The biomechanical contribution of customized hybrid implant abutment zirconia-titanium

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ABSTRACT:

Introduction: Implant-supported fixed dental prosthesis is a standardized restoration method that is often used when an anterior single tooth is missing. However, when a titanium abutment is used in thin peri-implant mucosa in the anterior area, the metallic aspect can be visible through the mucosa. In order to offer an alternative solution to zirconia abutments and titanium abutments, the use of zirconia implant abutments connected to titanium base (Ti-base) has advanced to combine the advantages of the two kind of implant abutments. The aim of the present systematic review is to investigate the mechanical resistance of zirconia implant abutments connected to titanium bases and compare it to one-piece zirconia implant abutments and titanium implant abutments.

Materials and Methods: The literature research has been performed using the PubMed electronic database, we selected relevant studies published in English between 2010 and 2020/ 05/ 01. According to the following keywords and Boolean equations: “Customized zirconia implant abutments” OR “customized hybrid implant abutment” OR “cad-cam zirconia implant abutment” OR “tow piece cad cam zirconia implant abutment” OR “zirconia with titanium base” AND “fracture” AND “resistance” NOT peri-implant.

Results: The electronic research identified 54 articles. 35 articles has been excluded based on initial screening of the title and abstract, as they are not relevant to the objectives of the present review. After the application of the inclusion and exclusion criteria and the second screening based on the critical assessment of the full-texts, 13 articles has been included in the present study. The results of our research have allowed us to identify several elements that may be included in the study of the biomechanics of implant abutments. Thus, our review highlighted the contribution of titanium bases to improve the fracture resistance of customized zirconia abutments.

Conclusion: Within the limitations of this study, it could be concluded that the use of the customized zirconia-titanium implant abutments connected to titanium bases allow avoiding the damage of the titanium interface of implant caused by the zirconia abutments. Further studies may be required with a greater standardization of the study design and testing methods.

***IndexTerms*: implant abutment, hybrid abutment, Ti-base , zirconia-titanium abutment**

Introduction

Implantology has revolutionized the therapeutic options for edentulousness and offers increasingly aesthetic solutions. The clinical result does not only concern osseointegration, but also the success of the mucosal integration of the prosthetic reconstruction around the implants. This is an interlocking of different parts resulting in prosthetic rehabilitation fixed on the implant through or without an intermediate part: the implant abutment which forms a connection between the endosseous implant and the endobuccal prosthesis. It must perform several roles both biologically by offering optimal biocompatibility, and aesthetically by integrating in the most natural way to the smile, or even mechanically by promoting the transmission of occlusal forces.

Several types of implant abutments using different materials have been described and used, prefabricated abutments have a standard morphology that can adapt to the vast majority of patients with a similar result. They are available in different diameters, heights, shapes and angulations depending on the diameter of the implant, but also the height of the peri-implant mucosa. They can be straight, angled, modifiable and non-modifiable. [1]

Currently, titanium and zirconia are the two materials of choice for CAM in a custom implant abutment. The titanium abutments were considered the "gold-standard",they have been shown to be effective and durable, mainly because of their mechanical resistance capacity. [2] However, when applying mechanical forces to materials of different stiffnesses, the deformation curve is distributed to the element with the lowest Young's modulus, in this case the titanium. Clinically, the occlusal stresses cause micromovements at the zirconia abutment / titanium implant interface. The implant connection then undergoes wear by friction: this is "fretting wear" [3], [4] From a clinical point of view, damage to the implant head may lead the practitioner to change the abutment. In the most extreme cases, removal of the implant is necessary. Biologically, this titanium debris is not beneficial to bone volume or the stability of the emergence profile. Also, a zirconia connection is often less precise than a titanium. The pre-existing microhiatus is further amplified by the phenomenon of “fretting wear”. This area conducive to the development of bacteria is harmful for the sustainability of the profile of emergence .[5]

However, patients are becoming more and more demanding and require personalization of restorations. There are two types of abutments: fully custom abutments, and custom abutments on a machined base, such as UCLA (Universal Castable Long Abutment).

The constant progress of CAD / CAM technologies has led to abandon these methods of casting or overcasting.

The personalized abutment is individually designed by CADCAM to ensure better adaptation of the peri-implant soft tissues (marked gingival scallops, etc.) and better biomechanical behavior (thanks to the homothety of the thicknesses of the materials it offers). [1]

An alternative to solve these problems could be the choice of a new type of abutment trying to combine the mechanical properties of titanium with the aesthetic properties of zirconia. Thus, constituting a hybrid zirconia-titanium abutment, also called Ti-Base abutment. These abutments are composed of two parts assembled by friction or by gluing: The zirconia part related to the crown and the titanium part related to the implant. With this design, the problem of the fragile interface seems to be excluded, since the connection is given by a titanium base [6]

The main objective of this work, which is in the form of a systematic review of the literature, is:

▪To evaluate the mechanical strength of custom hybrid abutments and compare it to that of full zirconia and titanium abutments.

I. Materials And Methods

2.1. Type of the study :

this is a systematic review of the literature comparing and discussing the results of scientific publications on the topic of biomechanics of custom hybrid zirconia implant abutments from the period 01/01/2010 to 01/05/2020.

before starting we have pre-established a detailed research protocol.

2.2. Strategy of research :

this work followed three main stages:

• A first step focused on researching scientific publications related to the subject.

• A second step aimed at the selection of works that meet the eligibility criteria and whose methodology respects the reading scales (CASP).

• And a third and final step in which the articles validated in the previous step will be classified according to the evaluation criteria and analyzed in order to be able to draw conclusions.

