Republic of Iraq
Ministry of Higher Education
and Scientific Research
University of Mosul
College of Dentistry

# Advance material in dental implant

A Project Submitted to
The College of Dentistry, University of Mosul, Department of Maxillofacial Surgery in Partial Fulfillment for the Bachelor of Dental Surgery

By
**Dalal Tahseen Younis**

Supervised by:

**Lecturer Dr. Abdulsattar Salim Mahmood**

**B.D.S., M.Sc., Ph.D. Oral Histology**

**March 2025**

# Certification of the Supervisor

I certify that this project entitled ( **Advance material in dental implant** ) was prepared by the fifth-year student **Dalal Tahseen Younis** under my supervision at the College of Dentistry/University of Mosul in partial fulfilment of the graduation requirements for the Bachelor Degree in Dentistry.

Supervised by:

**Lecturer Dr. Abdulsattar Salim Mahmood**

**B.D.S., M.Sc., Ph.D. Oral Histology**

# Dedication

- I dedicate my research to my parents, they were the first supporters of me in all my career and they did not stimp on me with love or effort to achieve my dreams.
- My brothers, all the words do not fulfil their right and do not do justice to my thanks to them.
- To my sisters and friends, my companions and help me in every step.

**Thank you for everything you did for me**

# Acknowledgment

I am very grateful for the opportunities that provided me the opportunity to complete my graduation study at the University of Mosul and College of Dentistry. I am extremely grateful to **Dr**. **Rayan Salim Hamed**, Dean of the College of Dentistry, for his scientific support to the undergraduate students.

My great pleasure is to thank my supervisor, **Dr. Abdul-Sattar Salim Mahmood**, for her keen remarks, valuable advice, and endless encouragement throughout this research.

My Family did not waste any effort in providing comfort and assistance to me on this long journey, so I dedicate this research to them

# Table of Content

# List of Figures

# INTRODUCTION

Implant dentistry is the second oldest discipline in dentistry after oral surgery. Root form implants have been used for thousands of years. 4000 years ago, the ancient Chinese used carved bamboo pegs, tapped into the bone, to replace lost teeth. 2000 years ago the ancient Egyp tians used similarly shaped pegs made of precious metals, Some Egyptian mummies were found to have trans- planted human teeth, and in other instances, teeth made of ivory (Gahlert M el., 2007).

The rehabilitation of completely and partially edentulous patients with dental implants is a scientifically accepted and well documented treatment modality(Depprich R et al.,2008). Currently, titanium and titanium alloys are the materials most often used in implant manufacturing and have become a gold standard for tooth replacement in dental implantology. These materials have attained mainstream use because of their excellent biocompatibility, favorable mechanical properties, and well documented beneficial results (Steinemann SG., 2000). When exposed to air, titanium immediately develops a stable oxide layer, which forms the basis of its biocompatibility. The properties of the oxide layer are of great importance for the biological outcome of the osseointegration of titanium implants (Sykaras N et al.,2000).

The principal disadvantage of titanium is its dark grayish color, which often is visible through the peri-implant mucosa, therefore impairing esthetic outcomes in the presence of a thin mucosal biotype. Unfavorable soft tissue conditions or recision of the gingiva may lead to compromised esthetics. This is of great concern when the maxillary incisors are involved(Tschernitschek H et al.,2005).

Furthermore, reports suggest that metals are able to induce a nonspecific immunomodulation and autoimmunity. Galvanic side effects after contact with saliva and fluoride are also described. Although allergic reactions to titanium are very rare, cellular sensitization has been demonstrated (Valentine-Thon E et al.,2003).

Because of these disadvantages, novel implant technologies that produce ceramic implants are being developed(Kohal RJ et al.,2004). However, ceramics are known to be sensitive to shear and tensile loading, and surface flaws may lead to early failure. These realities imply a high risk for fracture(Andreiotelli M et al.,2009).

In recent years, highstrength zirconia ceramics have become attractive as new materials for dental implants. They are considered to be inert in the body and exhibit minimal ion release compared with metallic implants. Yttrium-stabilized tetragonal zirconia polycrystals appear to offer advantages over aluminum oxide for dental implants because of their higher fracture resilience and higher flexural strength(Sennerby L et al.,2005). They have also been used successfully in orthopedic surgery to manufacture ball heads for total hip replacements; this is still the current main application of this biomaterial(Piconi C et al.,2003). Zirconia seems to be a suitable dental implant material because of its toothlike color, mechanical properties, and therefore biocompatibility. Apical bone loss and gingival recession associated with implants often uncover portions of the metal implant, revealing a bluish discoloration of the overlying gingiva. The use of zirconia implants avoids this complication and accedes to the request of many patients for metal-free implants. The material also provides high strength, fracture toughness, and biocompatibility(Langhoff JD et al.,2008). The inflammatory response and bone resorption induced by ceramic particles are less than those induced by titanium particles, suggesting the biocompatibility of ceramics(Puleo DA et al.,2006). Zirconia has received great interest as a dental material. The mechanical stability of zirconia is increased by the addition of tetragonal polycrystals of yttrium. Because of improvements in mechanical stability, zirconia implants have recently been introduced to implant dentistry and are increasingly used as fixtures to replace missing teeth. An advantage of zirconia over titanium is its ivory color. However, at the start of their clinical use, the impact of surface modifications of zirconia implants on osseointegration was not clear. Therefore, as with the titanium implants over the last 25 years, particular attention was paid to the effect of modification of zirconia surfaces on osseointegration in experimental animal studies. These preclinical studies have revealed bone apposition on zirconia implants with various surface modifi-cations, including sandblasting, etching, sintering and coating. Some of these studies showed that subtle changes of the zirconia surface had a high impact on bone apposition onto the implant surface. A recent study in miniature pigs demonstrated that acid-etching, but not alkaline-etching, of sandblasted zirconia implants caused more bone-to-implant contact than did sandblasting alone. Alkaline-etching resulted in lower bone-to-implant contact values compared with sandblasting alone. Interestingly, both acid-etching and alkaline-etching increased the presence of multinucleated giant cells on the implant surface(Kayahan Z et al.,2011).

# Aim of a study

The primary aim of comparing different dental implant materials is to evaluate their biocompatibility, functionality, and impact on oral tissues to determine the most suitable material for long-term success in dental implantology.

**Specific Objectives:**

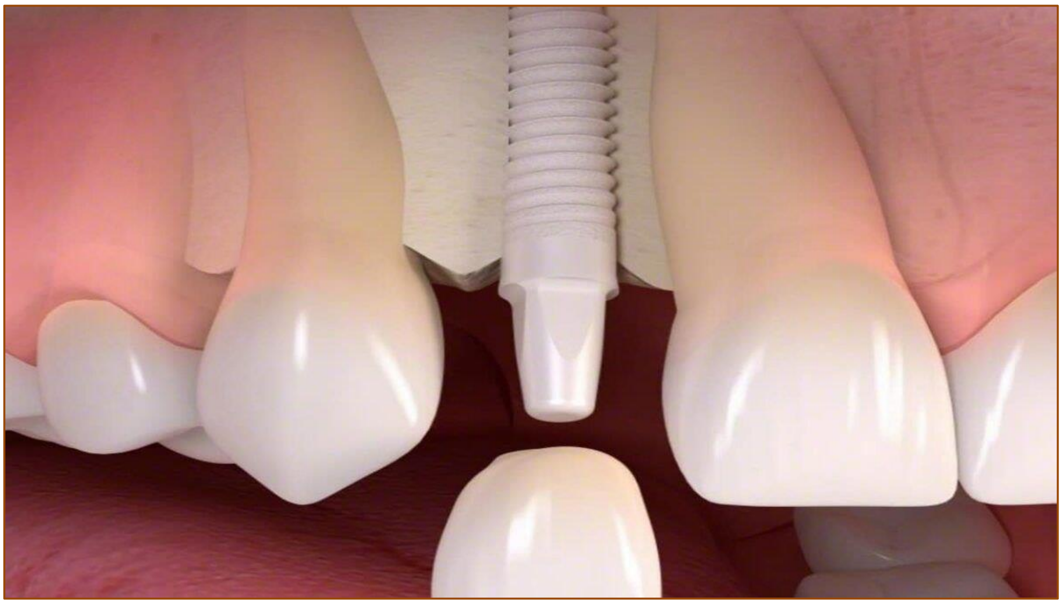
1. Biocompatibility
2. Osseointegration
3. Tissue Response
4. Mechanical Properties
5. Aesthetic Outcomes
6. Long-Term Success and Complications
7. Identify Patient-Specific Recommendations

# Chapter one:
# Review of literature

# 1. DENTAL IMPLANT

Dental implant can be defined as a biocompatible device placed within, or on, the bone of the maxilla or mandible (alveolar and basal bone), to provide a support for the dental prosthesis such as a crown, bridge, denture, facial prosthesis or to act as an orthodontic anchor (Jalbout & Tabourian, 2004).

Dental implant is an artificial and biocompatible material placed into (endosseous) or onto (subperiosteal or supraperiosteal) the jawbone to support a fixed prosthesis( Figure1), or to stabilize a removable prosthesis (Singh, 2013).



( Figure 1: Zirconia implants)

## Osseointegration

which is a key biologic and biophysical process for the success of dental implant therapy, regarding osseointegration there is two ways to define it.

**The first** one is histologically as direct structural and functional connection between organized, living bone and the surface of a load- bearing implant without intervening soft tissue between the implant and bone (Das et al., 2019).

**The second** is clinically as the asymptomatic rigid fixation of an alloplastic material (the implant) in bone with the ability to withstand occlusal forces. the important point here is that The primary goal in implant placement is to achieve and maintain an intimate bone-to-implant connection which as explaned earlier as dental osseointegration (Parithimarkalaignan and Padmanabhan, 2013).

## 1.1 Indications for dental implants.

- Intolerance to removable dental prosthesis.
- Need for long span fixed prosthesis with questionable prognosis.
- Single tooth loss that will make it necessary to prepare sound adjacent teeth for a fixed prosthesis.
- Unfavourable condition, location and number of abutment teeth. (Abraham, 2014)

## 1.2 Contraindications for dental implants

- the mandible is severely atrophic as there is a high risk of fracture.
- there is an alveolar bone deficiency and the patient declines bone grafting.
- The patient is emotionally and psychologically unstable (eg, bruxism, poor home care).
- underlying disease or disorders of the bone are present (eg, osteoporosis). (Warreth, 2018)

