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Hybrid Implant Abutments: A Literature Review

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Abstract

Ceramic implant abutments are becoming increasingly popular due to the growing esthetic demands of patients. Two-piece ceramic abutments have the advantages of both ceramic and titanium abutments. This study aimed to review the published articles regarding hybrid abutments and their characteristics.

Published articles regarding two-piece abutments were retrieved by electronic search of PubMed, Embase, Scopus, Medline, and Google Scholar databases using certain keywords. Articles highly relevant to our topic of interest were selected and reviewed.

The presence of titanium inserts in hybrid abutments can overcome the brittleness of ceramic, increase the overall fracture resistance, prevent the implant connection wear, and provide better marginal fit compared with one-piece zirconia abutments. Hybrid abutments enable the fabrication of monolithic metal-free implant restorations with optimal esthetics. Furthermore, the risk of porcelain chipping, which is a common complication of implant restorations, is eliminated due to the monolithic structure of these restorations.

According to the available literature, hybrid implant abutments have shown promising results with regard to optimal esthetics in the rehabilitation of the esthetic zone. However, long-term clinical studies are required to assess the long-term durability of all-ceramic restorations supported by hybrid abutments.

Keywords
- dental abutment
- dental implant
- porcelain
- two-piece abutment

Introduction

Titanium implant abutments are widely used due to their optimal physical and mechanical properties, including high strength and biocompatibility. However, these abutments compromise the esthetic appearance of the final restoration due to their gray color, especially in patients with a thin mucosa.[1,2] Over time, the development in ceramics and computer-aided design and computer-aided manufacturing (CAD/CAM) systems, along with an increasing esthetic demand of patients, led to the fabrication of all-ceramic abutments that improved the esthetic outcome of treatments.[3,4] High-strength ceramics, including zirconia, are now an optimal option for the fabrication of implant abutments. Customized zirconia abutments are fabricated in two forms, one-piece and two-piece abutments. One-piece zirconia abutments have several shortcomings. Evidence shows titanium abutments have a significantly better fit than zirconia abutments as ceramics cannot be machined as accurately as metals.[5] The mean gap size in the zirconia abutments is 3 to 7 times larger than that in the titanium abutments.[6] High rate of fracture is another drawback of one-part zirconia abutments, which either occurs at the implant–abutment connection or in the transmucosal part of the abutment.[2]

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In contrast, significant differences in the physical properties of zirconia and titanium, especially, in terms of hardness and modulus of elasticity, can cause wear and damage to the internal components of the implant fixture.[7,8] Due to the aforementioned limitations, the idea of hybrid abutments was suggested. Hybrid abutments consist of a titanium insert, which is connected to a ceramic mesostructure using a resin cement; thus, these types of abutments have the advantages of both ceramic and titanium abutments, including improved esthetics, optimal biological response, and superior mechanical properties, with no adverse effects on the implant–abutment interface.[9] This study aimed to review the different characteristics of these abutments.

Materials and Methods

Databases including PubMed, Embase, Scopus, Medline, and Google Scholar were searched for articles on hybrid abutments. Studies regarding different characteristics of hybrid abutments were selected. The search keywords included "hybrid abutment," "customized ceramic abutment," and "two-piece ceramic abutment."

After reviewing the retrieved articles, the extracted data were categorized in the following order:

- Cement or screw-retained restorations.
- Material selection.
- Digital and conventional workflow.
- Bonding to titanium abutments.
- Effect on peri-implant soft tissue and bone.
- Mechanical properties.
- Mode of failure.

Cement or Screw-Retained Restoration?

Restorations supported by hybrid abutments can be cement-retained or screw-retained. Several advantages and disadvantages have been described for cement- and screw-retained restorations in the literature.[10-12] The main advantages of screw-retained over cement-retained restorations include retrievability, better tissue tolerance, and insignificant biological complications.[12-14] However, a higher rate of technical complications, including screw loosening and ceramic chipping, have been reported for this kind of restoration.[15] Because of an easier laboratory fabrication process, cement-retained restorations are more frequently used compared with screw-retained restorations. The main advantage of these restorations is esthetics due to the absence of a screw access opening.[10,13,14] Because of the small cement space that serves as a stress breaker, it is easier to achieve passivity.[16,17] The main disadvantage of cemented restoration is excess cement that can cause peri-implantitis.[18-20] To benefit from the advantages of both cement- and screw-retained restorations, the combination implant crown technique (screw-cemented-retained restorations) was proposed.[21,22]