2.3. Keywords and Boolean equations:

The research relied on the Boolean equation through keywords from several recent publications that address the subject:

"Customized zirconia implant abutments" OR "customized hybrid implant abutment" OR "cad-cam zirconia implant abutment" OR "tow piece cad cam zirconia implant abutment" OR "zirconia with titanium base" AND "fracture" AND "resistance" NOT peri- implant

Authors use different terms to define the Hybrid Custom Abutment, so we opted for the following combination:

• The "OR" operator between the main keywords;

• The "AND" operator enters other words.

2.4.Articles selection:

The data extraction as well as the evaluation of the quality of the publications (according to the CASP scales) was completed by two readers independently, with formal processes of discussion and consensus-building if disagreement occurred in order to minimize subjectivity during the multiple stages of realization.

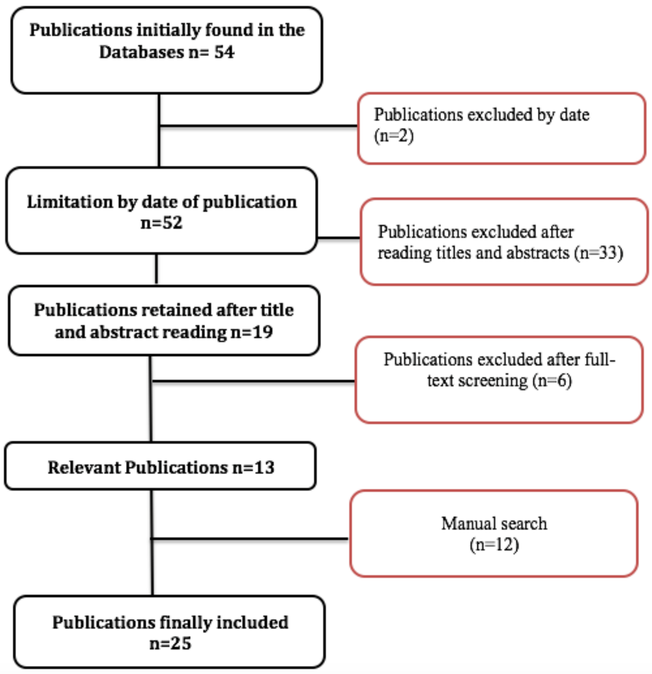
Thus, we initially found 54 studies, from which we selected 52 studies that concerned the specified research period, in this case, the last 10 years, from 2010/01/01 to 2020/05/01.

After the first selection, which was carried out based on reading the titles and abstracts, we selected 19 studies after eliminating 33 that were not relevant to our problem:

Based on the 19 pre-selected articles, we eliminated six after full-text reading, guided by the article critical reading scales proposed previously. This allowed us to obtain thirteen potentially relevant articles.

After reading the full-texts, the references of the selected articles were screened for other articles related to our study. Through this manual search we were able to retain 12 articles more.as shown in the flow diagram bellow.which lead us to obtain finally 25 relevant articles of high level of evidence.

Flow diagram



II. RESULTS:

Different types of studies were found in our systematic review, including: in vitro trials, two prospective studies, a systematic review and meta-analysis, a study by finite element analysis and a randomized controlled clinical trial.

We have succeeded in carrying out a critical inventory of the literature currently available on this subject, by trying to best define the elements that come into play in the study of the biomechanics of personalized hybrid abutments, namely:

- Materials of hybrid abutments
- Titanium pillar / base assembly method
- Types of hybrid implant-abutment connections
- Abutment thickness and diameter
- Angulations of the abutments
- Materials of the superstructure

3.1. Hybrid Abutment Materials:

The biomechanical behavior of the pillars as a function of the recommended materials has been addressed in eight studies: Guilherme et Coll. 2016 [7], Gungor et al. 2019 [8] show that custom zirconia hybrid abutments are more resistant compared to lithium disilicate hybrid abutments. These two studies confirmed that the hybrid CAD / CAM zirconia abutments offer significantly higher reliability to withstand static and dynamic masticatory loads. However, artificial aging decreased the fracture resistance of all specimens.

Gehrke et al. 2015 [5] compared the fracture resistance of prefabricated zirconia abutments, CAD / CAM designed and machined all-zirconia abutments, versus custom hybrid zirconia abutments. They concluded that the hybrid abutments have the best strength (291.4 ± 27.8 N) compared to the other abutments. The major failure of these abutments is deformation with loosening of the titanium implant screw. Thus, Elsayed et al. 2017 [9] did not report any fracture or detachment of the ceramic structure of different hybrid pillars studied. However, a deformation of the implant screw of the titanium abutments and hybrid zirconia abutments was observed.

Likewise, the study by Chun et al. 2015 [3] confirmed the contribution of titanium bases in improving the fracture resistance of all-zirconia abutments.

However, a randomized controlled clinical trial reported that the survival rate of the CAD / CAM all-zirconia abutments at 11 years was 88.9%, with failure of only six abutments out of the seventy-five studied. Chipping occurred at three ceramic-metal crowns [10]. A single prospective clinical study accurately determined the survival rate of 141 hybrid abutments at two and a half years. A single hybrid abutment titanium base lift-off was noted, resulting in a survival rate of 99.2%. (28)

3.2. Assembly method of the titanium base and the personalized zirconia abutment:

The studies found in our systematic review dealt on the one hand with the assembly method: friction or bonding, and on the other hand the shape of the abutment / titanium base joint and the nature of the preferred adhesives:

Mieda and Coll. 2018 [11] compared the stress concentration at the level of the three forms of titanium abutment / base joint. They showed that the specimens with a fillet joint with a return in the structure of the titanium bases, present a low concentration of stresses at the level of the junction (pillar / base), in this case a better dissipation of the loads, compared to the other specimens with joints in the form of a straight shoulder and a single fillet.

Two studies compared the tensile strength and failure mode of hybrid zirconia abutments with different titanium base retention mechanisms: in the study by Kim et al. 2013 [12] the glue used is RelyX Unicem; for Mascarenhas et Coll. 2017 [6] Panavia F 2.0 was used for bonding the titanium chainstays. Both studies reported better resistance of abutment samples bonded to titanium bases compared to abutments bonded by friction.

