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Review Article

Implant Abutment Selection Criteria

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Abstract

Dental implants have been successfully used to treat tooth loss for many years. Titanium owing to its well-documented biomechanical properties, it is accepted as standard material for implant abutments. However, metal components often cause gray reflection from gingiva. For these reasons ceramic-based abutment materials have entered dental sector. There might be a relationship between material selection and implant restoration success. Long-term follow-up of implant treatments is important. Prosthetic, periodontal and esthetic examinations of the restorations should be performed in these follow-up appointments. We made a search of articles of peer-reviewed Journals in PubMed/Medline, crossing the terms "Dental Abutment Material", "Titanium", "Dental Porcelain" and "Zirconia". The review was divided by subtopics: mechanical evaluation, biological evaluation and esthetic evaluation. A number of studies have examined whether there is a relationship between these factors and dental materials. No significant difference was found between abutment material and success rates in available studies. Selection of abutment should be done by assessing the requirements for each case. The studies in which ceramic abutment materials are evaluated in the present studies are lower time and lower number than those of titanium. Long-term clinical follow-ups should be performed to obtain clearer information. The purpose of this review were to update available literature and to evaluate the relationship between material selection and mechanical, biological and esthetic factors.

Keywords: Implant; Abutment Material; Titanium; Zirconium Abutment; Bone Loss

Abbreviation

Y-TZP: Yttria Stabilized Zirconia

Introduction

Dental implants have been successfully used to treat tooth loss for many years [1,2]. Moreover, many researchers reported that ideal survival rates for reconstructions supported by titanium abutments [3,4]. Titanium (Ti) owing to its well-documented biomechanical properties, it is accepted as standard material for implant abutments [5,6]. However, metal components often cause gray reflection from gingiva. This situation is more important for region where the gingival biotype is thin [7]. In addition, color of restoration can be affected by metal abutment when using ceramic crowns in the restoration of titanium abutments [8]. Along with the improvements in dentistry, the translucency mimicking the natural appearance has been increased and materials without metal are needed. This has led to the development of aesthetically compatible and biocompatible ceramics [9].

To achieve higher esthetic results, ceramic abutments have been developed and manufactured in 1994 by CerAdapt company using intensely sintered pure aluminum oxide. All ceramic implant abutments are two types: aluminum oxide and yttrium-reinforced zirconium dioxide [10]. These materials are not only optical properties but also acceptable materials with appropriate mechanical properties, adequate clinical properties and longevity [9]. Nowadays, yttrium-reinforced zirconium dioxide implant abutments are frequently used to their superior properties than alumina [11,12]. Zirconia was first used as abutment material in 1996 [10]. Ceramics are naturally fragile and susceptible to tensile stresses, so use of ceramics as implant abutments is limited [13]. However, zirconia ($ZrO2$) ceramics show great biocompatibility and advanced esthetics due to their high flexural strength (900-1200 MPa), fracture toughness (6 MPa·m1/2) and compressive strength (2000 MPa) [10,14,15]. Contrary to these favorable properties, decrease in toughness and strength could be observed after that aging and sensitivity to low-temperature [10].

There are many studies available that were compared survival and failure rates of titanium and zirconia implant abutments. In a 5-year study by Zembic., et al. they found that zirconia and titanium abutment is comparable and using of zirconia as an abutment is clinically suitable [4]. Because of these reasons zirconia has a wide use area.

The choice of abutment material is very important for the success of the prosthetic treatment and requires the evaluation of many criteria. The purpose of this review were to update available literature and to evaluate the relationship between material selection and mechanical, biological and esthetic factors.

Search strategy: A Medline search was conducted, and the publications of the last twenty years have been taken into consideration. The key words used in the Pubmed search are: 'dental implants', 'dental abutments', 'titanium', 'gold', 'ceramic', 'alumina' and 'zirconia'. This publication includes about sixty articles in only English.

Mechanical evaluation

In implant restoration therapies, it is necessary to have features such as adequate fracture toughness, suitability for intraoral conditions, and survival in order for the materials to be successfully identified. For proper material selection, the mechanical properties of the material and suitability for the case should be carefully examined.

Fracture Strength

Absolute minimum strength is not specified for abutments but that must show resistance to functional loading [16]. The studies were reported about 206N loads and a maximum of 290N chewing forces in the aesthetic area [17,18]. To assess the success of a restoration, it is desirable that abutments be able to withstand higher forces than these forces and be used for at least five years [19].

