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Research Article

Titanium Bases in Implant Dentistry: A Comprehensive Narrative Review

Luis Gabriel Ladino*, Angy Sanabria and Michael Cruz

Postgradaute Program of Prosthodontics, Insitituciόn Universitaria Colegios de Colombia UNICOC, Colombia

***Corresponding Author:** Luis Gabriel Ladino, Postgradaute Program of Prosthodontics, Insitituciόn Universitaria Colegios de Colombia UNICOC, Colombia.

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Abstract

Different materials have been used to develop abutments including titanium, that has shown excellent mechanical properties, however, in some cases aesthetics may be compromised. The titanium bases were developed to improve upon the disadvantages previously mentioned. The purpose of this narrative review was to describe the different kinds of titanium bases and their management in implant dentistry restorations. This review was done by performing a search up to May 2020 in the following databases: PubMed, Embase, Google Scholar and LILACS and a total of 454 articles were found. After reading the abstract and title and full text, seventeen articles (n = 17) were included in the review. The reviewed literature assessed the use of titanium bases regarding its surface topography and their luting protocol, also whether does not interfere with the health of the tissues surrounding the implant, mechanical and aesthetic properties. Titanium bases are a predictable alternative in screw-retained or cement-retained implant restorations, the benefits in terms of aesthetics in the anterior region could be high.

Keywords: *Dental Implants; Implant Abutment; Titanium Base, Implant Dentistry, Review*

Abbreviations

Cr-Co: Chrome-Cobalt; CAD/CAM: Computer Aided Design/Computer Aided Manufacture; 10-MDP: 10-Methacryloyloxydecil Dihydrogen Phosphate

Introduction

Dental implants have become a predictable solution to replace missing teeth, its success rates have been reported to be 97% at 10 years and 75% at 20 years [1,2]. A component of fixed implant prosthodontics is the abutment, which is the intermediate structure between the implant and the crown, it allows the retention of the restoration and provides support [3].

Currently, various materials are available regarding abutments: titanium, chrome-cobalt (Cr-Co), zirconia, and gold [4]. Titanium and Cr-Co abutments have high resistance, however, they can cause a grey shadow in the mucosa surrounding the implant, which can affect aesthetics of final restoration; for this reason, zirconia abutments were developed, which offer a better color match to natural teeth because they have better light transmission [5,6], nonetheless, it can wear or fracture because of the implant platform [7-10].

The titanium bases appear as an alternative to avoid the possible fracture of the connection in zirconia abutments. Because of its metal composition, the titanium bases provide optimal resistance, allowing adequate stability and biocompatibility with adjacent soft tissues [11,12]. These abutments are fabricated with a type V titanium alloy. Some implant manufacturers offer an anodized coating on their abutments, also, they offer two different designs, smooth or fluted, in which the surface treatment done at the moment of luting is of vital importance to the success of the restoration [13,14].

The titanium bases were designed because it was compatible with CAD/CAM technology; it allows faster working times, and acceptable adaptation, creating the hybrid concept in abutments, in which it can use a screw-retained or cement-retained system, that could be indicated in the following clinical situations: (1) well-positioned implants ready for crown placement and (2) in tilted implants, the position can be corrected with modifying the abutment with burs and luting the customized coping followed by the crown, in which case it's not viable to recover [15].

The main advantage to titanium bases is that you can recover the abutment and the crown, just like with the customized abutments or any screw-retained system, because of it being cemented extra orally it allows to remove any cement excess, thus avoiding possible tissue inflammation produced by the cement, and after this, it can be fixed with the screw [16,17].

The central theme of the published articles related to abutments is the mechanical behavior of them, including the connection and the type of restoration; however, the titanium bases remain understudied in the literature, this is likely associated to the fact that this has been used for a short time in clinical situations.

Purpose of the Study

The purpose of this narrative review was to describe the different kinds of titanium bases and their management in implant dentistry.

Materials and Methods

An electronic search was carried out until May 2020 in Databases: PubMed, Embase, Google Scholar and LILACS, using the keyword "Titanium Bases". Two reviewers selected all the titles and abstracts obtained for possible inclusion. Full-text articles were retrieved based on abstract selection; any disagreement provided by the article information was resolved through discussion with a third reviewer.

