uyarınca yukarıdaki jüri tarafından uygun görülmüş ve Enstitü Yönetim Kurulu'nun .15.../02.../2019... tarih ve ...2019/03-30.........sayılı kararı ile onaylanmıştır.

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DECLARATION

I hereby declare that this thesis is my own work, I have not had any unethical behaviors from the planning up to the writing of the thesis, I obtained all information in this thesis in compliance with academic and ethical rules, I included references to all information and interpretations that were not collected by this thesis and stated these references in a list of sources, and I did not take part in any behaviors that would infringe upon patent rights or copyrights during the procedures in and writing of this thesis.

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mm: Millimeter

Ti: Titanium

Co: Kobalt

Cr: Chromium

Mo: Molybdenum

CT: Computed Tomography

Cent: Century

TCP: Tricalcium Phosphate

HA: Hydroxyapatite

HCL: Hydrochloric Acid

H_2SO_4: SulfuricAcid

Ncm:Newton centimeter

MAO: Micro Arch Oxidation

Ca: Calcium

P: Phosphate

IAN: Inferior Alveolar Nerve

RFA: Resonance Frequency Analysis

ISQ:Implant Stability Quotient

SD: Standard Deviation

ATH:Acceleration Time History

ABSTRACT IN ENGLISH

Nizam O. (2019). Calculation of Insertion and Extraction Torques of Dental Implants with 5 MM and 8 MM Sizes in D2 and D4 Types of Bones, Conduction of Resonance Frequency Analyses and Comparison of Primary Stability Values. Yeditepe University, Health Sciences Instute, Department of Oral and Maxillofacial Surgery, PhD Thesis. Istanbul. The most effective treatment method today for missing teeth in patients involves dental implants. They have great significance in terms of prevention of harm on other teeth prosthetically and restoratively and their easy functioning as teeth. The most important factor in the success of dental implant treatment is primer stability and osteointegration. Nowadays, because of the sustainability of patient cooperation, avoidance of financial difficulties and high costs and no necessity of secondary surgical procedures, short dental implants are frequently used as an alternative to bone augmentation techniques.

In this study, it was aimed to compare short dental implants with a height of 5 mm placed onto polyurethane PCF05 and PCF20 bone blocks (#1522-23, #1522-03: Sawbones, Malmö, Sweden) that imitated the D2 and D4 bone types to 8-mm dental implants that are accepted as the standard height based on their primer stability and placement and extraction torque forces by resonance frequency analysis. A total of 40 DeTECH (Turkey) dental implants were applied so that each block would carry 10 implants with heights of 5 mm and 10 implants with heights of 8 mm, all with the same diameter.

As a result of our study, similar ISQ, placement torque and extraction torque values were observed between the 5-mm and 8-mm dental implants placed onto the PCF20 block that imitated the D2 bone type, while a significant increase was observed in the values of the 8-mm dental implants. There were decreases in all values on the PCF05 block that imitated the D4 bone type, and the differences between the values of the 5-mm and 8-mm implants were not significant.

Consequently, it was found that, among the implants with the same diameters, the 8-mm implants were more reliable than the 5-mm implants, 5-mm implants maybe used as an alternative to augmentation techniques in the mandibular posterior region based on the statistical data that were obtained, but they were not reliable in the maxillary posterior region, and there is a need for research on different sizes for non-aggressive implant types.

Key Words: Primary Stability, Implant Stability Quotient, Insertion and Extraction Torque

ABSTRACT IN TURKISH

Nizam O. (2019). 5 MM ve 8MM Boylarındaki Dental İmplantların D2 ve D4 Kemik Tiplerinde Yerleştirm eve Çıkarma Torklarının Hesaplanması ve Rezonans Frekans Analizinin Yapılarak Primer Stabilitelerinin Karşılaştırılması. Yeditepe Üniversitesi, Sağlık Bilimleri Enstitüsü, Ağız Diş ve Çene Cerrahisi Anabilim Dalı Doktora Tezi. İstanbul. Günümüzde hastalarda bulunan diş eksikliklerinin en etkin tedavi yöntemi dental implantlardır. Protetik ve restoratif olarak diğer dişlere zarar verilmemesi ve fonksiyonel olarak diş görevini rahatlıkla yerine getirebilmesi açısından büyük önem teşkil ederler. Dental implant tedavisinin başarısındaki en önemli faktör ise primer stabilite ve osteointegrasyondur. Günümüzde hasta kooperasyonun sürdürülebilirliği, maddi zorluk ve yüksek maliyetlerden kaçınmak, sekonder cerrahi işlemlerei htiyaç duyulmaması açısından kemik ogmentasyon tekniklerine alternatif olarak kısa dental implantlar sıkça kullanılmaktadırlar.

Yapmış olduğumuz çalışmada D2 ve D4 kemik tiplerini taklit eden poliüretan PCF05 ve PCF20 kemik blokları (#1522-23, #1522-03 :Sawbones, Malmö, İsveç) üzerine yerleştirilen 5 mm boyundaki kısa dental implantların, rezonans frekans analizi yapılarak primer stabilitelerinin, yerleştirme ve çıkarma tork kuvvetlerinin standart boy olarak kabul edilen 8 mm boyundaki dental implantlar ile karşılaştırılması amaçlanmıştır. Her iki blok üzerine çapları eşit 10 adet 5 mm ve 10 adet 8 mm boyunda implant yerleştirilmek üzere toplam 40 adet DeTECH (Türkiye) marka dental implantlar uygulanmıştır.

Çalışmamız sonucunda D2 kemik tipini taklit eden PCF20 blok türü üzerine yerleştirilen 5 mm ve 8 mm boyundaki dental implantlarda benzer ISQ, yerleştirme ve çıkarma tork değerleri gözlenirken, 8 mm boyundaki dental implantların değerlerinde anlamlı artış gözükmektedir. D4 kemik tipini takli teden PCF05 blok türü üzerinde ise bütün değerlerde düşüş gözlemlenmiştir ve 5 mm ve 8 mm boyundaki implantların arasındaki değerler anlamlı bulunamamıştır.

Sonuç olarak ise aynı çaplardaki 8 mm boyundaki implantların, 5 mm boyundaki implantlara göre daha güvenilir olduğu, elde edilen istatistiksel verilere göre 5 mm boyundaki dental implantların mandibula posterior bölgede ogmentasyon tekniklerine alternatif olarak kullanılabileceği fakat maksilla posterior bölgede güvenilir olmadığı, agresif olmayan implant tipleri için de farklı boylar için araştımalara ihtiyaç olduğu düşünülmektedir.

AnahtarKelime: Primer Stabilite, İmplant StabiliteOranı, Yerleştirme ve ÇıkarmaTorku

1. INTRODUCTION AND PURPOSE

In recent years, dental implants carry a great significance especially for the prosthetic and surgical restoration of toothless regions. Considering it in terms of both eliminating missing teeth and providing the patient with the ability that the patient has lost, implant treatment has become a primary treatment option.

While dental implants provide great advantages for the physician and the patient, they are financially costly and long treatment processes(1).

For being able to apply dental implants to the patient, there is a need for a both horizontally and vertically adequate bone. Otherwise, there may be failures in implants to be applied. Today, with the help of advanced technology and several different bone augmentation operations, areas where dental implants may be applied, namely indications, also increased.

It is very important to systemically examine the patients in periods before and after application of implants. According to several studies;

- The surgical method to be applied
- Type of implant
- The material used for making the implant
- Age of the patient
- Sex of the patient
- The morphology of the bone to be used for application
- And inserting dental implants appropriately and accurately are main criteria that are effective on the success of dental implants(2).

This study aimed to compare the insertion torque and extraction torque values of 5-mm implants that are considered to be short and 8-mm implants that are considered to be standard size into different types of bones (D2 and D4 bone densities), ISQ values, primary stability values and investigate their probability of successful usage.

2. LITERATURE REVIEW

2.1.Dental Implants:

In the past centuries, people have tried to develop several methods that would replace missing teeth to serve functionally and aesthetically the same purpose. Implant treatment is one of such methods. Implants are defined as objects that are placed on living tissues in the human body to serve different functions. Structures that are planned to replace functions of teeth by placement into mucosa, on the bone or in the bone are known as dental implants(Figure 2.1)(3). The purpose of these treatments is regaining phonetic, aesthetical, functional and psycho-social integrity(4).

It was found that different levels of integration may be found in the connection between the implant surface and the bone. It was reported that bone residues and normal bone tissue could be found in this interface in addition to hematoma that occurs at the stage of implantation.

These findings brought into attention the concept of osseointegration between the titanium surface in implants and the bone(5).

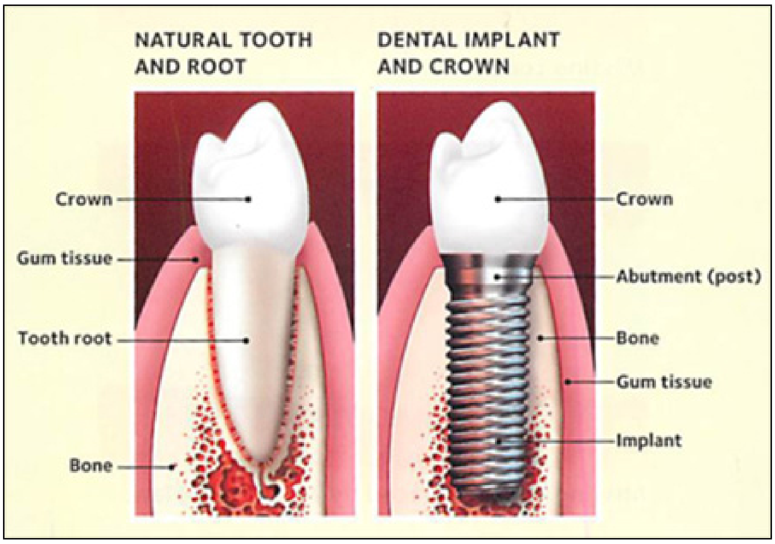

Figure 2.1. Dental İmplant

2.2. History ofOral Implantology:

It was seen that, before the discovery of the Americas, the tooth sockets on the mandible were filled by seashells in previous archeological findings(6,7). Additionally, ivory teeth that were found in Ancient Egypt were among the oldest examples of implantology(8).

In the 16th century, Ambroise Pare focused on transplantation, and several trials were made in the following centuries(9). For example, in the 17th century, Mr. Dupont removed the nerved from the teeth he extracted and placed them back into their sockets. In the 18th and 19th centuries, in British and American colonies, the teeth of poor people were extracted and planted on rich people. However, it was observed that all trials resulted in ankylosis or root resorption(10).

Maggiolo(1809) placed golden implants in the place of newly extracted teeth but observed that pain and inflammation developed in the region. As the year went by, several materials that could be used as dental implants were tried out. In the early 1900, Lambotte produced soft steel implants that are coated with silver, aluminum, magnesium, gold, nickel and red copper(11).

In 1938, Strock placed an endosseous implant that consisted of chromium-cobalt molybdenum screw and conically designed for cementation. The patient died in 1955, and there was no problem related to the implant in the process between. The implant stayed asymptomatic and stable. This why, it was proven for the first time that a metallic implant was successful in people(12).

In 1978, for the first time, two-stage, grooved and root-shaped implants were introduced in Northern America by Per-Ingvar Branemark.Branemark experimented on rabbits and saw that titanium disks that he placed on femoral bones were osseointegrated(13). In later years, Branemark et al. played a substantial role in the development of implant systems(14).

2.3.Implant Materials

2.3.1. Metals and alloys:

Titanium and titanium 6 aluminum – 4 vanadium

Cobalt – chromium – molybdenum

Iron – chromium – nickel

Among metals, titanium is the most frequently preferred one. One reason for this is that it is resistant to attacks by fluids that are produced by the organism. Other reasons for titanium to be suitable for dental implant design include that it is highly resistant to loads and corrosion and good biocompatibility with the bone structure. Titanium is passivized by itself in the organism, and a titanium oxide layer develops on its surface. By coating hydroxyapatite on pure titanium, foreign body reaction decreased, and an effective recovery process was observed(1).