## 1.3 The dental prosthetic

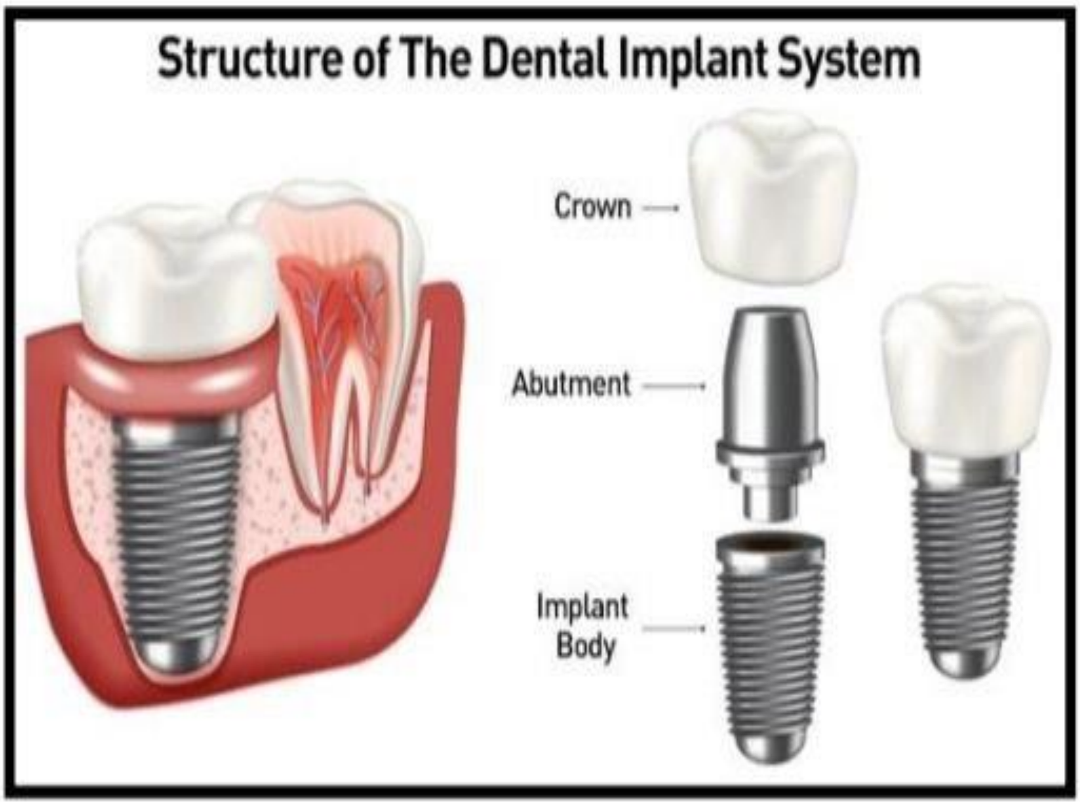
is the visible portion of the dental implant that can either be adental crown, bridge, or denture. Dental crowns are generally used to replace a single tooth or multiple missing teeth that are not adjacent to one another, while dental bridges are generally used to replace two or more missing teeth that are adjacent to each other. Finally, dentures are used to replace an entire arch of missing teeth, as well as an entire mouthful of missing teeth( Figure 2) . (Saini, *et* al., 2015).

- **Implant abutment**

The component which attaches to the dental implant and supports the prosthesis ( Figure 2) (Muddugangadhar, et al., 2011).

- **Abutment screw**

A screw used to connect an abutment to the implant ( Figure 2) .




( Figure 2: Structure of the dental implant) (Saini, *et* al., 2015)

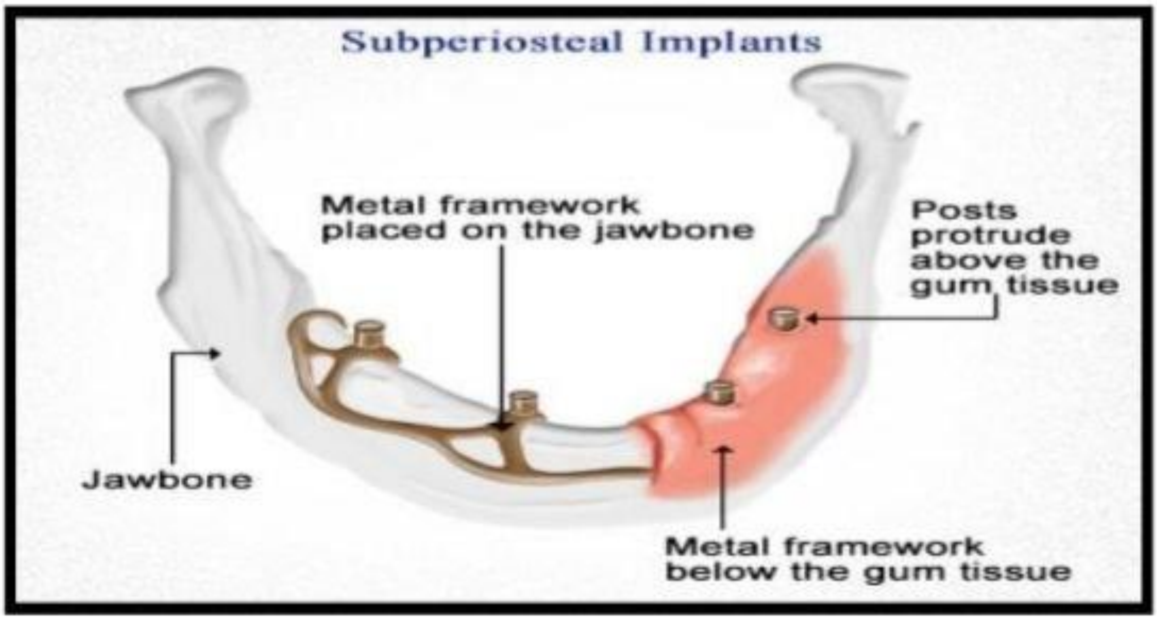
## 1.4 Dental Implant Classification

### 1.4.1 According to Implant Design

Several dental implant designs have been developed based on research and clinical trials to provide optimal implant therapy to patients by achieving optimal osseointegration with the bone, easiness of placement, allow immediate placement into the extraction sockets, achieve adequate primary stability, immediate or early loading protocols, and to give a wide range of prosthetic options (Singh. 2013).

### A. Subperiosteal (custom frame) implants

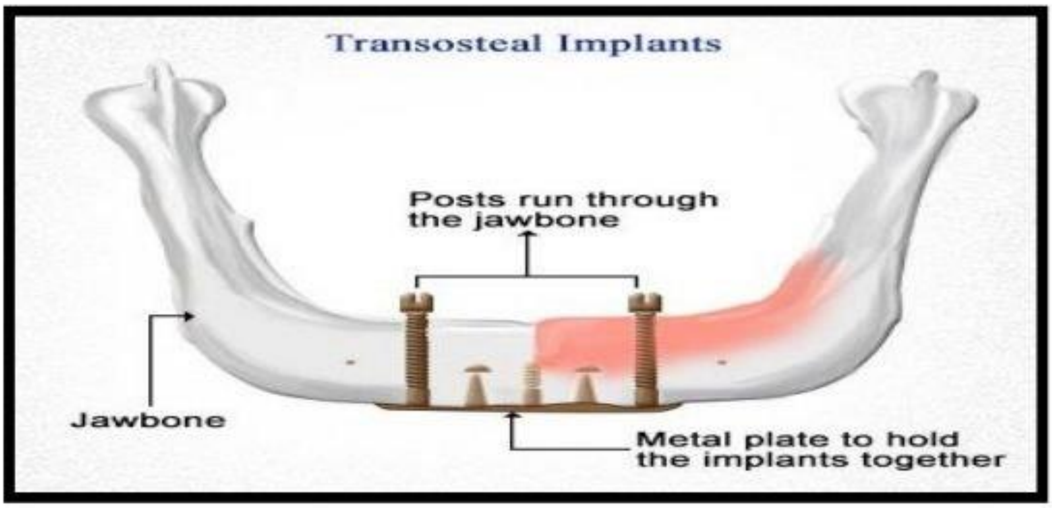
These implants are placed below the periosteum and over the bony ridge to be fixed to it while holding the removable or fixed type of prostheses. ( Figure 4) These implants are used in cases of severely resorbed mandibles where the placement of endosseous implants are difficult because of insufficient dimensions of the bone and the proximity of the mandibular canal to the crest of the bony ridge (Singh, 2013).




**( Figure 4: Subperiosteal Implants) (Kurtzman GM,1995)**

**B. Trans-mandibular implants**

Those implants were developed to retain dentures in the edentulous lower jaw where the ridge is extremely resorbed with a minimal ridge height of less than 10 mm. A submandibular skin incision is made for the implant to be inserted and the operation must be done under general anesthesia( Figure5) Due to the high incidence of complications and the need for general anesthesia, the transmandibular implant design is rarely used nowadays (Newman, et al., 2019).



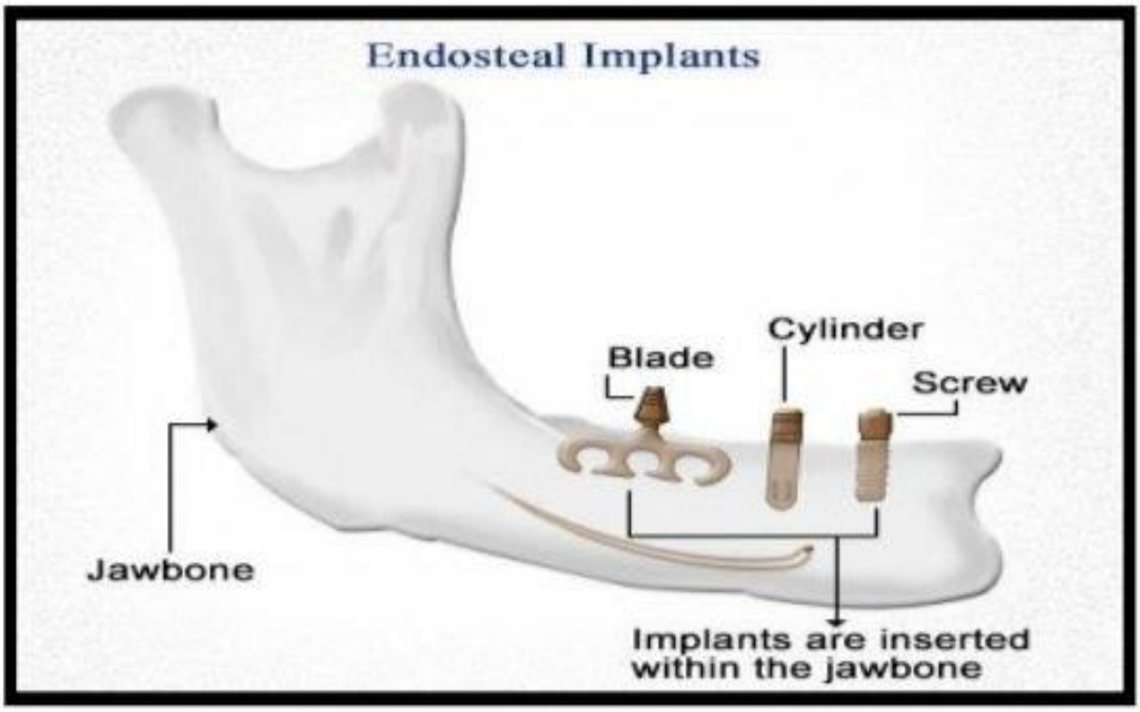

**( Figure 5: Transosteal implants) ( Noorthoek DR,2013)**

**C. Basal osseointegrated implants (BOI)**

Those implants are integrated into the high-density basal bone or they are engaged bi-cortically by their basal discs to prevent any movement during the function. To insert these implants, a lateral slot is prepared through the facial cortical plate and the implant of the same size and shape is tapped from the lateral access into the prepared slot (Singh. 2013).

**D. Endosseous Implants**

A device that is placed into the alveolar and/or the basal bone of the maxilla or mandible and is used to support a dental prosthesis (Jalbout & Tabourian, 2004). Several macro-designs of Endosseous Implants have been used as Blade implant, Pins, Root form, cylindrical (hollow and full), Disk-like, Screw shaped, Tapered and screw-shaped (Newman, et al., 2019).

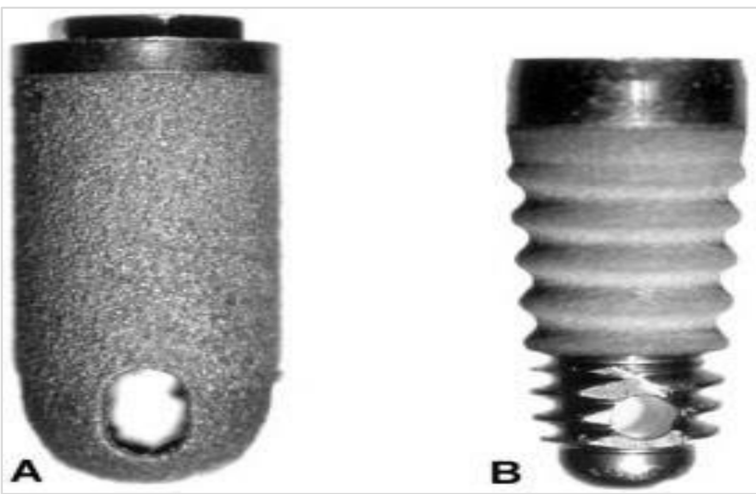



( Figure 3: Endosteal implants) (Singh, 2013)

**Endosseous root-form implants are now the most widely used implants.**

They can be classified according to (Singh., 2013) into:

1. **Based on surface design**: Non-threaded implants or Threaded implants (Figure 6 ) (Losenická, J.; et al 2021).