Results and Discussion

17 articles were selected, including 4 *in vitro* studies that evaluated the biomechanical behavior of titanium bases with different designs of restorations; 3 articles used monolithic ceramic crowns, zirconia crowns, and zirconia cores with feldspathic ceramic coating; besides, one article evaluated transmucosal abutments attached to titanium bases. 6 *in vitro* articles evaluated different protocols for luting, mechanical surface treatment (sandblasting with aluminum oxide particles and tribochemical treatment), using self-curing cement, and dual polymerization cement. 3 *in vitro* articles evaluated the retention strength of ceramics to different abutments among which they studied lithium disilicate, zirconia, and hybrid ceramics cemented to a titanium base and prefabricated zirconia and titanium abutments. One *in vitro* study evaluated different margin designs (posterior conical, chamfer, and shoulder); a single *in vivo* prospective randomized cohort study with a 12-month follow-up where the behavior of titanium bases and titanium abutments with peri-implant tissues was evaluated.

Mechanical behavior of titanium bases with different restorations

Esthetic restorative CAD/CAM materials can generally be divided into two main categories: ceramic and composite materials [18]. Comparing both categories, composite restorations are stronger, easier to finish and polish, less abrasive for the antagonist, and allow easy occlusal adjustment [19]. In contrast, ceramic restorations have better biocompatibility, superior aesthetics, greater wear resistance and greater color stability [20]

Tribs., *et al*. [21], evaluated the stress distribution of cemented ceramic crowns to titanium bases with different restorative techniques, using 75 titanium bases with cone morse connection, divided into three groups: first, a ceramic abutment applying silane for 60 seconds and it is cemented to the titanium base and being restored with a ceramic monolithic crown; second, monolithic ceramic directly cemented to the titanium base which silane was applied to it for 60 seconds and monolithic crown cemented to the titanium base with the access conduit which was conditioned with 5% hydrofluoric acid for 60 seconds and silane was applied and sealed with composite resin. The analysis showed a high prevalence of failure in the area of the emergence profile of the restoration, this area is critical since it is close to the fulcrum point of the crown and also because it has the thinner ceramic volume.

About fracture resistance, the esthetic restorative material of choice is zirconia since it has been shown to have great mechanical properties and that crowns can be manufactured in a monolithic or layered way, and is, in turn, can be cemented on titanium either for use in the posterior or anterior sector; but this type of restoration generates unknowns on which have better mechanical behavior, therefore Elshiyab., *et al*. [22], carried out a study where they evaluated 40 titanium bases; restoring 20 titanium bases with monolithic zirconia crowns in the form of a lower first molar and 20 with layered crowns with zirconia copings using the IPS e-max ceramic system (Ivoclar Vivadent) in the shape of a lower first molar, reporting that the structure of the layered crowns had a 50% survival rate within two years clinically simulated, compared to monolithic crowns, suffering a superficial fracture on the vestibular side of the crown of the mandibular first molar. This superficial fracture makes the crowns less aesthetic and more prone to massive fractures with lower masticatory loads, when multiple implants are connected with a screwed restoration, there is a need for the use of a transmucosal abutment to correct the differences in positions of the implants and create a passive insertion pathway. McGlumphy., *et al*. [23]; introduced the term "combined implant crown" which was made up of a torqued titanium base on a transmucosal abutment and is attached to the implant, although this type of restorations is widely used in dentistry there is not enough evidence-based data to investigate the mechanical failure of this type of restorations. Heller., *et al*. [24], conducted a study using 36 straight transmucosal abutments restored by 18 with monolithic zirconia crowns cemented to titanium bases, then torqued to the transmucosal abutments and the other 18 placing the crown directly to the transmucosal abutment, reporting that the crowns screwed to straight transmucosal abutments presented static maximum load resistance values of 872 Ncm; and at dynamic load, they presented deformation, fracture of the transmucosal abutment, fracture of the zirconia connection and screw deflection, while the crowns cemented to titanium bases and then torqued to the straight transmucosal abutment. presented values at static load, of 718 Ncm. At the dynamic load, transmucosal abutment failures and adhesive failures occurred. Therefore, both types of restorations are viable treatments that do not represent a statistically significant difference.

Adolfi., *et al*. [25], evaluated 40 implants with a cone morse connection, where half of the ceramic restorations were adhesively cemented to conventional titanium bases, which were sandblasted with 50 μm aluminum oxide particles, at a pressure of 2.5 bar for 10 seconds. At a distance of 10 mm, a pretreatment agent for titanium conditioning (Alloy Primer - Kuraray) was applied and cemented with Panavia 2.0 (Kuraray); the other half of the crowns used an experimental titanium base with notches in the ceramic restoration, all the samples were thermocycled and were restored with a zirconia crown. For the notched group, the vertical mismatch before aging was greater than after aging. 100% of the cemented group restorations failed in the screw, and 100% of the notched group restorations failed in the internal hex of the crown. The finite element simulation showed that both modalities presented a similar stress distribution on the external surface of the crown and the threads of the implant.

