TECHNIQUE FOR ACHIEVING A PASSIVE FRAMEWORK FIT: A CLINICAL CASE REPORT

Stephen T. Swallow, DDS

KEY WORDS

Passive fit
Framework
Bar
Impression
Implant-abutment connection

The clinical application of a 4-step technique for achieving the passive fit of an implant-supported cast bar or framework is reported. Implant-level transfers were attached, splinted intraorally with pattern resin, picked up in an open-tray elastomeric impression, and used to fabricate a working cast containing implant analogs. A light-cured template was used to verify master cast accuracy. A ceramometal fixed partial denture restoration was fabricated on the working cast with a preliminary try-in of the cast metal framework. A passive prosthesis fit was achieved. Failure to create an accurate working cast can distort the intended fit of a cast framework on the abutments in the patient's mouth. Optimal positioning of the implant analog in the master cast depends on (1) the transfer technique and (2) the ability of the system to maintain precise rotational orientation of the transfer components. The splinted transfer technique developed 20 years ago has sometimes been effective in improving the accuracy of framework fit with external hexagon implant-abutment connections, but it has not been documented with newer implant-abutment connections. Techniques for reestablishing master cast accuracy and correcting the superstructure are presented. The use of the presented technique resulted in a passive-fitting framework.

INTRODUCTION

The importance of achieving a passive fit between a cast metal framework or bar and the supporting implant abutments is frequently cited in the dental literature as essential for the long-term success of an implant-supported restoration.[1–3] The "passive fit" concept, however, remains controversial and only partially understood.[2] At present, there is no clear consensus as to what constitutes a passive fit, although failure to eliminate distortion between the cast framework and the implant abutments has been suggested as one reason for biologic complications or delayed component failure.[2,4–15] If distortion is defined as the relative movement of a single point or a group of points away from some originally specified reference position such that permanent deformation is apparent,[16–18] then cast superstructures that deviate from their intended relationship with the

Stephen T. Swallow, DDS, *is with the Center for Restorative Dentistry, 12 Newmarch Street, Kittery, ME 03094. Correspondence should be addressed to Dr Swallow, c/o Mike Warner, 1900 Aston Avenue, Carlsbad, CA 92008 (e-mail: s-kswallow@comcast.net).*

implant abutments may be considered as having failed to achieve a passive fit.[2]

Published data on the long-term clinical effects of nonpassive fitting or distorted frameworks are conflicting and still open to question. Some clinical studies utilizing both animal and human models have suggested that no biologic or mechanical complications may arise from a nonpassive-fitting implant framework.[2] Other reports in the dental literature state that, if a malfitting superstructure exerts any tension or stress on the supporting abutments, occlusal loading could result in a host of prosthodontic complications (eg, component joint opening,[4] repeated screw loosening,[5,6] component stress fractures[5–7]) and adverse tissue reactions (eg, ischemia, microfractures of the peri-implant bone,[7] pain, tenderness, marginal bone recession, loss of osseointegration[8,9]).[1] These problems can reportedly intensify in partially edentulous jaws, where the implant-abutment interface and abutment retention screw are subjected to greater lateral bending loads, tipping, and elongation than are bilaterally splinted implants in edentulous jaws.[1,9–13] Construction-related distortion also tends to increase in proportion to the length of the cast bar or framework span[14] and can be exacerbated by the nonparallel placement of dental implants.[1] However, the ability to achieve a distortion-free fit is only relative because of a variety of variables, such as flexure of the mandible, differences in machining tolerances among components, and distortion factors that can arise during fabrication of the superstructure.[1–3]

To correct the abutment-superstructure relationship when gross misfit occurs, cutting the framework or bar and reconnecting the segments by soldering or electrowelding have been advocated, but both techniques can further distort the fit.[1,19–20] Soldered joints are also inherently weaker than solid, 1-piece castings and may be subject to fracture under prolonged occlusal loading.[1] To avoid the need for such corrections and remakes, some clinicians have focused on improving the initial fit of cast superstructures.[21] Factors that can influence the accuracy of the initial bar or framework fit include the material[22,23] and technique[21–23] used for impressioning and the design[21–23] and positional stability[21,23–24] of the transfer posts. Air entrapment within the impression material and incomplete seating of the transfer posts can also negatively affect master cast accuracy.[22]