Mehl et al. 2018 [13] analyzed the tensile stresses of zirconia abutments with titanium bases, using 4 different self-adhesive glues: Panavia, Cement Automix; RelyX Unicem 2 Automix; MaxCem Elite and SmartCem 2. After artificial aging, the bond strength of Panavia (1002 N) was highest, followed by that of RelyX Unicem (614 N), MaxCem Elite (550 N) and SmartCem2 (346 N)), with a significant difference ($P < .001$). Von-maltzahn et al. 2016 [1] also compared the bond strength of custom zirconia abutments and titanium bases, specimens were divided into two groups depending on the glue used: Panavia F 2.0 and RelyX Unicem. No significant difference was observed between these two groups, however, the adhesion strengths are significantly influenced by the recommended pretreatment technique ($p < 0.001$)

Likewise Gehrke et al. [14] evaluated the bond strength between zirconia abutments (CAD / CAM) and titanium bases using three different adhesives. The Panavia 21 (Kuraray Co); Multilink Implant (Ivoclar Vivadent) and SmartCem2 (Dentsply DeTrey). The results of the pull-out test showed adhesive breaks, the average values of adhesion forces did not show any significant difference.

Alsahhaf et al. 2017 [15] evaluated the tensile strength and bending moments of hybrid zirconia abutments with different joining methods, using glass ionomer cement, and Panavia F 2.0 adhesive. This team concluded that hybrid abutments have higher mechanical strength than zirconia abutments, regardless of the recommended base assembly method.

3.3. Types of connections implant/abutment:

Regarding the connection, the two studies analyzed showed the following results:

- The study by Truninger et al. [16]; revealed that the bending moments of hybrid abutments with internal connections (429.7 Ncm 62.8)
were significantly higher (Po0.001) than those of hybrid abutments with external connections (379.9 Ncm 59.1).

Jarman et al. 2017 [17] reported that hybrid zirconia abutments with an internal connection showed better strength when applying static charges. Concerning the groups with external connections, loosening of the implant screw was noted.

3.4. The abutment diameter:

In our systematic review, two in vitro studies evaluated the resistance to fracture of small diameter hybrid abutments:

Sailer et al. 2018 [18] tested the bending moments of narrow diameter hybrid abutments (3.3 to 3.5 mm). They found that the bending moment values of hybrid zirconia abutments are substantially identical to those of titanium abutments of the same diameter, and significantly higher than those of all-zirconia abutments ($p < .05$).

Stimmelmayr et al. 2013 [19] compared the fatigue and breaking strength of hybrid zirconia abutments of different diameters (3, 75 mm and 5.5 mm) compared to those made entirely of zirconia. No abutment fracture or screw loosening was observed. In addition, for the abutments of small diameter (3.75mm), statistically significant differences were observed between the abutments entirely in zirconia and the hybrid abutments. 526 N (± 32 N) and 1241 N (± 269 N), respectively. ($P < .001$)

3.1.5. Abutment thickness and angulation:

Zandparsa et al. 2016 [20] compared the fracture resistance of hybrid zirconia abutments under different angulations, they elucidated that angulated custom abutments are more susceptible to fracture under static loads, compared to straight abutments, with a difference statistically significant ($p = 0.045$). Abutments with a thickness of 1 mm showed better resistance to fracture compared to abutments of 0.7mm ($p = 0.005$).

Joo et al. 2015 [21] evaluated the fracture resistance of hybrid custom abutments based on different thicknesses (0.5mm, 0.7mm, 0.9mm). The breaking load of 0.5mm thick pillars is higher (392.61 ± 50.57 N), than for pillars with a thickness of 0.7 mm and 0.9 mm: 317.94 ± 30.05 N and 292, 74 ± 37.15 N. Respectively ($P < 0.05$). They concluded that the fracture load of hybrid abutments is inversely proportional to the reduction values of the axial walls.

3.1.6. Materials of the superstructure:

Three in vitro studies [22], [4], [2] evaluated the strength of hybrid abutments as a function of the superstructure materials: Among these studies, two tests [22], [2] analyzed the bending moments to determine the type and fracture scheme of hybrid zirconia abutments, restored with monolithic ceramic crowns, zirconia and lithium disilicates:

The study by Pitta et al. 2019 [2] has shown that the hybrid abutments restored by monolithic zirconia crowns exhibit significantly higher bending moment values 385.5 ± 21.2 Ncm than the other abutments restored by lithium disilicate crowns ($p < 0.05$). No difference was found between hybrid zirconia abutments and custom titanium abutments ($p > 0.05$).

The study by Joda et Coll. 2015 [21] also reported a statistically significant difference ($P < 0.05$) in the fracture resistance values of all-zirconia abutments (Astra), restored by lithium disilicate crowns (366 N) compared to hybrid abutments (CARES) 541 N. ($P < 0.05$).

However, Nouh et al. 2019 [4] investigated the correlation between the fracture strength of custom hybrid abutments and the way the prosthetic superstructure is assembled. This study showed that zirconia restorations, regardless of the crown assembly method (screw-retained hybrid abutment crown or bonded crown) had a significantly higher fracture resistance (3730 N) compared to lithium disilicate hybrid abutment crowns. (1295 N) ($P \leqslant 0.05$). Thus, according to this team, screw-retained hybrid abutment crowns in lithium disilicate are contraindicated in the posterior sector.