An important factor to consider at the time of restoration is the diameter of the implant platform, in a study by Zenthöfer., *et al*. [26], where they compared the retention force of cemented zirconia abutments to titanium bases on two different platform diameters (4.8 and 6.5 mm), reporting that the greater disunity forces are associated with a wider platform diameter.

A prosthetic treatment option when multiple teeth are lost is an implant-supported or implant-tooth supported fixed restorations; in the study by Kolbeck., *et al*. [27], evaluating the behavior of an implant-tooth supported restoration supported with a zirconia abutment cemented on a titanium base and a titanium abutment compared to a tooth-supported prosthesis, found that the best distribution of forces was presented in the tooth-supported fixed prosthesis but did not show a statistically significant difference with the implant-tooth fixed prosthesis supported on a titanium base.

Biological behavior of titanium bases

Bacterial microleakage between the different types of supported implant prosthesis retention can affect peri-implant bone loss; however, biological complications can be significantly increased according to the cementation technique adopted [28]. Excess cement generates a biological complication that can act as a mechanical irritant and bacteria deposit. Marginal peri-implant bone loss and other inflammatory soft tissue parameters differ in the presence of cement [29]. The titanium bases allow an extraoral control of the cementation line, thus avoiding biological complications and giving greater long-term stability of the treatment. Pamato., *et al*. [30], carried out a prospective randomized clinical study in 23 patients where they placed 55 implants, divided into 2 groups, the control group: cemented abutment (24 implants) and the study group: titanium base (28 implants). Clinical (probing bleeding and probing depth) and radiographic (mesial, distal bone levels, and crown/implant ratio) evaluations were performed at the time the implants were loaded, at 6 months and 12 months. Bleeding at probing was not statistically significant and considering mesial and distal bone loss is associated with the antagonist and the place where the implants were placed, the titanium bases did not interfere with the health of the peri-implant tissues. In contrast, there is a study by Asgeirsson., *et al*. [31], where they evaluated in 24 patients the clinical, technical and aesthetic parameters of the zirconia abutments with feldspar coating cemented on titanium bases, reporting that at the end of one year, no statistically significant difference was found in terms of technical and aesthetic results, but about clinical results, significant increases in depth and bleeding when probing were evident.

Regarding peri-implant bone loss, there are studies by Linkevicius., *et al*. [32] and Erhan., *et al*. [33], who found in radiographic and tomographic parameters, the presence of less bone loss in thick soft tissues and immediately loaded personalized abutments compared to soft tissues and delayed-loaded abutments.

Luting protocol

Implant-supported and tooth-supported restorations can be classified according to the ceramic material to be used, where we find 2 classifications: 1) acid-sensitive ceramics: they are those that in their content are largely made of a vitreous matrix that is responsible for providing aesthetics, and 2) acid-resistant ceramics that are formed in a large amount of crystalline phase to improve their resistance [34]. Several factors influence the adhesion between ceramic and titanium bases, such as the composition of fixing agents and restorative materials, the type of surface, the treatment, and adhesion mechanisms (chemical, mechanical, or both). Therefore, it is important to select the ideal surface treatment protocol for each material as this influences the long-term success of the restoration [35].

Among some studies, where they evaluate the effect of different surface treatments, the research by Kemarly., *et al*. [36], where they evaluated 90 titanium bases which were divided into three groups of thirty each. Thirty of the titanium bases received no surface treatment. Thirty were sandblasted with 50 um aluminum oxide particles at 2.0 bar pressure and the remaining 30 titanium bases were treated with tribochemical treatment at 2.0 bar pressure for 15 seconds. In each of the three groups of 30 titanium bases, 10 were conditioned with a universal primer on the bonding surface for 60 seconds and dried, 10 were treated with a treatment agent to condition the metal for 60 seconds and the remaining 10 received no chemical treatment. There was no statistically significant effect for any of the three chemical treatments; Regarding mechanical treatments, sandblasting with aluminum oxide particles was statistically significant. A parameter to take into account when selecting the surface treatment to be performed on the titanium base is the topography it presents, since in a study by Celin Arce., *et al*. [13]; they evaluated 60 titanium bases that had 15 150-micron deep grooves on the surface, which were subjected to different surface treatments: adhesive containing the 10-MDP molecule, 15 titanium bases were sandblasted with 50-micron aluminum oxide particles for 20 seconds, 15 titanium bases were sandblasted with 50-micron aluminum oxide particles for 20 seconds, and an adhesive containing the 10-MDP molecule was applied to the zirconia crowns and 15 titanium bases did not receive any surface treatment. Sandblasting with 50-micron aluminum oxide particles is contraindicated in this type of titanium bases since they seal the microgrooves affecting the topography and decreasing the adhesion force, in terms of surface treatment with an adhesive that contains the 10-MDP molecule, demonstrated the highest values of adhesion. In another study by Linkevicius., *et al*. [37], where they evaluated another type of topography of the titanium bases, which presented a Laser Lock surface treatment, comparing the retention force of two cementation protocols, one in which the titanium bases were sandblasted with oxide particles 50-micron aluminum and another where no surface treatment was made; reporting that the alumina particles that remain on the surface of the titanium bases weaken the bond strength between the titanium and the ceramic, recommending the cementation of this type of titanium bases without any treatment prior to cementation.