Material Selection

Zirconia

Zirconia abutments exist in the form of prefabricated (stock) or CAD/CAM-customized abutments. Prefabricated abutments have drawbacks compared with customized abutments, including lower load-bearing capacity and limited ability for individualization.[23] CAD/CAM-customized abutments enable the fabrication of abutments with the desired shape and size, optimal finish line design and emergence profile according to the soft tissue position. Customized zirconia abutments are fabricated in two general forms: one-piece (monolithic) or two-piece (hybrid) zirconia abutments. One-piece zirconia abutments are fabricated as one-part components and are directly connected to the implant (►**Fig. 1**). The implant-abutment interface is fabricated out of semi-finished zirconia blanks during manufacturing and only the external geometry of the abutment is milled based on the clinical conditions. The strength of these abutments is significantly lower than that of two-piece abutments.[24,25] In addition, these abutments are less frequently applied due to the possibility of clinical complications as mentioned before. In contrast, the restorative vertical height and the implant connection design can affect the success of these abutments.[26] Hybrid abutments are made up of two components, a titanium insert and a transmucosal zirconia part, which are connected to the implant by the titanium insert (►**Fig. 2**). The titanium insert is prefabricated by the implant manufacturers and its accuracy is as high as titanium abutments. The ceramic mesostructure is customized by CAD/CAM technology based on the esthetic needs. Partially prefabricated mesoblocks are made of pre-sintered zirconia and have connection geometry for attachment to the titanium insert. The interface between the titanium base and zirconia abutment often contains an anti-rotation feature that prevents the rotation of abutment and helps in the correct bonding of two components.[27]

Precrystallized Lithium Disilicate

Introduction of pre-crystallized lithium disilicate blocks (IPS-Emax CAD), which have a perforation that provides an intimate fit with the titanium insert, enabled the fabrication of monolithic implant-supported restorations even with the chair-side CAD/CAM systems. The monolithic nature of restorations prevents some complications such as ceramic fracture

Fig. 1 One-piece zirconia abutments.[93,94]

Fig. 2 Two-piece (Hybrid) zirconia abutments. These abutments consist of two parts, a titanium insert and ceramic mesostructure.[95]

and chipping.[28] Lithium disilicate is the strongest and toughest glass-ceramic, with moderate flexural strength,[29] moderate fracture toughness,[30] and excellent translucency.[31] Lithium disilicate abutments can be used in the form of hybrid abutment with a separate crown (cement-retained restoration) or hybrid abutment-crown with the abutment and crown fabricated as one piece, which will then be bonded to the titanium insert (screw-retained restoration) (►**Fig. 3**).

Hybrid Ceramic Blocks

Polymer-infiltrated ceramic network material is a new category of materials with an interconnected dual network structure of ceramic and polymer (VITA ENAMIC, Vita Zahnfabrik).[32] This group of materials has the advantages of both ceramics (optimal durability and color stability) and composite resins (improved flexural properties and low abrasiveness).[33] Enamic by VITA is among these materials, which is composed of a pre-sintered feldspathic ceramic (86 wt% or 75 v%) reinforced by a polymer network (14 wt% or 25 v%).[33,34] The Enamic-perforated blocks used for the fabrication of monolithic screw-retained implant-supported restorations have an integrated connection, which is compatible with the titanium bases (►**Fig. 4**). Restorations fabricated using these materials do not require sintering or post-mill firing, which results in reduced fabrication duration.[35]

CAD/CAM Polymethyl Methacrylate Blocks

Polymethyl methacrylate blocks (Telio CAD and VITA CAD temp) are indicated for implant-supported, long-term provisional single restorations for the purpose of soft tissue management. These blocks are available with a connection geometry for attachment to a titanium insert.[36,37] (►**Fig. 4**).