Tables summarizing the results of all included studies according to PICO

Author/study	Population: Samples of abutments studied	Interventions	Comparison	Results
Gungor et Al 2019. [8] *In vitro*	100 custom abutments (CAD / CAM) (Cerec, Sirona Dental Systems) are divided into 5 groups: Group (G1): Hybrid crown/abutment in lithium disilicate, Group (G2): crown bonded to a hybrid abutment (in lithium disilicate) Group (G3): Lithium disilicate crown bonded to a hybrid zirconia abutment Group (G4): zirconia crown bonded to a hybrid zirconia abutment Group (G5): Lithium disilicate crown bonded to a prefabricated zirconia abutment The titanium bases were bonded to the abutments using cement (Multilink Hybrid Abutment, Ivoclar Vivadent)	- The groups were divided into two sub-groups of 10 specimens (with and without the application of artificial aging) -The abutments are fixed in the self-curing resin simulating the jawbone then the loads (100N) were applied to the cingula at an angulation of 30° -The compression test was carried out with a universal machine (Compression / Tension Device, Esetron Smart Robotechnologies) -the specimens were examined with a special magnifying glass (Opt-on magnifier; Orange Dental, Biberach, Germany).	The fracture resistance and failure modes of hybrid zirconia abutments compared to lithium disilicate hybrid abutments	Groups 3 and 4 have the highest fracture resistance value ($p < 0.05$) - Groups which underwent artificial aging showed the lowest average values of fracture resistance: Without aging 795.72 ± 304.32; with aging 623.24 ± 297.55) -The most observed mode of failure is abutment fracture followed by crown fracture. -The screws of the titanium bases of six specimens of group 4 were fractured - the screws of two group 3 specimens were bent. Conclusion: Artificial aging decreases the fracture resistance of hybrid abutments Zirconia hybrid abutments are the strongest of the other abutments tested
Gehrke et al 2015 [5] *In vitro*	21 specimens are prepared and divided into 3 groups: Group (SZ): Zirconia trade abutments Group (OP): CAD / CAM zirconia abutments Group (TP): CAD / CAM hybrid zirconia abutments with a titanium base	All samples have been subjected to fatigue testing and thermal cycling. Then a load of 100 N was applied for 120,000 cycles at a frequency of 1.2 Hz, for 10 min (universal testing machine) at an angulation of 30 °	Compare the fracture resistance of Custom Hybrid Abutments with that of Full Zirconia Custom Abutments and Zirconia Prefabricated Abutments.	The OP and SZ abutments (232.1 ± 29.8 N) (251.8 ± 23.2 N) show significantly lower fracture resistance than the TP abutments (291.4 ± 27.8 N). All of the SZ and OP abutments were fractured, however the major failure of the TP abutments was deformation with loosening of the implant screw. conclusion Hybrid CAD / CAM abutments (zirconia – titanium) have better resistance to fracture. They can be recommended in unitary rehabilitation of posterior zones in the PM-M sector (high masticatory load)

Guilherme et al. 2016 [7] ***In vitro***	57 abutments are divided into three groups: Group (ZR): custom CAD / CAM zirconia abutment (Lava Plus; 3M ESPE) bonded to a titanium base (Ti-6Al-4V) Group (RC): abutment in composite resins CAO / CAM (Lava Ultimate; 3M ESPE) bonded to a Ti-6Al-4V titanium base Group (LD): Customized lithium disilicate CAD / CAM abutment (IPS e.max CAD, IvoclarVivadent) bonded to a Ti-6Al-4V titanium base	Application of static compressive loads (150 N, 200N, 300N, 400N) then the samples are subjected to cyclic sinusoidal loads at 2 Hz (100,000 cycles) in a water bath at 37C °. The specimens are examined under a stereo microscope (SZH-10; Olympus) and a scanning electron microscope (SEM) (JEOL JSM-6010PLUS) The reliability of the specimens was calculated using the Weibull probability curve.	Comparison of the effect of different abutment materials on improving fracture resistance and dissipation of masticatory loads.	Significant difference in fracture resistance between ZR group and other groups (P <.10) * Fractures of the (RC) and (LD) group samples occurred for loads of 130 N to 220 N, in the cervico-proximal region of the abutments. * For the ZR group, a deformation of the titanium bases followed by a fracture at loads of 250 to 310 N, observed between the abutment neck and the titanium base. Custom Zirconia Abutments have shown significantly higher reliability to withstand static and dynamic masticatory loads.
Elsayed et Al 2017 [9] ***In vitro***	40 implants (4.2 / 11.5) with conical connection using the concept of "platform switching" 5 groups of 8 samples with custom abutments and lithium disilicate crowns: * Ti: Titanium abutments * ZrO2: abutments entirely in zirconia * ZrT: hybrid zirconia abutments * LaT: lithium disilicate hybrid abutments * LcT: one-piece supra-implant prosthesis (lithium-titanium disilicate)	All crowns and titanium bases have been bonded (Multilink Hybrid Abutment, lot: T35016; Ivoclar Vivadent AG) The samples were stored in distilled water for 72 hours then the compression test was applied to the palatal face at an angulation of 30 ° (100, 200, 300 and 400N) Each sample was examined under an optical microscope (Carl Zeiss) then x-rays were taken for the titanium abutments	Compare the failure mode of hybrid abutments versus titanium abutments	* The mean ZrO2 group fracture load is 218.5 ± 14.4 N. Fracture localized in the cervical regions. ZrT, LaT and LaC groups withstood higher forces without fracture or detachment of the ceramic superstructure, with no significant difference in flexion. The Ti group showed significantly higher strain compared to the titanium bases of the ZrT group. Titanium bases have improved the fracture resistance of custom hybrid abutments and could be a reliable alternative for unitary restoration of anterior regions
Chun et al. 2015 [3] ***In vitro***	15 abutments are divided into 3 groups: Group 1: titanium abutments (titanium screws) Group 2: personalized abutments entirely in zirconia (titanium screws) Group 3: hybrid custom abutments (titanium base and titanium screws)	The abutments screwed on implants (Dentium) of dimensions (4.5 / 10mm): torque of 30 Ncm for the G1 and 32 Ncm for the G2 and G3 * Application of hydraulic artificial aging (858 Mini Bionix II machine) and static compressive loads along an axis of 30 ° * the abutments are examined under an electron microscope	Comparison of the fracture resistance of different abutments: titanium abutments, custom zirconia abutments and hybrid abutments	* Titanium abutments are the most resistant. The resistance to fracture of the hybrid abutments is significantly high / to the all-zirconia abutments. Under maximum load, the titanium abutments are all deformed, the zirconia abutments are all fractured at the connection level with damage to the titanium bases. Conclusion: titanium bases improve the fracture resistance of all-zirconia abutments
Zembic et al. 2015 [23] **Etude prospective**	* 27 patients (16 women, 11 men) receiving 54 implant restorations (25 incisors, 14 canines, 15 Premolars,) in both arches. * 54 full zirconia abutments are prepared.	* Full zirconia abutments were screwed onto the respective implants (gold screws) ceramic crowns are bonded (Panavia TC,) follow-up was done after 1 month, 1 year, 4 years and 11 years old. * A clinical and radiological control was performed according to the criteria: fracture of the abutments, loosening of the screws, marginal adaptation, probing, accumulation of plaque and gingival recession.	Compare the appearance of biological and biomechanical complications of zirconia abutments depending on the region restored: anterior and posterior.	The survival rate was 96.3% for abutments and 90.7% for crowns. 4 women and 6 men were lost to follow-up Two losses of abutment screws, three crowns had cracks. Absence of biological complications

