

Dental Implant Materials and its Effect on the Alveolar Bone (Osseointegration) and Periodontal Tissues

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Abstract:

One of the difficult things that face dentists is selecting the appropriate material in the biological environment of the human body in general and the mouth in particular. Because of the immune response of the human body to the implanted material due to the body's immunity, and vice versa, the effect of the implanted material on the human body is due to its properties. It has become very important to know the types of implanted materials whence their properties and effects. This is the most important success factor in the selection of dental implant materials, many materials have been selected in the past and present, and this is what was presented in this work.

Keywords: Dental Implant Materials, Alveolar Bone, Jaw Bone, Prosthetics, Titanium, Cobalt Chromium, Polyethylene, Ceramic Materials.

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مواد زراعة الأسنان وتأثيرها على العظم السنخي (الاندماج العظمي) وأنسجة اللثة

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الملخص

من الأمور الصعبة التي تواجه أطباء الأسنان هو اختيار المادة المناسبة للبيئة البيولوجية لجسم الإنسان بشكل عام والفم بشكل خاص. وبسبب الاستجابة المناعية لجسم الإنسان للمادة المزروعة وذلك عن طريق مناعة الجسم، والعكس صحيح بتأثير المادة المزروعة على جسم الإنسان بسبب خصائصها. أصبح من المهم جداً دراسة ومعرفة أنواع مواد الزرع من حيث خصائصها وتأثيرها، وهذا هو عامل النجاح الأهم في اختيار مواد الزراعة وقد تم اختيار وتجربة العديد من المواد سواء في الماضي أو الحاضر وهذا مات عرضه في هذا العمل.

الكلمات المفتاحية: مواد زراعة الأسنان، العظم السنخي، عظم الفك، الاستعاضة، التيتانيوم، كروم الكوبالت، البولي إيثيلين، مواد السيراميك.

1. Introduction:

In this article, we will discuss the materials used for dental implants, and we will focus on the advantages and disadvantages. and recent additions to improve and reduce problems of the implanted materials and to help to select the appropriate material in all respects, A natural tooth consists of a crown (the part you see above the gum), and the root (the part hidden under the gum). The root is the part that is embedded in the jawbone that actually holds the natural tooth in its place.

A dental implant is a small man-made titanium fixture that serves as a replacement for the root portion of a missing natural tooth and it's used because it is the most compatible with our human body.

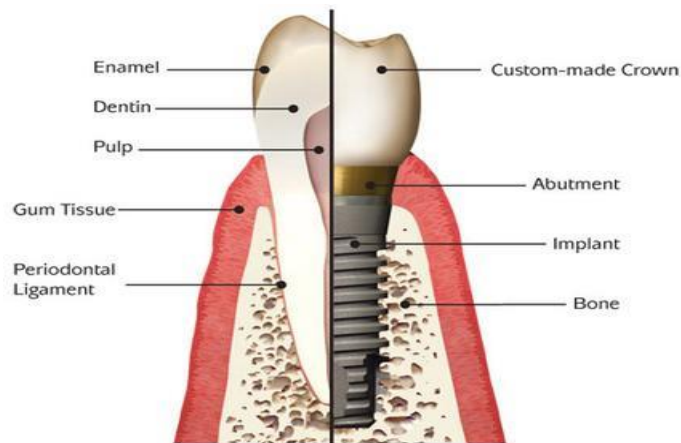


Figure1 a natural tooth and replaced parts by dental implants.

The dental implant is one of the appropriate instances of different dental materials and their application, which is the combined procedure of technology and science in physics, biomechanics, and surface chemistry from macroscale to nanoscale surface engineering and manufactured technologies. In recent decades, biomaterials in implant therapy promote bone response and biomechanical ability, which is long-term from surgical equipment to final prosthetic restoration. Biomaterials have a crucial role in rehabilitating the damaged structure of the tooth and supplying acceptable outcomes correlated with clinical performance.^[1]

The dental implant is placed in the bone of the upper or lower jaw and functions as an anchor for the replacement tooth. After the bone has grown around the implant, implants can hold a crown, bridge or overdenture just like roots hold natural teeth in place.