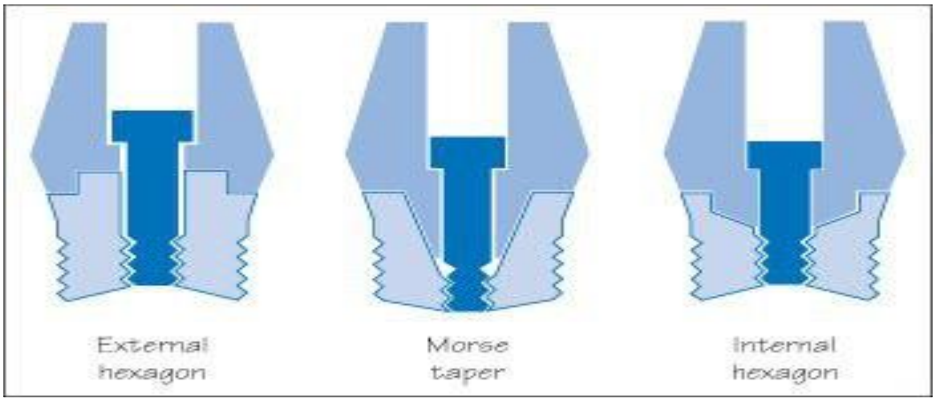



**( Figure 6: Based on surface design)**

2. **Based on body design**: Parallel body implants or Tapered body implants ( Figure 7) (López-Valverde, N.; et al 2020).


**( Figure 7: Based on body design)**

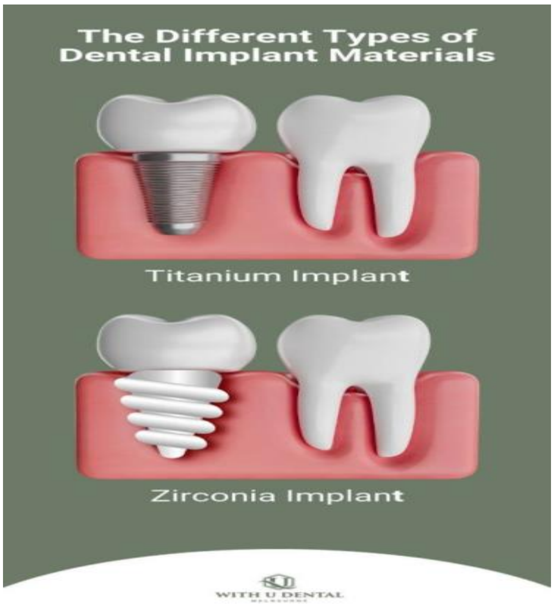
3. **Based on implant connection**: External connection (external hex) or Internal connection (internal hex) (Figure 8) .




**( Figure 8: Based on implant connection) (Singh., 2013)**

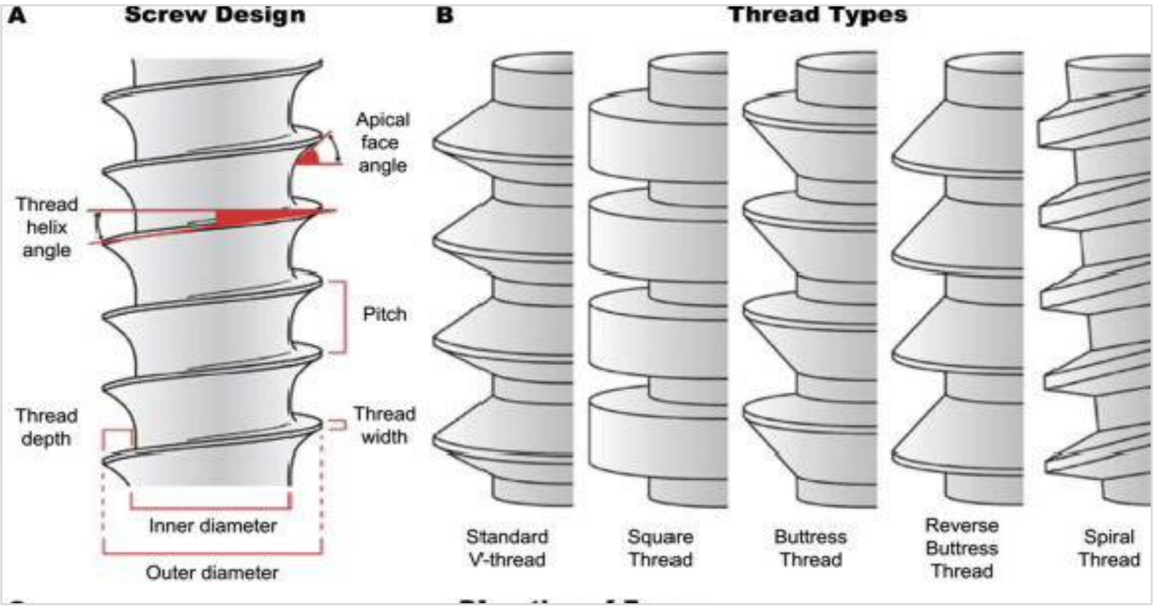
4. **Based on connection design**: Triangular design, Hexagonal design, Octagonal design, Smooth surface/non-hex (cold-weld) design or Morse taper connection(López-Valverde, N.; et al 2020).

5. **Based on implant material**:Titanium alloy implants or Zirconium implants(Figure 9) (Losenická, J.; et al 2021).



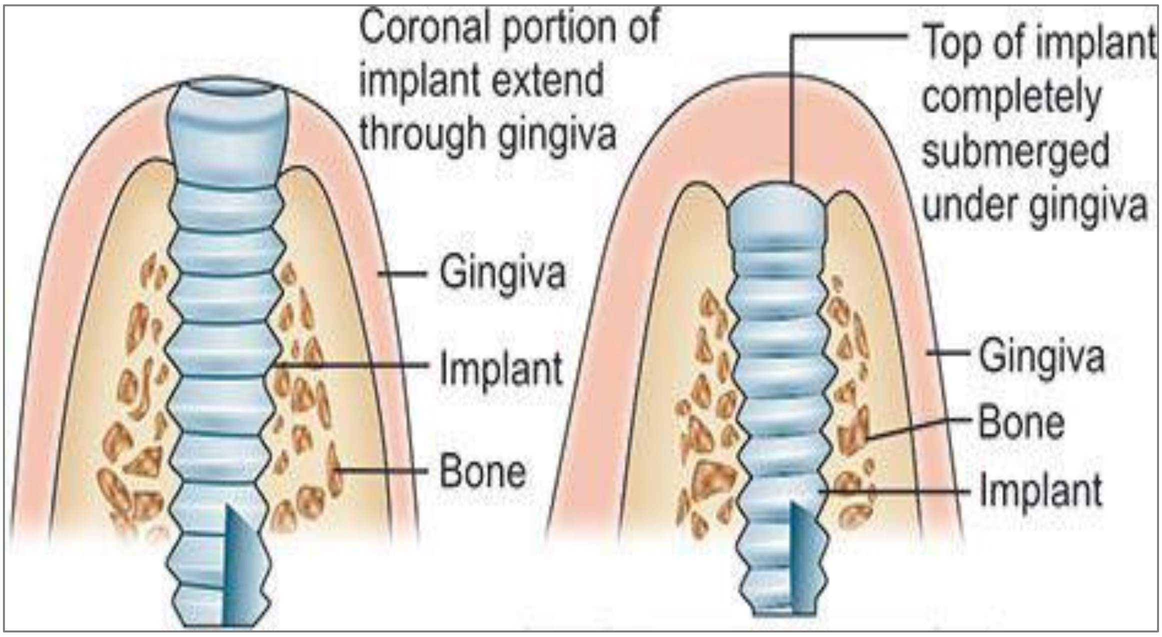

**( Figure 9: Based on implant material)**

6. **Based on thread design**: Square/U-shaped (non-cutting) thread implants, Sharp/V-shaped (cutting) thread (self-tapping) implants or Variable thread (cortico-cancellous) design implants(Figure 10) (Singh., 2013)




**( Figure 10: Based on thread design)**

**Based on the crestal polished collar**: Subgingival (two-stage) implants or Transgingival (one-stage) implants(Figure 11) (Singh., 2013)




**( Figure 11: Based on the crestal polished collar)**

7. **Based on implant pieces**: Two-piece implants or One-piece implant(Figure 12) (Losenická, J.; et al 2021).


**( Figure 12: Based on implant pieces)**

### 1.4.2 Depending on the reactivity with bone

A. Bilotolerant

B. Bioinert

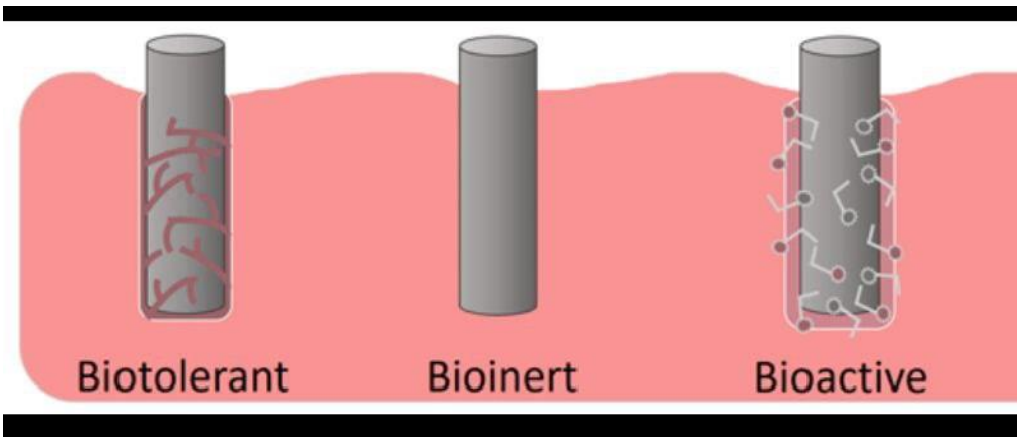
C. Bioactive

Biologic classification is based on tissue response and systemic toxicity effects of the implant and is divided into three classes of biomaterials: biotolerant, Bioniert, and bioactive. In terms of the long-term effects at the bone implant interface(Sykaras, et al., 2000)..

Biotolerant materials, such a polymethyarcrylate (PMMA), are usually characterized by a thin fibrous tissue interface.The fibrous tissue layer develops as a result of the chemical products from leading to irritation of the surrounding tissues(Craig, 1993).

Bioinert materials, such as titanium and aluminum oxide, are characterized by direct bone contact, or osseointegation, at the interface under favorable mechanical conditions. Osseointgation is achieved because the material surface is chemically non reactive to the surrounding tissues and body fluids (Misch, 2008)

Finally bioactive materials, such as glass and phosphate ceramics, have a boneimplant interface characterized by direct chemical bonding of the implant with surrounding bone(Figure 13) . This chemical bond is believed to be caused by the presence of free calcium and phosphate compounds at the implant surface (Block et al., 1997).