Digital versus Conventional Workflow

Hybrid abutments may be produced in a digital or conventional workflow. In the conventional method, the abutment-crown is formed over the prefabricated titanium base with wax that will be transferred to lithium disilicate through the pressing technique (IPS e.max Press). The restoration should be tried in the oral cavity prior to bonding the hybrid abutment/crown to the titanium base due to the required correction. In the digital technique, a digital

Fig. 3 Lithium disilicate blank (IPS-Emax CAD, Ivoclar Vivadent) for single-unit restoration in two forms of hybrid abutment crown (right) or hybrid abutment with separate crown (left).[96]

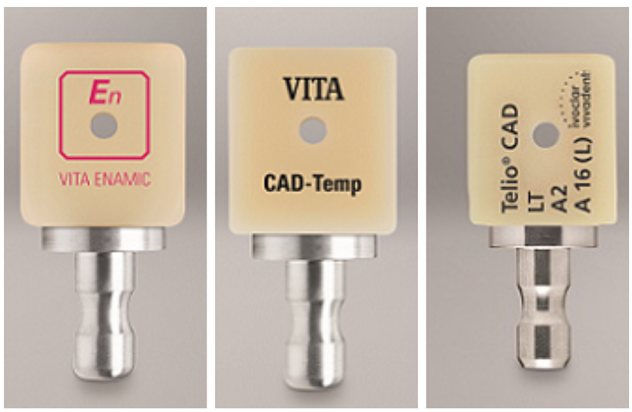

Fig. 4 CAD/CAM blank based on hybrid ceramic (VITA ENAMIC, Vita Zahnfabrik) and PMMA (Telio CAD and VITA CAD temp).[97]

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impression is made either from the oral cavity by a scan body/scan post or from the cast. The proper titanium insert is selected according to the implant system and then CAD/CAM software is intended to design and fabricate the abutment or abutment/crown.[27]

Bonding to Titanium Insert

The weak point of hybrid abutments is the adhesive connection between the titanium insert and ceramic mesostructure, which plays an important role in the long-term clinical success of restorations.[38] In the following, several factors that affect the retention force between these two components are discussed.

Surface Treatment

Surface treatment is considered for both ceramic and titanium insert surfaces. Several conditioning treatments for zirconia were suggested to obtain a strong bond between the zirconia and resin cement. Sandblasting with aluminum oxide particles (Al_2O_3) with different shapes and sizes (30 to 250 µ), pressure values, and time duration is the most common method to achieve this goal.[39] However, the effect of this method in increasing the surface roughness of zirconia is still a subject to debate.[40-45] Considering the shortcomings of sandblasting, some other surface treatments were suggested for zirconia, including tribochemical silica coating,[46] selective infiltration etching,[47] laser irradiation,[48] and nanostructured alumina coating.[49] Evidence shows that airborne-particle abrasion of zirconia and application of phosphate monomers such as dipentaerythritol penta-acrylate phosphate or 10-methacryloyloxydecyl dihydrogen phosphate (10-MDP) increase its bonding to resin cements.[50-53] Mechanical adhesion to lithium disilicate can be achieved by airborne-particle abrasion with 50 µ aluminum oxide particles or acid etching with hydrofluoric acid and application of a silane primer. Previous studies have demonstrated that hydrofluoric acid etching,[54-56] airborne-particle abrasion.[57] or both[58-60] increased the bond strength between lithium disilicate and resin cements. In general, hydrofluoric acid etching is the preferred method for roughening the surface and increasing the retention of lithium disilicate ceramics.[61-63] The effect of ceramic etching depends on the substrate constitution, surface topography, acid concentration, and duration of etching.[64] Several studies have assessed the effect of titanium surface treatments on its bond strength to different cements, and different surface roughening techniques, including airborne-particle abrasion, tribochemical silica coating systems, and hydrofluoric acid etching, have been suggested for this purpose.[65,66] However, the results of studies regarding the effect of airborne-particle abrasion on the bond strength of luting agents to the metal substructure are controversial.[67-70]

Cement Type

In hybrid abutments, resin cements are recommended to obtain a stable bond with high retention and good marginal accuracy due to a chemical bond to both titanium and ceramic components.[38] To ensure the passive fit in computer-milled zirconia prostheses, they are fabricated with minimal mechanical retention. Thus, the retention provided by the cement is more important.[71] Evidence shows that resin cements containing methacryloyloxydecyl dihydrogen phosphate (MDP) can form a long-term durable bond to the sandblasted surface of zirconium oxide ceramic.[46,72] However, adequate information regarding the retention of zirconia copings cemented on titanium inserts in two-part abutments is not available and there is no consensus on the effect of resin cement type on the retentive strength of the ceramic and metal components in two-piece abutments.[52,70] ►**Table 1** summarizes the results of available articles on the retentive strength in hybrid abutments.