Author/study	Population/ sample of abutments	Intervention	Comparison	Results
Mieda et al. 2018 [11] ***In vitro/ finite elements Analysis***	30 custom hybrid zirconia (CAD / CAM) abutments were used and divided into three groups according to the shape of the titanium abutment / base joint: Group 1: 10 hybrid abutments with fillet joint with a return to the structure of the titanium bases. Group 2: 10 hybrid abutments with joint in the form of a straight shoulder Group 3: 10 abutments with joint in the form of a fillet * All the abutments are pretreated (tribochemical treatment) before being bonded to the titanium bases (Multilink Hybrid, Ivoclar Vivadent), then are screwed onto the respective implants.	A two-dimensional finite element model of the system (zirconia abutment / titanium base) was constructed for analysis in this study. After artificial aging (55 ° C for 20,000 cycles, 20 s) an application of static charges (2KN held for 30s) and compression and tensile tests. Von Mises stress values were assessed. The specimens were examined under an electron microscope	Comparison between three different shapes of titanium/zirconia hybrid abutments	The stresses are concentrated at the titanium bases for group 1. For groups 2 and 3, the stress is concentrated at the marginal limit of the zirconia abutments. Electron microscopic examination revealed cracks in the breasts of the group 3 abutments, and a gap in the titanium abutment / base bonding interfaces for the G 2 and 3. Group 1 showed better bond strength.
Kim et al. 2013 [12] ***In vitro***	3 groups (n = 20) of custom zirconia implant abutments: AllZr Group: Abutment entirely in zirconia (Aadva CAD / CAM Zirconia Abutment), FrZr group: zirconia abutment bonded to a titanium base by friction (NobelProcera Abutment Zirconia) BondZr group: zirconia abutment (Lava Zirconia abutment) bonded to a titanium base by bonding (RelyX Unicem). All the abutments have been restored by zirconia crowns.	The samples were embedded in acrylic supports. After aging (20,000 cycles between 5 ° C and 55 ° C) Application of static loads (universal testing machine) then the maximum fracture load was recorded. * The samples were examined under a scanning electron microscope.	Compare the fracture resistance and failure mode of hybrid abutments according to the way the titanium bases are assembled	The mean maximum capacity (SD) of the abutments was 503.9 (46.3) N for the AllZr group, 484.6 (56.6) N for the FrZr group, and 729.2 (35.9) N for the BondZr group. The maximum load capacity of the zirconia abutments bonded to a titanium base was significantly higher than that of the other abutments (P <05). For the FrZr group: before the fracture of the samples, the separation of the titanium bases from the respective abutments and the damage to the implant platform was observed
Mascarenhas et al. 2017 [6] ***In vitro***	15 abutments were prepared for the study: Friction group: five prefabricated zirconia abutments connected to the titanium bases by friction (Procera abutment) Bond group: five personalized zirconia abutments bonded to titanium bases (Panavia F 2.0) Ring group: five prefabricated zirconia abutments with a titanium cervical ring. The abutments were restored by metal crowns	To simulate intraoral conditions, samples were subjected to artificial aging (5 ° C and 55 ° C for 15,000 cycles, 15s) The loads are applied at an angle of 30 ° until the abutments fracture, the load (N) was increased as follows: 110, 148, 222, 296, 339, 415, 491, 567, 643 and 720 N.	Compare the fracture resistance and failure mode of hybrid zirconia abutments as a function of the way the titanium bases are assembled.	A statistically significant difference between the abutments tested with respect to the number of cycles and the breaking load: The group of abutments bonded to titanium bases showed better resistance to fracture (P <.001) The failure mode of the Friction Group Abutments is to remove the titanium bases from the zirconia abutments, without any apparent fracture. For the bond group, fractures occurred at the abutment / titanium base interface and the abutment / implant interface. For the ring group, vertical fractures of the abutments were observed.
Mehl et al. 2018 [13] ***In vitro***	128 hybrid zirconia abutments are divided into 4 groups depending on the cement used for bonding the titanium base: Group (SA): Panavia SA Cement Automix, Group (UK): RelyX Unicem 2 Automix Group (ME): MaxCem Elite Group (SC): SmartCem 2	Before bonding the bases, the samples were sandblasted and ultrasonically cleaned. Artificial aging consists of storing samples in distilled water (37C ° / 3 days), or thermocycling (37,500 cycles / 150 days). After detachment of the bases, the rupture modes (adhesive or cohesive) are analyzed under an optical microscope and a scanning electron microscope.	Compare the failure modes (adhesive or cohesive) of the hybrid abutments according to the different adhesives used.	After artificial aging, the bond strength of group SA (1002 N) was highest, followed by that of RU (614 N), ME (550 N) and SC (346 N) (P 0.05). (P <.001). The failure modes of the zirconia abutment surfaces were primarily adhesive, while those of the titanium surfaces were primarily cohesive. Panavia SA and RelyX Unicem provide promising results for bonding titanium bases, and should be the subject of further studies.