Implants provide additional support where teeth are missing without putting forces onto remaining natural teeth. They may be used to support the replacement of a single missing tooth or a complete functional set for patients who have lost many or all of their teeth.

There are many types of materials used in dental implant and we will study some of these types like (titanium, cobalt chromium, polyethylene, ceramic materials, stainless steel) and which of them is the better and more compatible to the alveolar bone and periodontal tissues.

2. Implant materials in dentistry:

There are various types of implant materials used in medical applications, including orthopedic implants, dental implants, and cardiovascular implants. Some commonly used implant materials in dentistry are:

1. **Titanium:** Titanium is widely used in dental implants due to its properties as corrosion resistance, biocompatibility, and mechanical strength. The elemental metal titanium was first discovered in England by "William Gregor" in 1790, but in 1795 "Klaproth" gave it the name titanium. The combination of low density, high strength to weight ratio, good biocompatibility and improved corrosion resistance with good plasticity and mechanical properties determine the application of titanium.^[2]
2. **Cobalt-chromium alloys:** Cobalt-chromium alloys are commonly used in dental implants due to their high wear resistance and strength. Cobalt-chrome (Co-Cr) is a metal alloy of cobalt and chromium. Because of its high strength, temperature endurance and wear resistance, it is commonly used in dental and orthopedic implants, in orthopedic implants it is usually composed of cobalt with chromium, molybdenum, and traces of other elements. Co-Cr alloys are especially useful where high stiffness or a highly polished and extremely wear-resistant material is required.^[3]
3. **Polyethylene:** Polyethylene is rarely used for dental implants, but widely used for joints (articulating surfaces) in the human body such as total hip and knee replacements because it is known for low friction and wear resistance.

It's has been used extensively in knee arthroplasty since the mid-20th century. Progress in material manufacturing and processing has led to newer polyethylenes over the last few decades with different material properties.^[4]

It's used in biomedical applications due to its high wear-resistance, ductility, and biocompatibility.^[5]

4. **Ceramic materials:** Ceramics such as alumina and zirconia are used in dental implants and due to their biocompatibility and resistance to wear. Ceramic material has excellent health compatibility and biological properties are ideal. But Ceramic implants also have some disadvantages such as break, longer healing, the risk of overheating the bone, and higher costs.

All-ceramic dental implants have been identified as a potential alternative to the traditional titanium-based implant systems used in dentistry. Among the all-ceramic implants introduced in dentistry, zirconia implants have emerged as the forerunner. The success of zirconia as an implant material has paralleled that of titanium in the short-term, however, few clinical studies assess success in the long-term. Failures of zirconia dental implants have been linked to improper operator techniques, manufacturing defects, and unfavorable loading.^[6]

5. **Stainless steel:** Stainless steel is a commonly used implant material due to its low cost and high strength. It is used in a variety of medical applications, including orthopedic implants.

3. Osseointegration between alveolar bone and periodontal tissue and implant:

3.1. Osseointegration:

defined as a direct structural and functional connection between living bone and the surface of a load-carrying implant, is critical for implant stability, and is considered a prerequisite for implant loading and long-term clinical success of end osseous dental implants. The implant tissue interface is an extremely dynamic region of interaction. This complex interaction involves not only biomaterial and biocompatibility issues but also the alteration of mechanical environment. The processes of osseointegration involve an initial interlocking between alveolar bone and the implant body, and later, biological fixation through continuous bone apposition and remodeling toward the implant. The process itself is quite complex and there are many factors that influence the formation and maintenance of bone at the implant surface.^[7]

3.2. The alveolar bone:

It is alveolar processes of the mandible and maxilla line the alveolus and provide structural support and maintenance for teeth as part of the periodontium, consisting of the periodontal ligament (PDL), cementum, connective tissue, and gingiva. Alveolar bone is especially susceptible to inflammation-induced bone resorption due to high rates of progressive periodontitis.^{[8][9]}

Sufficient bone volume, height, and width are necessary to ensure implant stability and osseointegration that can sustain optimal bone-implant contact biomechanical loading. Other dental procedures that involve grafting include maxillary sinus floor augmentation, which is employed for patients with bone loss in the posterior maxilla that houses premolar and molar teeth. Bone defects in the oral cavity resulting from trauma, chronic infection, congenital defects, or surgical resection require clinical intervention, most frequently using autologous bone grafting techniques.^{[8][9]}