An ideal implant material should;

- Not be cytotoxic or carcinogenic.
- Not cause allergies.
- Be biocompatible.
- Be resistant against pressures and not experience changes.
- Be a bio-adhesive.
- Be economical.
- Be sterilizable.
- Resist abrasion.
- Be possible to shape(1).

2.3.2. Titanium in Biocompatibility:

Biocompatibility is the ability of a material to show an appropriate host response as a result of a specific implementation(15).

The most important reason for titanium and its alloys to be preferred is their biocompatibility. The biocompatibility characteristics of titanium and its alloys come from their high resistance to corrosion. This corrosion resistance is formed by the protection of the material from electromagnetic attacks by the oxide layer that forms on the surface of the material. Other criteria that determine biocompatibility are that titanium has excellent osseointegration with the bone and it allows the formation of a calcium phosphate-rich layer that resembles hydroxyapatite(16,17). Biocompatibility studies that have been carried out with titanium as a biomaterial extend from highly varied in vitro tests to animal experiments and in vivo studies. In the literature, it was shown that corrosion products of titanium that is used as implant material accumulate in local lymph nodes and internal organs and create galvanic side effects. In addition to this, some researchers also reported allergic reactions to titanium (18,19,20,21).

In the late 20th century and early 21st century, the term biocompatibility usually referred to low toxicity. The reaction of the implant in the soft tissue in the region it is placed in is in the form of creating a relatively acellular foreign body capsules, and titanium perfectly fits this definition by its low level of ion emission (Thomsen et al. 1997).

Urban et al.'s in vivo study showed that corrosive products could prevalently spread around the body but did not create toxic effects in patients who had hip/knee prosthetics(19). In vitro studies showed that titanium does not have mutagenic or other toxic effects.

The biocompatibility of metallic implants is based on surface characteristics such as metal emission and protein binding affinity. A study that compared chromium-cobalt (Co-Cr-Mo) and titanium implants demonstrated that chromium was released more in comparison to titanium, and there were differences in the protein binding and conformation mechanism of the surfaces(22). Biofilm composition and metal ion release based on the type of metal and alloy determine the bioreactivity of implant alloys. Superior biocompatibility of titanium is based on low ion release and protein conformation when it encounters bodily fluids.

The surface characteristics of implant materials play an effective role in the biological response that develops against these. The main problem related to implants today is the characteristics of the implant-tissue interface. The parameters that determine surface characteristics are chemical characteristics, crystallization, heterogeneity, roughness and wettability. Each parameter has significance over the biological response. In order to improve the surface characteristics of titanium implants, procedures such as hydroxyapatite coating, laser and plasma application and ion implantation are carried out(23).

2.4. Classification of Dental Implants:

1) Subperiosteal implants
2) Intramucosal inserts
3) Endosseous(endosteal) implants
4) Transosseous(trans-mandibular) implants

2.4.1. Subperiosteal Implants:

These are applied in the case of highly resorbed crests and inadequate vertical bone height. Partial and total prosthetics may be carried without fitting the oral mucosa. These implants were applied in 1940s, their 5-year success rate was reported as 93%. In time, a set of changes were made for the incoming forces to be distributed more equally. A change was the extension of the implant body towards the retromolar region and the lateral of the ramus. Additionally, for a more ideal connection between the implant and the bone, the implant was coated with hydroxyapatite. By placing autogenous bone graft on an atrophic bone, the researchers achieved raising the bone and providing enough bone for the implant, a 3-dimensional model was obtained by using CT (computerized tomography), applied the implant on this model and carried out the surgical process in one step(Figure 2.2)(1).

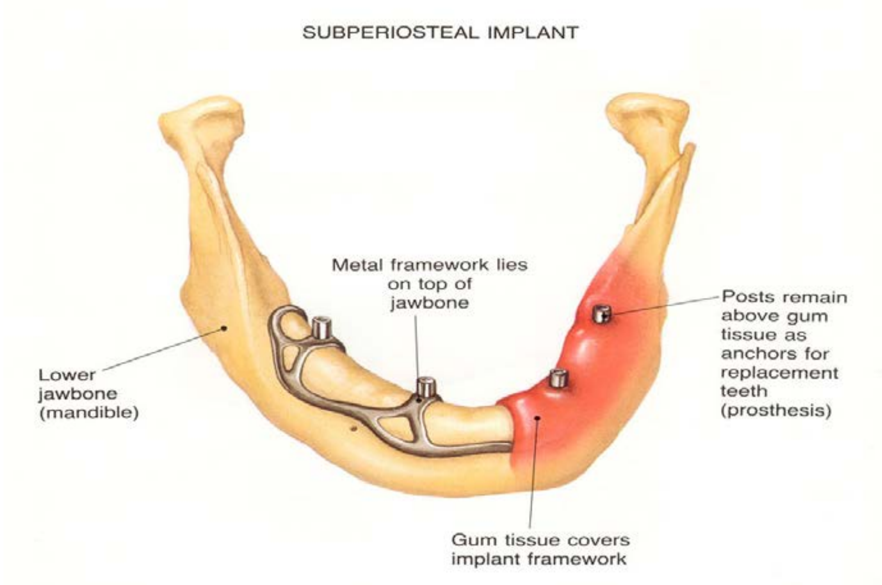

Figure 2.2.Subperiosteal implant

2.4.2. IntramucosalInserts:

These structures were proposed by GustauDahi in 1943. They are mushroom-shaped titanium structures that are used especially in maxillary prosthetics. These are used when it is aimed to keep the labial extension of the prosthetic short, or when the palatinal section is not wanted, and there is a need for retention due to atrophic maxilla. However, these are not preferred much today (1).

2.4.3. Endosseous (endosteal) Implants:

These are implants that are placed inside the bone and osseointegratedwith the bone directly. There is no gap or any connective tissue between the bone and the implant.

Recently, these types of implants are focused on, and different implants are constantly being promoted by various firms. Today, all around the world, there are endosseous implants with several brands. The most frequently preferred ones are root-shaped screwed or cylindrical implants. Such implants are more successful in comparison to others.

Osseointegration in screw-shaped implants is achieved by new bone formed by osteoblasts among grooves. This type of implant may be loaded earlier, and its primary stability is higher than those of others. Additionally, the incoming forces are more evenly transferred to the bone. Implant surface retention and the size difference between the implant diameter and implant socket in cylindrical implants directly affect primary stability. For bone development to took place towards the inside of the implant and a more successful integration between the bone and the implant, cylindrical implants may be prepared in perforated forms(Figure 2.3)(1).

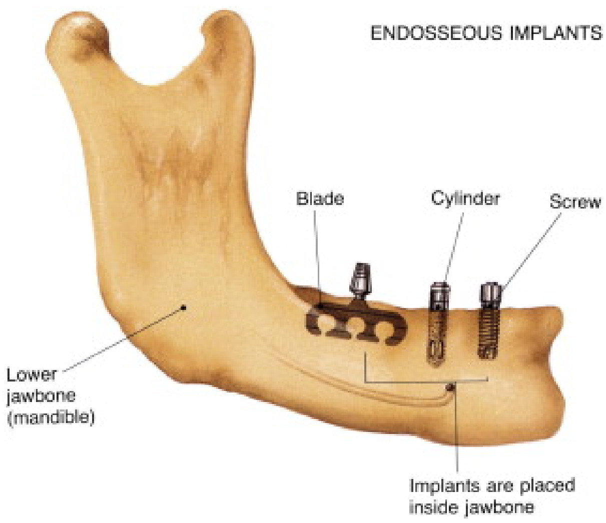

Figure 2.3. EndosseousImplant

2.4.4. TransosseousImplants:

This type of implants that were developed in 1973 is especially applied on toothless and excessively atrophied mandible. These are used in individuals who have had accidents or tumor or cyst formation in their mandible and advanced level of defect due to surgical operation. While most of their indications are the same as those of subperiosteal implants, they may be applied in the canine region with at least 9 mm of alveolar bone thickness(Figure 2.4) (1).

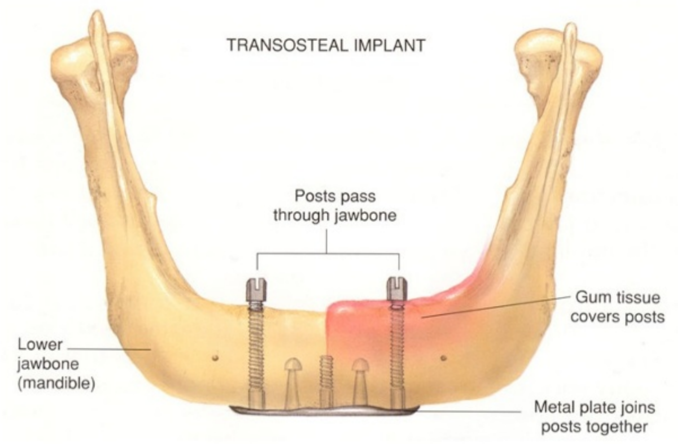

Figure 2.4.Transosseous Implant

2.5. Classification of implants based on surface characteristics:

a) Unprocessed implants

b)Implants with processed surfaces

- Acid-etched surfaces
- Sandblasted surfaces
- Polished surfaces
- Sandblasted and acid-etched surfaces(SLA)
- Surfaces roughened by lasers
- Porous surfaces
- Porous sintered surfaces

c)Implants with coated surfaces

- Surfaces coated by plasma spray
- Surfaces coated by ceramics

  1)Tricalcium phosphate (TCP) coating

  2)Hydroxyapatite (HA) coating

d)Combined implants(24).

2.5.1. Implants with unprocessed surfaces:

This is the surface structure of implants that have just come out of the milling machine. In implants with machined surfaces, circular and parallel lines with depth and with of 0.1nμalongside the long axis of the implant are the most common findings.

2.5.2. Acid-etched surfaces

Studies have shown that acid-etching increases the amount of bone formation on the implant. Acid-etching may be achieved by hydrochloric acid / sulfuric acid (HCL/H_2SO_4) or 2% hydrofluoric acid and 10% nitric acid baths. It was reported that the amount of abrasion in this method is dependent on the type and concentration of the acid that is used (25).

Experimental studies showed that acid-etching at high temperatures provides a more homogenous micro-rough surface and higher bone-implant contact in comparison to TPS surfaces(26,27).

The acid-etching method no only increases the surface area, but it also plays a role in the improvement of the bone-implant contact by removal of residual substances on the metal surface(28,29).

In a previous study, the researchers ran torque tests on polished Ti and acid-etched (HCL/H_2SO_4) (Osteotite) 3.25x4 mm implants that placed on rabbit femoral bones. As a result of the two-month recovery period, the Osteotite and polished Ti presented the respective values of 20.5 Ncm and 4.95 Ncm, the torque resistance value that was approximately four times for the acid-etched surface was statistically significant, and it was concluded that rough surfaces increase bonding with the bone (30).

Buser et al. (1999) reported that noticeably higher torque values were needed to remove acid-etched and sandblasted implants. Cochran et al. also showed reductions in bone resorptions in the neck region before and after loading the implants that were acid-etched and sandblasted(28).

In addition to this, chemical processes may reduce the mechanical properties of titanium. For example, acid etching may create microcracks on the surface by causing hydrogen embrittlement and reduce the implants' wear resistance values (31).