Alsahhaf et al. 2017 [15] ***In Vitro***	* Mandibular bone was simulated by the use of self-curing acrylic resin 5 groups of 16 samples Group 1 (G1): Zirconia abutments manufactured by CFAO, Group 2 (G2): prefabricated titanium abutments, Group 3 (G3): zirconia abutments bonded to a titanium base, (Panavia 21;). Group 4 (G4): prefabricated abutments entirely in zirconia Group5 (G5): zirconia abutments connected to a titanium base by a glass ionomer cement * The ceramic-metal crowns were then bonded (Panavia 21)	Application of a dynamic loading of 1.2 million cycles of 49 N in a chewing simulator with thermal cycling. Samples which have survived artificial aging are subjected to the compression test in a universal testing machine (Zwick, 2010 / TN2S, Ulm, Germany) Then examined with a 5X magnifying glass	Comparison of tensile strength and bending moments of hybrid zirconia abutments with titanium abutments	The survival rate is 100% in groups 2, 3, 4, 5 The survival rate in group 1 is 25%, fracture of the screw head under dynamic load and the (internal) connection under static load was noted. most of the fractures were observed at the level of the implant screw. Group 1 and 4 specimens show low fracture resistance (172.5; 580.8 respectively) For groups 2, 3, 5 no significant difference was shown hybrid abutments have significantly greater mechanical resistance than Zirconia abutments, regardless of the recommended base assembly method
Von-Meltzahn et al. 2016 [1] ***In Vitro***	* Two different cements to assemble the zirconia abutments and titanium bases (Panavia F 2.0 and RelyX Unicem) * Before bonding, the samples are divided according to pre-treatment: sandblasting with aluminum oxide; Application of primer (Alloy Primer or Clearfil); Tribochemical treatment (Rocatec)	* All samples were thermocycled (10,000 cycles, 5 ° C and 55 ° C). * A pull-off test was performed to determine the bond strength. * Statistical analysis was performed (two-way ANOVA), and the fracture surfaces were examined under a scanning electron microscope.	Compare the bond strength of hybrid abutments on titanium bases depending on the cement used	No significant difference was found between Panavia F 2.0 and RelyX Unicem, but the bond strengths are significantly influenced by the pre-treatment technique used ($p < 0.001$)
Gehrke et al. 2014 [14] ***In vitro***	21 custom zirconia abutments were made CAD / CAM (CERCON Compartis, Degudent, Hanau, Germany) and then bonded to the titanium bases (XIVE Ti-Base, Dentsply Friadent), using three different adhesives: Group A: Panavia 21 (Kuraray Co); Group B: Multilink implant (Ivoclar Vivadent,); Group C: SmartCem2 (Dentsply DeTrey).	The zircon abutments are all sandblasted (aluminum oxide particles) and bonded by the same operator. they were stored in distilled water (37 ° C) for 60 days and then thermocycled (15,000 times between 5 ° C and 55 ° C for 30 seconds). All specimens were subjected to the pull-out test in a universal machine (Zwick, Ulm, Germany) Failure modes have been observed and recorded	Comparison of the bond strength between hybrid abutments and titanium bases, depending on the different adhesives used	The values of the adhesion force are 924.93 ± 363.31 N for the Panavia 21 group; 878.05 ± 208.33 N for the Multilink group and 650.77 ± 174.92 N for SmartCem2. No significant difference ($p = 0.1314$) * the ruptures of all the abutments are adhesive. * all the cements tested showed better adhesion without significant difference

Author/study	Population/sample of abutments	Intervention	Comparison	Results
Sailer et al. 2018 [18] ***In vitro***	20 personalized abutments are prepared and divided into 5 groups: Group (T1): Zirconia abutments with internal connection. Group (T2): zirconia abutments with external hex connection Group (T3): hybrid zirconia abutments with internal connection Group (T4): hybrid zirconia abutments (Ti-base) Group (C): One-piece titanium abutments with internal connection * Implants / abutments had a narrow diameter ranging from 3.3 to 3.5mm * The titanium bases are bonded Using (Rely X Unicem, ESPE)	60 abutments are restored by crowns designed and machined by CFAO (IPS Empress CAD, Ivoclar Vivadent) All samples underwent artificial aging before application of loads (1,200,000 cycles, 49 N, 1.67 Hz) Static load was applied up to the fracture (ISO 14801 standard). Bending moments were calculated for the comparison of groups. Values were compared using ANOVA with p values using Tukey's procedure The rupture patterns were analyzed descriptively.	Compare the fracture resistance and bending moments of different small diameter abutments (3.3 to 3.5 mm): hybrid abutments versus titanium abutments.	Titanium abutments (C) exhibited significantly higher bending moments than identical zirconia abutments in diameter of 3.3 mm ($p < 0.05$) The mean bending moments: For unrestored abutments is: 521 ± 33 Ncm (T4), 404 ± 36 Ncm (C), 311 ± 106 Ncm (T1) 265 ± 22 Ncm (T3) and 225 ± 29 (T2). For the restored abutments the values are lower: 278 ± 84 Ncm (T4), 302 ± 170 Ncm (C), 190 ± 55 Ncm (T1) 80 ± 102 Ncm (T3) and 125 ± 57 (T2) Small diameter zirconia hybrid abutments with an internal connection exhibited a higher tensile strength than hybrid abutments with an external connection
Stimmelmayr et al. 2013 [19] ***In vitro***	32 abutments are screwed onto implants, integrated into acrylic resin cylinders and divided into 4 groups according to the diameter of the abutments: Group [Zr3.75]: abutments entirely in zirconia with a diameter of 3.75 mm Group [Zr5.5]: abutments entirely in zirconia, diameter 5.5mm Group [ZrTi3.75]: hybrid abutments with a diameter of 3.75 mm Group [ZrTi5.5]: hybrid abutments with a diameter of 5.5 mm	All samples were thermal cycled at 5 ° C and 55 ° C and were loaded with 100,000 cycles at 120 N, at a 30-degree angulation. The samples were examined under an electron microscope. * Data was analyzed using testXpert software using Mann-Whitney U test. The level of statistical significance was set at 5%.	Compare the fatigue and fracture strength of hybrid zirconia abutments of different diameters versus that of full zirconia abutments	No abutment fracture or screw loosening was observed during the application of the loads The mean values of fracture resistance and standard deviations were 526 N (± 32 N) for the group [Zr3, 75], 1241 N (± 269 N) for the group [ZrTi3, 75]. 1894 N (± 137 N) for the group [Zr5, 5] and 2225 N (± 63 N) for the group [ZrTi5.5]. For each diameter, statistically significant differences were found between all-zirconia abutments and Ti-base abutments.