Ti-Base Height

It has been reported that the abutment geometry, especially the degree of taper and height, are among the factors affecting the retention of implant-supported restorations.[73] Abbo et al showed that a 1-mm increase in titanium abutment height leads to higher resistance of zirconia copings to tensile forces.[74] In contrast, Cano-Batalla et al concluded that a 1-mm difference in the abutment height had no significant effect on restoration retention.[75] The majority of relevant studies have assessed the effect of abutment length on the retention of traditional titanium abutments; however, the condition of titanium inserts is different from that of stock abutments because titanium inserts have mechanical interlocking and a lower degree of taper. According to Silva et al, the length of the titanium base (4 vs. 2.5 mm) has no significant effect on the retention of zirconia suprastructure.[76] The retentive part of the titanium base should have a height of around 4 to 6 mm; although titanium bases with 3.5 mm height are also available in the market, they may not be able to provide sufficient retention for the restorations.[69]

Luting Gap

The cement space is one of the determinants of the retentive strength between the titanium and zirconia components in two-piece abutments.[52,77] Ebert et al showed that zirconia copings fabricated with a 30 µ luting gap had significantly higher retention than those with a 60 µ luting gap.[38] Mehl et al demonstrated that cement gap (60 vs. 100 µ) had a significant effect on the retention between titanium inserts and zirconia components.[52]

Surface Characteristics

Evidence shows higher retention values in titanium inserts than conventional titanium abutments.[78,79] It can be due to the surface geometry of titanium bases and the presence of mechanical interlocking on their surface, which could improve the retention of zirconia suprastructure.[69]

Effect on Peri-Implant Soft Tissue and Bone

The mucosal attachment formed around titanium or ceramic abutments is composed of two parts: junctional

epithelium and connective tissue.[80] Mehl et al assessed the effect of hybrid abutments made of zirconia or lithium disilicate bonded to a titanium base by resin cement on peri-implant tissues. They revealed that the abutment material and the use of two-piece abutments with adhesive resin joint had no significant effect on bone loss and soft tissue anatomy except that the height of junctional epithelium was longer around one-piece titanium abutments compared with two-piece zirconia abutments.[81] Mehl et al, in another study, demonstrated that two-piece implant abutments with a machined surface led to better adhesion of host cells than abutments with a polished or rough surface. They found no significant difference in cell adhesion to zirconia and lithium disilicate discs with machined surfaces.[82] Both studies confirmed the biocompatibility of zirconia and lithium disilicate hybrid abutments bonded to titanium bases.

Mechanical Properties

Several studies have reported that the use of titanium base in ceramic abutments can overcome the brittleness of ceramic and provide ceramic abutments with better support and higher fracture resistance.[2-5,9,83] A recent systematic review showed that titanium inserts bonded to zirconia increased the overall fracture resistance, prevented the implant connection wear, and resulted in better marginal fit compared with one-piece zirconia abutments.[84] Elsayed et al concluded that hybrid ceramic abutments made of zirconia and lithium disilicate can tolerate heavier loads compared with the