2.5.3. Sandblasted and Acid-Etched (SLA) Surfaces:

The SLA method is used to roughen the surface by applying a strong acid after sandblasting with large-grained particles. As an alternative to TPS coatings, the SLA technique has started to be used to obtain a better surface chemistry and topography. This process is applied as a consecutive roughening process of a combination of grit-blasting and acid-etching to obtain macro-roughness and micro-holes and achieve increased surface roughness in addition to osseointegration (32,33). Histomorphometricstudies and biomechanical tests have shown higher reverse torque values(34,35). After such experimental findings, SLA implants started to be used for early loading in clinical studies in such short times as 6 weeks. The 3-year clinical monitoring of these implants reported a success rate of approximately 99%(37,36).

SLA implant surfaces were marketed by Straumann in 1997 as sandblasted and acid-etched titanium surfaces. SLA surfaces are not a method of surface coating. Microroughness is achieved by spraying large grains of sand towards the implant surface. Micro holes with depths of 2-4 μm are obtained by applying the acid on the surface. SLA implant surfaces have medium roughness values. The degree of roughness is uniform alongside the entire implant surface. A study demonstrated that the alkaline phosphatase activity in osteoblast-like cells was higher in SLA surfaces in comparison to TPS surface(29).

2.5.4. Surfaces coated by plasma spray:

The plasma spraying technique usually involves a thick layer of accumulation such as hydroxyapatite (HA) andtitanium (Ti). The coating process is in the form of thermally melted materials sprayed onto the implant surface. In principle, plasma spraying increases the surface area of implants by increasing their surface roughness (38).

Metal implants are typically coated with calcium phosphate layers that consist mainly of hydroxyapatite. After inserting the implant, calcium phosphate release into the peri-implant region increases the saturation of body fluids and a biological apatite precipitates onto the implant's surface. The biological apatite layer may be used as a matrix that contains endogenous proteins for osteogenic cell attachment and growth. This is why the process of recovery for the bone around the implant is developed by this layer. The biological fixation of titanium implants to the bone tissue is faster in the presence of calcium phosphate. In comparison to non-coated titanium implants, it is known that these calcium phosphate coatings increase clinical success(39,40).

One of the greatest concerns related to plasma spray coating is the probability of delamination of the coating from the implant surface, and as a result of this, chance of failure although the coating is well-attached to the bone tissue. When the size of the dental implants is not suitable, coating delamination was reported as the activity of the plasma spray does not reach a desired level. Loosening of the coating has been reported especially in implants that were placed into dense bone(41,42,43).

2.5.5. Surfaces coated by ceramics:

Micro-arc oxidation (MAO)

This method is an advanced electrochemical technique that uses an electrolyte solution under high voltage which was developed for coating porous surfaces such as metals and ceramics. The MAO method is used to coat surfaces by controlling the composition and concentration of Ca and ions(44,45). In terms of biomedical practices, the significance of this process is that it may increase the bioactivity potential of alloys of metals such as titanium as theCa and PO_3 ions in the electrolyte during the MAO process penetrate the ceramic layer(46).

During this process, a positive voltage is applied on a Ti sample submerged in the electrolyte, and as a result of the anodization of titanium, an oxide layer is formed on the surface. When the voltage that is applied is increased up to a certain point,a micro-arc is observed at the point where degradation starts in the oxide layer (nonconductor degradation). At the point where nonconductor degradation starts, Ti ions and the OH ions in the electrolyte start to move in the opposite direction and immediately repair the degraded oxide layer. This newly formed layer has a tightly attached porous structure, and this form is highly beneficial for bioactive surfaces (47,44).

In recent years, studies on improvement of the biological response of Ti implants have reported the MAO method as one of the best methods for surface modification (48).

2.6. Indications and contraindications of dental implants:

a) Indications:

- If the attachment of removable dentures is insufficient,
- If stability cannot be achieved in removable dentures,
- If the patient feels functionally disturbed in the period where they use removable dentures,
- If the patient psychologically refuses removable dentures,
- Presence of parafunctional habits that will prevent the stability of prosthetics,
- If the number and distribution of the regions that would be used as support are inadequate,
- If the number of teeth that are to be used as anchors in making fixed prosthetics is not sufficient,
- For taking anchorage in orthodontics,
- If there is one missing tooth and the neighboring teeth are healthy,
- If teeth are missing congenitally
- If the patient wants conservative treatment(49).

b) Contraindications:

- If there is a significant psychiatric disorder in the patient,
- If there is an uncontrollable systemic disease,
- If the patient is addicted to alcohol or drugs,
- If the patient is in their growth period, at ages where bone development still continues or at older ages,
- If there is an insufficient and inadequate quality of bone in the patient,
- In cases of inadequate intra-occlusal opening,
- In patients under risk(history of radiotherapy treatment, sever bruxism or osteoporosis) (49).

2.7.Short Implants:

In cases of missing teeth today, usage of implants has become highly prevalent. If there are adequate vertical and horizontal dimensions in the alveolar bones, dental implant applications have higher success rates. In cases where these dimensions are inadequate, it is not possible to insert dental implants, and it is a prevalent practice to place dental implants after providing sufficient bone height by using advanced surgical techniques such as inferior alveolar nerve repositioning, bone augmentation and raising the sinus base. Although several successful reports were made for such procedures, it is known that these increase the risk of complications and patient morbidity in addition to increasing the treatment time and cost(50).

Short implants, which were introduced as 7-mm implants with the Branemark system for the first time in 1979, were defined as shorter than 10 mm by some researchers, while 8 mm was reported as the upper limit for some others(51,52,53,54,55).Telleman et al., considering that an implant may be inserted on different horizontal levels, described implants with vertical heights of 8 mm or shorter in the bone as short implants. In addition to these, there are also studies which reported on implants shorter than 7 mm as short or extra short implants(56,57). Considering the results of previous studies, there is a wide interval of 5-10 mm for defining short implants(58). Publications have not had a consensus on such a definition yet (59,60).

2.7.1. Surface properties for short implants:

While that are various studies which compared standard implants and short implants, there has been no consensus yet(61). Due to reduced osseointegration and primary stability, short implants were reported to have higher failure rates(52).Pommer et al. conducted studies by considering the first year of functional loadings made on implants and found that the failure rates of short implants were significantly lower(62). Bahat, in their clinical study which defined 7-mm implants as short implants, found the failure rate of these implants as 9.5%, while the same rate was 3.8% for longer implants (63). It was reported that improve surface characteristics in short implants supported osseointegration between newly produced implant systems and the bone in addition to increase numbers and depths of grooves(53).

It was stated that, in cases of low bone density, machined macro-surface implants pose a risk (64). In comparison to processed surfaces, implants with machined surfaces can be separated with lower torque values (65).Porosity that is formed on the implant surface allows a stronger bond between the bone and the implant in the short-run(54).Deporteret al. reported that modifications made on the implant surface played an important role in the success and survival rates of the implant, in addition to its clinical performance (66). It was stated that short implants with improved surfaces that are placed by the suitable surgical method into a bone with the suitable thickness have a positive performance(67). Malo stated that short implants with anodic oxidized surface characteristics provided 95% success in 1 year following their application on the bone with low density, and this success was directly related to implant surface characteristics (68).

It was stated that the low success rates of implants were related to the surface characteristics of the implant rather than its height(69). It was shown that improve surface characteristics provided a surface that was more resistant to the tension forces of implants(56).When short implants and long implants prepared with machined surfaces were compared, short implants had 5-10% higher failure rates, while comparison of short and long implants with rough surfaces provided similar results(70,55). It was argued that, for a good prognosis, the heights of implants with machined surfaces should at least be 11-133 mm, while their diameters should at least be 3.75 mm or 4 mm(71).Gotfredsen and Karlsson compared various sizes of implants that were roughened by $TiO_2$and found the bone presence on the roughened surfaces to be higher(72). Atieh et al. observed that implant surface and implant design were not superior to each other in terms of the survival rates of short implants (58).

2.7.2. Bone properties for short implants:

Bone density is gravely important in the success of an implant(73). They are frequently used especially in the posterior parts of the jaws and missing molar teeth that are atrophied and experienced early loss (74). Some researchers recommended not using short implants in the posterior maxilla due to the low density of bone as D4 (54,60). As short implants that are applied on this area are usually combined with long implants by restorations, the findings on these are not clear (68).

When short implants on the mandible were compared to those on the maxilla were compared, it was found that those on the mandible were more successful (75).A study which compared short implants made on the maxilla and mandible provided success rates of 87% and 100%, respectively(76). While it was reported that clinical findings on the maxilla are not clear, it was emphasized that a period of at least three years is needed to achieve successful results in the mandible(77).A meta-analysis reported that there was no significant difference between the mandible and the maxilla (56). Despite several studies and analyses that have been carried out so far, there has not yet been a consensus on the survival rates of short implants that are placed into the mandible and maxilla (Figure 2.5)(78).

Figure 2.5.Bicon dental implants with heights of 5mm and 6 mm

2.7.3. Indications of short implants:

Short implants are used in mandibular and maxillary posterior regions where the vertical alveolar bone height is limited by especially maxillary sinus and mandibular canal and there is sufficient bone width. They are alternatives to bone augmentation methods(54).

2.7.4. Advantages of short implants:

In the presence of inadequate bone heights in patients, placement of long implants creates a risk in maxillary sinus and IAN. While bone grafts are used to reduce these risks, patients may avoid these treatments due to both cost issues and lengthened treatment time. This is why short implants are more acceptable for patients, while they also provide easy and permanently predictable treatment opportunities. With the help of short implants, patients who lack sufficient vertical bone dimensions may also avoid risks that are believed to be related to graft processes, costs, increased expenditures and long recovery times.

Therefore, by using short implants:

- Anatomical structures that are believed to be fatal may be avoided.
- Bone graft procedures are minimized.
- Implant positioning is made easier.
- It is believed to be more acceptable for patients.
- It is a simple and easy to implement surgical procedure.
- Sinus lifting minimizes the indication of operation(80).

2.7.5. Some criteria for avoiding complications that may occur while placing short implants:

- Usage of processed short implants should be avoided (54,59,124).
- Short implants should be indicated in cases of good bone quality values(54,59).
- Cantilever should not be used in application of short implants(80, 122).
- There are parafunctional habits in some patients, and short implants should not be used in these patients(59).
- Surfaces that guide lateral movements should be avoided(80,122).
- Surgeons should have sufficient clinical experience(80,122).

2.8. Concept of Osseointegration:

Branemarket al. defined the structural and functional connection between the live bone tissue and the implant as osseointegration (Figure 2.6)(92).

Branemark, who worked on microcirculation, discovered titanium sites that adhere to the bone strongly and directly. They observed that the bone could directly bond with titanium without soft connective tissue in in vivo animal studies. With this discovery, they achieved permanent connection between prosthetics and live tissues in reconstructive surgery (81,82).

Branemark pioneered the development of osseointegrated implant systems. While some researchers defended the idea that fibrous tissue needs to form around the implant, Branemark argued that this will affect the success of the implant, and without fibrous tissue, there needs to be a tight integration between the implant and the bone. They called it osseointegration(83).

In 1986, ADA(American Dental Association) accepted the Branemark system, and with this development, this treatment method started to be prevalent(84).

The structure of the bond where the implant will be applied, the compatibility of the material of the implant with the tissue, the design of the implant, the correct surgical technique and the surface characteristics of the implant have an important place in the optimal achievement of osseointegration. Differences in the surface characteristics of the implant also resulted in differences in the bone's response to it (34).An ideal implant surface should not prevent the recovery mechanism in the bone. It was reported that implant surface should have an effect that will increase recovery positively without dependence on anatomical regions, bone quantity and quality(34,84).

In summary, for good osseointegration it is needed to;

- Use a biocompatible material such as titanium,
- Apply an atraumatic and correct surgical technique,
- Achieve primary stabilization in the implant;
- Achieve a recovery process of 4-6 months for the maxilla and 3-4 months for the mandible without load transfer (85,86).