3.3 Periodontal tissue:

New technology coupled with a better understanding of tissue biology has played a key role in restoring the somewhat tarnished image of implant dentistry. Thanks to carefully conduct longitudinal studies, it has now become clear that the replacement of missing teeth by artificial implants integrated into the living tissues of the jaws is a predictable procedure, as long as certain guidelines are followed in the manufacture of the implant in its placement, in its eventual functional loading, and in its maintenance.^[10]

Yet, functional success for a natural tooth is dependent on a number of anatomic, physiologic, and environmental considerations which differ in some important respects from those that ensure the functional success of an implant.^[10]

Alveolar bone resorption is a major cause of teeth missing and jeopardizes the osseointegration of dental implants, greatly affecting the patient's quality of life and health. It is still a great challenge to completely regenerate the alveolar bone defect through traditional Guided Bone Regeneration (GBR) membranes due to their limited bioactivity and regeneration potential.^[11]

4. Implant material requirements:

Tooth loss is one of the most common problems during life, therefore, the quality of the material used in dental implant must be ensured according to the following requirements:

1. Non-toxic, non-carcinogenic.
2. Tissue compatibility.
3. Appropriate cost.

4. Suitable mechanical properties including:
(wear resistance, corrosion resistance).

There is a relationship between each the previous requirements, for example, rapid fixation do not need high tissue compatibility that an implanted might require.^[12]

Compatibility is considered one of the most important factors for the success of dental implants, because the human body is compatible with a little number of materials, and by selection the type of material facilitates the success of dental implants. However, every implant material must have documented performance in the above areas.

The corrosion resistance of dental implant materials depends on several factors, time of dental implant, body reaction to corrosion of implant surface, and others.^[12]

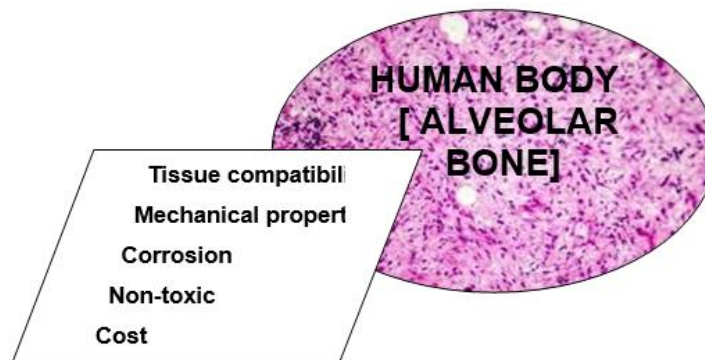


Figure 2 Implant material requirements.

4.1. Non-toxic, non-carcinogenic:

Titanium and titanium-based alloys are the most widely used metallic materials for dental implants, Oral peri-implantitis remains a major post-operative concern. Peri-implantitis has long been believed to have a microbial aetiology, but more recently has been associated with aseptic inflammation around an implant due to the release of metallic particles and ions from the implants. Although titanium-based prostheses are considered biocompatible (non-toxic), particles and ions released from them may not be. The implants are considered biocompatible because cell death (necrosis) around implants over short time scales is negligible and they pass in vitro cytotoxicity tests.^[14]

A wide range of compounds are utilized in dentistry such as dental composites, resins and implants, the successful clinical use of dental materials relies on their physiochemical properties as well as biological and toxicological reliability.^[15]

Many compounds that used in dentistry such as resins, implants, and dental composites, the optimal clinical use of dental materials depends on the physiochemical properties as well as toxicological and biological reliability.^[15]

The great spread of dental implants by several companies without standards in the end, it led to the emergence of several complications, and these complications can be described as malignant in the areas adjacent to the dental implant site.

- 48% of them are in the neck area.
- 90% of them in the oral cavity, which histopathologically shows oral squamous cell carcinomas (OSCC), women are less affected by squamous cell carcinoma than men (1:5).^[16]

4.2. Tissue compatibility:

Biocompatibility is the ability of a material to perform with an appropriate response from the host under specific conditions.