Splinting impression posts together with autopolymerizing acrylic,[25] light-cured resin (Triad, Dentsply, York, Pa),[26–29] and various other materials before pick-up in a custom impression tray was first introduced nearly 20 years ago to improve master cast accuracy for implants with external hexagon connections. This was possible, in part, because of a minute void that existed at the implant-abutment interface, which helped ensure that the abutment would fully seat on the implant.[30] The interfacial void also facilitated the ability to pick up the post in a transfer impression. Before the fixation screw was tightened, the interfacial void enabled the abutment to be rotated back and forth horizontally from 4° to 6.7° in some implant systems, depending on the range of machining tolerances set by the manufacturer.[30–34] After screw tightening, occlusal loading could cause rotational slippage or micromovement of the abutment within the range of the interfacial void.[9,10,30,31,35–37] Such rotational micromovements, as well as abutment tilting from nonaxial forces and occlusal stresses directed at the abutment fixation screw, have been reported to destabilize the implant-abutment connection and cause screw loosening.[30,34,38,39]

The design, precision, and strength of the implant-abutment interface help reduce reliance on the fixation screw to maintain joint stability; thus, it has a direct bearing on the long-term stability of the restoration.[13–14] To address the problem of screw loosening, some implant manufacturers have developed newer implant-abutment connections with narrower manufacturing tolerances and alternative interface designs (Table 1). Compared with the original external hexagon connection, many of the newer connections achieve more intimate contact between the mating components, which serves to minimize[14] or eliminate[12–13] rotational movements by the abutment. The narrower interfacial voids between the mated surfaces of the newer implant-abutment assemblies would necessitate that multiple implants be relatively parallel with each other to create a common path of draw for direct pick-up by transfer impressions. In addition, there would need to be sufficient intraoral vertical access to disengage the mated transfers from the implants and retrieve the impression from the patient's mouth.

This paper presents a case that successfully utilized the splinted transfer technique and other safeguards to ensure master cast accuracy for implants with an alternative implant-abutment connection, and it proposes a 4-step technique for achieving similar results with most current implant systems.

Case Report

Patient evaluation

A 61-year-old Caucasian male presented in a private dental practice for rehabilitation of an edentulous maxillary jaw through implant prosthodontics. One year earlier, his lower posterior jaw had been restored with 6 dental implants (Figure 1) (Spline Twist MTX, Zimmer Dental Inc, Carlsbad, Calif), and the upper jaw was restored with an immediate full denture after extraction of all residual periodontally hopeless teeth. The improvement in the mandibular fixed restoration was so marked compared with the maxillary removable denture that the patient requested a comparable restoration for the maxillary jaw.

Clinical and radiographic examinations were conducted. An updated health history was reviewed to evaluate the patient's present health condition and to rule out diseases or other factors that would contraindicate dental implant therapy. A diagnostic workup was performed to evaluate the volume and location of available bone, the esthetic and functional needs of the case, and how to best address the desires of the patient. Jaw relationships, available occlusal dimensions, proposed implant positions, crown-root ratios, and potential complications were evaluated on a mounted study cast. A surgical template to guide implant placement relative to the proposed prosthesis was fabricated from the prosthetic wax-up. After thoroughly discussing all treatment options and alternatives, a signed informed consent was obtained, and the patient was scheduled for surgery.

Table 1
Examples of newer implant-abutment connections

Design	Systems
Internal hexagon	Tapered Screw-Vent,* AdVent,* Frialit-2†
External spline	Spline Twist*
Internal octagon	Tapered SwissPlus,* SwissPlus,* ITI synOcta‡
Multiple internal pin holes	Starlock Starvent§
Internal cone	Astra Tech‖
Internal morse taper	Bicon,¶ ITI‡
Multiple internal slots	Camlog,# Replace Select**

*Zimmer Dental Inc, Carlsbad, Calif.
†Friadent North America, Irvine, Calif.
‡Straumann Dental, Waltham, Mass.
§Park Dental Research, New York, NY.
‖Astra Tech Inc, Waltham, Mass.
¶Bicon, Boston, Mass.
#Altatech Biotechnologies, Wurmberg, Germany.
**Nobel Biocare, Yorba Linda, Calif.