Another important factor during cementing is the type of cement; the investigations of Wiedenmann., *et al*. [38] and Gehrke., *et al*. [39], evaluated the behavior of zirconia abutments cemented to titanium bases with different bonding agents: Multilink Hybrid Abutment- Monobond Plus (Ivoclar Vivadent), Panavia F2.0 and V5 - Clearfil Ceramic Primer Plus (Kuraray) and SmartCem2 (Dentsply); which reported the highest values of adhesion in the Multilink Hybrid Abutment-Monobond Plus bonding agent. In addition, in the study by Freifrau., *et al*. [40] the use of another ceramic material for the abutment is reported, such as lithium disilicate cemented to titanium bases; they made a comparison of bond strength between these two ceramic materials using different resin cement, Multilink Hybrid Abutment- Monobond Plus (Ivoclar Vivadent), Panavia F2.0 - Clearfil Ceramic Primer Plus (Kuraray) and RelyX Unicem - Relyx Ceramic Primer (3M ESPE); reporting greater bond strength for the Multilink Hybrid Abutment- Monobond Plus for two ceramic materials. In addition, to these studies, the one by Güngör., *et al*. [41], where they study a different bonding agent such as Zirconite (DJM), which is a dual-polymer self-adhesive universal resin cement specially designed for zirconia cementing, being compared to Multilink Hybrid Abutment (Ivoclar Vivadent) Panavia F2.0 (Kuraray) using Clearfil Ceramic Primer Plus (Kuraray) as a conditioning agent, Zirconite presented the highest values of adhesion followed by Multilink Hybrid Abutment.

When evaluating the success of restorations, it will not only be affected by the bond strength but also, aesthetic factors such as the maintenance of the restoration's color will be taken into account, because this can be influenced not only for the components of the cement but also for the choice of its color. In the study by Liu., *et al*. [42], which evaluated the color stability of the restorations with different cement: Variolink Esthetic, Translucent glue, Zinc oxide temporary cement, Multilink Hybrid Abutment HO 0, Relyx Unicem A2, Panavia V5 clear, Panavia V5 A2, Panavia V5 White, Panavia V5 opaque; these cement were used in unsanblasted titanium bases; Multilink Hybrid Abutment HO 0, Relyx A2, Unicem A2, Panavia V5 clear, Panavia V5 A2, Panavia V5 White, Panavia V5 opaque, they were used in sandblasted titanium bases, representing a clinical situation of a left upper lateral incisor, the evaluation was performed using the spectrophotometer. The effect of sandblasting on the color result depended on the type of cement used; for unsandblasted titanium abutments, the results were favorable for Multilink Hybrid Abutment HO 0 cement (Ivoclar Vivadent), followed by Panavia V5 A2 (Kuraray) and Panavia V5 Opaque (Kuraray). When the titanium abutments were sandblasted, the resin cement Multilink Hybrid Abutment HO 0 (Ivoclar Vivadent), was the only cement that presented a value below the detection of the human eye.