Biocompatibility of dental implant refers to the interaction of a living system or living tissue (alveolar bone) with the materials of a medical component or device (implant screw, in other words, biocompatible of dental implant materials do not harm or toxic to the patient.

Biocompatibility defined it as the characteristic of being compatible with a living tissue or a living system in that it is not toxic or harmful, and that it does not cause immune rejection, biocompatibility is a test to determine potential toxicity resulting from physical contact with a dental implant.

Medical compatibility is vital for dental implants, it evaluates local and systemic interactions, a systemic reaction effects of parts of the body that are far from direct contact with the substance or dental implant.

The vagueness of this term reflects the continuing development of insights into how biomaterials (dental implants) interact with the human body (tissues or bone like alveolar bone), and how these interactions determine the clinical success of dental implants.

Modern dental implant is often made of one or more materials so it is not always sufficient to talk about the biocompatibility of a certain material.

4.3. The cost:

The cost of a dental implant depends on a number of factors including, the type of implant, the amount of jawbone is left around where the tooth is broken or lost, as well as the location and function of the implant.

Different types of implants exist for different purposes; Implants are used to replace a single missing tooth, multiple teeth or to support a denture, costs do differ on implants and components that are needed for a particular purpose.^[17]

The number of jawbones is a major factor in the cost. The loss of bone may need bone grafting, which is a procedure to increase the amount of bone in which the implant was replaced.

Also, the cost of a dental implant depends on if the patient needs to lift of maxillary sinus that needed to increase the height of the jawbone, as well as The implant maybe more expensive if the jawbone needs splitting to increase the width of the bone.

Recently the best width and height of maxillary and mandibular bone are measured by CBCT scan, Implants are covered by some dental insurance companies, so cost is a complicated discussion! The truth is it really depends on your condition and what the patient wants.^[17]

Regardless of the type of implant, the cost varies depending on other factors, the cost varies according to each country, but there is a relative price ratio like as the following:

Single dental implants:

The price of a dental implant per unit from 1,000\$ 3,000\$, which is expensive, add to that the cost of abutment and crown can reach from 500\$ to 3,000\$.

Multiple dental implants:

If the patient needs more than one implant, the cost will increase even more, also implant require healthy gums and bone so that they can be attached safely, this requires an increase in cost if the patient needs a bone grafting or gum treatment.

Full-mouth dental implants:

In cases of edentulous patients, bridges or multiple implants cannot be accomplished so patient needs to. full mouth dental implants.

Dental implant and extraction:

Further increasing the cost of many dental implants, it's often the case where the dentist must extract existing teeth before they can install your implant, While the cost of extraction depends heavily on particular teeth and how long and difficult.

Often the teeth in the implant site must be extracted by a dentist, this operation increases the cost of dental implants, and the cost of the extraction operation depends greatly on the number of teeth that must be extracted, the difficulty of doing, and time consuming.

Material cost,

Titanium or zirconium (ceramic) implant can cost up to 2,000\$, Additionally, the abutment that connects the crown to the implant can cost about 500\$, while the crown that is inserted into the implant abutment can cost about 300\$, so the total cost may reach up to 5000\$.



Figure 3 Types of dental implant according number

4.4. mechanical properties: (wear resistance, corrosion resistance).

Compared with ceramics and polymers, metals exhibit significant advantages as biomedical implant materials due to their high strength and plasticity.

One of the most important options for dental implants and orthopedic is Ti-based alloy, as it has a high degree of tissue biocompatibility, high corrosion resistance, and good mechanical properties, It's can be affected by corrosion wear, failure, and "particle disease" caused by wear debris. Moreover, biomedical Titanium amorphous alloys have higher strength and hardness as compared to crystalline Ti-based alloys, which gives them high wear resistance in dry friction.^[13]