Thickness and angulations of abutment materials can affect the fracture resistances. Albosefi., et al. compared fracture resistance of the abutments that different thickness and individual zirconia. They reported that while thickness of restoration wasn't significantly different, angular individual zirconia abutment was showed lower fracture resistance [20].

The mean fracture load of abutments supported by glass infiltrated ceramic crowns is 170N for aluminum abutment and 737N for zirconia abutment [21,22]. Butz., *et al.* compared titanium, zirconia and alumina abutments after chewing simulation and static loading. Mean fracture values obtained as a result of the study; for alumina 239N, for zirconia 294N and for titanium 324N [12]. Foong., *et al.* reported that mean load of titanium abutments is statically higher than zirconia abutments [23].

The long-term success of the implant depends on many factors, such as bone quality and quantity in the recipient region, treatment planning, oral hygiene and characterization of implant components [24]. According to available information, five year failure rates of metal and ceramic abutments are similar [25]. Failure rate of alumina abutments is slightly higher than prefabricated metal abutments [26]. Propagation of cracks during alumina abutment preparation causes abutment fracture and failure [27].

Full ceramic abutments cannot be manufactured to the equal degree of precision as metal abutments. Inadequate implant abutment connection can lead to screw loosening and clinical failures such as infection and bone loss [28]. Implant-abutment interface design is one of the factors among the reasons for failure. The internal implant-abutment connection distributes forces more widely through the interface than external design [16].

Ceramic abutment production requires a time-consuming and precise procedure. Microcraks can be occur during abutment production and customization, after that a decrease in fracture toughness of the abutment can be observed [27].

Yıldırım., *et al*. tested external hexagonal implant connections and Mitsias conical seal design tested implant connections. Both have found that when zirconia abutment assemblies fail, they fail in the cervical portion of the abutment near the gold screw and implant platform. This area is assumed to be the area of the highest torque and stress concentrations due to the pulling effects. The present data suggests a malfunction point near the abutment screw head bed [16].

Internal/external connections

There are two types of abutment and implant connection: external connection and internal connection. The connection between abutment and implant is via a screw. The problems associated with abutment screw as loosening or fracture are the most common complications on implant rehabilitation. The lots of researcher focused on this subject on their studies [25].

The type of implant-abutment connection may affect to incidence of screw loosing. In vitro study, external hexagonal connection was exhibit significantly lower strength than internal conical connection. Similarly, Norton., *et al.* and Khraisat., *et al.* found that the complication of abutment screw was lower with an internal connection [29,30].

During occlusal loading in implant restorations, the region around head of the abutment screw is the region with highest torque stress. Similar occlusal forces create screw fractures in metal and ceramic abutments, but occur screw deformation in metal abutments [25].

Asvanund., *et al.* reported that external implant abutment connection is more stressed than internal implant abutment connection when the prosthesis anteriorly and unilaterally loaded at the implant and abutment connection level. The studies indicated that internal abutment connection exhibited fatigue resistance that was high to the external connection. The other study by Mollersten., et al. also showed more succeed the internal abutment connection. The authors indicated that internal abutment connection was more resistant to bending moments [31].

Biological evaluation

Beside esthetic and mechanical properties of the abutment material, biological properties of the abutment material are also important because it affects stability of peri-implant soft tissue and bone. The type of abutment material effects attachment of between mucosa and abutment surface. Depending on the nature of the material, plaque accumulation and bacterial adhesions that occur later in the period result in periodontal infection and bone loss, threatening the health of peri-implant tissues [32,33].

Biocompatibility of ceramics have indicated paralel soft tissue integration of alumina, titanium and zirconia [33-35]. In a systemic review, the cumulative rate for biological complications was 5.2% for ceramic abutments and was 7.7% for metal abutments (there was no statistically difference) [4,32]. Unlike this studies, a review showed a higher incidence of soft tissue recession at ceramic abutments. The cumulative rate for recession after five years was 3.8% with metal abutments and 8.9% with ceramic [25].

Periodontal health

Due to technical or aesthetic reasons, the clinical condition of the implant treatment may require titanium alternative materials in the transmucosal portion of the implant. However, the choice of material should be based on the ability to support the integration of the peri-implant mucosa into the connective tissue during recovery [36].

Bleeding on probing of zirconia abutments is slightly more [37]. Sailer., *et al.* was found same results for bleeding on their 1 year of clinic study. Degidi., *et al.* evaluated peri-implant soft tissue and was compared titanium and zirconium dioxide healing cap. It was found that zirconium dioxide produced less reaction in tissues than other restorative materials such as titanium. Inflammatory infiltration and the microvascular density were reported higher around titanium healing caps [38].

