CORPUS PUBLISHERS

Open Access Journal of Dental and Oral Surgery (OAJDOS)

ISSN: 2833-0994

Volume 4 Issue 5, 2023

Article Information

Received date : October 10, 2023

Published date: October 25, 2023

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DOI: 10.54026/OAJDOS/1070

Keywords

Abutment Materials, Characteristics, Literature Review

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Review Article

Abutment Materials. Which Material to choose? Literature Review

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Abstract

The study is a literature review regarding the characteristics of different abutment materials and their indications. Titanium is still the first choice regarding the construction of the abutments. Anyway, with the increase request for aesthetic, new materials with adequate aesthetic are being considered. The most used materials as abutment materials are: titanium, zirconia, cast gold, alumina, PEEK and resin, surgical stainless steel. There is lack of evidence regarding the properties, the survival rate, the biological complications, technical complications, the response of the soft and hard peri implant tissue of the different abutment materials. Based on the literature, titanium should continue to be considered the first choice in constructing abutments. However, other materials, especially zirconia and alumina, have demonstrated to work equally well and should be considered appropriate for clinical use. There is a need for further research, especially on soft tissue integration and the anti-biofilm properties of the abutment materials.

Introduction

Implant prosthetic restorations are being preferred more and more because of the advantages they have. There are two different kinds of restorations: screw retained and cemented prosthetic restorations. it depends on the clinician choice which type to use [1,2]. The abutment can be designed and constructed, or it is pre-fabricated by the implant manufacturer. Despite the many improvements there have been made, in realizing metallic abutment designs, there is the possibility, that some metallic abutments' area are exposed. Also, in clinical cases when positioned inside the gingival sulcus, a gray appearance does not give a natural view to the gingiva. The gray color is thought to be as a cause of a thin tissue that does not cover the light reflection from the abutment [3]. In order to improve aesthetic, ceramic abutments were constructed. They assure an adequate hygiene and the repair process is easier [4]. With the market demand increasing day by day, new restoration materials have been introduced. It is necessary to evaluate their properties. It is a challenge to combine longevity and aesthetic, where glass and polycrystalline ceramic materials have sometime the priority [5-7]. The use of implant abutments is a key element in the success of implant-prosthetic restorations. Abutment material is considered an important element, that influence the stability of the peri-implant mucosa and crestal bone. The standard stock titanium abutment has been the choice of the clinicians for many years8. Different materials are available for the fabrication of individually customized prosthetic abutments, such as metals, ceramics, hybrid materials [9] and composites [10]. Research has demonstrated the excellent properties the titanium abutment has, anyway there are clinical cases where the abutment material should differ. The zirconia as a polycrystalline ceramic material diminishes the grayish effect on the mucosa promoting adequate aesthetics and durability [11]. During the masticatory forces, zirconia abutment can develop surface defects and enhance plastic deformation in the metal [12]. The most used material is metal ceramic crown over the titanium abutment. As the aesthetic requests are increasing day by day, the focus is now on the ceramic abutment and all ceramic crown. An option for the clinician in order to maintain a healthy peri-implant tissue is to use the hybrid abutment composed of a ceramic mesostructure and a metallic part to keep the aesthethics [13,14]. The selection of the abutment material is an issue itself. The criteria which should be considered are: Resistance during the mastication process, biologic criteria, aesthetic, the need for modification, the space available. It is a challenge the choice of the abutment material for each clinical case. Based on the literature, there is low rate of complications of abutments itself, when determining the success and complication rate of the implant-prosthetic restorations [15]. It is important that the design of the abutments resembles those of the prepared natural tooth, by respecting the gingival profile [16]. The most used materials for the construction of the abutments are: titanium, zirconia, titanium base with zirconia superstructure, Cr-Co abutments, cast gold, alumina, resin and PEEK abutments.

Titanium abutment

Titanium abutment are the material of choice due to their long lasting and adequate mechanical properties during mastication forces. There have been attempts to position the margin of the abutments more than 1 mm sub-gingivally, but based on the clinical studies, this has led to peri-implantitis [17,18]. Their disadvantage is the limited aesthetic they offer. Titanium abutments are proven to cause more discoloration to the soft tissues compared to ceramic abutments, while hueing (gold or pink) slightly improved their color performance [19]. It assures adequate biocompatibility and resistant to corrosion. As a result, it is recommended in the posterior region. The biological complications of ceramic and metallic abutment were rated in a similar scale [19].