5. the comparison between the most important dental implant materials

Table 1 the comparison between the most important dental implant materials

	Titanium	Ceramic	Chrome cobalt	Stainless steel
Compatibility "Allergenic"	Titanium is one of the most widely used biomaterials for medical implants because of its excellent mechanical properties and exceptional biocompatibility. ^[27]	It is used in patients with hypersensitivities.	One of the reactions for implant incompatibility is that there is an allergy when coming into contact with the components of cobalt chrome or bone cement, so there is adverse reaction from the human body to the components of the implant. ^[18]	Having an allergy or sensitivity doesn't mean getting a metal implant entirely off limits or that the body will reject it. But while reactions to surgical hardware and implants are rare. ^[19]
Hypersensitivity	skin redness around the implant, and inflammation of gum tissue.	hypersensitivity to metal can cause the failure of ceramic dental implants in a few numbers of patients. ^[20]	Metal ion release by orthopaedic implants may cause local and systemic effects and induce hypersensitivity reactions. ^[21]	Most skin reactions to metal implants are eczema, allergy, urticarial, bullous, and vasculitic rashes, these skin reactions to metal orthopedic or other implants are widely documented in literatures. ^[22]
corrosion resistance	The titanium has low electrical conductivity and is highly corrosion resistant.	the ceramic enhances corrosion resistance and has greater biocompatibility.	Chromium cobalt protects the alloy from corrosion and at high temperatures improves oxidation resistance. It is not as resistant to corrosion as titanium. ^[23]	Offer excellent corrosion resistance.
Strength	Titanium mini-implants are widely used due to their property of high mechanical strength. ^[25]	It possesses lower strengths, used as a surgical implant due to low ductility and brittleness.	It's a metal alloy of exceptional strength, along with resistance to wear and	Stainless steel has been and continues to be among the most widely used

	very strong and highly resistant to damage.		corrosion. Cobalt chrome is often used for dental implants due to these characteristics and its biocompatibility.	metals for implant applications. ^[26] Uncompromising Strength.
Cytotoxicity	Low toxicity.	Ceramic composites showed no cytotoxicity. ^[29] Few ceramics have shown to be cytotoxic in vitro. ^[30]	The reduction of Cr results in the formation of reactive intermediates contribute to the cytotoxicity. ^[28]	The stainless steel showed lower cytotoxicity level. ^[31]
carcinogenic	No evidence of carcinogenic activity.	There is very little information on the effects associated with the potentially harmful bioceramic material and the mechanism of toxicity. ^[32]	There are known carcinogenic materials such as compounds of chromium, arsenic, cobalt, cadmium, and nickel, and their action mode is not fully understood except the chromium. ^[24]	There aren't any reports of that causing the development of cancer in a patient.
Cost	More expensive, the Price reaches 2,000\$ without the crown and abutment.	That is why they will generally cost \$500 to \$1,000 more than titanium implants.	Cheaper than titanium.	Stainless steel implants are known to be less constable than some of the other options available

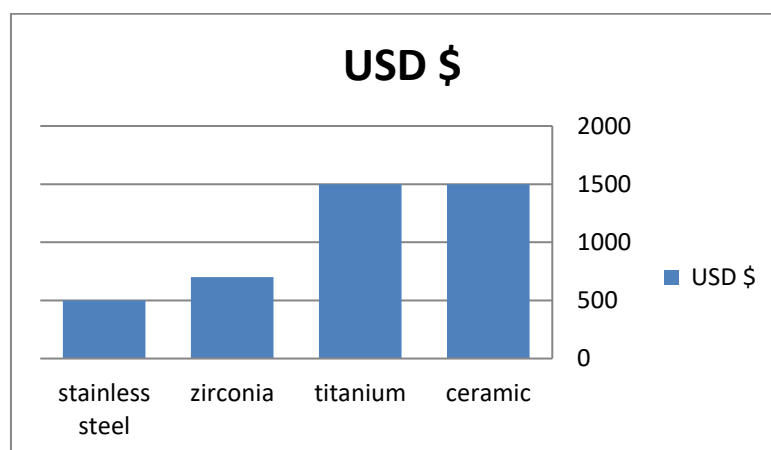


Figure 4 the cost of dental implants types in the USA.