**( Figure 13: Depending on the reactivity with bone)** (Block et al., 1997)

### 1.4.3 Depending on the type of integration

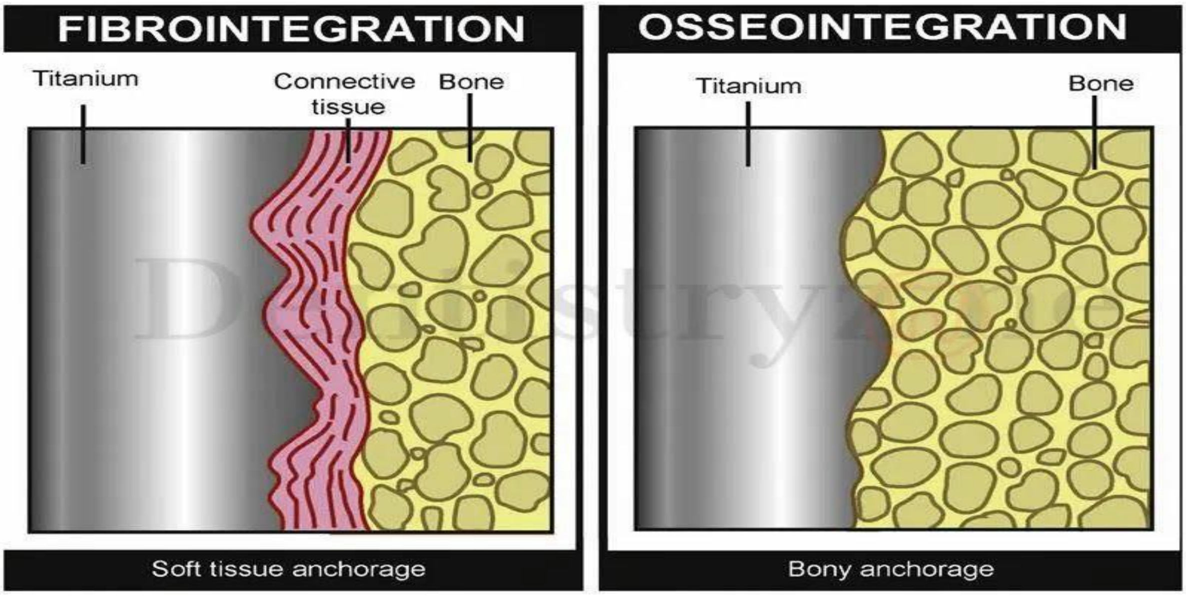
A. Ossointegrated

B. Fibrointegrate

Branmark (1982) proposed that implants integrate with bone such that the bone is laid very close to the implant material without an intervening connective tissue. Osseointergration can be defined as:

1. Osseous integration (1993) the apparent direct attachment or connection of osseous tissue to an inert alloplastic without intervening connective tissue(Block et al., 1997).
2. The process and resultant apparent direct connection of the endogenous material surface and the host bone tissues without intervening connective tissue (Singh, 2013).
3. The interface between alloplastic material and bone(Veerauyan et al 2003).

Weiss theory states that there is a fibro-osseous ligament formed between the implant and the bone and this ligament can be considered as the equivalent of the periodontal ligament found in the gomophosis, He defends the presence of collagen fibers at the bone-implant interface(Figure 14) . He advocates the early loading of the implant (Veeraiyzn, 2003 ;,Bhat et al.,2003).




**( Figure 14: Depending on the type of integration) (Veerauyan et al 2003).**

## 1.5 Properties of zirconia implant

1. Zirconia implant is made from a lustrous, grey-white, strong transition metal named Zirconium (Symbol Zr) (Cionca N., et al.,2017).
2. It is a crystalline dioxide of zirconium (ZrO2).
3. Jons Jakob Berzelius in 1824 was the first to isolate zirconium in an impure form(Hempel U.et el.,2010)..
4. The first research paper on the use of ZrO2 as a biomaterial was published by Helmer and Driskel in 1969.
5. The white, opaque color of zirconia, along with its good biocompatibility and low affinity to bacterial plaque, make it a material of interest in biomedical sciences(Cionca N., et al.,2017).
6. Zirconia also exhibits several promising physical and mechanical properties(Hempel U.et el.,2010)..
7. Initially, zirconia was used in various orthopedic surgical procedures for manufacturing ball heads for total hip replacements, artificial hips, finger and acoustic implants prosthesis (Sennerby L, et al 2005).
8. In the early 1990s, zirconia was introduced to dentistry and has been made widely available through the computer-aided design/computer-aided manufacturing (CAD/CAM) technology (Cionca N., et el.,2017).

### 1.5.1 Chemical composition, structure, and phases of zirconia implants

1. The pure form of Zirconia occurs in two major forms:

(a) the crystalline zirconia which is soft, white, and ductile,

(b) the amorphous form which is bluish-black powder in nature.

2. The powder form of Zirconia is refined and subsequently treated synthetically at high temperatures to yield optically translucent form of crystalline zirconia (Hempel U.et el.,2010).
3. After purification, the powder form of zirconium is filled into malleable dies and processed under high pressure (2000-4000 bar) and temperature molds to form homogenous implants of exact dimension(Sivaraman K.et el.,2018).

**Three crystalline phases occur in zirconia implants.**

- Pure zirconia is monoclinic (m), under ambient conditions (Hempel U.et el.,2010).
- With increasing temperature, the material transforms to a tetragonal crystal structure (t) at~1170 °C. and Then to a cubic crystal structure (c), followed by a fluorite structure at ~2370 °C with melting at 2716 °C( Figure 15).
- The ZrO2 ceramic shows a hysteretic, martensitic transformation during the heating and cooling processes, while its reversible transformation occurs at ~950 °C upon cooling (Hempel U.et el.,2010).
- Pure zirconia along with various stabilizing oxides such as CaO, MgO, Y203 or CeO2 allows the retention of the tetragonal structure at room temperature. Therefore, it controls stress-induced transformations.
- Alumina has also been added to Yttria stabilized-tetragonal Zirconia polycrystal (Y-TZP) in low quantities (0.25 wt%) to yield tetragonal zirconia polycrystal with alumina (TZP-A) with significant improvement in the durability and stability of zirconia crystals under high temperatures and humid environment (Apratim A..et el.,2015).
- Studies have shown that implants without alumina when exposed to the artificial mouth have a survival rate of 50%, whereas implants with alumina have a survival rate of 87-100% (Hempel U.et el.,2010).

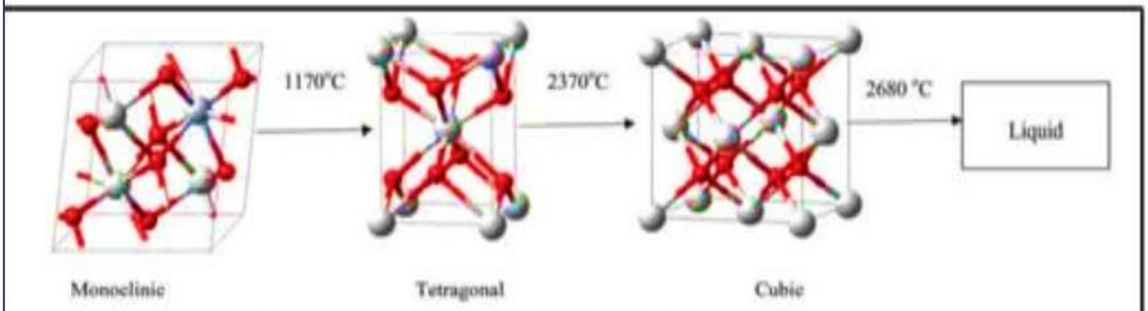


Fig. 1 Crystallographic phase change with the variation of temperature of the three $ZrO_2$ phases.[17,18]

**( Figure 15: zirconium) (Hempel U.et el.,2010)**

### 1.5.2 Physical and mechanical properties of zirconia implants

**The mechanical and physical properties of zirconia implants depend upon:**

Its composition, nature of crystals, metastable polymorphic structure, ratio of the monoclinic to tetragonal phase, percentage of stabilizing metal oxide, ageing process, macro and microdesign of the implant, nature of the finish line on the implant abutment, characteristics of implant abutment, and amount of occlusal load (Hempel U.et el.,2010).

- Yttria-stabilized tetragonal zirconia polycrystalline (Y-TZP) materials exhibit:
  - ❖ **superior corrosion** and wear resistance, as well as a high flexural strength (800-1000 MPa) compared to other dental ceramics, It was also found that flexural strength of zirconia increases by mechanical modification of its surface (Cionca N., et el.,2017).
  - ❖ **compressive strength** of blade type of zirconia implants was tested, it was found to be adequate in occlusion (Sennerby L, et al 2005).
  - ❖ **Fracture strength** (512.9 N) of unloaded zirconia was found to be more than the fracture strength (401.7 N) of loaded zirconia, It was also found that the implant preparation and cyclic loading decrease the fracture strength of one-piece zirconia implants, but these values were still within clinically acceptable limits to withstand average occlusal forces even after an extended interval of artificial loading (Bächle M.et el.,2007).
  - ❖ **environmental conditions**: Due to severe environmental conditions of moisture and stress, the resulting zirconia may transform more aggressively to the monoclinic phase with micro crack formation(Apratim A..et el.,2015).

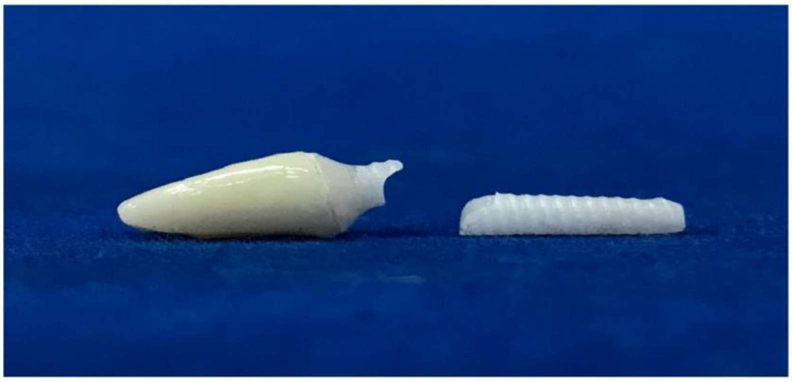
- **This mechanical property degradation in zirconia is known as "aging" of the material.**

**This can lead to(Cionca N., et el.,2017):**

- Increase in the water penetration and resultant corrosion(Figure 16)

**( Figure 16: corrosion implant)**

- Crack propagation(Figure 17)



**( Figure 17: Fracture implant)**

- Surface deterioration
- Phase destabilization and
- Decreased resistance to load.

- The aging process depends on various factors like porosity, residual stresses, grain size, and the content of stabilizer (Cionca N., et el.,2017).
- It was found that decrease in grain size and increase in stabilizing oxide content reduce the transformation rate (Apratim A..et el.,2015).
- Aging is accelerated due to changes in processing technique and can be avoided by more accurate processing (Hempel U.et el.,2010).

- Some in vitro studies have found that the aging reduces the mechanical properties of zirconia, even though within clinical acceptable limits, in simulated dental treatment conditions(Cionca N., et el.,2017).