Implant selection

The implant used in this case was a self-tapping screw with a microtextured surface (Spline Twist MTX). It featured a prosthetic platform with 6 projections and slots that interdigitated with the abutment. This design was selected based on the documented advantages of using a roughened surface[25–36] and a stable prosthetic connection.[14,37]

Surgical and preliminary prosthodontic procedures

An interocclusal record was made immediately before surgery. The patient was anesthetized by local infiltration and prepared for surgery. Primary (midcrestal) and secondary (releasing) incisions were made with a scalpel (#15 Bard-Parker, BD Medical Systems, Franklin Lakes, NJ), and a full-thickness, mucoperiosteal flap was carefully elevated to expose the ridge. Because the nonparallel placement of dental implants can complicate the fit of a cast superstructure, a surgical template and drill-guide pins were used to carefully prepare osteotomies that were mutually parallel and optimally positioned to support the prosthesis. Sequential cutting was performed with internally irrigated drills by using standard procedures, and 12 implants were placed according to the manufacturer's protocol.

After removing the fixture mounts from each of the implants, impression posts were attached and an open-tray transfer impression was made to fabricate a preliminary working cast. The transfers were replaced with surgical cover screws, and primary closure was achieved with 4-0 coated vicryl sutures (Ethicon/Johnson and Johnson, Somerville, NJ). One week later, the sutures were removed, and the patient resumed wearing his relieved and softlined (Coe-Soft, GC America Inc, Alsip, Ill) denture until the uncovering appointment.

During the submerged healing period, transitional abutments and a second provisional prosthesis were prepared for the primary implants in the dental laboratory. Four months after placement, the implants were surgically exposed. Clinical osseointegration was confirmed

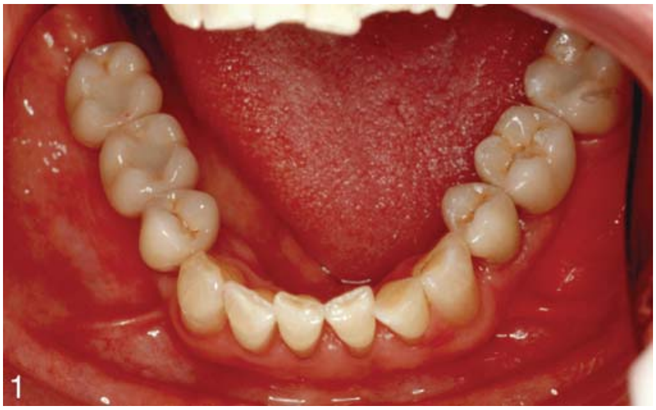

FIGURE 1. The patient presented with an implant-supported bilateral posterior reconstruction (6 Spline implants) that was completed the previous year and with a full maxillary denture.

TABLE 2

A 4-step technique for achieving a passive bar or framework fit

Step	Procedure
1	Utilize a splinted transfer technique.
2	Verify master cast accuracy with Ford's[1] and Ford and MacLarty's[40] Accuracy Verification Template.*
3	Reestablish master cast accuracy, if necessary.†
4	Establish a passive superstructure fit with Ford's[1] Heat-Activated Solderless Passivation technique.‡

*See Table 3.
†See Table 4.
‡See Table 5.

radiographically and by manual testing. The sterilized transitional abutments were attached to the implants, the soft tissues were sutured with 4-0 coated vicryl sutures (Ethicon/Johnson and Johnson) around them, and the provisional fixed prosthesis was cemented onto the abutments. The sutures were removed after 1 week, and the second provisional prosthesis was allowed to function for 30 days to allow for complete soft-tissue maturation.

Restorative procedures

Before commencing restorative procedures, open-tray transfers were attached to the preliminary working cast and a custom impression tray with open occlusal access was fabricated for use with implant-level direct transfers (Figure 2). The finished custom tray was removed and a 4-step technique was implemented to ensure the passive fit of the final cast framework (Table 2).

Step 1: Splinted Transfer Technique

The transfers were splinted together on the master cast with GC Pattern Resin (GC Corporation, Tokyo, Japan) (Figure 3). A fine saw blade was used to carefully sever the connection between each abutment. The patient was appointed and the provisional prosthesis was removed. After attaching the transfers to the implants in the patient's mouth, each severed connection was reluted intraorally with GC Pattern Resin, polymer, and monomer by a "salt and pepper" technique, and the tops of the transfers were blocked out with cotton (Figure 4).