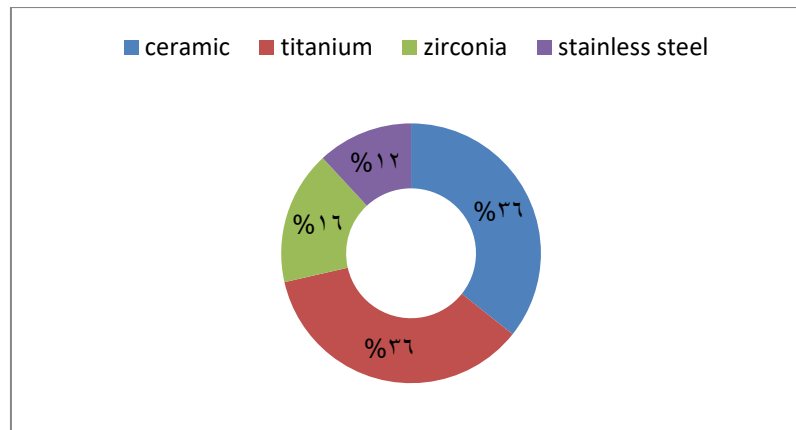


Figure 3 Statistics for the use of dental implants types in the USA. ^[34]

6. Methodology.

This article concerns dental implant material used in of orthopedic surgery of alveolar bone, generally, orthopedics can be defined as the science concerned with the form and function of the musculoskeletal system and its supporting structures and their grafts, such as alveolar bone in dental implant.

After the tooth is completely extracted, the alveolar bone deformed, and the implant must be inserted into the alveolar bone of replaced tooth, therefore there must be a compatibility between the implant and the alveolar bone that depends on the type of dental implant material.

In this article we will focus on dental implant materials, both prosthodontics and stabilization devices, synthetical biomaterials are itself a large category including metals, ceramics, plastics, composite materials, glasses, ... etc.

However, this is not to suggest that equally important problems and solutions do not involve one of the dental implant materials, other material types would require complete studies in themselves.

7. The aim of study:

One of the best treatment options that a patient may need is a dental implant, dental implants are the replacement of the tooth root with an implant inside the bone.

The object of our article is to compare the articles about implant materials and abstract the basic and expected requirements for the success of dental implants.

8. Conclusion

the main question surrounding dental implant types:

Are they safe?, This isn't a simple question: Some dentists claim that all metals and plastics are safe in the mouth, while others claim ceramic is always safe. We believe the answer depends heavily on the individual.

What's safe for one person might be toxic to another? We are all unique, a concept called biochemical individuality, which means how "compatible with life" certain dental materials are.

A dental material that doesn't generate any reaction in one person could be very unhealthy for someone else. like all the people with allergies to common foods, like nuts or corn. Millions of people can eat these foods with no problems, yet others can end up in the emergency room after consuming a trace amount.

Because of biochemical individuality (compatibility), it is part of our standard practice to test materials with each individual to determine true bio-compatibility. there is a test to determine what type of implant is the best match for the human body.

9. Recommendations:

- The ceramic and Titanium Implants are the most common types and have high success rates and biocompatibility.
- Both are FDA-approved.
- Both are greatly beneficial to people with missing teeth, and decent costs.
- Finally, the selection of material depends on the patient's desire and personal options.
- Zirconia implants with small diameters are prone to cracking.
- For a single implant, the ceramic is more favourable to adjacent natural teeth.
- For multiple implants the titanium implants are more preferred.
- Ceramic is hypoallergenic, corrosion resistant, holistic dentistry compliant, and it's similar to natural teeth.

- Ceramic implant materials are more popular than other implant materials although they are recent dental materials.
- Ceramic implants are hefty cost, but it's give the best cosmetic results.
- The cobalt chrome implant is known as very little about their behavior and biological impact as framework materials in implant dentistry.[33]
- The patients with an allergic history, the Cobalt is a well-known sensitizer and should be avoided.
- The development of a fibrous of stainless-steel implant material is fluid-filled and exists on the surface of the implanted bone and creates an ideal environment for bacteria, although Some of types of stainless steel is the most corrosion resistant especially when there is contact with biological fluid, especially when adding the chromium element (16%) so must be avoided.
- Magnetic implants like stainless steel are contraindicated due to their susceptibility to heating which changes the shape of metal implant.
- There are wonderful advantages of dental implants such as: the natural appearance of the teeth, feeling of comfort, and they can remain in the mouth for a lifetime, and preserve adjacent teeth and prevent bone loss, comfort while eating, not annoying.

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