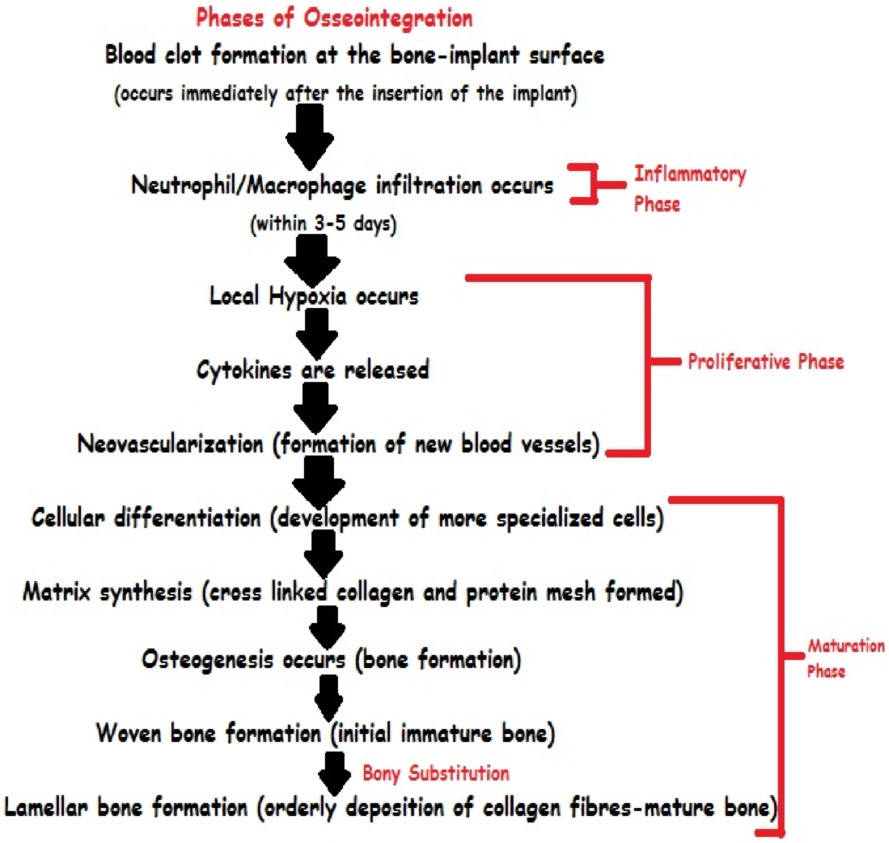

Figure 2.6.Phases of Osseointegration

2.8.1. Biological phases of osseointegration:

Bone recovery around the implant that is applied occurs at 3 stages;

- Osteophyticphase
- Osteoconductivephase
- Osteoadaptive phase(87)

2.8.1.1. OsteophyticPhase:

After the implant with porous surface is place into the cancellous bone, blood fills in the gap between the bone and the implant, and coagulation occurs. The implant has very little contact with the bone. Extracellular fluid and cells form the other parts. At this phase, collagen synthesis and molecule production are regulated. Cytokines are secreted for these regulations. Cytokines also have functions such as regulating bone metabolism and changing cell proliferations.

Inflammatory cells are formed at the end of the first week. These cells emerge as a response to foreign antigens. On the 3rd day, vascular development starts at vital organs. At the end of the 3rd week following implant placement, a better vascular development is observed. Cellular differentiations, proliferation and cellular activation start.

With the start of ossification in the first week, osteoblastic migration is observed. The time of the osteophytic phase is 1 month (87).

2.8.1.2.OsteoconductivePhase:

By the time bone cells reach the implant surface, they spread towards the metal surface of the implant. Bone cells, which are an immature connective tissue matrix at first, later become “woven” bone as the bone that accumulates later takes the form of a thin layer.

At this phase, fibrocartilaginous callus transforms into bone. This transformation takes place in the 3rd month. In this process, more bone has accumulated on the implant surface. The maximum amount of bone has covered the implant surface in the 4th month following the placement of the implant(87).

2.8.1.3. Osteoadaptive Phase:

This is the final phase which starts in the 4th month. Remodeling starts in this phase, and there is no loss of gain of bone around the implant. Woven bone gets thicker in this phase and turns into lamellar bone(87).

Remodeling is the last phase of osseointegration. This continues for life and is important for implants to last long(88).

Osseointegration and primary stability are important for an implant to be successful(90).Primary stability is the absence of mobility in the placed implant, and it is required to achieve osseointegration(90,91,93).

2.9. PrimaryImplant Stability

An important factor for the success of implant treatment is the stability of the implant at the time of insertion. Primary stability is dependent on the amount and quality of the bone where the implant will be placed, the diameter, height and types of implant and the surgical technique to be applied during the placement of the implant. In the case that primary stability has not been achieved, micromovements take place in the implants, and recovery is disrupted. Clinical failure is inevitable with the start of mobility in the implant(94,99, 100,101).

Two important factors for achieving primary stability are the amount of connection between the implant and the bone and the compression stressed between the two. Several researchers have reported that implants in the dense cortical bone were more stable than those in the trabecular bone. Before placing the implant, the cavity may be prepared by a handpiece that is smaller than the diameter of the implant, and the implant is placed into this cavity. This is how the implant is more tightly positioned in the cavity. While this provides advantages of stability, it may also cause necrosis or ischemia in the bone(95,96).

According to Gapski et al., early-stage failure rates increase as a result of mechanical forces match the implants with poor primary stability. Primary stability is also highly important in early loading protocols. Immediate functional loadings may be made in cases where stability is sufficient. As implants that are placed into spongious bone have poor primary stability, a sufficient duration of recovery should be allowed, and loading should be made after this.

2.9.1. Implant Stability Measurement Methods:

The preliminary condition for achieving osseointegration is reaching primary stability(92). In addition to this, primary stability may also provide information about the osseointegration process(94,92). The methods that are used for stability measurements are as the following:

1. Insertion torque test
2. Extraction torque test
3. Implatest
4. Periotest
5. Percussion test
6. RFA(resonance frequency analysis)
7. Dynamic model test(102).

2.9.1.1. Insertion Torque Test:

Johansson,StridandColomina reported that torque amounts that are calculated while installing implants by using an electronic motor may provide information on implant stability and bone quality(105,106). This test, which is still being used safely today, is the torque value that is applied while inserting the implant to a previously prepared socket. It was become a method that is frequently used for immediate loading(95,107). In 2006,Türkyılmazet al.andOttoni determined that the torque values in the implants that were used on patients with high bone quality were also high, and these implants had high ISQ values(85,107). However, Friberg et al. argued that there is no connection between insertion torque and ISQ(104). Sullvianet al.compared insertion torque values based on bone quality, found that there was no statistically significant difference in type 2 and type 3 bones, but the value decreased significantly in type 4 bone(103).Ottoniet al. stated that immediate loading may be carried out for implants with higher than 32 Ncm of insertion torque, and the rate of failure may increase for those with an insertion torque value of 20 Ncm(108). It is reported that insertion torque test is a reliably and simple method to measure implant stability(106).

2.9.1.2.Extraction Torque Test:

In 1987,Albrektssonand Johansson tried experimental implants on rabbit bones and tested the stability values of these implants by extraction torque testing. This test was explained as separating the placed implant from its bone connection by loosening it by a reverse torque movement(108). The researchers claimed that torque tests are the only tests that explain bone formation and bone maturation on implant surfaces.

It was explained that this test may be used to measure the maximum shear strength that can be tolerated by the interface between the bone and the implant. In addition to implant geometry, the quality of the bond between the implant and the surrounding tissues also plays a significant role in the degrees revealed by such measurements(97).

Torque test are still utilized today, but it is difficult to use them in in vivo studies, and they cannot be used in clinical studies due to ethical considerations. These are the greatest disadvantages of these tests (108).

2.9.1.3.Implatest:

This test was developed in 2002 by Dario et al. It involves digital observation of the stability of the implant. Impulse test, which is frequently used in the field of engineering and a structural analysis, is prevalently used in aviation. In Implatest, the accelerometer that is placed on the in its structure is placed on the device that makes a recording. During recording, the accelerometer receives as stimulus from the moving mechanism of the device, and this stimulus is transmitted to the implant. When the tip of the device contacts the implant, the data that have been obtained (ATH data) are recorded. While the tip of the device is in contact with the implant, initially obtained data are not included in the analysis. The remaining data are. After the data are analyzed, the screen of the device shows a plot, and the stability of the implant is assessed based on this plot. If osseointegration is good, the curve in the plot is smooth. If the curve has fluctuations in it, this means osseointegration was insufficient(103).

2.9.1.4. Periotest:

The Periotest device, which as firstly developed at the University of Tubingen by Siemens in 1980s, is currently being produced by (Bensheim, Germany)(111).It purpose is to numerically measure reduced support in the periodontal structures surrounding the tooth, if there is such a reduction, and assess the tooth in terms of mobility(96,111).Today, it had three forms as Periotestclassic (Figure2.7), Periotest S and newly introduced wireless Periotest M(Figure2.8). Periotest S allows storage of the measured data. Periotest is a noninvasive diagnosis method, and it allows assessment of the stability between the bone and the implant surface(113,114,115).Periotestis an electromechanical process. It works with and monitored by electricity. The moving tip of the device hits the implant or the tooth 16 time by a percussion movement, and the entire measurement is made in 4 seconds. The pressure-sensitive moving tip part measures the time of contact with the implant or the tooth. The longer the contact time is, the higher will the Periotest value be. High values indicate low stability of the tooth or the implant. If the contact time is short and the Periotest value is low, the stability value is considered as good.

The measurement values in Periotest vary between -8 and +50 (Table1.1). According to these values(108,116);

Table 2.1.Periotest measurement values

Periotest value interval	**Interpretation**
-8 to 0	Sufficient osseointegration, implant may be loaded
+1 to +4	Clinical examination is needed, implants are not yet ready to be loaded in many cases
+10 to +50	Osseointegration is insufficient, the implant should not be loaded

Periotest values may vary based on the angling of the device, position of recording and usage of the physician. Additionally, because the dynamic characteristics of the implant change after abutment is placed and the crown is constructed, Periotest values may also change. This is why some researchers do not consider this method as a healthy one in assessing osseointegration(94,92,117,115).

Figure 2.7.Periotest Classic

Figure 2.8.Periotest M

2.9.1.5. Percussion Test:

This is considered to be a subjective method. It is a simple process and carried out by assessing the sound the implant makes when it is hit by the back of hand tools such as mirrors. Whether or not there is mobility in the implant and the implant is stable is assessed by the blunt sound that it makes. If the sound is weak, it is thought that the implant is not osseointegrated, and it is surrounded by fibrous tissue(108).

2.9.1.6. Resonance Frequency Analysis (RFA):

This method was developed by Meredith et al. It is an electronic method that measures implant stability. It is noninvasive and objective. This method makes an in vivo numerical measurement of osseointegration(94,95,92,118). It was considered that conventional methods fall short in implant systems that constantly transform, and it was needed to develop a device that will improve implant stability in a noninvasive and objective way. They named the device that makes this measurement asOsstellTM (96)(Figure2.9). A set of changes was made on the device later, and then it was marketed as Osstell Mentor TM. As a result of research, the advantages of the device were reported as the following:

1.Osstellallows measurement of the stability of the implant and quality of the bone and receiving information about the loading time of the implant.

2.The changes and improvements around the implant are measured, and the suitable time of restoration is determined. Possible errors may be detected beforehand, and it helps taking precautions. This way, clinical failure is prevented.

3.The clinical performance of the implant to be applied may be measured. This allows making a selection among different implants.

4. Dentists may keep the records of Osstell measurements and patient records together. This helps the physician in terms of both patient monitoring and legal practices(94,95,119).

Figure 2.9.Ostell TM

The measurements that are made for the primary stability values on the inserted implants are determined based on ISQ values, and these values vary in the range of 1 to 100 as shown below (Figure 2.10).