Authors/study	Population/sample of abutments	Intervention	Comparison	results
Zandparsa et al. 2016 [20] ***In vitro***	Forty custom hybrid zirconia abutments have been divided into four groups as follows: Group A1: thickness 0.7 mm and angulations 0 °; Group A2: thickness of 0.7 mm and angulations of 15 °; Group B1: thickness of 1 mm and angulations 0 °; Group B2: thickness of 1 mm and angulations 15 °.	Replicas of implants are mounted in self-curing acrylic jigs, then the personalized abutments are screwed in (a torque of 35 Ncm) * Samples are subjected to shear stresses until fracture, using a universal testing machine. * A computer software system, designated the stress-strain diagram and recorded the loads to failure. * The breaking loads are then recorded and analyzed (bidirectional ANOVA and Kolmogorov-Smirnov).	Compare the fracture resistance of straight and angled hybrid zirconia abutments.	Under static loads, angulated custom abutments are more susceptible to fracture, compared to straight abutments with a statistically significant difference ($p = 0.045$). Abutments with a thickness of 1mm showed better resistance to fracture compared to abutments with a thickness of 0.7mm ($p = 0.005$).
Joo HS et al. 2015 [21] ***In vitro***	36 Hybrid Custom Abutments (ZenostarZr translucent, Wieland, Germany) are divided into three groups Group A: 0.5mm abutments Group B: 0.7mm abutments	* Crowns in lithium disilicate (IPS e.max) replacing the maxillary central incisor, were bonded to the abutments (Rely X Unicem). Each group was divided into 2 sub-groups (with or without artificial aging: thermal cycling according to the protocol (ISO 10477) * A cobalt-chrome indenter with a rounded tip simulates the antagonist, then a chewing simulator applies 1,200,000 cycles at 1.67Hz and 49 N. * The modes of fracture were then identified under a microscope The breaking loads were treated statistically (SPSS) and analyzed by ANOVA ($p < 0.05$)	Comparison of the fracture resistance of hybrid custom abutments based on different wall thicknesses.	The breaking load of hybrid abutments with an axial reduction of 0.5mm is significantly higher (392.61 ± 50.57 N), than those of abutments with low preparation thicknesses: ($P < 0.05$): * 0.7mm thick abutments: 317.94 ± 30.05 N * Abutments 0.9 mm thick: 292.74 ± 37.15 N Conclusion: the axial reduction of hybrid abutments affects their resistance to fracture. (inversely proportional)