### 1.5.3 Surface roughness of zirconia implants

1. While direct bone apposition can occur on different types of surfaces, it has been demonstrated that a certain degree of surface roughness is beneficial in accelerating bone apposition to implant surface(Figure 18).
2. Various surface modifications have been developed to enhance the osseointegration of zirconia implants. Such as (Stübinger S.et el.,2008):

- Acid etched Zirconia
- sandblasted Zirconia
- plasma sprayed
- anodized,
- Machined

- chemically modified (plasma-anodized)
- coated (calcium phosphate, or collagen type I with chondroitin sulphate)

nanotechnology surface modified (Calcium phosphate nano layer)


(Fig:18. Various surface modifications of zirconia implants) (Stübinger S.et el.,2008)

- These surface modifications at microscopic level enhance osseointegration by increasing the roughness, wettability and expression of integrin's alpha5 and betal mediated osteoblast-gene expression and osteoblast-like cells adhesion, spreading and migration on the zirconia implant substrates(Stübinger S.et el.,2008).
- When osteoblast differentiation on two different zirconia surfaces (sandblasted with alumina particles or SLA in a mixture of hydrofluoric acid and sulfuric acid) was compared with standard titanium surface (sandblasted and acid-etched),zirconia substrates showed better osteoblastic adhesion and proliferation compared with titanium(Hempel U.et el.,2010).
- Bachle et al. evaluated the cell proliferation on machined, sandblasted, and Sandblasted, large grit, acid etched (SLA) zirconia surfaces and found that airborne particle abrasion and acid-etching increased the surface roughness of zirconia implants with enhanced cell proliferation compared to machined zirconia implants (Bächle M.et el.,2007).
- Bioactive glass as a surface coating material has also been tried for zirconia implants with promising results like enhancement of the early osseointegration rate as compared to non-coated implants.

- Bioactive glass coated Zirconia implants is useful in geriatric patients with poor bone quality or osteoporotic bone (Hempel U.et el.,2010).

- High hardness of the zirconia implants makes the process of surface roughening very difficult. So, recently, laser has been used to engrave a pattern on the zirconia surface (Sennerby L,et al 2005).
- A scanning electron microscopic (SEM) study done to find the influence of (Er: YAG), ($CO_2$), and diode laser irradiation on the surface properties of polished zirconia implants demonstrated that diode and Er: YAG lasers did not cause any visible surface alterations. However, the $CO_2$ laser produced distinct surface alterations to zirconia (Stübinger S.et el.,2008).

### 1.5.3 Biocompatibility of zirconia implants

1. Various in vitro tests were conducted on osteoblasts, fibroblasts, lymphocytes, monocytes, and macrophages to test the biocompatibility of zirconia (Hempel U.et el.,2010).
2. It was observed that zirconia had no cytotoxic effect on fibroblasts, osteoblasts and made the cells capable of elaborating the extracellular matrix by synthesizing various essential and structural proteins (Sykaras N,et al. 2000).
3. Laser-modified zirconia showed better adhesion to osteoblasts due to the better wettability characteristics.
4. Both powder and particles of zirconia tested in vitro on different cell lines (human and murine) of lymphocytes, monocytes, or macrophages did not induce high cytotoxicity or inflammation (Stübinger S.et el.,2008).
5. Biocompatibility tests were also conducted in vivo for zirconia, and it was found that when it was implanted in the soft tissue, it became encapsulated by a thin layer of fibrous tissue similar to that seen in the case of alumina (Bächle M.et el.,2007).
6. Also, there was no cytotoxicity in the soft tissue in relation to wear products of zirconia (Kohal RJ.et el.,2013).

## 1.6 Surface Topography

Generally, the root form implants presently used are of a threaded and nonthreaded design.

### 1.6.1 Threaded Implants

Threads have been incorporated into implants to improve initial stability, enlarge implant surface area and distribute stress favorably (Fig19). It has been proposed that threads, due to their uneven contour will generate a heterogeneous stress field, which will match the physiologic overload zone, thus prompting new bone formation (Abuhussein H, et al.  2009).

The threaded implant is the most common type of implant design today. There are different configurations of implant threads along with the requisite manufacturer's claims of superiority but they all work essentially the same (Avhad, R. et al, 2020).

The advantages of threaded design are that they stabilize the implant when it is initially placed, increases the surface area and provide a great means of proprioception for the dentist placing the implant giving lots of information about the implant site (del Olmo, R.; et al 2023).

The disadvantages is that it requires pretapping for placement into very dense bone (Avhad, R. et al, 2020).

Threaded implants are the most versatile and effective implants in the group and, hence, are the most favored implant system presently ( Ivanoff C.J, . et al, 2001) .

Thread patterns in dental implants currently range from microthreads near the neck of the implant (Astra Tech, Lexington, MA) to broad macrothreads on the mid-body (BioHorizons, Birmingham, AL; Steri-Oss, Nobel Biocare) and a variety of altered pitch threadsto induce self-tapping and bone compression (Implant Innovations, Palm Beach Gardens, FL, Nobel Biocare) (Rungcharassaeng, K.; et al 1999).

They increase the surface area but require pretapping for placement into dense bone. A plethora of modifications has been employed by implant companies to accentuate the effect of threads, the rationale of some of them is not yet documented scientifically(Figure 19) (Avhad, R. et al, 2020).

(Fig:19. Threaded Implants) (Abuhussein H, et al. 2009)

### 1.6.2 Nonthreaded Implants/Implant Cylinders

Nonthreaded implants/implant cylinders have less surface area when compared to threaded implants and, hence, require coating (Fig. 20). They are usually placed by preparing an osteotomy slightly smaller than the implant size and slowly tapping the implant with a mallet (Avhad, R. et al, 2020).

It is advantageous that it is very easy and quick to place these implants but the initial stabilization and propioception is much less than threaded implants and, hence, is not favored by many implantologists( Ivanoff C.J, . et al, 2001) .

(Fig:20 Nonthreaded Implants) (Winkler S, et al 2000)

## 1.7 Enhancement of osseointegration

Several techniques to enhance the implant surface have been proposed to improve the success rate of oral rehabilitation with osseointegrated implants (Elias CN et al, 2008).

However, osseointegration in many cases can occur between 3-6 months But to shorter this healing period roughness and coating technique can made on dental implant , Initially, one could expect that increasing the surface area of the implant should result in more sites for cell attachment, facilitating tissue growth and improving mechanical stability. However, this is not a general rule and may vary depending on the cell type (Tummler HP al,2002).

Fibroblasts avoid rough surfaces and accumulate on smooth ones. On the other hand, macrophages exhibit rugophilia, that is, they prefer rough surfaces, whereas epithelial cells are more attracted to rough surfaces than to smooth ones (Van Oosterwyck H, et al 1998).

Osteoblastic cells adhere to rough surfaces more easily, a finding also observed in commercially available implants with chemically treated surfaces ( Seunghan Oh,2015).

Chemical composition of the surface has an influence on the secondary stability and reactivity of the implant(Tummler HP al,2002).

Schneider et al. reported the effect of surface chemistry on the cell behavior of osteoblasts using a variety of cell cultures and animal models (Stanfordet al,2004).

Recently, many works have been carried out on surface treated commercial titanium implants to enhance the osseointegration function By increasing the surface roughness, an increase in the osseointegration rate and the biomechanical fixation of titanium implants have been observed (Shinji Kuroda el at 2016)

The implant modifications can be achieved either by additive or subtractive methods. The additive methods employed the treatment in which other materials are added to the surface, either superficial or integrated, categorized into coating and impregnation, respectively (Van Oosterwyck H, et al 1998).

While impregnation implies that the material/chemical agent is fully integrated into the titanium core, such as calcium phosphate crystals within Ti02 layer or incorporation of fluoride ions to surface, the coating on the other hand is addition of material/agent of various thicknesses superficially on the surface of core material. The coating techniques can include titanium plasma spraying (TPS), plasma sprayed hydroxyapatite (HA) coating, alumina coating, and biomimetic calcium phosphate (CaP) coating.( Seunghan Oh,2015).

### 1.7.1 Modification of Microtopography (mechanical surface treatment)

Microtopography is linked to microroughness on a micrometer scale (1-100 um) and is modified by manufacturing techniques like machining, acid-etching, anodization, sandblasting, grit-blasting, and different coating procedures. Commonly used scientific parameters to describe the surface roughness are the 2-dimensional (profile roughness average) and the 3-dimensional (area roughness average). The majority of dental implants on the market have a moderate rough surface of 1-2 um (Van Oosterwyck H, et al 1998)

According to Albrektsson and Wennerberg, by this range seems to provide an optimal degree of roughness to promote osseointegration. Pits, grooves, and protrusions characterize the microtopography and set the stage for biological responses at the bone-to-implant interface(Figure 21) . The modifications of microtopography contribute to an increase in surface area
( Shinji Kuroda el at 2016).

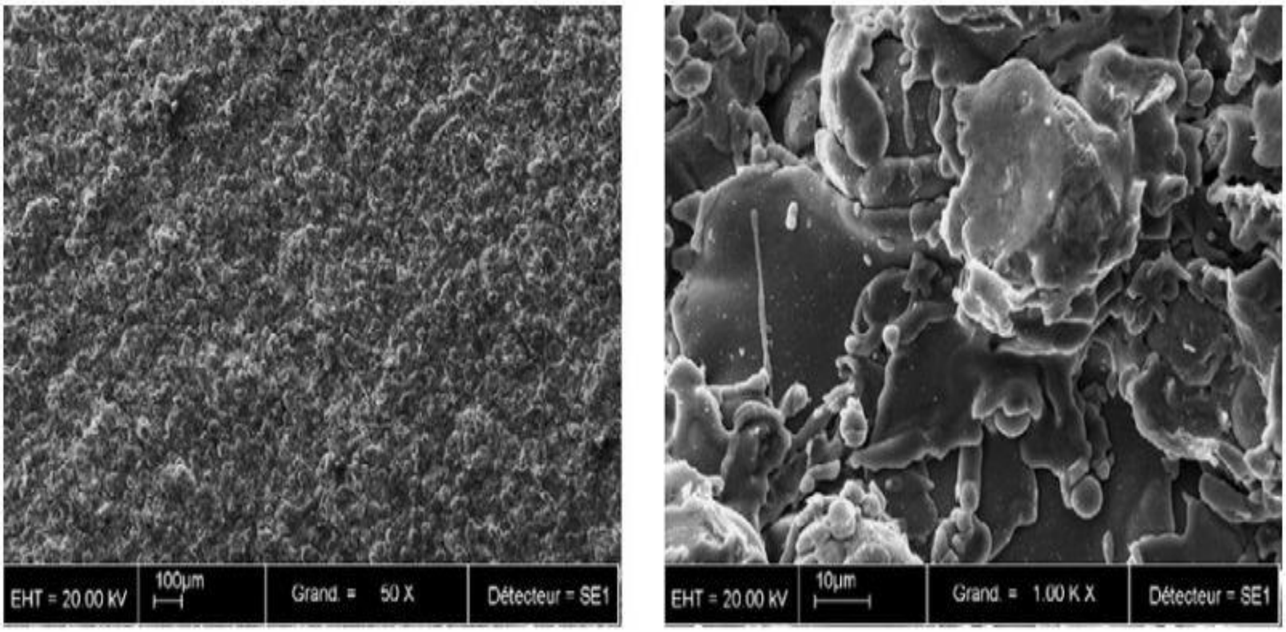



**Figure 21**: SEM micrographs of a titanium plasma-sprayed (TPS) surface (Courtesy of Cam Implants BV, The Netherlands). (Elias CN et al, 2008).

### 1.7.1.1 Plasma spray treatment

A titanium plasma-spraying (TPS) method has been used for producing rough implant surfaces (Fig.22) This method consists in injecting titanium powders into a plasma torch at high temperature. The titanium particles are projected on to the surface of the implants where they condense and fuse together, forming a film about 30m thick. The thickness must reach 40-50 m to be uniform. The resulting TPS coating has an average roughness of around 7 m, which increases the surface area of the implant(Fousová, M., el at.,2017).

It has been shown that this three-dimensional topography increased the tensile strength at the bone/implant interface. In this preclinical study using minipigs, the bone/implant interface formed faster with a TPS surface than with smooth surface implants presenting an average roughness of 0.2 m (Hadzik, J.; et al 2023).