Microgap

The impermeability of the abutment and implant interface has been explored in detail and remains one of the most crucial challenges that must be overcome in longtime therapy with two piece implants. Throughout this interface, bacterial leaks have been reported continuously *in vitro* and *in vivo* studies [24]. Micrograps are suitable for colonization of microorganisms and these microgaps are seen in implant and abutment connection areas. Bacterial accumulation in these areas can cause inflammation in peri-implant tissue. Baldassari., *et al.* examined implant connections of titanium and zirconia abutments and found that micro gap were 3 - 7 times less in the titanium abutment-implant connection than zirconia abutments [39]. Similarly, Abrahamsson., *et al*. found that there was more bacterial contamination in ceramic abutments compared to titanium abutments due to greater microgap formation [33]. Unlike the other studies, there was no significant difference between the titanium, aluminum oxide and zirconium oxide abutment groups regarding the microgap at the abutment and implant interface in study of Yüzügüllü., *et al* [40].

Bone loss

Bone loss can also be influenced by abutment material, as well as by reasons such as insufficient oral hygiene, incompatible implant abutment attachment and periodontal infection associated with them. Kohal., *et al*. found that there was no difference in the osseointegration of titanium and zirconium in their studies. Differently, Sailer., *et al.* found that bone loss around metal abutments was higher than that of ceramic abutments in a systematic review study [25].

Andersson., *et al.* performed short and long-term clinical evaluations of implants and upper structures. In all cases of the study, the soft tissue around the implant was found to be healthy but peri-implant bone loss of titanium abutment was found to be higher than the ceramic abutments. The mean bone loss was found 0.4 mm for titanium abutment and 0.2 mm for alumina abutment [26].

Bacterial adhesion

The composition and surface properties of abutment materials can directly affect the adherence and permanence of oral biofilm and consequently affect the colonization and growth of microorganism in the oral cavity [41]. Surface roughness and surface free energy have been shown to be effective on colonization. Zirconia has been shown to be an alternative to titanium because of its esthetic properties and potentially fewer bacterial adhesions [24]. The gingival barrier is necessary to prevent periodontal damage which is due to occur bacteria and toxins reaching the biological space. The biocompatible properties of zirconia are better than titanium. Bacterial adhesion of zirconia restorations is less than titanium [42-44].

Scarano., *et al.* recorded a degree of bacterial coating of 12.1% in the zirconia, compared to 19.3% in the titanium. They reported that bacterial adhesion is less than titanium in ceramics like zirconia [44]. Similarly, Rimondini., *et al.* showed with an *in vivo* study in which crystals of yttrium-TZP accumulated less bacteria than titanium [42]. Zembic., *et al.* declared that plaque accumulation is similar for zirconia and titanium [37].

Burgers., *et al.* evaluated biofilm formation on two different titanium surfaces by *in vitro* and *in vivo*. Similar to the results of Nascimento., et al. authors define less bacterial adhesion on pure titanium compared to sanded titanium [24,45]. In another similar study, Grobner-Schreiber., et al. founded less rates of total bacterial colonization on zirconia compared to titanium surfaces. No significant difference was observed in the diversity of the determined bacterial species among all the surfaces analyzed [46].

Microorganisms in the first order in the biofilm are effective in increasing the number of pathogens, peri-implantitis and loss of implants. For this reason, the development of a material that decreases initial adhesion of microorganisms may reduce prevalence and progress of oral infections [24].

Survival rate

Survival rate of metal abutments very high due to their excellent properties. Metals are ductile material thus that can tolerate to small cracks or defects. In contrast, ceramics are fragile material and they do not resistance to tensile force. As a result of the development of high strength ceramics such as zirconia and alumina, this materials have been successfully used as abutment materials [25].

Sailer., *et al*. reported that the survival rate of ceramic abutments was 99,1% and survival rate of metal abutments was 97.4% in their systemic review. They found no significant different in the survival rates of metal and ceramic abutments [25]. In another study, survival rate is 93 - 100% [47] for alumina abutments and 100% [48,49] for zirconia abutments in single crowns applied in anterior and premolar regions. Unlike the first work, the survival rate of zirconia abutments was significantly lower than that of titanium abutments [23].