Osstell ISQ Scale

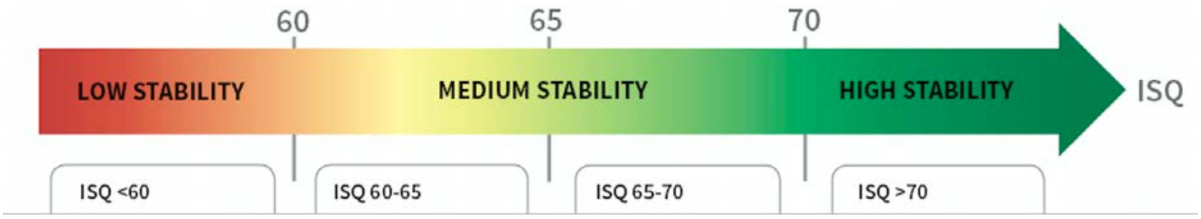

Figure 2.10.Osstell ISQ Scale

ISQ values vary in the range of 55-80 under normal conditions. Studies have reported higher levels measured in the mandible in comparison to the maxilla. While ISQ > 70 represents high stability, 60-69 represents medium stability and < 69 represents low stability.

Implant values of ISQ < 60 are considered to be risky, and they should not be loaded in the short-run. While it was emphasized that traditional loading may be used for implants with ISQ values in the range of 60-69, implants with ISQ > 70 may be immediately loaded more comfortably(98).

Primary stability measurement values (ISQ) are directly related to the type of bone where the implant is place in addition to how the implant is placed. There are 4 different types of bones in human mouths.LekholmandZarb classified these types as the following.

D1: Consists of a little spongious and thick compact bone. It is seen more in the anterior region in toothless mandible.

D2: Consists of thick spongiousand thick compact bone. It is seen in the posterior and anterior regions in the mandible and palatinal region in the maxilla.

D3: Consists of narrow spongious and thin compact bone. It is seen in the posterior and anterior regions in the maxilla.

D4: Consists of spongious bone with frequent gaps and thin bon. Ut is seen more in the posterior region in the maxilla(Figure2.11)(125).

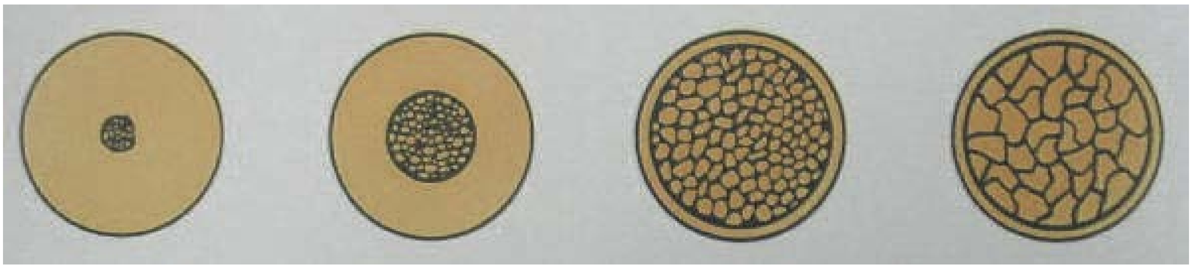

Figure 2.11.Types of bone (Lekholmand Zarb,1985)

2.9.1.7. Dynamic Model Test:

This method was developed in 1996 by Elias et al. In this technique, where a circular hammer that resembles a pendulum is used, the hammer hits the implant and creates vibration. The hammer which contains a piezoelectric crystal inside create a voltage signal by the incoming force. Based on the values that emerge, a plot indicating force and time is obtained. The area under the force-time curve in the plot gives the pushing force. The data vary based on the magnitude and place of application of the force. It was reported that this measurement is highly difficult in implants with poor stability(109).

3. MATERIAL AND METHOD

Our study was carried out to compare the insertion and extraction torque values and primary stability values of implants placed onto polyurethane blocks (#1522-23, #1522-03: Sawbones, Malmö, Sweden) imitating theD2(PCF 20)and D4(PCF05)bone structures(Figure3.1). All procedures were carried out at the National Metrology Institute of TÜBİTAK in Gebze, Turkey.

Figure 3.1. Sawbones,PCF 20(D2) and PCF05(D4) polyurethanebones

The implants that were placed onto artificial bone blocks were obtained from DETECH in Turkey(Figure3.2), and the implant sockets were opened with a DETECH implant kit (Figure3.3). The DETECH-branded implants that were inserted had a total internal contact of 3 mm, including 2 mm of conic contact and 1 mm of hexagonal contact. The purpose was to prevent cement leaks during prosthetic cementation by preventing screws from breaking. The implants had SLA surfaces, and micro-arc surface oxidation was applied with the help of electrolysis. In the implants with aggressive groove structures, the groove depths were 0.4 mm, while the groove spacing values were 0.8 mm.

Figure 3.2. DETECH, Turkey, dental implants with dimension of 4.5x5mm ve 4.5x8mm

Figure 3.3. DETECH implant kit

We used a total of 40 implants in two groups of 20 implants (4.5x8 mm and 4.5x5 mm) to place on the bone blocks. The implants were planned in a way that their diameters would be the same and only their heights would be different. The final milling diameter for the sockets that were opened for inserting the implants was planned as 4.3 mm, and the final milling was carried out for both the D2 and D4 bone types. The implant sockets were prepared at equal distances and spacings in both bone blocks. After leaving 4 cm of margins from the top point and left edge of the bone blocks, 1 cm gaps were left between each socket. 20 implants were placed on each block by dividing them into two groups of 10 between the 4.5x5 mm and 4.5x8 mm (Figure 3.4).

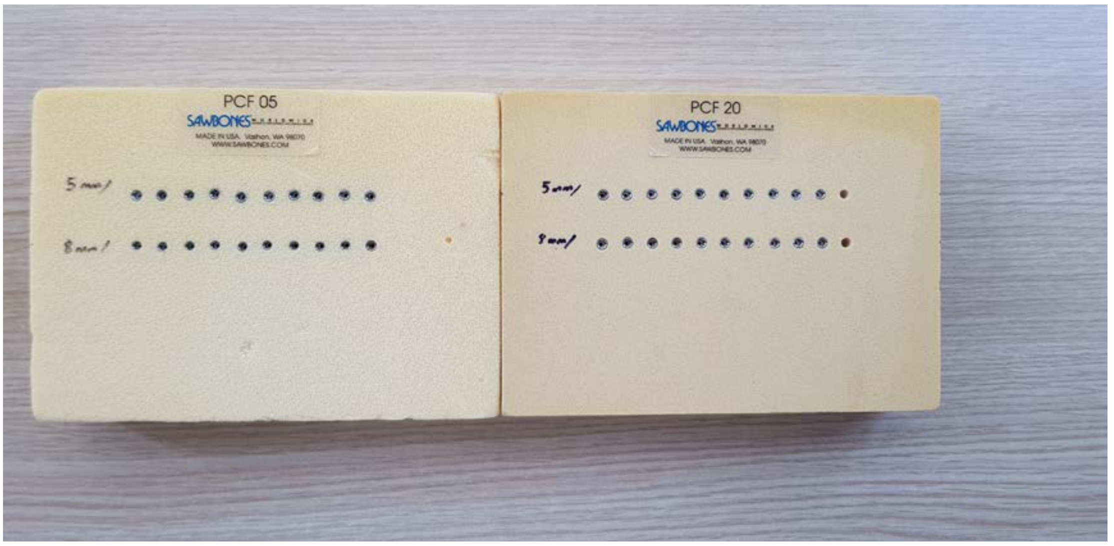

Figure 3.4.20 implant sockets that were opened for each of the PCF 20 and PCF05 block types at heights of 5 mm and 8 mm

The study compared the insertion torques, extraction torques and primary stability values (ISQ) of a total of 40 implants with the same diameter and heights of 5 mm and 8 mm that were placed on blocks representing the D2 and D4 types. All implant sockets were opened at a speed of 650 rpm. All implants were placed onto the bone blocks at a speed of 40 rpm. Measurements of the insertion and extraction torque values or the implants were made by a SaeshinImplaCube(Korea) physio dispenserdevice (Figure 3.5).

Figure 3.5.SaeshinImpla Cube physio dispenser(Korea)

While inserting and extracting the implants, the torque values at each iteration were observed, and the mean values were taken from the beginning to the end. Insertion torque values were calculated until the implants reached the bone level. The values obtained by the physio dispenser were compared to those that were obtained by the torque measurement tool (Figure 3.6) that was obtained from TÜBİTAK as calibrated (Torqueleader Wrench, the United Kingdom).

Figure 3.6.TorqueleaderWrench torque measurement (the United Kingdom)

The resonance frequency analyses of the implants were carried out withsmartpeg(type 27; Osstell, Gothenburg, Sweden)(Figure 3.7) placed onto them.

Figure 3.7. Type 27 smartpeg; Osstell, Gothenburg, Sweden

The measurements of the resonance frequency analysis were carried out by holding an Osstell device (Osstell AB, Gothenburg, Sweden) approximately 1 cm from the smartpeg on the implants (Figure 3.8). The observed values were in ISQ (implant stability quotient). 3 measurements were made for each implant. The measurements were made on the right, left and top points of the implants and average values were taken. Attention was paid to make the measurements by the same operator, the same measurement device and under the same conditions.

Figure 3.8.Osstell AB, Gothenburg, Sweden

4.RESULTS

The data that were obtained in the study were statistically analyzed by using SPSS (the Statistical Package for the Social Sciences) for Windows 21.0. The results were examined at a 95% confidence interval and a significance level of $p<0.05$.

Table 4.1. The insertion, extraction torque and primary stability values of the implants placed on PCF 20 and PCF 5 blocks

		N	X(N/cm)	Sd.	p
InsertionTorqueValue	PCF20	20	15.791	1.498	
	PCF 5	20	3.018	0.251	**0.000***
Extraction TorqueValue	PCF20	20	8.740	1.769	
	PCF 5	20	2.100	0.357	**0.000***
ISQ Value	PCF 20	20	61.450	3.510	
	PCF 5	20	24.767	2.292	**0.000***

***p<0.05**

The insertion torque values were compared based on the type of bone and analyzed by Mann-Whitney U test. There was a statistically significant difference ($p<0.05$). The insertion torque value of the PCF 20 block imitating theD2 bone type (X=15.791 N/cm) was significantly higher than that of the PCF 5 block imitating theD4 bone type (X=3.018 N/cm).

The extraction torque values were compared based on the type of bone and analyzed by Mann-Whitney U test. There was a statistically significant difference ($p<0.05$). The extraction torque value of the PCF 20 block imitating the D2 bone type (X=8.740 N/cm) was significantly higher than that of the PCF 5 block imitating the D4 bone type (X=2.100 N/cm).

The ISQ values were compared based on the type of bone and analyzed by Mann-Whitney U test. There was a statistically significant difference ($p<0.05$). The ICQ value of the PCF 20 block imitating the D2 bone type (X=61.450 N/cm) was significantly higher than that of the PCF 5 block imitating the D4 bone type (X=24.767 N/cm) (Table 4.1).

4.1. Comparison of PCF 20 Block Type Based on Implant Sizes:

Table 4.2. The insertion, extraction torque values and primary stability values of 8-mm and 5-mm implants on the PCF 20 block

		N	X(N/cm)	Sd.	p
Insertion Torque Value	8 mm	10	15.866	2.001	0.733
	5 mm	10	15.717	0.850	
Extraction Torque Value	8 mm	10	9.880	1.570	**0.001***
	5 mm	10	7.600	1.119	
ISQ Value	8 mm	10	64.433	0.969	**0.000***
	5 mm	10	58.467	2.300	

$^*p<0.05$

Comparison of insertion torque values on the PCF 20block based on implant sizes was carried out by Mann-Whitney U test. The mean insertion torque value of the 8-mm implants was found at 15.866 N/cm, while that of the 5-mm implants was 15.717 N/cm). There was no statistically significant difference ($p>0.05$).