Mechanical properties

In terms of wear on the implant connection surface, zirconia abutments caused more severe wear, more scratches, and more rounding of the hexagonal angles at the implant connection interface compared to titanium abutments. In terms of misfit at the connection interface, zirconia abutments showed greater misfit than titanium abutments. Elsayed [14] made a comparison of the fracture strength of different kinds of abutments: titanium, zirconia, zirconia with titanium inserts, lithium disilicate abutments with titanium inserts, and combined lithium disilicate abutments and crowns with titanium inserts. All abutments were positioned with lithium disilicate crowns and screwed to titanium implants. The conclusion was that the lowest fracture resistance was for one-piece zirconia abutments, with the fracture at or above the implant shoulder level, while abutments with titanium inserts had significantly higher fracture resistance, and failure occurred as a result of the bending of the titanium inserts and screws [14]. The height of titanium base abutments differs based on the size of the restorative space [20,21]. Silva [20] studied the influence of two different heights of titanium base abutments (4 and 2.5 mm) on the retention of crowns made of zirconia

using the pull-out test in a universal testing machine. They concluded that there was no significant effect of the abutment height on the crown retention.

Soft and hard tissue response

In a review of Mokhtar [22], Zirconia abutments had superior advantages over titanium abutments in a more response of the alveolar bone. Kohal [23] evaluated and compared the conditions of soft and hard tissues in contact with zirconia and titanium implants in monkeys. Bone and soft tissues demonstrated good integration with zirconia as well as titanium. There was no statistical important difference between the probing depth, bleeding on probing or plaque accumulation. In a study where zirconia and titanium abutments were compared, significantly higher levels of bleeding on probing were noticed in titanium abutments. Also, it was noticed higher plaque accumulation around titanium abutments compared to zirconia. In the study of Vigolo [24] 40 implants. Titanium or gold abutments were positioned in 20 patients. Tissues were examined clinically, with radiography, with a follow up for four years. Probing depth and marginal bone loss was measured. In 4 years, 4,7% had gingival inflammation around titanium abutment, 4,5% gingival inflammation around gold abutments. No statistical difference was noticed between the two groups. Degidi [25] evaluated 10 implants in 5 patients, where titanium or zirconia healing abutments were situated. The situation of peri implant tissues was evaluated clinically, radiographically and tissue biopsy was done. Healing abutment were examined in SEM. A higher cell infiltration was found in titanium healing caps compared to zirconia healing abutments.

Zirconia abutment

There are two different types of zirconia abutments: solid zirconia and zirconia with titanium insert. Most of clinicians prefer zirconia with titanium inserts, as it is considered to have better mechanical properties. Anyway, this is a version which is not part of every brand. Now-days zirconia comes in different shades. Their use is recommended especially in the anterior teeth. Customized made abutments have several advantages, they offer adequate aesthetic and create an adequate emergence profile. According to Chen [26], zirconia abutments supporting all-ceramic crowns in frontal region single implant showed a high implant survival rate, good biological response and high esthetic. Despite the mechanical properties, zirconia has high esthetic, corrosion resistance, biocompatibility and high loading capacity. As a result, it is more preferred compared to alumina [27]. Similar rates of survival were found for implants over titanium and zirconia abutments [28]. In the prospective clinical studies, it was observed that zirconia abutments would not cause technical or biologic problems, at least for 40 to 48 months [29,30]. This was confirmed by another study with a follow up of 36-months [31].

Evaluation of the response of peri implant soft tissues

The bacterial adhesion is another component to consider, the bacterial adhesion in zirconia abutments were 12,1%, while in titanium abutments 19,3% 32. Zirconia abutments are proved to simulate blood circulation in the peri-implant tissue more compared to titanium abutment [26]. According to Sampatanukul zirconia abutment enhances the peri-implant health by reducing the inflammation process. It has also less hemorragy on probing [33]. In the review of Mokhtar, who compared the biological complication between the titanium and zirconia abutments, the two types of abutments had only minor statistically significant differences. They had no difference in effect on alveolar bone stability, no differences on pocket probing depths. While, van Brakel [34] showed significantly lower pocket probing depth around Zirconium abutments compared to Titanium abutments. A new in vitro study [35] demonstrated that the surface roughness of the different abutment materials has an important effect in the performance of cells on Zirconia or Titanium abutment. It was concluded that polished Zirconia surfaces give better adhesion media for epithelial cells, in comparison to Titanium surface [36]. This could occur because of the decreased pocket probing depth around implant abutment, which is in deep relation with gingival cells to the abutments. Indeed, it is difficult to evaluate the influence of abutment material on plaque accumulation as the abutment is not visible in the oral cavity.