Esthetic evaluation

Esthetics is one of the most important criteria in dentistry. Especially in frontal area restorations, it is necessary to pay careful attention to material selection in order to obtain a natural appearance. There are studies to produce more aesthetic and mechanically stronger restorations at the same time in the dental sector.

Esthetic

One of the disadvantages of the titanium abutment is the dark gray color that is reflected from gingival margin [50]. Because of this reflection, it is difficult to obtain an aesthetic result when the gingival thickness is less than 2 mm. The shoulder type of the restoration can be selected subgingival to reduce gray reflection but it is more difficult to clean the cement [8]. Zirconia was first used as abutment material in 1996 [51]. Zirconia abutments was developed for optimal mucogingival esthetics. Choice of abutment material is one of the important factors for success of restoration [25,52].

Restorating a dental implant can be challenge, especially when working in anterior region because esthetics appearance is important. Several methods have been tried to improve aesthetic properties such as the use of gold-colored titanium nitride-coated abutments and use of ceramic abutments made of zirconia or alumina [23]. The zirconia abutment is pure white. If shade of low was required this situation maybe it could be problem. It is necessary to increase the porcelain thickness to obtain the desired color [8]. Alumina abutment is higher esthetic advantage than zirconia abutment [22]. But zirconia is a more popular material than alumina with its superior fracture resistance and high biocompability.

Bressan., *et al*. were compared Cad/Cam titanium abutment, Cad/Cam zirconia abutment and cast gold alloy abutment in twenty patients. Three types abutment is also restored with all ceramic crowns. Color change of peri-implant mucosa were evaluated by spectrophotometer. Color change in peri-implant mucosa is least shown in zirconia abutments. As a result of the work, color change of peri-implant mucosa was found to be lowest in zirconia abutment and the highest in titanium abutment [53].

The researchers found that if the thickness of the mucosa was more than 2 mm, color change of between titanium and zirconia abutments in peri-implant mucosa is may not be perceived subjectively stated [54].

Discussion

In the past, implant abutments were made exclusively of metal. In order to answer the esthetic demands of dentists and patients, prefabricated or individual abutments were manufactured. Titanium abutment prevents corrosive and galvanic reactions at the implant abutment interface. However, extreme oxidation of titanium at ceramic melting temperatures and low adhesion. Oxides on the surface of this material can be an issue in titanium/porcelain systems. Metal abutments can only partially find a way out the aesthetic, functional and hygienic problem [7].

The disadvantage of the metal abutment is the dark gray color that is reflected from gingival margin. Ceramic abutments has been developed to solve this problem of metal abutments. Because of the mechanical properties of zirconia, it has been found suitable for use as an abutment. The first ceramic abutments were CerAdapt that made of alumina. Andersson., et al. evaluated short and long term clinical functions of CerAdapt abutments. Two years later, the cumulative survival rate was 97.2% for restorations on implants (94.7% for ceramic abutments and 100% titanium abutments). Marginal bone loss of ceramic abutment (0.2 mm) was less than titanium abutments (0.4 mm). It has been found by the authors that the use of ceramic abutments is appropriate [26,55,56].

In a study comparing alumina abutments and zirconia abutments, although both are acceptable in the literature, of the zirconia abutment is found to be twice that of alumina. There are many case reports in the literature that show the clinical success of zirconium abutments. Zirconia allows for the production of posterior fixed dentures thanks to its adequate mechanical properties. Some physical and mechanical properties of zirconia: zirconia can be found in three different forms; monoclinic, tetragonal and cubic. It is in monoclinic form at room temperature, it transforms to tetragonal form when it reaches above 1170. Among these forms, phase transformations can affect the physical properties of the material. Stabilizing agents such as MgO, CeO_2 and Y_2O_3 are added to minimize these phase transformations. The most commonly used and most adequate properties are 2 - 3 moles of Y_2O_3 [43,55,57]. This addition produces a stronger and harder material than the other ceramics. Factors such as water, moisture and polishing can weaken the material by causing the material to transform from tetragonal to monoclinic form [9].

The fit between implants and implant-supported prostheses effect biologic response of the peri-implant in tissue and complications of prosthesis restoration. Adjustment between the internal hexagon of the implant and external hexagon the of the abutment should permit rotation of less than 5° to keep the screw union constant. Vertical and horizontal deflections apply extra load to bone and implant. Therefore, some complications as loosening of the prosthesis retention, abutment fracture and crestal bone loss may occur [55,58].