Author/study	Population/sample of abutments	Interventions	Comparison	Results
Pitta et al. 2019 [2] *In vitro*	48 implants with an internal connection (Conelog, Camlog) were restored with hybrid CAD / CAM abutments, and divided into 3 groups depending on the crown material: (T1): monolithic lithium disilicate (e-max CAD, Ivoclar) (T2) monolithic hybrid ceramic (T3) monolithic zirconia (Lava Plus). witness (C): 12 custom titanium abutments restored with monolithic lithium disilicate crowns (e-max cad, Ivoclar) All the crowns were bonded with (Panavia 21, Kuraray)	The samples were embedded in acrylic supports. After aging (1,200,000 cycles, 49N, 1.67 Hz, 5 ° C to 50 ° C, 120 s), a static load was applied until the fracture (standard ISO 14801) The bending moments were then calculated. Values were compared statistically using an ANOVA test followed by a post hoc Tukey test ($p < 0.05$). * The types and patterns of rupture have been analyzed descriptively.	Compare the bending moments and fracture pattern of hybrid (zirconia-titanium) abutments and restored custom titanium abutments with lithium disilicate monolithic crowns	The mean bending moments were 356.4 ± 20.8 Ncm for (T1), 357.7 ± 26.3 Ncm for (T2), 385.5 ± 21.2 Ncm for (T3) and 358.8 ± 25.3 Ncm for (C). The T3 group had significantly higher mean bending moment values than the other groups ($p < 0.05$). No difference was found between hybrid zirconia abutments and custom titanium abutments ($p > 0.05$). No failure was recorded during aging. The fractures occurred at the level of the abutment of the internal connection. For the material of the crowns, monolithic zirconia was found mechanically superior to other materials.
Nouh et al. 2019 [4] *In vitro*	32 Implant-supported restorations simulating a maxillary first premolar CAD / CAM divided into 2 groups depending on the material of the hybrid abutments: (n = 16) zirconia (Z) and lithium disilicate (L) with titanium bases 3mm in length. * Each group was subdivided into 2 sub-groups according to the design of the superstructure (n = 8): one-piece screw-retained restoration (ZS, LS) and two-stage restoration (ZC, LC), using self-adhesive cement (SpeedCEM More; Ivoclar Vivadent)	The abutments are screwed to the implants (torque of 20 Ncm) then were integrated into acrylic supports. The samples were stored for 2 hours in distilled water (37 ° C). Each group was subjected to 1.2 million cycles simulating masticatory loads of 120 N load. The surviving specimens were subjected to a static load in a universal testing machine. To determine the mode of failure The specimens were examined under an electron microscope.	Compare the tensile strength and failure mode of customized hybrid abutments according to the material and the method of assembly of the prosthetic superstructure (bonded or screw-retained)	43.8% of the lithium disilicate hybrid abutments were fractured, however 18.8% of the zirconia hybrid abutments were fractured. The ZC group had a significantly higher fracture resistance (3730 N) compared to the LC (1295 N) and LS (849 N) groups ($P \le 0.05$). All the samples of group LS, LC, ZC were fractured, 3 specimens of group ZS (screw-retained crowns) survived. The fractures are located in the titanium bases (zirconia abutments) and the ceramic superstructure. (lithium disilicate abutments)
Joda et al. 2015 [22] *In vitro*	20 Monolithic lithium disilicate crowns bonded to abutments (Panavia F 2.0, Kuraray Noritake Dental). Group A (n = 5): titanium abutments (Straumann) Group B (n = 5): prefabricated titanium abutments (Medentika) Group C (n = 5): Custom hybrid abutments in zirconia (Cares, Straumann) Group D (n = 5): Customized full zirconia abutments (Astra, Atlantis).	The abutments are screwed (35Ncm) onto implants (Bone Level Implant, SLA, RC 4.1 10 × 12 mm, Straumann Institute) and integrated into polymethyl methacrylate supports then a static load was applied (universal testing machine) Stiffness and strength were evaluated and calculated statistically with the Wilcoxon rank sum test.	Compare the stiffness and resistance to fracture of the different abutments restored by monolithic lithium disilicate crowns	* Absence of fractures. * Titanium abutments (G: A and B), have better resistance. * zirconia abutments (G: C and D) Statistically significant difference ($P < 0.05$) between the strength values of abutments (Astra) 366 N and abutments (CARES) 541 N. the mean value of stiffness is 884 N / mm (Astra) and 1751 N / mm (CARES) ($P < 0.05$). Cracks were observed under the microscope at the level of the connections (L: C and D)

III. DISCUSSION:

We were faced with the difficulty of synthesizing all the research findings, because of the great heterogeneity of the protocols. Regarding the materials of the abutments: Guilherme et Coll. [8] compared the maximum resistance to static stresses, hybrid zirconia abutments, hybrid abutments in composite CAD / CAM resins (Lava Ultimate; 3M ESPE) and custom abutments in lithium disilicate (IPS e.max CAD, IvoclarVivadent) . Fractures were observed between the abutment neck and the titanium base. This team concluded that the hybrid CAD / CAM zirconia abutments showed significantly higher reliability compared to the other abutments tested. Likewise, other studies have looked at the resistance of hybrid zirconia abutments by comparing them to alumina abutments.

Zhu et al. [24] studied the survival rate of 141 custom abutments for two and a half years. A detachment of the zirconia structure of the titanium base, of a single hybrid abutment was noted, allowing a survival rate of 99.2%. However, in this study, the follow-up period is very short, which calls into question the validity of the published result. In fact, to be considered a reliable therapeutic alternative, the abutments must demonstrate the same mechanical and biological qualities as or better than the titanium abutments over a period of at least 5 years. [16]

Regarding the method of assembly All authors agree that there is a significant difference in the fracture resistance of hybrid abutments with different modes of assembly. Whether in the study by Kim et Coll. [12] with the “Lava” abutments or that of Mascarehnas et Coll. [6] With the “Variobase” abutments, bonding offers better mechanical results than friction. As for them, Alsahhaf et al. [15] compare bonding and sealing with a glass ionomer cement. They found a cement with adhesive potential (Panavia F 2.0) to be the most suitable. In contrast, no significant difference between brands of cement was demonstrated in the study by Gehrke et al. [14], Similarly, Von Maltzahn et al. [1] compare the retention between the zirconia part and the titanium base on 120 hybrid abutments. No significant difference was found between Panavia F 2.0 (cement with adhesive potential) and RelyX Unicem (self-adhesive cement). However, the retention forces were influenced: By the surface treatment technique and by the length of the titanium base.

Concerning the type of connection According to Truninger et al. [16], who compared the failure modes of hybrid abutments based on different connections, the internal connections show greater resistance to bending and improve the distribution of forces.

The indication of angulated hybrid abutments should be limited. However, it is recommended to favor straight hybrid abutments, with an internal connection and a thickness of at least 0.5mm in order to avoid any risk of deformation and to minimize possible chess.

It should also be remembered that these results should be considered conscientiously, because they remain the result of in vitro work. It remains absolutely essential to validate them in vivo thanks to clinical research, in order to confirm the positive data obtained in the laboratory.

CONCLUSION:

The combination of titanium and ceramic in the hybrid abutments enables the advantages of these two materials to be combined. This personalized abutment appears to meet the biological and mechanical requirements of implant rehabilitation. In addition, the personalized zirconia superstructure of a hybrid abutment meets the aesthetic challenges of the previous sector. It adapts to all possible forms of emergence profile. Thus, based on our review of the literature, zirconia has shown better reliability compared to other materials used for the design of hybrid abutments. The results of prospective studies point to good success rates for hybrid abutments. However, further, longer-term studies with larger patient samples will be needed to clarify this conclusion.

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