Effect of abutment materials on the crestal bone height

According to Vinayak [37], titanium implant abutment junction demonstrated change with time passing in Crestal Bone Height despite of the abutment material. Zirconia abutment positioned on titanium implants showed lesser reduction in crestal bone height then titanium abutment in a 1 year follow up. The less reduction in crestal bone level with zirconia abutment may be as a result of the difference in surface energy of the two materials. Zirconia has less surface energy, this is a reason it might demonstrate decreased plaque accumulation compared with titanium [38]. It has been demonstrated that zirconia enhances microcirculatory processes in the peri implant tissues. Also, around titanium abutments there is an increase of the leptin compared to the zirconia abutment. This can also be a reason of the higher level of bone resorption around titanium implants [39,40]. The crestal bone loss was similar for the titanium and zirconia abutments, but at the end of 12 months follow up, the level of bone resorption for the zirconia abutments was less compared to the titanium abutments. According to Mokhtar, there is some evidence that demonstrate mechanical and biological performance of zirconia abutment compared to titanium abutment [22].

The mechanical properties of zirconia abutments

In vitro, the mechanical flexural strength of zirconia was from 900 to 1,200 MPa, which is approximately twice of the alumina flexural strength. The fracture load of zirconia abutment is also more than twice of the alumina fracture load. Yildrim [41] concluded an average fracture load of the zirconia abutments of 737 N. Other studies supported this conclusion [42,43]. Gehrke [44,45-47] showed decreased strength of zirconia from 672 N without cyclic loading to 405 N after cyclic loading using loads between 100 and 450 N for up to 5,000,000 loading cycles. Thermo mechanical fatigue articles [13-15] on zirconia at loads of less than 50 N for 1,200,000 loading cycles showed decreased strength (between 457 and 281 N) compared to the results of Yildrim. Zirconia abutments have optimal mechanical properties related to the stress transformation toughening mechanism [22,23]. According to Protopapadaki, who evaluated the fracture strength of zirconia abutments, in an in vitro study by applying forces for 6 months, no failure was detetected [52]. Moon concluded that Zirconia abutment requires a thickness higher than 0,8 mm for fracture resistance. Zirconia abutment has high mechanical strength as a result of its unique stress induced transformation toughening mechanism. Related to fracture strength, survival rate, failure mode, Butz and Vigolo demonstrated that zirconia abutments have similar results to titanium and alumina abutments [48,49-58]. Fracture of the ceramic abutment was more often in the cervical area of the internally connected one-piece abutments or in the weakened area as a result of over-preparation of prefabricated abutments [19]. Regarding the mechanical and biologic qualities, zirconia abutments seem to be as applicable as titanium or alumina. It remains to be determined whether this assumption will hold true for follow-up periods over 5 years in prospective randomized controlled clinical trials. To evaluate the long term efficacy of the zirconia abutments, it is of a great importance to evaluate the influence of the aging process on zirconia. Taking into account, these properties of zirconia abutments we can conclude that they are recommended in clinical cases where aesthetic is required.

Resin and PEEK-type

These type of abutments are usually only indicated for temporary use and provisional restorations. Further research is necessary to evaluate the possibility of using PEEK abutments for permanent restorations. Abutments made of PMMA and PEEK are recommended for abutments in constructing provisional restorations, specifically to design the emergence profile [59-61]. PEEK has several advantages such as [62] excellent aesthetic, biocompatibility, chemical stability, and anti-adhesive and anti-bacterial effect [63,64]. Its disadvantages is that it does not have the adequate biomechanical properties to function as a permanent abutment. Although, it can be an option, especially in the frontal area or in parafunctional clinical cases [65]. The recommended materials for abutments for definitive prosthetic restorations are titanium, gold, zirconium dioxide, and aluminum oxide-based ceramic. To improve the bio mechanical properties of PEEK, some articles reinforce them with carbon fibre. However, this material has dark color and soft tissue swelling when it is removed from the PEEK core [66,67]. Regarding the ceramic-reinforced PEEK (RPEEK), there is no sufficient evidence, anyway there are studies that use this material as an abutment material as a result of its adequate biomechanical properties and biocompatibility. In a study by Al-Rabab'ah [65], the RPEEEK was used as a permanent abutment. After two years, the bone and soft tissue around the implant had good stability. It is of scientific interest to conduct research related to the dynamic fatigue, fracture resistance, torque loss and bacterial adhesion in a humid environment that created the intraoral situation and to evaluate the clinical efficacy of PEEK with different restorative materials as antagonists. It is also recommended to study the surface treatment techniques that improve the bioactivity of PEEK.