In order to accept other abutment types as a viable alternative, they must exhibit similar or superior mechanical and biological properties to the universally used titanium. The strength rate of the abutments must be higher than the 90 - 370N (maximum bite force for the anterior region region). Yıldırım., *et al.* compared the fracture resistance of different abutments materials. Fracture resistance of zirconia abutments was found higher than alumina abutments. Both materials showed a resist able to bear incisal forces documented in the literature. Yıldırım., et al. had similar results to the results of Att., *et al*. study [49,56,59].

There are many studies on the fracture strength of abutments. El Sayed and colleagues examined the fracture strength and failure mode of different ceramic implant abutments and reported that the fracture strength of ZrO_2 without metal matrix is the lowest. However, no statistically significant difference was found between the groups [60].

In Butz., et al. study, was compared survival rate, fracture strength and way of failure of the ceramic abutments. The authors determined the strength of the zirconia abutments was comparable to those of titanium. Therefore, the authors proposed zirconia abutments as an alternative for restoration of implant rehabilitations in the anterior area [12].

The composition and surface properties of abutment materials can directly affect the adherence and permanence of oral biofilm and consequently affect the colonization and growth of microorganism in the oral cavity [41]. Surface free energy and surface roughness have been shown to be effective on colonization [24]. In some studies, surface roughness has been reported to be the most important factor supporting microbial adhesion on titanium surfaces [61,62]. In other studies, surface free energy in the formation of the first fungal biofilm on the surface of zirconia has been shown to be more important [63,64].

Implant materials cannot fully prevent bacterial adhesion and colonization. A number of studies have been conducted to reduce implant-abutment interface contamination. In studies, it has been reported that if the penetration of bacteria through the interface is not controlled, the long term success of the implant can be jeopardized. The mechanical properties of the materials affect the adhesion of the bacteria. For this reason, the development of materials that reduce microorganism adhesion may improve periodontal health [24].

Sampatanukul., *et al.* evaluated different abutment materials and examined histological changes and inflammatory responses around anutment. As a result, they found that the tissues around the gold alloy abutments were worse than titanium and zirconia abutments [65]. In a different study, Hahnel and colleagues showed that biofilm formation on the surface of PEEK is equal to or lower than titanium and zirconia, within the limits of their work [66].

In a systemic review, the rate of biological complications was 7.7% for metal abutments and was 5.2% for ceramic abutments. Unlike this studies, a review showed a lower incidence of soft tissue recession at metal abutments. This result is not clear. This may be due to the fact that ceramic abutments are usually used in anterior region and that there is more recession in this region than posterior area [25].

The gingival barrier is necessary to prevent periodontal damage which is due to occur bacteria and toxins reaching the biological space. The biocompatible properties of zirconia are better than titanium. Bacterial adhesion of zirconia restorations is less than titanium [42-44].

There are two types of abutment and implant connection: external connection and internal connection. The connection between the abutment and the implant is via a screw. The problems associated with abutment screw as loosening or fracture are the most common complications on implant rehabilitation. Incidence of screw fracture is not affected by the type of connection and material (metal-based or zirconia-based). However, it has been shown in available studies that the type of connection is effective on screw loosening. The external connection type shows more screws loosening for both metal-based and zirconia. The screw must be pre-loaded and tightened at the recommended torque to reduce complication incidence [67].

The type of implant and abutment connection affects to incidence of screw loosing. External hexagonal connection was exhibit significantly lower strength than internal conical connection. The complication of abutment screw was lower with an internal connection [25]. Szpak., *et al*. reviewed the effect of survival on implant abutment connection type and reported 1.1% implant loss for conical implants and 0.7% implant loss for hexagonal implants [68]. Sailer., *et al.* investigated the effect of internal and external connections of zirconia implant abutments on narrow diameter implants and showed that narrow diameter zirconia abutments with inner connections exhibit higher fracture strength than outer connections and zirconia abutments [69].

Sailer., *et al.* have shown that there is no statistical difference between ceramics and metal abutments in their review. Successful survival rates for both alumina and zirconia have been demonstrated. In short, highly durable ceramic abutments can be successfully used and show similar survival rates as metal abutments [25].

Conclusions

There is no significant difference in the 5-year failure rates and technical/biological results of ceramic and metal abutments according to the available studies. Both type abutments of survival rates are similar. However, number and period of studies evaluating ceramic abutments is less than metal abutments. In order to achieve clearer results on ceramic and metal abutments, *in vivo* and *in vitro* studies with longer follow-up time are needed.

Conflict of Interest

We have no conflict of interest to declare.

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