Comparison of extraction torque values on the PCF 20 block based on implant sizes was carried out by Mann-Whitney U test. The extraction torque value of the 8-mm implants (X=9.880 N/cm) was significantly higher than that of the 5-mm implants(X=7.600 N/cm) ($p<0.05$).

Comparison of ISQ values on the PCF 20 block based on implant sizes was carried out by Mann-Whitney U test, and there was a significant difference ($p<0.05$). The ISQ value of the 8-mm implants (X=64.433) was significantly higher than that of the 5-mm implants (X=58.467) (Table 4.2).

While the mean value of the maximum values of the insertion torques of the 8-mm implants in this block was 39.5 N/cm, the mean value for the 5-mm implants was 34.7 N/cm. While the mean value of the maximum values of the extraction torques of the 8-mm implants in this block was 25.3 N/cm, the mean value for the 5-mm implants was 18.1 N/cm.

As the difference in the insertion torque values was insignificant, it could not be shown on the chart. The comparison of the extraction torque and ISQ values on the PCF 20 blocks was as seen in the chart below(Figure 4.1).

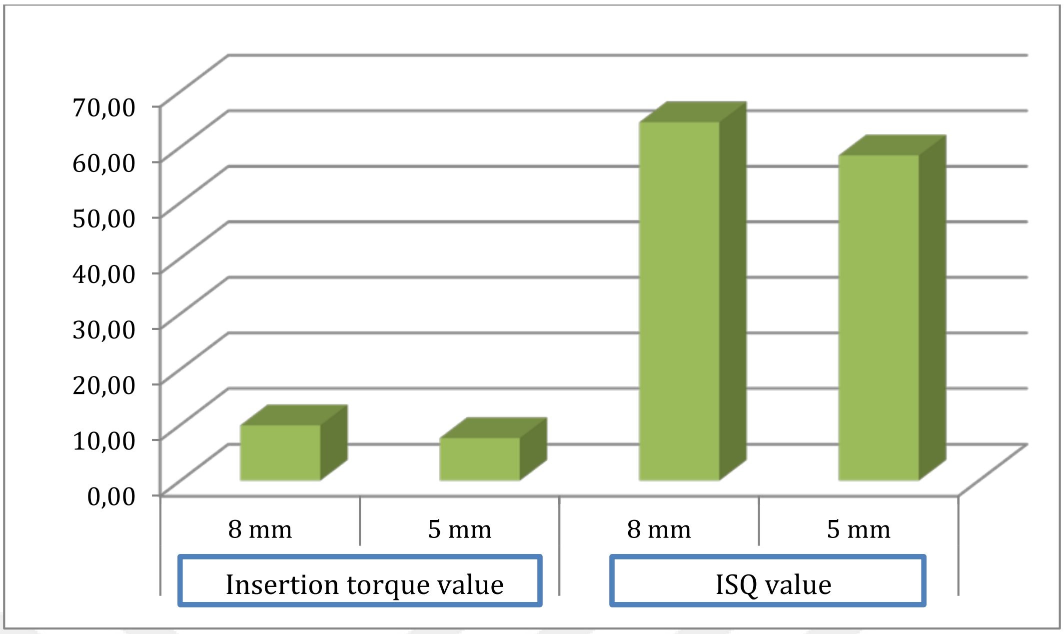

Figure 4.1.Comparison of the extraction torque and ISQ values of the 8-mm and 5-mm implants on the PCF 20 block

4.2. Comparison of PCF 5 Block Type Based on Implant Sizes:

Table 4.3. The insertion, extraction torque values and primary stability values of 8-mm and 5-mm implants on the PCF 5 block

		N	X(N/cm)	Sd.	p
Insertion Torque Value	8 mm	10	2.960	0.263	0.159
	5 mm	10	3.075	0.237	
Extraction Torque Value	8 mm	10	2.000	0.264	0.155
	5 mm	10	2.200	0.422	
ISQ Value	8 mm	10	23.000	1.257	**0.000***
	5 mm	10	26.533	1.604	

$*p<0.05$

Comparison of insertion torque values on the PCF 5 block based on implant sizes was carried out by Mann-Whitney U test, and there was no significant difference (p>0.05). The insertion torque value of the 8-mm implants (X=2.960 N/cm) was lower thanthat of the 5-mm implants (X=3.075 N/cm) (p=0.159).

Comparison of extraction torque values on the PCF 5 block based on implant sizes was carried out by Mann-Whitney U test, and there was no significant difference (p>0.05).The extraction torque value of the 8-mm implants (X=2.000 N/cm) was lower than that of the 5-mm implants (X=2.200 N/cm) (p=0.155).

Comparison of ISQ values on the PCF 5 block based on implant sizes was carried out by Mann-Whitney U test, and there was a significant difference (p<0.05). The ISQ value of the 8-mm implants (X=23.000) was found to be lower than that of the 5-mm implants (X=26.533) (Table 4.3)

While the mean value of the maximum values of the insertion torques of the 8-mm implants in this block was 4.3 N/cm, the mean value for the 5-mm implants was 4.8 N/cm. While the mean value of the maximum values of the extraction torques of the 8-mm implants in this block was 3.2 N/cm, the mean value for the 5-mm implants was 3.8 N/cm.

The primary stability values (ISQ values) of the 8-mm and 5-mm implants were as seen below (Figure 4.2).

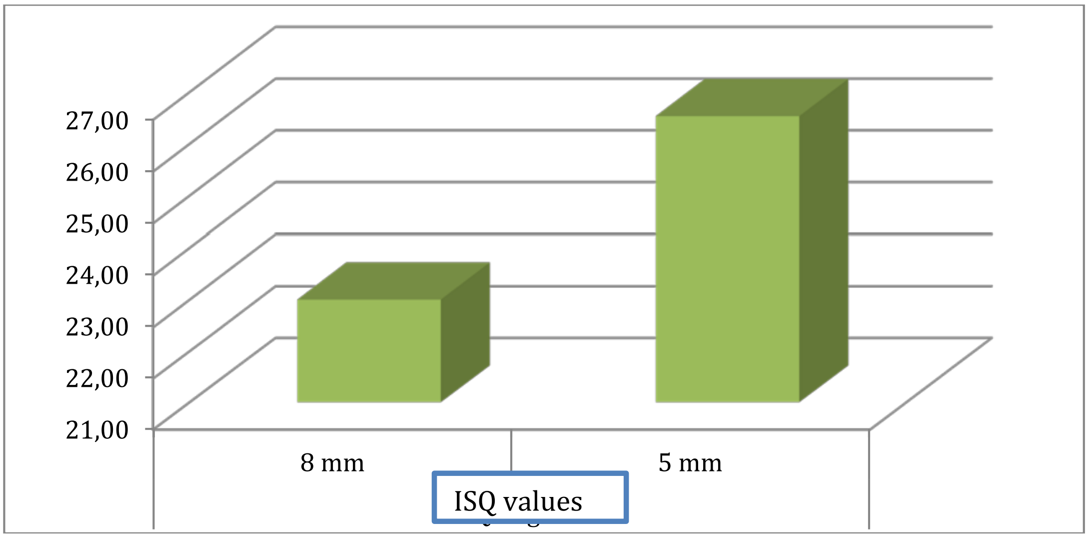

Figure 4.2.Comparison of the ISQ values of the 8-mm and 5-mm implants on the PCF 5 block

4.3. Comparison of the 8-mm Implants Based on Block Types:

Table 4.4. The insertion, extraction and primary stability values of the 8-mm implants on the PCF 20 and PCF 5 blocks

		N	X(N/cm)	Sd.	P
Insertion Torque Value	PCF 20	10	15.866	2.001	**0.000***
	PCF 5	10	2.960	0.263	
Extraction Torque Value	PCF 20	10	9.880	1.570	**0.000***
	PCF 5	10	2.000	0.264	
ISQ Value	PCF 20	10	64.433	0.969	**0.000***
	PCF 5	10	23.000	1.257	

***p<0.05**

Comparison of the insertion torque values of the 8-mm implants based on block type was carried out by Mann-Whitney U test, and there was a statistically significant difference ($p<0.05$). The insertion torque value of the implants applied on the PCF 20 block (X=15.866 N/cm) was higher than that of those on the PCF 5 block(X=2.960 N/cm).

Comparison of the extraction torque values of the 8-mm implants based on block type was carried out by Mann-Whitney U test, and there was a statistically significant difference ($p<0.05$). The extraction torque value of the implants applied on the PCF 20 block (X=9.880 N/cm) was higher than that of those on the PCF 5 block (X=2.000 N/cm).

Comparison of the ISQ values of the 8-mm implants based on block type was carried out by Mann-Whitney U test, and there was a statistically significant difference ($p<0.05$). The ISQ value of the implants applied on the PCF 20 block (X=64.433 N/cm) was higher than that of those on the PCF 5 block (X=23.000 N/cm) (Table 4.4).

Comparison of the insertion, extraction torque and ISQ values of the 8-mm implants placed on the PCF 20 and PCF 5 block types was as the following (Figure 4.3).

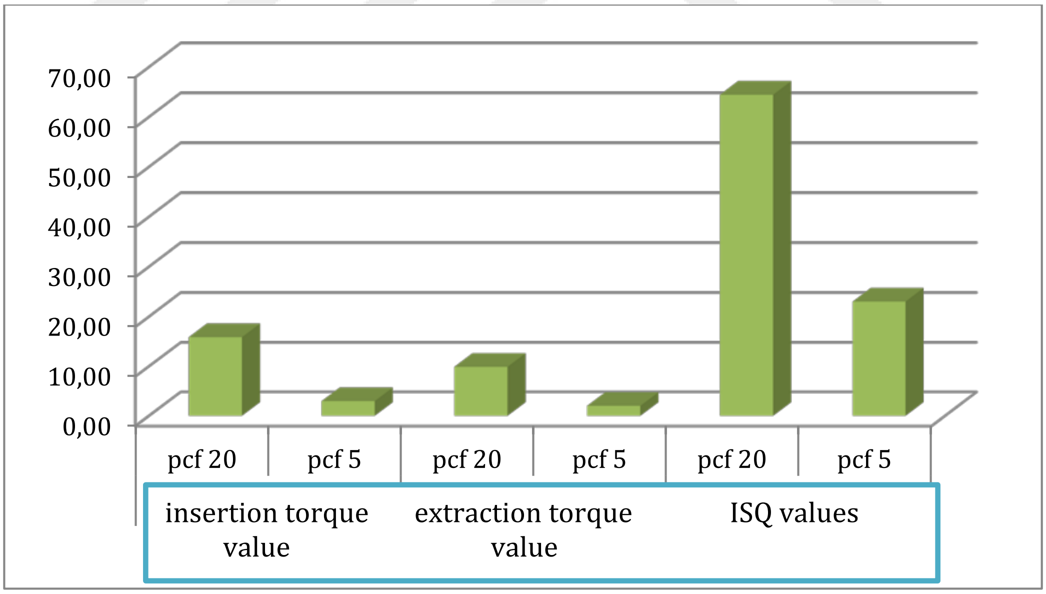

Figure 4.3.Comparison of the insertion, extraction torque and stability values of the 8-mm implants placed on the PCF 20 and PCF 5 block types

4.4. Comparison of the 5-mm Implants Based on Block Types:

Table 4.5. The insertion, extraction and primary stability values of the 5-mm implants on the PCF 20 and PCF 5 blocks

		N	X(N/cm)	Sd.	p
Insertion Torque Value	PCF 20	10	15.717	0.850	**0.000***
	PCF 5	10	3.075	0.237	
Extraction Torque Value	PCF 20	10	7.600	1.119	**0.000***
	PCF 5	10	2.200	0.422	
ISQ Value	PCF 20	10	58.467	2.300	**0.000***
	PCF 5	10	26.533	1.604	

$*p<0.05$

Comparison of the insertion torque values of the 5-mm implants based on block type was carried out by Mann-Whitney U test, and there was a statistically significant difference ($p<0.05$). The insertion torque value of the implants applied on the PCF 20 block (X=15.717 N/cm) was higher than that of those on the PCF 5 block (X=3.070 N/cm).