Surgical grade stainless steel

The surgical stainless steel has alloying of elements such as chromium, nickel, and molybdenum. The chromium imparts the metal's resistance to corrosion. A polished and smooth finish is provided by the nickel. Molybdenum increases hardness and keeps a cutting edge sharp. Stainless steel has high strength, is corrosion-resistant, and simple to clean. Implant abutments can be constructed of alloys of nickel, chromium, and molybdenum, however immune system sensitivity to nickel is a risk. Although it can

be used for temporary implant abutments, surgical grade stainless steel is not the best material for a permanent implant abutment.

The cast gold

UCLA [68-71] type of abutment directly attaches to the implant and provide a pattern for fabrication of screw retained restoration [6]. They are indicated in single implants, in limited interocclusal space, or in cases of tilted implants. It requires a highly accurate impression of the implant. These have been used over the past 25 years in the restoration of osseointegrated implants. They have a subgingival margin allowing them to be used in minimal interocclusal clearance. Individually waxed and cast UCLA-type abutments use has decreased, after the development of CAD/CAM-milled or prefabricated technology. Anyway, the casting technique is an alternative for the design and construction of overdentures retained by telescopic crowns. A plastic UCLA abutment is waxed up and customized to the geometry and shape. After investing, the wax and plastic UCLA are burned out of the pattern following the lost wax process. The UCLA abutment's gold base component is included into the casting of molten alloy into the investment mold, which creates a machined interface that exactly fits the implant. The non-oxidizing alloy used to make the gold base encourages the chemical adherence of the cast alloy but prevents the adhesion of porcelain. Linkevicius17 In the systematic review of the stability of peri implant tissues between titanium abutments versus gold alloy, zirconium oxide or aluminum oxide abutments. Included animal and human studies must be controlled and at least 12 months duration. 9 studies included. In one histological animal study, it was demonstrated recession around the peri implant tissue of gold alloy abutment. The results were rejected, 10 years later by the same group. In one human study, it was found no difference between the situation of peri implant tissues around the gold alloy and titanium abutments. In another histological study, no difference was found regarding the peri implant tissue around titanium and alumina abutment. A reduced inflammation was demonstrated around zirconia abutments. 3 studies that compared bone resorption around titanium and alumina abutments has contradictory results.

Alumina abutment

The use of alumina abutments has decreased since the development of zirconia and e-max abutments. Alumina abutments have good biological qualities, adequate biocompatibility and aesthetic properties. Their disadvantage is the risk of fracture, in the implant-abutment junction [72]. Three studies [64-66] compared the strength of zirconia abutments with alumina abutments. Two of them showed that zirconia abutments had significantly higher strength than alumina abutments, whereas one failed to show any significant difference between them. Although it is not possible to compare fracture strength values between various studies because of differences in study design, the reviewed articles demonstrated that zirconia abutments could be used in the anterior region of the dentition safely, where the physiologic maximal occlusal forces reach approximately 300 N [74]. Concerning mechanical strength, zirconia abutments work as well as alumina abutment. A prospective study on alumina abutments supporting short fixed partial dentures showed a cumulative success rate of 98.1% over 5 years [75]. Based on the reviewed studies, it can be concluded that zirconia abutments, with superior mechanical properties compared to alumina, will serve as abutments for frontal FPDs with a success rate that resembles to or is better than alumina.

Suggestions for single implant abutment

In custom abutments should be in margins within 1mm of the gingiva. Custom titanium abutments are recommended in single posterior restorations and in anterior restorations with low lip line and thick gingiva. Shaded, custom zirconia abutments are recommended for anterior single unit restorations (reduced gray gingiva). Cemented crowns should have the access hole in such a position to help retrieval. Screw retained are adequate in single restorations where retrieval is in plan.

Conclusion

All material studied have their advantages and disadvantages, with their respective clinical indications. All abutment materials have a satisfactory biologic reaction. Titanium should continue to be the first choice in the selection of the abutment material. However, other materials: zirconia and alumina, have been shown to work equally well and should be considered appropriate for clinical use. In particular, zirconia has been found to achieve better results than titanium in regard to plaque accumulation and bleeding on probing.

Acknowledgements and Funding

We would like to express our sincere gratitude to the Ministry of Education and Sport of Albania, which, based on Order No. 468, dated 02.08.2022, for "Financing/Co-financing of Joint Projects in the Framework of Internationalization of Study Programs", financed the study and the project entitled "Evaluation of fixed metal-ceramics and all-ceramics implant supported restorations".

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