However, particles of titanium have sometimes been found in the bone adjacent to these implants. The presence of metallic wear particles from endosseous implants in the liver, spleen, small aggregates of macrophages and even in the para-aortic lymph nodes have also been reported. Metal ions released from implants may be the product of dissolution, fretting and wear, and may be a source of Cancers due to their potentially harmful local and systemic carcinogenic effects. (Jiang, P, el at., 2023).

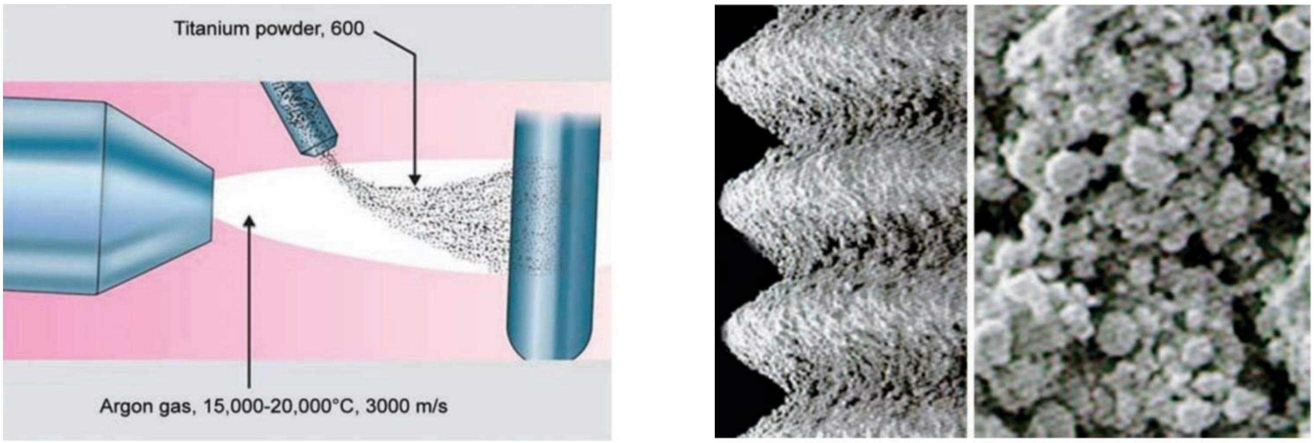



**Fig.22: Magnified view of TPS surface (Hadzik, J.; et al 2023).**

### 1.7.1.2 Laser ablasion

The process of selectively remove material fromsurface of dental implant by irradiating it with laser ablastion the main problem of surface treatment is the contamination of the surface during the roughening procedure (fig.23). Using laser techniques for roughening the implants surface, contamination is avoided, because the laser enables implant surface treatment without direct contact, and an easier control of the micro-topography is achieved. Laser irradiation has here been demonstrated to be a suitable, clean and easy method to improve bon response (Kolarovszki, B.; et al 2024).

The micro- or nano-topography created by laser texturing can provide to the improved stability and longevity of the implant , Lasers can create precise antimicrobial properties, which help in reducing the risk of infection around the implant. and controlled surface textures on dental implants. This is achieved using different types This is particularly important for preventing peri-implantitis, a common complication in of laser pulses, such as femtosecond, picosecond, and nanosecond pulses, which allow for dental implantology (Fenelon, T., el at.,2022).

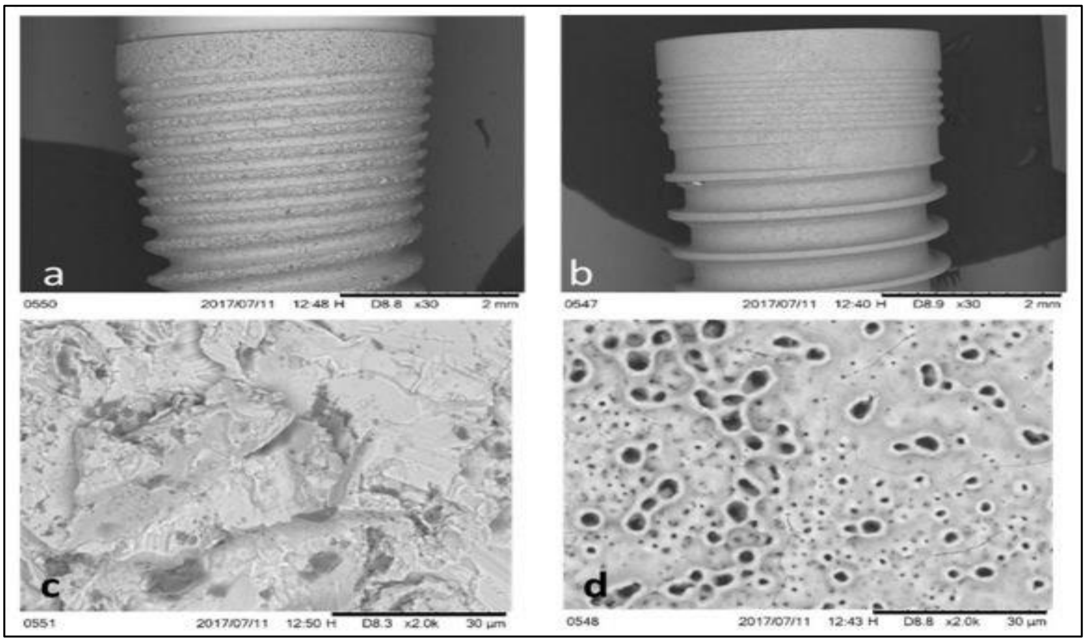



Figure23: Scanning Electronic Microscope images of the two different implants tested: (a) dental implant sandblasted and acid-etched surface (SA); (b) dental implants with oxidized surface (OS); (c) surface of SA dental implants; (d) surface of OS dental implants (Kolarovszki, B.; et al 2024).

### 1.7.1.3 Acid Etching

In acid etching, the use of acids on metal surfaces is not only to clean the surface but also to modify the roughness. A strong acid like hydrofluoric (HF), nitric ($HNO_3$), and sulphuric ($H_2S0_4$) or a combination of these acids is commonly used in this technique. Acid etched surfaces had increased cell adhesion and bone formation, thus enhancing the osseointegration, Due to its dissolution ability HF has been used for etching restorative ceramic materials in order to increase the bonding surface for luting agents. The significance of this technique also renders the substrate with homogeneous roughening regardless of the sizes and shapes (Rosales, et al 2010).

The roughness of titanium is one of the of the factors that helps in determining the stability of bone formation and resorption at the interface of bone implants(fig.24). reported that a nanotopography that allows bone ingrowth via acid etching on an implant may improve the roughness. Previous study has reported that the rate of etching depends on the type and concentration of the acid, However, the suitability of these acids in etching was not determined as they required further tests particularly on the bone implant contact and torque removal. Titanium samples etched by $H_2SO_4$ with different concentrations demonstrated an increase in surface roughness (Lee, J.H., el at.,2011).

Concentrated $H_2O_4$ has been proven as an effective solution to roughen the surfaces particularly for biological applications.

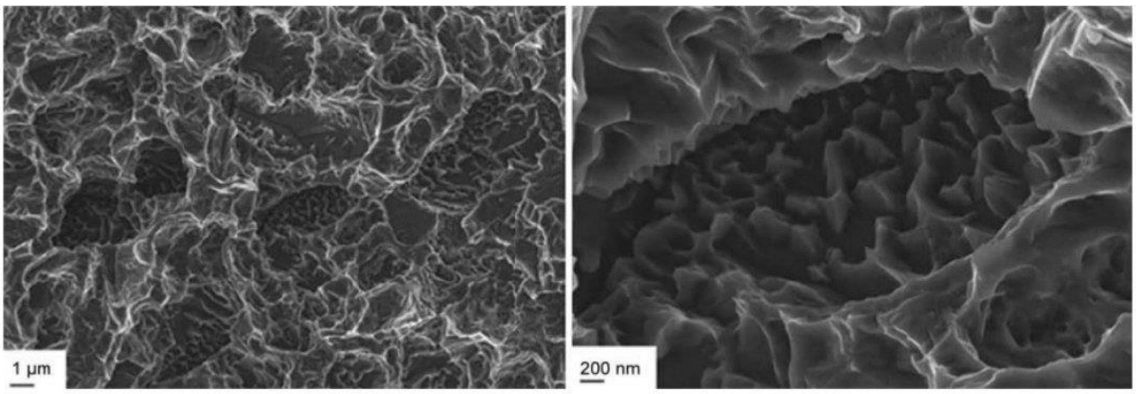



Figure 24: Acid Etching (Rosales, et al 2010).

#### 1.7.1.4 Blasting ceramic particles

Another approach for roughening the Titanium surface consists in blasting (also called grit-blasting or sand-blasting) the implants with hard ceramic particles. The highly roughened implants have been shown to favor mechanical anchorage and primary fixation to bone (Lee, J.H., el at.,2011).

The SLA process involves two main steps: large-grit sandblasting followed by acid etching. This combination creates a surface with both macro-and micro-roughness. The sandblasting step uses large particles to create a macro-rough surface with large pores and sharp edges, which increases the surface area for bone contact. In the sandblasting process of the SLA-type surface, typically Al2O3 (250-500 µm), $TiO_2$, or HA are used as abrasives (Zinelis, S.,et al 2015).

The acid etching step further refines the surface, creating micro-pits and a micro-rough texture that enhances the surface's ability to retain bone cells and promote bone growth. The resulting surface topography includes large dips, sharp edges, and small micro-pits. This complex structure provides an ideal environment for bone cells to adhere and proliferate (Bok, W.M., el at.,2015).

The Ra values typically range around 1.5 µm, which indicates a higher roughness than machined and DE surfaces, and has been shown to improve osseointegration (Lee, J.H., el at.,2011).

### 1.7.2 coating surface treatment

#### 1.7.2.1 hydroxyapatite coating material

HA is one of the most biocompatible material ,HA enhance bone healing adjacent to the implant and a popular surface modification on dental implants (fig.25) (Kuroda, K.; et al 2012).

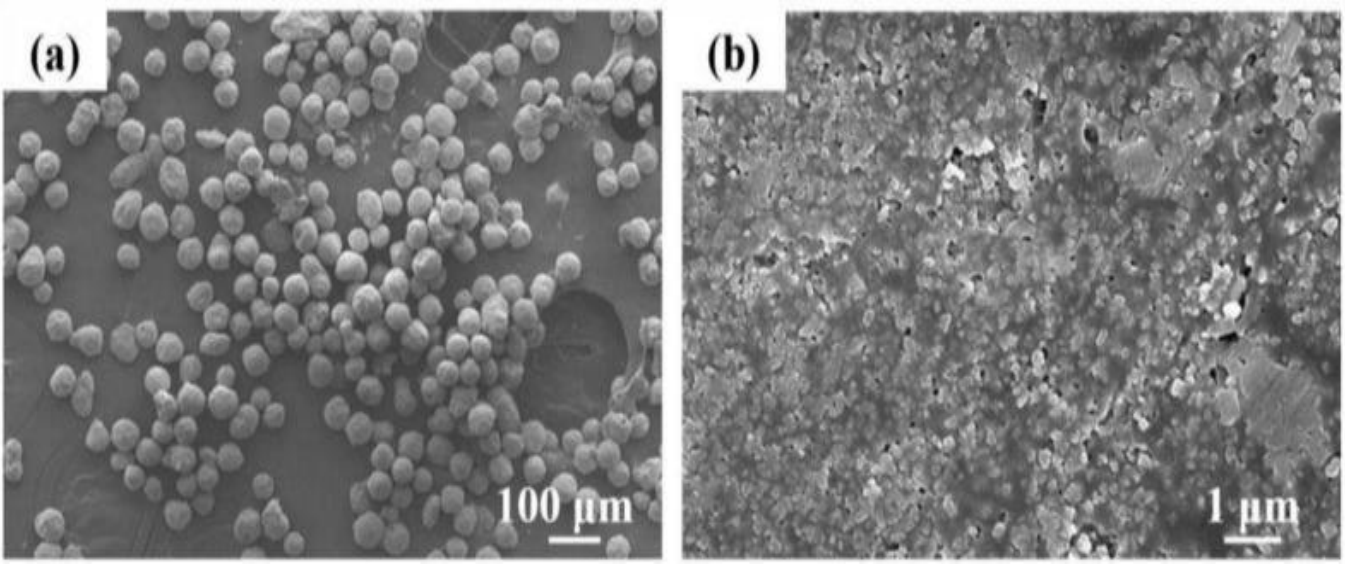



**Figure 25**: Hydroxyapatite (HA) powder morphology: (a) surface morphology; (b) cross-section morphology (Yang ,et al 2005).