Comparison of the extraction torque values of the 5-mm implants based on block type was carried out by Mann-Whitney U test, and there was a statistically significant difference ($p<0.05$). The extraction torque value of the implants applied on the PCF 20 block (X=7.600 N/cm) was higher than that of those on the PCF 5 block (X=2.200 N/cm).

Comparison of the ISQ values of the 5-mm implants based on block type was carried out by Mann-Whitney U test, and there was a statistically significant difference ($p<0.05$). The ISQ value of the implants applied on the PCF 20 block (X=58.467 N/cm) was higher than that of those on the PCF 5 block (X=26.533 N/cm) (Table 4.5).

Comparison of the insertion, extraction torque and ISQ values of the 5-mm implants placed on the PCF 20 and PCF 5 block types was as the following(Figure 4.4).

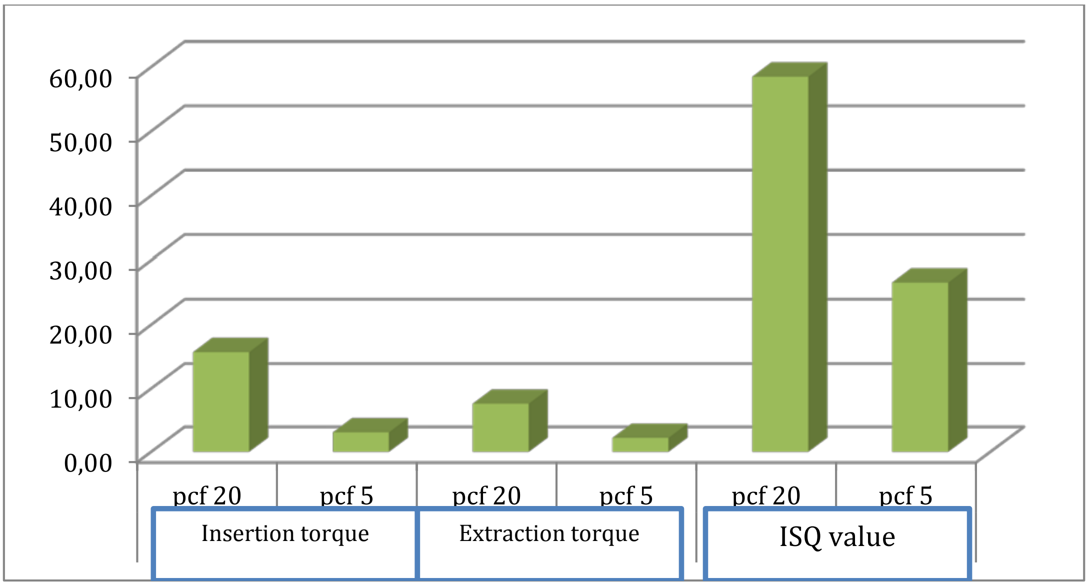

Figure 4.4.Comparison of the insertion, extraction torque and stability values of the 8-mm implants placed on the PCF 20 and PCF 5 block types

4.5. Group interactions:

Two-way ANOVA was used to examine the interactions among the groups in the study. With the help of this test, we could examine the effects of the PCF 20 and PCF 5 block types that imitate human bones, implant sizes and interaction of both parameters on insertion, extraction torques and primary stability values.

Table 4.6. Interactions of block types, implant sizes and interactions of both parameters with insertion torque values

Insertion Torque Value	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**p**
BlockType	1631.708	1	1631.708	1345.484	**0.000***
Implant Size	0.003	1	0.003	0.002	0.961
Block Type * Implant size	0.175	1	0.175	0.144	0.707

The insertion torque values varied significantly based on block type (p=0.000)(p<0.05). The insertion torque values of the implants applied onthe PCF 20 block(X=15.791 N/cm) were higher than those applied on thePCF 5 block (X=3.018 N/cm).

The insertion torque values did not vary significantly based on the sizes of implants (p>0.05).

The insertion torque values did not significantly interact with the effects of the interaction between bone type and implant size (p>0.05) (Table4.6).

The interaction between block types and insertion torque values was as the following(Figure 4.5).

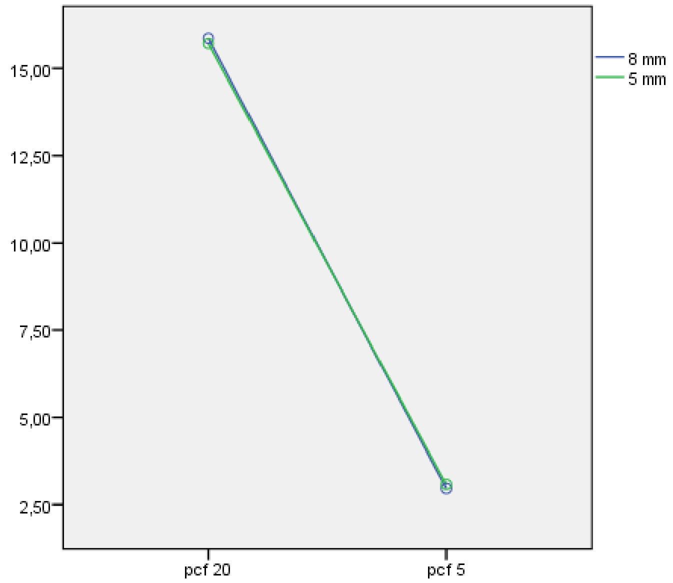

Figure 4.5.The interactions between the PCF 20andPCF 5 block types and insertion torque values

Table 4.7. Interactions of block types, implant sizes and interactions of both parameters with insertion torque values

Extraction Torque Value	Type III Sum of Squares	df	Mean Square	F	p
Block Type	440.896	1	440.896	444.900	**0.000***
Implant Size	10.816	1	10.816	10.914	**0.002***
BlockType * Implant Size	15.376	1	15.376	15.516	**0.000***

The extraction torque values varied significantly based on block type (p<0.05). The extraction torque values of the implants applied on the PCF 20 block (X=8.74 N/cm) were higher than those applied on the PCF 5 block (X=2.10 N/cm).

The extraction torque values varied significantly based on implant size (p=0.002) (p<0.05). The extraction torque values of the 8-mm implants (X=5.94 N/cm) were higher than those in the 5-mm ones (X=4.90 N/cm).

The extraction torque values varied significantly based on the interaction between implant size and block type (p=0.000) (p<0.05) (Table 4.7).

The interaction between block types and extraction torque values was as the following (Figure 4.6).

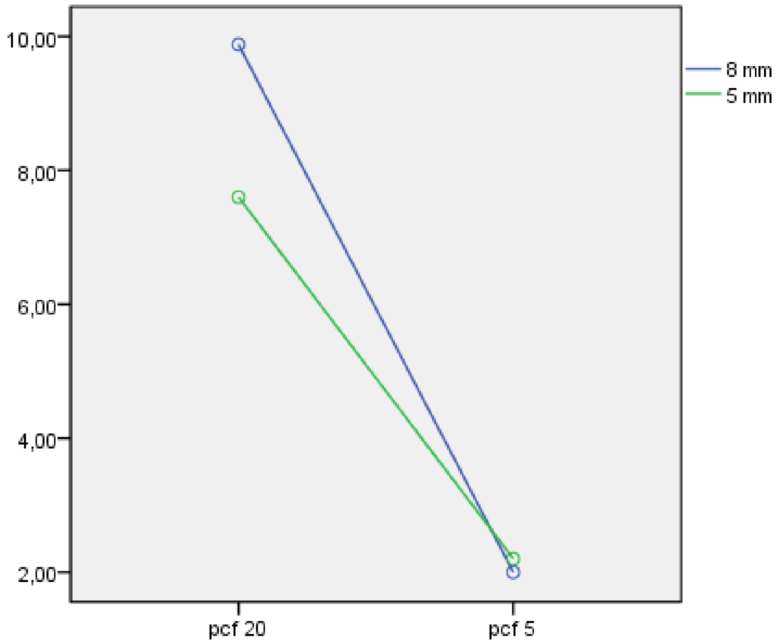

Figure 4.6.The interactions between the PCF 20 and PCF 5 block types and extraction torque values

Table 4.8. Interactions of block types, implant sizes and interactions of both parameters with extraction torque values

ISQ Value	Type III Sum of Squares	df	Mean Square	F	p
Block Type	13456.669	1	13456.669	5184.874	**0.000***
Implant Size	14.083	1	14.083	5.704	**0.022***
Block Type *Implant Size	225.625	1	225.625	86.934	**0.000***

The ISQ values varied significantly based on block types(p<0.05). The ISQ values of the implants placed on the PCF 20block(X=61.450) were higher than those on thePCF 5block (X=24.767).

The ISQ values varied significantly based on implant sizes (p=0.022) (p<0.05). The ISQ values of the 8-mm implants (X=43.71) were higher than those in the 5-mm implants (X=42.5).

The ISQ values were significantly related to the interaction between implant sizes and block types ($p<0.05$)(Table4.8).The plot of this relationship is shown below(Figure 4.7)

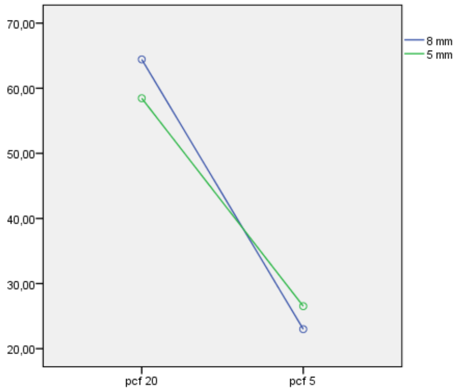

Figure 4.7.The interactions between the PCF 20 and PCF 5 block types and ISQ values

- The placement and extraction torque values of the 8-mm implants that were placed on the D2 and D4 bone types and their maximum ISQ values were as in Table 4.9.

Table 4.9. The placement and extraction torque values of the 8-mm implants that were placed on the D2 and D4 bone types and their maximum ISQ values

Mean maximum placement torque value of 8-mm dental implants placed on the D2 bone type	39.5 N.cm
Mean maximum placement torque value of 8-mm dental implants placed on the D4 bone type	4.3 N.cm
Mean maximum extraction torque value of 8-mm dental implants placed on the D2 bone type	25.3 N.cm
Mean maximum extraction torque value of 8-mm dental implants placed on the D4 bone type	3.2 N.cm

- The placement and extraction torque values of the 5-mm implants that were placed on the D2 and D4 bone types and their maximum ISQ values were as in Table 4.10.