The custom tray was tried into the patient's mouth to verify that the screws of the splinted impression posts penetrated through its occlusal openings without hindrance (Figure 5). A full-arch, open-tray impression was made with light- and heavy-body elastomeric materials (Permadyne, 3M Espe, St Paul, Minn) (Figure 6). After the material set, the screws were removed through the occlusal openings in the custom tray, and the splinted impression posts were carefully removed from the patient's mouth inside the impression. Implant analogs were attached to the embedded posts, and the impression was poured in soft-tissue replica material (Coe-Soft) and dental stone (VelMix Stone, Kerr, Orange, Calif). After the definitive working cast was separated, the impression posts were removed.

Step 2: Verifying Master Cast Accuracy

At this stage, it was necessary to determine if the positioning of the implant analogs in the master cast was congruent with the implants in the patient's mouth to avoid a non–passive-fitting framework. Ford[1] and Ford and MacLarty[40] developed a simple procedure for verifying the accuracy of a master cast by using an Accuracy Verification Template (AVT) (Table 3) and for reestablishing master cast accuracy in the event of a discrepancy (Table 4). The AVT is a light-cured framework fabricated on the master cast and transferred to the implants in the patient's mouth to verify the accuracy of the cast. If the framework remains intact, the working cast is deemed accurate and restorative procedures can continue. In the present case, verification showed that the splinted transfer technique maintained precise component locations and that an accurate master cast had been produced. The provisional prosthesis was reattached and the patient was dismissed until the definitive prosthesis delivery appointment.

FIGURES 2–6. FIGURE 2. During a postuncovering period of provisionalization, direct transfers were attached to a preliminary working cast, and a custom open tray was fabricated. FIGURE 3. Open-tray transfers on the preliminary working cast were splinted with GC pattern resin, and then each connection was carefully severed between the transfers with a fine saw blade. FIGURE 4. The open-tray transfers were attached to the implants, and the connections were luted together intraorally with GC pattern resin. Cotton was used to block out the transfer tops. FIGURE 5. The custom tray was tried into the mouth to verify that the transfers penetrated the occlusal openings without hindrance. FIGURE 6. The splinted transfers were picked up in an elastomeric impression.

Step 3: Reestablishing Master Cast Accuracy

If the AVT distorts or breaks when it is attached to the implants in the patient's mouth because of an inaccurate working cast, the framework segments are severed and reluted intraorally. The corrected AVT is then removed from the patient's mouth. A new master cast may be fabricated with the appropriate trans-

TABLE 3

Accuracy Verification Template (AVT) for verifying master cast accuracy

Step	Procedure
1	Fabricate a master cast and attach a waxing sleeve to each incorporated abutment replica.
2	Slightly roughen each sleeve with a sandpaper disc or arbor band, and apply a small amount of composite material bonding agent or cyanoacrylate adhesive to the areas of each sleeve that will be splinted.
3	Weave low-shrinkage, light-curing composite material around and between each sleeve in a tightly condensed, figure-8 pattern to form the AVT. Light-cure the assembly on the master cast according to the manufacturer's directions. Lightly finish and polish the cured AVT.
4	Section the AVT between each of the sleeves with a separating disc, then lute the segments back together with a nonfilled composite gel to enable the AVT segments to easily break if any tensile force is exerted on it during try-in.
5	Place the finished AVT on the abutments in the patient's mouth and secure it in place with fixation screws. Visually inspect each abutment-sheath interface to make sure there are no gaps or spaces present. If gaps are present, section the AVT with a separating disc to ensure that each incorporated waxing sleeve fully seats on the abutment.
6	If the AVT is fully intact and all its joints are stable and closed after it is fully seated and secured in place, the master cast is accurate and restorative procedures can continue. If the AVT breaks or requires sectioning to achieve full passive seating of its incorporated waxing sleeves, the master cast is inaccurate and must be corrected.*

*See Table 4.