HA coatings have the advantage of increasing surface area, decreasing corrosion rates, and accelerating bone formation via faster osteoblast differentiation (Usinskas, P.; et al 2015).

Other advantages of HA include the more organized bone pattern and higher degree of mineralization at the interface, as well as increased bone penetration (which improves fixation) (Santos, A.F.P.;et al 2024).

The bone bonding capabilities of HA make it a very desirable surface and probably the most reliable surface up to date. Due to their brittle nature, HA and fluorapatite cannot be used as implants in load-bearing applications (Narayanan R,. et al 2008).

Therefore, load-bearing implants have been coated with HA and fluorapatite (Baltatu, M.S.;et al 2021).

The objectives of employing apatitic coatings are to cause an earlier stabilization of the implants in the surrounding bone and to eliminate the use of polymethyl methacrylate bone cement around hip prostheses (Usinskas, P.; et al 2015). Numerous methods of depositing HA on metallic implants have been reported. The current deposition process for commercial dental and orthopedic implants is plasma spraying or arc plasma spraying (Santos, A.F.P.;et al 2024).

Plasma spraying of HA usually takes place under normal atmospheric conditions, as opposed to the plasma spraying of some metallic powders during which a vacuum or an inert atmosphere is used to minimize oxidation (Narayanan R,. et al 2008).

It has been reported that plasma spraying of HA results in coatings with a thickness greater than 30 um. This is a thermal spraying process that utilizes a gas stream to carry HA powders, which are then passed through an electrical plasma produced by a low-voltage, high-current electrical discharge (Yang ,et al 2005).

The semi-molten HA powders are sprayed onto the titanium substrate, where they solidify.Advantages of plasma spraying include a rapid deposition rate and sufficiently low cost (Łukaszewska-Kuska, M.; et al 2018).

However, problems cited with the plasma-sprayed coatings include variation in bond strength between the coatings and the metallic substrates, alterations in HA structure due to the coating process, and poor adhesion between the coatings and metallic substrates (Santos, A.F.P.;et al 2024).

As in the case of the adhesion between the plasma-sprayed coatings and the metallic substrates, the nature of the substrate plays an important role (Baltatu, M.S.;et al 2021). The bonding of the plasmasprayed HA coatings appears to be entirely mechanical in nature. Evidence has been presented that a highly roughed substrate surface exhibits a higher bond strength when compared with a smooth substrate surface (Meyer. et al, 2004).

### 1.7.2.2 Carbon coatings:

carbon coatings as a type of implant coating material. Thin car bon film with a chemical composition of Ti0.500.3C0.2 has been used to coat TI implants. Carbon-coated implants were reported to give a good and stable chemical inertia between the carbon coating and the etching agent used. The carbon coatings were also found to be hemocompatible, histocompatible, bio stable, and chemically stable in vitro and in vivo (Özkurt Z. et al., 2007)

The corrosion resistance of the carbon coating could be improved by plasma immersion ion implantation and deposition or by direct carbon bonding. The surface properties together with the biologic properties were found to be improved by carbon plasma immersion ion implantation and deposition. The direct carbon bonding actually allows for osteoblast adhesion and proliferation at the surface of the nickel-titanium (NiTi) shape memory alloy. Even though this seems to be a promising form of implant coating, not much long-term data could be found and most studies focused on other more innovative materials(Nakae , et al., 2005 ).

### 1.7.2.3 Bioactive glass and bioactive ceramics:

Bioactive glasses and ceramics also have been proposed as good, innovative surface coatings for dental implants due to their glass properties, which would help obtain better implant osseointegration and reduced prosthetic corrosion in the body fluids (Saini, et al., 2015).

The thermal expansion coefficients of the bioactive glass es and ceramics are usually much larger than those of Ti oxide (Schupbach, P.; et al 2019).

This thermal expansion can be reducedby increasing the silicon dioxide ($SiO_2$) content of the bioglass. On the other hand if the $SiO_2$, content is increased the bioactivity of the glass coating is reduced significantly (Saini, et al., 2015).

The main disadvantage of these coatings is the limitation of use in load-bearing areas. Bioactive glass is actually a family of glass compositions that allow bonding to the peri-implant tissues within a short span of time (Anil, et al., 2011)..

In a recent study, a reactive plasma spray bioactive glass coating was used to demonstrate the behavior of this type of surface coat ing in loadbearing situations (Romero-Ruiz, M.M.; et al 2019).

It was concluded that a coating material can only be considered functional if it satisfies the following two criteria: (Misch, 2008; Muddugangadhar, et al., 2011).

Able to withstand the load-bearing forces imposed on them while maintaining a strong bond with the implant surface to be totally functional. In vitro results showed that the bioactive glass satisfied both criteria even after a couple of months of load-bearing analyses (Anil, et al., 2011).

It was also demonstrated that the silicate glasses have to have a weight percentage higher than 60% so as to be able to withstand corrosion and thermal expansion of the coating. Silica contents above 60% weight would delaminate and crack (Saini, et al., 2015).

This can be circumvented by partial substitutions of calcium oxide (CaO) by magnesium oxide (MgO) and Na:O by potassium oxide (KO) in the bioglass composition to match the thermal expansion between the coatings and that of Ti-based alloys (Anil, et al., 2011). bioactive glasses were applied as a coating on Ti dental implants by an enameling technique with HA coatings acting as a control. Overall results showed that the bioactive glass coatings were as equally successful as HA coatings in achieving osseointegration and bioactivity. (Saini, et al., 2015).

# Chapter Tow

# Discussion

# Discussion

found that a plasma-sprayed titanium surface exhibits the highest surface roughness but Reports in the literature caution about cracking and scaling of coatings because of the stresses produced by elevated temperature of processing and the risk of accumulation of abraded material in the interfacial zone during implanting of such implants (the surface was acid etched and grit blasted) (Knabe et al.,2019), etching with strong acids has been shown to cause hydrogen embrittlement of titanium, which can cause micro cracks on the surface, potentially undermining the structural integrity of the implant and ultimately leading to implant failure. (Cho *et al.,2019*).

lasers have been mainly used for surface modification of implant materials (71%), especially titanium and its alloys, to promote osseointegration Among the different types of lasers for surface modification, Nd:YAG is the most commonly used.Laser treated titanium implant surfaces demonstrated higher adhesion of human gingival fibroblasts and higher focal adhesion kinase values than polished and sandblasted Titanium (Baltriukiene.D et al.,2014). Similar findings were reported, where laser treated and PEEK surfaces exhibited more proliferation and guided gingival fibroblast attachment compared to machined titanium (Gheisarifar, M et al., 2021).

Laser treatment improved the bone response and ideal pores with a specific diameter, depth and intervals can be controlle. Laser treatment leads to contamination with carbon and oxygen, with 1.44% carbon on the surface. determined that carbon dioxide from the air may have provided the carbon and that laser was considered to be least contaminating surface treatment in comparison to the acid etching, sand blasting or the plasma spraying technique , when longer pulse durations are used such as 250–250 ms Using high peak powers and extended exposure times will however cause alterations to titanium implant surfaces . With excessively high exposure parameters, Er:YAG laser irradiation may cause deleterious effects on titanium implant surfaces, which will reduce adhesion of osteoblastic cells . Adverse surface changes such as melting and flattening of surface projections can be prevented by keeping the laser peak power low and also by using concurrent water irrigation(Hemlata G  et al., 2012).

Grit blasting is always followed by an acid etching to remove the residual blasting particles. Hence, the grit blasting is also considered as one of the means  to embed surface contaminants on the substrates. However, this technique is only Grit blasting is always followed by an acid etching to remove the  residual blasting particles. However, this technique is only(Darvell.,2020).

HA-coated implants with plasma spraying show good bond strength as against uncoated. The coated implants provide earlier and stronger fixation Nevertheless, due to high-temperature application, the plasma spraying technique is reported to produce nonuniformityin coating thickness and density, phase impurity, low crystalline hydroxyapatite coating and weak adhesion . Sol-gel is time-consuming and requires post-processing annealing, however, ion implantation has found its applications better than the plasma spraying and Sol-gel techniques(Rattan V et al, 2012).

In fact, HA has been widely used as implant coating in many previous studies to promote bone generation . It was demonstrated that HA coating on the surface of metal implants could significantly increase bone conductivity with the contact area percentage of new bone formation to nearly 100% . However, HA coating might also activate the macrophages around the implants, thus causing bone resorption (Chang Y. et al ., 2020).

Implant thread design was a major important factor in the biomechanical properties of the dental implants, implant threads usually enhance the initial contact, primary stability, insertion torque, and increases the surface area of implant, and stress distribution on the bone and implant contact area. The threaded implant design mainly improves the osteointegration and long-term success rate of implant by reducing the masticatory load on implant and bone interface, when primary stability is main concern in low bone density double and triple threaded implants increases the primary stability than the single threaded implant (Barfeie et al ., 2015).

# Chapter Three:

# Conclusions and Suggestion

# Conclusions and Suggestion

Advanced materials in dental implants have revolutionized the field, offering better integration, reduced complications, and improved patient satisfaction. While titanium remains the gold standard, materials like zirconia, PEEK, and graphene-based composites provide promising alternatives, especially for patients with specific aesthetic demands or metal sensitivities. Ongoing research focuses on smart implants, bioactive coatings, and personalized solutions to further improve outcomes and longevity.

Limited amount of research on zirconia proves that zirconia is biocompatible with the surrounding tissues. Limited amount of research on zirconia proves that zirconia is biocompatible with the surrounding tissues,Compared to titanium, its osseointegration is inferior and shows improvement after surface modification.

Strength of zirconia is good, but comparatively lesser than that of titanium, Zirconia is Osseoconductive as reported in some studies and has also shown favorable interaction with the soft tissue.

It has been found that zirconia reduces plaque formation on the implant surface, which leads to good healing and successful implant treatment, Most of the studies on zirconia implants are short-term studies and evidence of success in long-term clinical trials is lacking. More research is needed on zirconia dental implants before we could use it for frequent treatment needs, as compared to titanium implants.