Table 1 Studies related to bonding to titanium bases in two-piece abutments

Authors	Measurement methods	Materials	Conclusion
Von Maltzahn et al 2016[70]	Evaluated the retention force (by pull-off test) after simulated aging	Titanium base bonded to zirconia coping with two different resin cements (Panavia F2 and RelyX Unicem) pretreated with six surface modifications	1. No significant difference was found between the two cements 2. All adhesion surfaces should be pretreated by sandblasting and a phosphate-base primer
Geherk et al 2014[89]	Evaluated the bond strength (by pull-out test) after thermocycling	Titanium inserts bonded to zirconia coping with three different types of resin cements Surfaces were air-abraded with aluminum-oxide particles	1. No significant difference between the retention values of three cements was found 2. The use of resin cements in combination with air abrasion of the bonding surfaces of titanium and ceramic led to stable retention of hybrid abutment
Bankoğlu Güngör et al 2018[90]	Evaluated the tensile strength after thermomechanical aging	Custom zirconia abutment bonded to titanium inserts with three different resin cements	1. Resin cement type had an effect on the retentive strength of custom zirconia abutment bonded to titanium inserts
Mehl et al 2018[52]	Evaluated the tensile load after thermocycling	Zirconia copings bonded on titanium inserts in two-piece abutments with two luting spaces (60 and 100 µ) and three different resin cements. The bonding surfaces were air-abraded with aluminum-oxide particles	1. The type of resin cement used and luting space had a significant effect on tensile load of zirconia copings on titanium bases
Linkeviciene et al 2019[69]	Evaluated the tensile force after thermocycling	Zirconia copings bonded on titanium bases with three different resin cements with a luting gap size of 30 µ. Titanium bases were airborne-abraded with aluminum-oxide particles	1. Abrading the titanium bases with 50 µ aluminum oxide particles decreased the bond strength of the coping from the titanium base
Zenthöfer et al 2018[91]	Evaluated the debonding force (tensile force up to failure)	Zirconia coping cemented to titanium inserts using composite cement after sandblasting. Half of them luted after application of an additional bonding	1. Customized two-piece zirconia abutments are a promising prosthetic treatment option 2. All debonding forces for customized two-piece zirconia abutments exceeded ~600 N
Freifrau von Maltzhan et al 2019[92]	The retention forces with a pull-off test after thermal aging	zirconia and lithium disilicate ceramics copings were bonded on titanium inserts by seven surface modifications and three resin-based luting agents	1. No mechanical pretreatment of the titanium base resulted in the lowest retention. 2. Surface modifications and resin-based agents influence the retention of components of two-part abutments. 3. Lithium disilicate ceramic copings reached comparable results of retention to the typically used zirconia copings

physiologic loads applied to the anterior region (150–235 N). Therefore, they are suitable treatment options for single implant rehabilitation in the anterior region.[2] A few studies have investigated the mechanical properties of lithium disilicate as an implant abutment material. Nouh et al demonstrated that zirconia hybrid abutment fracture resistance was significantly higher than that of lithium disilicate. They also reported that the mean load required for the fracture of lithium disilicate restorations in both types of abutment-crown and abutment with a separate crown was higher than the maximum masticatory force reported for the premolar region (222–445 N). Therefore, these restorations can be successfully used in the clinical setting for rehabilitation of the premolar region.[85] Elsayed et al showed that hybrid abutments made of zirconia and lithium disilicate (both forms of hybrid abutment-crown and abutment with a separate crown) can tolerate 1,200,000 fatigue load cycles with no fracture in ceramic abutment or crown and no screw loosening. They concluded that hybrid abutments with a titanium base have a considerably higher fracture resistance than one-part ceramic abutments (> 900 N) but no significant difference was noted between the hybrid abutments applied.[5] The effect of restoration design (hybrid abutment-crown versus hybrid abutment with a separate crown) has been evaluated by some studies; these reported that hybrid abutment zirconia restorations with separate crowns had a higher fracture strength than zirconia hybrid abutment-crown but this difference was not significant. This finding can be explained by the fact that the hybrid abutment design with a separate crown can better distribute the stresses due to the presence of several interfaces. However, in lithium disilicate restorations, the hybrid abutment-crown group showed higher fracture strength than the hybrid abutment group with a separate crown. This difference was attributed to the higher strength of the material when fabricated as monolithic and one-piece, compared with the fabrication of a separate crown with minimal thickness.[85,86] ►**Table 2** summarizes the results of available articles on the mechanical behavior of two-piece abutments.