TABLE 4

Ford's[1] and Ford and MacLarty's[40] technique for reestablishing master cast accuracy

Step	Procedure
1	After placing the AVT* in the patient's mouth, use a light-curing resin to lute together any segments of the AVT that broke apart or had to be sectioned to ensure full seating. The reinforced AVT should now exhibit a perfect, passive fit in the mouth.
2	Place the corrected AVT on the master cast and identify which of the incorporated abutment replicas do not fit.
3	If more than 1 abutment analog in the master cast do not fit the corrected AVT, utilize the appropriate transfers to fabricate a new master cast. Attach the corrected AVT to the abutment replicas in the new master cast and verify that a passive fit has been achieved. If only 1 abutment analog does not fit, remove the dental stone from around the abutment replica and attach the extracted component to the corresponding sleeve in the AVT with a fixation screw. Pour dental stone into the extraction void and seat the AVT onto the master cast, allowing the attached abutment replica to fit into the wet dental stone. Reattach the remaining waxing sleeves in the AVT to their respective abutment replicas in the master cast with their fixation screws. Allow the dental stone to set before proceeding.

*AVT indicates Accuracy Verification Template. See Table 3.

fers. If only 1 implant analog is malpositioned in the original master cast, the implant analog is extracted from the dental stone and attached to the appropriate location on the AVT. The void in the cast is filled with dental stone so that the implant analog attached to the AVT will be correctly repositioned in the cast after the AVT is attached to the remaining implant analogs. If the AVT distorts or breaks as a result of a rotational micromovement problem inherent in the implant system, the definitive abutments would have to be retorqued into place, temporized, and not tampered with again.

In the present case, the definitive abutments were attached to the working cast, prepared (Figure 7), and coated with a separating medium (Die Lube, GW Smith and Sons Inc, Dayton, Ohio). A framework pattern was created directly on the prepared abutments and cast according to conventional laboratory procedures. The patient was then appointed for a try-in of the cast framework (Figure 8) to check for accuracy before porcelain was applied. The provisional prosthesis was removed, the definitive abutments were attached to the implants, and the framework was attached to the abutments with fixation screws. Clinical and radiographic examinations (Figure 9) revealed no evidence of gaps, tension, or stress among any of the components. When the fixation screws were removed, downward pressure on the bar did not elicit any rocking or movement by the cast superstructure, which continued to rest passively on the abutments. After verifying that a passive fit had been achieved, the provisional prosthesis was replaced and the patient was dismissed until the definitive prosthesis delivery appointment. The 6 posterior units used engaging shouldered abutments; the 6 anterior units used modified straight abutments that required no screws.

Step 4: Establish a Passive Superstructure Fit

If a passive fit has not been achieved, Ford's[1] Heat-Activated

FIGURES 7–11. FIGURE 7. A definitive working cast with soft-tissue replica was fabricated. The definitive abutments were attached, prepared, and used as dies for fabricating the framework pattern. FIGURE 8. The cast framework was tried in to verify that a passive fit was achieved. FIGURE 9. No gaps were radiographically visible between the cast superstructure and the implant abutments. FIGURE 10. Porcelain was applied to the cast framework according to standard laboratory procedures. FIGURE 11. The definitive prosthesis provided natural-looking esthetics.

Solderless Passivation (HASP) technique can be used to achieve a passive fit without soldering or electrowelding (Table 5). Once the accuracy of the master cast has been verified (Tables 3 and 4), implant or abutment analogs (depending on the system) are attached to the AVT, and a soldering jig is fabricated with soldering investment material. After the material hardens, the malfitting cast superstructure is secured to the embedded components with fixation screws. Care is taken to ensure that the improperly fitting interface is completely closed on each abutment or implant analog by using all force necessary to close the gap. Heat sink material (Hot-Stop Heat Protection Gel, Renfert GmbH, Hilzingen, Germany) is applied as a protectant to all sections of the superstructure that are not to be altered. A laboratory torch is used to heat the exposed portion of the superstructure that would normally be cut and soldered to correct a joint imperfection until it turns cherry red.[1] After each imperfect joint has been heated accordingly, the superstructure is allowed to

TABLE 5

Ford's[1] and Ford and MacLarty's[40] Heat-Activated Solderless Passivation technique for correcting the fit of a cast bar or framework

Step	Procedure
1	After an accurate master cast has been fabricated and verified,* attach abutment replicas to the AVT† and fabricate the soldering jig with soldering investment. Allow the soldering investment to completely harden before proceeding.
2	Screw the poorly fitting bar or framework into position on the abutment replicas in the soldering jig. Ensure that the improperly fitting interface is completely closed on each abutment replica by using all force necessary to close the gap.
3	Cover the area of the bar or framework on each side of the joint that is to be heated with material‡ that can act as a heat sink to prevent heating the adjacent metal of the bar that is not to be altered.
4	Use a laboratory torch to slowly heat the bar until it is cherry red in the areas where the joint imperfections are located (ie, the areas where the bar would normally be cut). After each of the imperfect joints has been heated to temperature, allow the bar to bench-cool before proceeding.
5	Remove the retention screws and try the cast bar or framework into the patient's mouth to verify passivity and proper fit.