# References


1. Abraham, C. M. (2014). A Brief Historical Perspective on Dental Implants, Their Surface Coatings and Treatments**. Open Dent J**, 8, 50-5.
2. Andreiotelli M, Kohal RJ. Fracture strength of zirconia implants after artificial aging. **Clin Implant Dent Relat Res**. 2009;11:158–166.
3. Aparicio C, Gil FJ, Fonseca C, Barbosa M, Planell JA. Corrosion behavior of commercially pure titanium shot blasted with different materials and size of shot particles for dental implant applications. **Biomaterials** 2003;24:263–73.
4. Apratim A. Eachempati P. Salian KK, Singh V. Chhabra S, Shah S.( 2015) Zirconia in dental implantology: A review. **Journal of International Society of Preventive & Community Dentistry**, May:5(3):147.
5. Avhad, R.(2020), Assessment of Dental Implant Thread Design on Marginal Bone Loss Running Title: Dental Implant Thread Design. **European Journal of Molecular & Clinical Medicine**, 7(8).
6. Bächle M, Butz F, Hübner U, Bakalinis E, Kohal RJ.( 2007), Behavior of CAL72 osteoblast-like cells cultured on zirconia ceramics with different surface topographies. **Clinical oral implants research**. Feb;18(1):53-9.
7. Baltriukiene.D , V. Sabaliauskas, E. Balčiunas, A. Melninkaitis, E. Liutke vičius, V. Bukelskiene, V. (2014) Rutkunas,The effect of laser-treated titanium surface on human gingival fibroblast behavior, J. **Biomed. Mater**. Res., 102 , pp. 713-720, 10.1002/jbm.a.34739.
8. Barfeie.A., Wilson J., Rees J (2015), Implant surface characteristics and their effect on osseointegration , **BRITISH DENTAL JOURNAL** , 2(1), 1-9.
9. Bok, W.M.; Kim, S.Y.; Lee, S.J.; Shin, G.-S.; Park, J.-M.; Lee, M.-H.(2015) Surface characteristics and bioactivation of sandblasted and acid-

etched (SLA) Ti-10Nb-10Ta alloy for dental implant. Int. J. Precis. Eng. **Manuf**., 16, 2185–2192.

10. Chang YL, Lew D, Park JB, Keller JC (2020). Biomechanical and morphometric analysis of hydroxyapatite-coated implants with varying crystallinity**. J Oral Maxillofac Surg**. 1999 Sep;57(9):1096-108; discussion 1108-9. doi: 10.1016/s0278-2391(99)90333-6. PMID: 10484111.
11. Cho SA, Park KT, (2019). The removal torque of titanium screw inserted in rabbit tibia treated by dual acid etching. **Biomaterials** Sep;24(20):3611-3617.
12. Cionca N, Hashim D. Mombelli A,( 2017) . Zirconia dental implants: where are we now, and where are we heading?. **Periodontology**. Feb;73(1):241-58.
13. Darvell B, Samman N, Luk WK, Clark RK, Tideman H.(2020). Contamination of titanium castings by aluminium oxide blasting. **J Dent** Oct;23(5):319-322.
14. Das, S., Dholam, K., Gurav, S., Bendale, K., Ingle, A., Mohanty, B., Chaudhari, P. and Bellare, J. (2019). Accentuated osseointegration in osteogenic nanofibrous coated titanium implants. **Scientific Reports**, 9(1), p.1.
15. Depprich R, Zipprich H, Ommerborn M, (2008). Osseointegration of zirconia implants compared with titanium: an in vivo study. **Head Face Med**. 4:30.
16. Elias CN, Oshida Y, Lima JH, Muller CA. (2008), Relationship between surface properties (roughness, wettability and morphology) of titanium and dental implant removal torque. J. Mech. Behav. **Biomed. Mater**. 1(3), 234-242. endosseous implants. J Prosthet Dent; 62(5): 567-572.

17. Fenelon, T.; Bakr, M.; Walsh, L.J.(2022), George, R. Effects of lasers on titanium dental implant surfaces: A narrative review. **Laser Dent**. Sci, 6, 153–167.
18. Fousová, M.; Vojtech, D.; Jablonska, E.; Fojt, J.; Lipov, J.(2017), Novel Approach in the Use of Plasma Spray: **Preparation of Bulk Titanium for Bone Augmentations**. Materials, 10, 987.
19. Gahlert M, Gudehus T, Eichhorn S, Steinhauser E, Kniha H, Erhardt W. (2007) Biomechanical and histomorphometric comparison between zirconia implants with varying surface textures and a titanium implant in the maxilla of miniature pigs. **Clin Oral Implants Res**.;18:662–668.
20. Gheisarifar. M, G.A. Thompson, C. Drago, F. Tabatabaei, M.(2021) Rasou lianboroujeniIn vitro study of surface alterations to polyetheretherketone and titanium and their effect upon human gingival fibroblasts J. **Prosthet. Dent**, 125 , pp. 155-164.
21. Hemlata G, Gaurav B, Arvind G (2012), Implant Surface Modifications: A Review, **Journal of Clinical and Diagnostic Research**. April, Vol-6(2): 319-324.
22. Hempel U, Hefti T, Kalbacova M,( 2010). Wolf- Brandstetter C, Dieter P., Schlottig F. Response of osteoblast-like SAOS-2 cells to zirconia ceramics with different surface topographies. **Clinical oral implants research**. Feb;21(2):174-81.
23. Ivanoff C.J, Hallgren C, Widmark G, Sennerby L, Wennerberg A. (2001) , Histologic evaluation of the bone integration of TiO(2) blasted and turned titanium microimplants in humans. Clin Oral Implants Res;12:128–34.
24. Jalbout, Z., and Tabourian, G. (2004). Glossary of implant dentistry. Upper Montclair, N.J.: **International Congress of Oral Implantologists**.
25. Jiang, P.; Zhang, Y.; Hu, R.; Shi, B.; Zhang, L.; Huang, Q.; Yang, Y.; Tang, P.(2023); Lin, C. Advanced surface engineering of titanium

materials for biomedical applications: From static modification to dynamic responsive regulation**. Bioact. Mater**., 27, 15–57.

26. Kayahan ZO , Kazazoglu E,(2011), Zirconia Dental Implants: A Literature Review**, Journal of Oral Implantology**, 37(3):367-76.

27. Knabe C, Klar F, Fitzner R, Radlanski RJ, Gross U, (2002). In vitro investigation of titanium and hydroxyapatite dental implant surfaces using a rat bone marrow stromal cell culture system. **Biomaterials** Aug;23(15):3235-3245.

28. Kohal RJ, Bächle M, Att W, Chaar S, Altmann B, Renz A, (2013). Osteoblast and bone tissue response to surface modified zirconia and titanium implant materials. **Dent Mater**:29:763-76.

29. Kohal RJ, Klaus G. (2004). A zirconia implant-crown system: a case report. **Int J Periodontics Restorative Dent**.;24:147–153.

30. Kumar PS, Grandhi VV, Gupta V (2019), The Effects of Titanium Implant Surface Topography on Osseointegration: Literature Review, **JMIR Biomed Eng**;4(1):e13237.

31. Langhoff JD, Voelter K, Scharnweber D, (2008). Comparison of chemically and pharmaceutically modified titanium and zirconia implant surfaces in dentistry: a study in sheep. **Int J Oral Maxillofac Surg**. 37: 1125–1132.

32. Le Guéhennec, A. Soueidan, P. Layrolle, and Y. Amouriq, (2007). "Surface treatments of titanium dental implants for rapid osseointegration," **Dental Materials**, vol. 23, no. 7, pp. 844-854.

33. Lee, J.H.; Kwon, Y.H.; Herr, Y.; Shin, S.; Chung, J.H.( 2011). Effect of Erbium-Doped: Yttrium, Aluminium and Garnet Laser Irradiation on the Surface Microstructure and Roughness of Sand-Blasted, Large Grit, Acid-Etched Implants. J. **Periodontal Implant**. Sci. 41, 135–142.

34. Meyer U, Joos U, Mythili J (2004). Ultrastructural characterization of the implant/ bone interface of immediately loaded dental implants. **Biomaterials**.;25(10):1959–1967.
35. Misch, C. E. (2008). Contemporary implant dentistry (3rd ed.). **St. Louis: Mosby Elsevier**.
36. Muddugangadhar, B. C., Amarnath, G. S., Tripathi, S., Dikshit, S., and MS, D. (2011). Biomaterials for Dental Implants: An Overview. **International Journal of Oral Implantology & Clinical Research**, 2(1), 13-24.
37. Nakae, M. Yoshida, and M. Yokota,(2005), "Effects of roughness pitch of surfaces on their wettability," **Journal of Materials Science**, vol. 40, no. 9-10, p. 2287-2293.
38. Narayanan R, Seshadri SK, Kwon TY, Kim KH. (2008). Calcium phosphate- based coatings on titanium and its alloys**. J Biomed Mater Res Part B: Appl Biomater**.
39. Newman, M., Takei, H., Klokkevold, P., and Carranza, F. (2019). Newman and Carranza's Clinical Periodontology (13th ed.). Philadelphia, **PA : Elsevier.**
40. Özkurt Z, Kazazoglu E. Zirconia (2011)., dental implants: a literature review. **J Oral Implantol**; 37: 367–76.
41. Parithimarkalaignan, S., & Padmanabhan, T. V. (2013). Osseointegration: an update. **Journal of Indian Prosthodontic Society**, 13(1), 2–6.
42. Piconi C, Maccauro G, Muratori F (2003), Brach del Prever E. Alumina and zirconia ceramics in joint replacements. **J Appl Biomater Biomech**.;1:19–32.
43. Puleo DA(2006), Thomas MV. Implant surfaces. Dent Clin North Am.;50:323–338. 20.

44. Rattan P V, Sidhu T.S, Mittal M (2012), An Overview of Hydroxyapatite Coated Titanium Implants, **Asian Journal of Engineering and Applied Technology** ISSN 2249-068X Vol. 1 No. 2, pp.40-43.
45. Rosales-Leal, M. A. Rodríguez-Valverde, G. (2010).,"Effect of roughness, wettability and morphology of engineered titanium surfaces on osteoblast-like cell adhesion." Colloids and Surfaces A: **Physicochemical and Engineering Aspects**, vol. 365, no. 1-3, pp. 222-229.
46. Saini, M., Singh, Y., Arora, P., Arora, V., and Jain, K. (2015). Implant biomaterials: A comprehensive review. **World Journal of Clinical Cases**, 3(1), 52-57.
47. Sennerby L, Dasmah A, Larsson B, Iverhed M(2005). Bone tissue responses to surface-modified zirconia implants: a histomorphometric and removal torque study in the rabbit. **Clin Implant Dent Relat Res**.;7(suppl 1):S13–S20.
48. Singh, A. V. (2013). Clinical implantology (1st ed.). ***Elsevier***. New Delhi.
49. Sivaraman K. Chopra A, Narayan Al, Balakrishnan D (2018). Is zirconia a viable alternative to titanium for oral implant? A critical review. **Journal of Prosthodontic Research.**;62(2):121-33.
50. Stanford, C.M.; Brand, R.(1999). Toward an understanding of implant occlusion and strain adaptive bone modeling and remodeling. J**. Prosth. Dent**. 81, 553-561.
51. Steinemann SG. Titanium—the material of choice? **Periodontol** 2000. 1998;17:7–21
52. Stübinger S, Homann F, Etter C, Miskiewicz M, Wieland M, Sader R. Effect of Er. YAG, CO (2008) and diode laser irradiation on surface properties of zirconia endosseous dental implants. Lasers Surg Med :40:223-8.
53. Sykaras N, Iacopino AM, Marker VA, Triplett RG.(2000), Woody RD. Implant materials, designs, and surface topographies: their effect on

osseointegration. A literature review. **Int J Oral Maxillofac Implants**. 15:675–690.

54. Tschernitschek H, Borchers L, Geurtsen W.(2005) Nonalloyed titanium as a bioinert metal—a review. **Quintessence Int.** 36:523–530.

55. Tummler HP, Thull R, Schaldach M(2002). The mechanism of repassivation and the concentration of corrosion products shown on TIALV. Proceedings of the World Congress on Medical Physics and Biomedical Engineering, **13th International Conference on Medical and Biological Engineering, and 6th International Conference on Medical Physics**; September 5–11; Hamburg, Germany.

56. Valentine-Thon E, Schiwara HW.(2003), Validity of MELISA for metal sensitivity testing. **Neuroendocrinol Lett**.24:57–64.

57. Warreth, A. (2018). Dental Implants: An Overview. **Dental update**, 44, 596- 620.

58. Yang Y, Dennison D, Ong JL.(2005) Protein adsorption and osteoblast pre- cursor cell attachment to hydroxyapatite of different crystallinities. **Int J Oral Maxillofac Implants**.