Mode of Failure

Application of a fragile material on natural teeth is not problematic due to the presence of periodontal ligament, while the same material may cause a range of mechanical complications, including fracture and chipping when applied as implant restorations.[87] Several studies investigated the mode of failure of the implant-supported restorations using hybrid abutments. Nouh et al, observed failure in both titanium base (bending and fracture) and ceramic suprastructure (fracture and adhesive failure).[85] Elsayed et al reported that the most common failure mode in one-piece zirconia abutments was a fracture at the abutment-implant connection slightly higher than the implant shoulder, while permanent plastic deformation of abutment screw and internal connection of titanium base or distortion of the labial platform of

Table 2 Studies related to mechanical behavior of two-piece abutments

Authors	Measurement methods	Materials	Conclusion
Elsayed et al 2017[2]	Evaluated the fracture strength and failure mode	Five different abutments: titanium, zirconia with and without metal inserts, lithium disilicate with metal inserts in two forms of combination abutment-crown and abutment with separate crown	1. Lithium disilicate abutments have the potential to withstand the physiological occlusal forces that occur in the anterior region 2. The fracture strength of lithium disilicate abutments is not influenced when they are used as a combination abutment-crown 3. Failure occurred as a result of deformation of the titanium inserts and screws while ceramic suprastructure remained intact
Elsayed et al 2017[5]	Evaluated the effect of fatigue loading on the fracture strength and failure mode	Five different abutments: titanium, zirconia with and without metal inserts, lithium disilicate with metal inserts in two forms of combination abutment-crown and abutment with separate crown	1. The use of titanium inserts enhances the strength of zirconia abutments 2. Hybrid abutment and hybrid-abutment crowns made of lithium disilicate show promising durability and strength after long-term dynamic loading
Guilherme et al 2016[4]	Evaluated the static failure load	Three tooth-colored implant custom abutment bonded to titanium inserts: zirconia, lithium disilicate, resin-based composite (Lava Ultimate)	1. Zirconia abutments demonstrate high maximum load capacity 2. Customized resin-based composite and lithium disilicate abutments showed no statistical differences
Roberts 2018[86]	Evaluated the fracture strength	Four groups of titanium-based lithium-disilicate and zirconia abutment crown	1. Lithium-disilicate hybrid abutment with separate crown had significantly higher fracture load than all other groups
Nou et al 2019[85]	Evaluated the fatigue resistance, fracture resistance and mode of failure (static loading after chewing simulation)	Posterior hybrid-abutment crown and hybrid abutment with separate crown with two materials: zirconia and lithium-disilicate	1. Zirconia and lithium-disilicate hybrid restorations with short titanium inserts failed in a considerable number during chewing simulation 2. Despite their high fracture resistance, the use in the posterior region should be considered critically

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the implant was observed, with no fracture in the ceramic, in zirconia and lithium disilicate hybrid abutments with a titanium base.[2,5] Gehrke et al. demonstrated that the fracture of all-ceramic abutments always initiated in the ceramic part beneath the implant shoulder; however, the failure of the samples mainly occurred in the abutment screw in two-piece zirconia abutments, which is the weakest within the assembly and was in the form of bending and eventual fracture.[3] In addition, Rosentritt et al. reported the bending and fracture of abutment screws as the most common failure modes of hybrid abutments.[88] The comparison of three types of tooth-colored implant custom abutments under fatigue test revealed that the titanium insert broke in the zirconia group while brittle fracture occurred in the tooth-colored part of lithium disilicate and Lava Ultimate groups.[4]

Conclusion

In esthetically challenging treatments, ceramic abutments provide more natural outcomes than traditional titanium abutments. In two-piece ceramic abutments, the presence of titanium inserts can overcome the brittleness of ceramic, improve fracture resistance, and prevent wear and damage to the internal connection of the implant fixture. In contrast, the monolithic nature of these restorations prevents some mechanical complications including ceramic chipping. Furthermore, extraoral cementation reduces the possibility of peri-implantitis. Although hybrid abutments are recommended by *in vitro* studies as a promising treatment option, there is a strong need for long-term clinical studies to evaluate the clinical performance of these abutments. Moreover, soft-tissue reaction to the bonding gap, especially in bone-level implants in the esthetic zone, remains unknown. Therefore, this type of abutment should be used bearing the current limitations in mind.

Authors' Contributions

Azam Sadat Mostafavi supported the manuscript and revised the final version.

Hamid Mojtahedi contributed to language editing, proofreading, writing assistance, and technical editing.

Afrooz Javanmard wrote the manuscript and designed the study, reviewed the literature and clinical evidence of research.

Conflict of Interest

None declared.

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