Ceramic resistance fracture

To provide restorations compatible with titanium bases, the abutment material, that abutment design and the crown material were evaluated, thus generating aesthetic and reliable components, in the study carried out by Bankoglu., *et al*. [43], evaluated 5 abutment/crown systems on titanium bases, among their research groups are: monolithic lithium disilicate crown cemented to the titanium base, monolithic lithium disilicate crown cemented to a lithium disilicate abutment and it is cemented in the titanium base, monolithic lithium disilicate crown cemented to a zirconia abutment and this is cemented in the titanium base; crown with zirconia cap and feldspar coating cemented in the titanium base and monolithic disilicate crown of lithium cemented on a prefabricated zirconia abutment, half of the groups were thermocycled then brought to failure by means of the universal instron machine and the other half was only brought to failure, among their results are that the group monolithic lithium disilicate crown cemented to a zirconia abutment and this cemented on the titanium base presented the highest values of resistance to the fracture in both the groups with and without thermocycling, while the group of lithium disilicate monolithic crown cemented to a lithium disilicate abutment and this one cemented to titanium base presented the lowest values reported in the study. In the study by Nouh., *et al*. [44] evaluated the fracture resistance and failure mode of monolithic zirconia crowns cemented on titanium bases, zirconia crowns cemented on zirconia abutments and these on titanium bases and monolithic lithium disilicate crown cemented on titanium bases, and lithium disilicate crowns cemented on lithium disilicate abutments and these on titanium bases; all groups were subjected to thermocycling; where the fracture resistance was higher in zirconia crowns cemented on zirconia abutments, and these cemented on titanium bases. In another study seeking to evaluate equally different ceramic systems both in the abutment and in the restoration using finite elements, Tribs., *et al*. [45] evaluated the stress distribution of different groups that were distributed according to the material of the crown and the abutment. The same crown material using a zirconia hybrid abutment significantly increased the strength of the restoration compared to a lithium disilicate hybrid abutment, demonstrating that the stress generated on these abutments differs significantly when the same crown restorative material is placed underneath.

Kyaw., *et al*. [46], evaluated the influence of the mechanical cyclic load on the transformation of the phase of the zirconia abutments, which presented significant effects on the amount of transformation of the monoclinic phase obtained from the aging techniques. To determine the bending moments and failure modes of zirconia abutments bonded to titanium bases Pitta., *et al*. [47], conducted a study with fully ceramic monolithic crowns after aging; among their ceramic materials they evaluated lithium disilicate monolithic crowns, hybrid ceramic monolithic crowns, zirconia monolithic crowns and lithium disilicate monolithic crowns on a titanium abutment, this being the control group. They found that the group of monolithic crowns of zirconia cemented on a titanium base presented the highest values of flexural strength, no statistically significant difference was found in the other groups. In another study by Gierthmuehlen., *et al*. [48], where they evaluated the clinical behavior of 28 patients restored with lithium disilicate monolithic crowns cemented on titanium bases; they evaluated marginal adaptation, surface roughness, color stability and anatomical shape. At the end of one year, the occlusal surface was rough, which was limited to the contact points or functional areas and was mainly related to the wear of the material and, as regards the other parameters evaluated, they remained stable during the follow-up time.

Margin design

The interface between the titanium base and the zirconia abutment has become a concern because the edge margin of the zirconia abutment is in the subgingival portion of the implant, the adhesion between the abutment and the titanium base component is very important since if a separation is made in this area, it can generate peri-implant diseases; Mieda., *et al*. [49], conducted a study using a chewing simulator to compare three types of zirconia margins on a titanium base: posterior taper, shoulder, and chamfer to determine the best margin shape for safe clinical application. Among their results they found that the zirconia margin with a posterior conical shape transferred the tension to the interior of the implant, on the contrary, the chamfer margin releases stress outside the implant; the shoulder and posterior conical groups did not present fractures in the margin of the zirconia coping. Only the chamfer groups had some small fissures, in terms of decementation and only the shoulder margin group had marked separation on both sides. Accordingly, the authors reported that the posterior taper margin prevents deformation and damage, generating greater long-term stability with high longevity for adhesive performance between the zirconia coping and the titanium bases.

The behavior of sterilization in titanium bases

The sterilization process of the titanium bases provides a bacteria-free surface generating greater epithelial adhesion, reducing the chances of the presence of any peri-implant disease. However, the effect of sterilization at the abutment/implant interface is unknown when using chemical or dual-cure cement, therefore the studies by Pils., *et al*. [50] and Fadanelli., *et al*. [51], evaluated the possible effects of an autoclave sterilization process on the tensile strength of zirconia abutments cemented on titanium bases compared when this process was not performed, there was no statistically significant effect for either group, however, the samples that were subjected to sterilization presented higher retention values.

Conclusion

This review mainly focused on the general information about the use of titanium bases in prosthetic implant dentistry to give dentists a basic knowledge about their possible applications in implant-supported restorations. Currently, their application is increasing in recent years in prosthodontics because of their benefits compared with conventional techniques, including avoiding peri-implant diseases and improve the esthetics. As a conclusion titanium bases are a predictable alternative in screw-retained or cement-retained implant restorations, the benefits in terms of aesthetics in the anterior region could be high.

Conflict of Interest

The authors declare no conflict of interest.

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