Table 4.10. The placement and extraction torque values of the 5-mm implants that were placed on the D2 and D4 bone types and their maximum ISQ values

Mean maximum placement torque value of 5-mm dental implants placed on the D2 bone type	34.7 N.cm
Mean maximum placement torque value of 5-mm dental implants placed on the D4 bone type	4.8 N.cm
Mean maximum extraction torque value of 5-mm dental implants placed on the D2 bone type	18.1 N.cm
Mean maximum extraction torque value of 5-mm dental implants placed on the D4 bone type	3.8 N.cm

5. DISCUSSION and CONCLUSION

Advanced surgical techniques such as bone augmentation procedures, sinus lifting and IAN nerve lateralization may lead to various complications in patients during and after the operation. Thus, researchers have reported that application of short dental implants may be a better treatment modality in terms of being a less invasive surgical procedure, and thus, patient satisfaction. A few retrospective studies determined that short dental implants had lower rates of failure than long implants. The survival rates of implants vary based on several factors such as bone densities, patient habits, surface characteristics of implants and prosthetic factors. For example, it was reported that the rate of failure could reach up to 29& in short dental implants with machined surfaces. Moreover, implants with larger diameters were reported to form better contact regions with the bone surrounding the implant and play an important role for a good osseointegration with more successful primer stability. It was stated that bone density is more determinant in short dental implant treatments. The survival rates of short dental implants that were applied on the maxilla were found to be lower, and with implants applied on the mandible where bone density is higher, the mechanical properties in the implant-bone interface were stronger, and this led to less stress on the bone. Due to peri-implant stresses and tensions in regions with low bone density, implant losses occurred in previous studies (138). In this study, for achievement of high placement and extraction torque values and ISQ values, instead of implants with machined surfaces, those with SLA surfaces were preferred. Additionally, an implant that was thought to have high primer stability due to its aggressive groove structure was selected.

In a study by Amir Reza Rokn et al. that compared short dental implants and standard dental implants, it was stated that there is no consensus on the differences between short and standard implants. Some studies emphasized that marginal bone loss, prosthetic failure and complication rates were similar between short and standard dental implants. In contrast, it is also known that the risk of failure is higher in short implants due to the smaller connection between the implant and bone (131).

As a result of clinical and radiographic examinations, it was concluded that short implants, in comparison to standard implants, could be safely used especially in atrophic jaws and regions where the bone densities of type 1 and type 2 are found. Misch et al. reported that a total of 2837 short implants they applied on the posterior regions in the period of 1991-2003 were successful by the rate of 85.3% (121). Das Neves et al. and Esposito et al.

found short dental implant applications as an alternative to advanced augmentation techniques to be an effective method (123,122). In another review where long dental implant and short dental implant treatments were compared, Kotsovilis et al. determined that short dental implants were as successful as long dental implants (126).

In studies they conducted with implants that were shorter than 7 mm, Malo et al. found the marginal bone loss value of 1.27 mm around the implant at the end of the first year (136). In similar studies, Espesito et al. reported the marginal bone loss in short dental implants as 1 mm, while this value was 1.2 mm for long ones (132). Renouard et al. followed up on 96 short dental implants for 2 years and reported a mean marginal bone loss value of 0.44, which they considered a safe extent (124).

J. L. Calvo-Guirado et al. compared the placement torques of dental implants with heights of 4 mm and 10 mm that they placed on the mandibles of 9 patients. They determined that 88% of the patients had the D2 bone type, 8% had the D1 bone type, and 4% had the D3 bone type. While the mean placement torque value of the 4-mm dental implants that were applied was 38.1 ± 1.2 N.cm, this value was found as 42.4 ± 2.1 N.cm for the 10-mm dental implants. In the resonance frequency analysis that was carried out to measure primer stability values, the ISQ values of the 4-mm implants were smaller than those of the 10-mm implants to an insignificant extent (127).

Van Assche et al. asserted that there is a lack of sufficient number of studies, but considering the studies that have been carried out, short dental implants could be used in atrophic jaws in D3 and D4 bones as an alternative to augmentation techniques. Furthermore, Neha Jain et al. determined in their study which associated dental implant preferences with bone densities and qualities that bone qualities are an important factor for the success of dental short dental implants, and the failure rates in especially the D3 and D4 bone types were higher. Considering the heights of short dental implants and low bone qualities together, they stated that these factors affected the stability of dental implants and the recovery process negatively (128).

Placed short dental implants on different types of bones and compared the primer and seconder stabilities of these implants. They placed a total of 39 implants with diameters of 4.1 mm and heights of 6 mm on the maxillary and mandibular posterior regions of 18 patients. For primer stability comparison, they measured placement torque values and conducted a resonance frequency analysis, and in the light of the information they collected, they found the placement torque and ISQ values of the implants they placed onto the D4 bone type to be significantly lower than those in the D1 and D2 bone types (129).

Ottoni et al. stated the immediate loading could be applied on implants with a placement torque value of higher than 32 N.cm, and the failure rate could be higher in those with a value of lower than 20 N.cm. They reported that placement torque test is a reliable and simple method for testing implant stability (107). In our study, the mean maximum placement torque value for the 5-mm implants placed onto the D2 bone type was 34.7 N.cm, while it was 39.5 N.cm for the 8-mm implants. As a result of these values, it is believed that early loading could be applied. These values were found respectively as 4.3 N.cm and 4.8 N.cm for the implants placed onto the D4 bone type. According to these values, it is believed that early loading should not be applied as these dental implants could fail.

The most significant method for assessment of primer stabilities is accepted as resonance frequency analysis (ISQ). Implant values of ISQ <60 are accepted as risky, and no loading should be applied on them in the short run. Conventional loading was reported to be possible for implants with ISQ values of 60 to 69, while immediate loading was stated to be possible for ISQ values of >70 (97).

Alghamdi et al. placed 40 short dental implants with varying diameters and heights onto cattle ribs which have a bone density similar to that of the D2 bone type and examined the extraction torque values and ISQ values of the implants. They selected the diameter values of 4.8 and 6.2 mm and the height values of 5 mm and 7 mm in four equal groups of 10 implants. In their study, the mean ISQ value of the 4.8x5-mm implants was found as 45.08, while a significantly higher mean ISQ value was found as 46.75 in the 4.8x7-mm implants. Likewise, the mean ISQ value of t he 6.2x5-mm implants was found as 50.5, while a significantly higher mean ISQ value was found as 51.57 in the 6.2x7-mm implants. The same study also reported on the maximum extraction torque values of the implants that were used. The mean maximum extraction torque value of the implants with a diameter of 4.8 mm and a height of 5 mm was found as 24.99 N.cm, while this value was 25.97 N.cm for the implants with the same diameter but a height of 7 mm, which was significantly higher. Likewise, the mean maximum extraction torque value of the implants with a diameter of 6.2 mm and a height of 5 mm was found as 27.77 N.cm, while this value was 28.98 N.cm for the implants with the same diameter but a height of 7 mm, which was significantly higher. According to their results, the ISQ value and extraction torque values increased significantly by keeping the heights of the implants and increasing their diameters or keeping their diameters and increasing their heights (130).

Alberto Monje et al. explained whether or not the heights and diameters of shorth dental implants were effective on the success of these implants based on studies conducted by several researchers. As they reported, Ten Bruggenkate et al. (1998) conducted a study on 253 implants branded Straumann (Basel, Switzerland), preferred the implant dimensions of 3.5x6 mm (diameter x height) and determined the recovery time as 4 months. In the follow-ups they performed on the implants that were placed onto the maxilla and the mandible at the end of 72 months, they reported an implant survival rate of 94% and a failure rate of 6% (133). Rossi et al. (2010) kept the heights of the implants with the same brand constant at 6 mm, used two different diameters as 4.1 mm and 4.8 mm and applied these implants on patients. The waited for a recovery time of 2 months for 19 implants that applied onto the mandible with dimensions of 4.1x6 mm, and following the loading process, they obtained a success rate of 89.5% and a failure rate of 10.5% in the 24-month follow-up. The implants with the dimensions of 4.8x6 mm were reported to provide an implant survival rate of 100% (133). Gulje et al. (2012) applied 60 AstraTech (Gothenburg, Sweden) implants with dimensions of 4x6 mm (diameter x height) on the mandibular regions of patients. Following the loadings that were applied after the 3-month osseointegration process, the 12th-month follow-ups revealed a success rate of 96.7% and a failure rate of 3.3% (133). Pieri et al. (2012) also applied 71 dental implants with the same brand, diameter and height on the maxillae of patients found a success rate of 98.6% and a failure rate of 1.4% as a result of the 36th-month follow-up after 4 months of recovery (133). In comparison to all these short dental implants, McGlumphy et al. (2003) placed 20 Nobel Biocare (Gothenburg, Sweden) dental implants considered to have standard dimensions (4x8 mm) onto the mandibles and maxillae of patients. After a waiting time between 3 and 6 months on average, loadings were applied, and in the 60-month follow-up, they found a success rate of 80% and a failure rate of 20% (133).

Benlidayi et al. applied a total of 147 implants on 38 patients with the mean age of 48.3 years. Their study included 86 short implants and 61 standard implants, and they determined the mean loading times as 36.6 ± 12.9 months for standard implants and 39.4 ± 13.5 months for short implants. After 3 years, the implant survival rates were found as 98.4% for standard implants and 96.5% for short implants, while the difference was not statistically significant. Marginal bone losses were significantly lower in short implants than those in standard implants. These loss values were 0.79 ± 0.72 mm for standard implants and 0.51 ± 0.54 mm for short implants as a result of 30 months. In the measurements 5 years after the placement of the implants, the authors found these values as 0.42 ± 0.36 mm and 0.66 ± 0.63 mm, respectively. Resonance frequency analysis revealed significantly lower ISQ values in short implants in comparison to standard ones. The authors stated that short implants may be an alternative to bone augmentation technique, but studies on this topic are still limited (137).

Some researchers investigated the effects of the designs of short dental implants on primer stability. Gonzales-Serrano et al. placed short dental implants with the same diameters (4.5 mm) and heights (6 mm) on cattle ribs that imitated especially the D3 and D4 bone types. Among the 60 implants in total, 30 had a single-helix design, while the remaining 30 had a double-helix design. As a result of resonance frequency analysis, the primer stability values of the implants with a double-helix design were found to be higher than those of the implants with a single-helix design (135).

In our in vitro study, we compared primer stability, which is the most important condition for osseointegration, between 5-mm short dental implants and 8-mm standard dental implants on the D2 and D4 bone types. The mean maximum placement torque value of the 5-mm dental implants placed onto the D2 bone type was found as 34.7 N.cm, while this value was calculated to be 39.2 N.cm for the 8-mm implants and significantly higher. In the resonance frequency analysis, which was carried out on the same bone type, the mean ISQ values were found to be 58.4 for the 5-mm implants and 64.4 for the 8-mm implants, again, significantly higher in the 8-mm implants.The mean maximum extraction torque value of the 5-mm dental implants with a diameter of 4.5 mm placed onto the D2 bone type was found as 18.1 N.cm, while this value was calculated to be 25.3 N.cm for the 8-mm implants and significantly higher. On the D4 bone type, the mean maximum extraction torque values were 3.8 N.cm for the 5-mm implants and 3.2 N.cm for the 8-mm implants, while the difference was statistically insignificant.

Consequently, osseointegration has great significance in dental implant treatments, and for a successful osseointegration process, the implant’s primer stability and placement and extraction torque values are highly important. Application of short dental implants is presented as an effective method for avoiding advanced surgical techniques, economic comfort and cooperation of the patient during the treatment process. Although there are still a few studies on the topic, these are reported as a good alternative treatment method to augmentation techniques on the D1 and D2 bone types especially in the mandibular posterior region. There is still no consensus among researchers for the D3 and D4 bone types.

Our study compared dental implants with heights of 5 mm and 8 mm and the same diameter on the D2 and D4 bone types. Accordingly,

- The dental implants with dimensions of 4.5x8 mm were more reliable than those with dimensions of 4.5x5 mm,

- In the statistical sense, the dental implants with dimensions of 4.5x5 mm could be successful in the D2 bone type which represents the mandibular posterior region in term on the placement and extraction torque values and ISQ values, but they provided low and insignificant torque and ISQ values in the D4 bone type which represents the maxillary posterior region,
- The dental implants with dimensions of 4.5x5 mm could be used as an alternative to augmentation techniques as their data were close to those of the findings reported in the literature,
- We believe there is a need for further studies on non-aggressive implant types and different implant dimensions.

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