*See Tables 3 and 4.

†AVT indicates Accuracy Verification Template. See Table 3.

‡For example, Hot-Stop Heat Protection Gel, Renfert GmbH, Hilzingen, Germany.

bench-cool. It is then removed from the jig and tried in the patient's mouth to verify that a passive fit has been achieved.

In this case, the framework fit passively (Figure 9), and porcelain was applied and finished according to conventional procedures for ceramometal restorations (Figure 10) by the dental laboratory. At the delivery appointment, the definitive prosthesis was attached to the implants (Figure 11). Occlusion was verified and final adjustments were made. Postrestoration radiographs revealed no gaps between any of the mated components. Oral hygiene instructions were reviewed, and the patient was dismissed.

DISCUSSION

Sophisticated strategies and meticulous and accurate prosthodontic procedures are still required to achieve a passive fit with an implant-supported bar or framework.[3] Potential limitations to fabricating a passive-fitting superstructure include (1) failure by the clinician to successfully make a precise transfer and (2) failure by the implant system to maintain rotational accuracy. Newer abutment connections, such as the Spline interface used in the present study, and the splinted transfer technique can mitigate these problems and help ensure the accuracy and passivity of the final restoration.

Important considerations in abutment selection include the occlusal plane of the proposed restoration, variations in the heights of the peri-implant sulci, depths of implant placement, and contours of the residual ridge. To adequately treat a case, the clinician needs to have an assortment of abutment heights and contours available at the abutment-placement appointment. In fabricating the definitive prosthesis, impressions of prepared abutments in the mouth often cannot record the intended margin of the restoration. The splinted, implant-level transfer technique can greatly simplify decisions for dentists by allowing the dental laboratory to select or fabricate the ideal abutments for the case. Abutments for multiple-unit splinted cases can be custom fabricated, or stock abutments can be modified in the laboratory with exact tissue relationships on the working cast with a soft-tissue replica. The technique eliminates additional procedures that can introduce errors into the framework fabrication process, thereby shortening chair time and helping ensure an optimum fit of the casting.

When a custom tray is fabricated for the case, additional time can be saved if indirect transfers are attached to the preliminary working cast and luted together with light-cure resin material. The connection should be cut with a fine saw blade and then reluted intraorally before the pick-up impression. Because of the shortened overall treatment time, provisionalization of the case is not necessary unless it is desired for progressive loading or patient requirements.

In this case, a full-arch working cast containing analogs of the implants in the patient's mouth was fabricated through a splinted transfer technique, then it was used to prepare abutments and wax multiple-span framework patterns. Four important steps were discussed (Table 2), which can be used to ensure the fabrication of a passive-fitting cast bar or framework. Newer implant-abutment connections have improved screw stability, yet they still provide sufficient flexibility to use the splinted transfer technique. This step proved to be highly successful in establishing initial master cast accuracy, which was easily verified by the AVT technique (Tables 3 and 4). Despite this high level of accuracy, try-in of the cast framework was a responsible step that afforded an excellent opportunity to evaluate the fit before applying porcelain. Had misfit occurred, it could have been easily addressed at that time by the HASP technique (Table 5). Porcelain was then applied to the framework according to routine laboratory procedures, and the definitive prosthesis was delivered to the patient with an excellent passive fit, as determined by clinical and radiographical evaluations.

On a clinical level, the procedures described in this paper have been successfully used throughout the United States with excellent results.[1] Further research is needed into new ways of ensuring the passive fit of implant-supported superstructures.

Conclusions

Utilization of the splinted impression technique, an AVT, the technique for reestablishing master cast accuracy, and the HASP technique with Spline implant connections can eliminate many of the problems associated with the fit and long-term stability of cast bars and frameworks for implant-supported restorations.

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