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To Evaluate the Shear Bond Strength of Gingiva-Coloured Indirect Composite Resin to Peek and Zirconia Framework Materials Subjected to Different Surface Treatments

[1]Dr. Jeyashree Bhuvaneshwari, Postgraduate, Department of Prosthodontics and Crown and Bridge, Vokkaligara Sangha Dental College and Hospital, Bengaluru, India

[2]Dr. Anupama N.M, HOD, Department of Prosthodontics and Crown and Bridge, Vokkaligara Sangha Dental College and Hospital, Bengaluru, India

[3]Dr. Jnanadev K.R, Professor, Department of Prosthodontics and Crown and Bridge, Vokkaligara Sangha Dental College and Hospital, Bengaluru, India

[4]Dr. Bharat Raj R, Reader, Department of Prosthodontics and Crown and Bridge, Vokkaligara Sangha Dental College and Hospital, Bengaluru. India

Corresponding Author: Dr. Jeyashree Bhuvaneshwari, Postgraduate, Department of Prosthodontics and Crown and Bridge, Vokkaligara Sangha Dental College and Hospital, Bengaluru, India

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Abstract

Introduction: Restoration with implant-supported fixed prosthesis in severely resorbed ridges results in an unesthetic long clinical crown. Alternatives for restoring such deficient tissues include prosthetic restorations veneered with gingival-coloured materials. Recently, newer materials such as zirconia and PEEK have been frequently used as framework materials for implant-supported fixed prosthesis and the bonding of these materials to indirect composite resin is still a topic to be researched.

Aim: To evaluate and compare the shear bond strength of gingiva-coloured indirect composite resin to surface treated PEEK and Zirconia framework materials.

Materials and Methodology: Forty-two samples of dimensions 10mm diameter and 2mm thickness were divided into three groups.

Group 1 (n=14): Surface treated zirconia discs bonded to gingiva-coloured indirect composite resin

Group 2A (n=14): Surface treated PEEK discs bonded to gingiva-coloured indirect composite resin (only airborne particle abraded)

Group 2B (n=14): Surface treated PEEK discs bonded to gingiva-coloured indirect composite resin (airborne particle abrasion & acid etching)

Following the respective surface treatments for the zirconia & PEEK discs, gingiva-coloured indirect composite resin was bonded to the disc specimens. During bonding, a constant pressure was applied to all the specimens. Samples were then subjected to shear testing in a universal testing machine.

Result: The mean shear bond strength values in MPa were 243.55, 127.78, 145.29 for group 1, group 2A and group 2B respectively. The shear bond strength of Group 1 was the highest and that of Group 2B was the lowest. The differences among Group 1, 2A and 2B were all significant (p=0.001).

Conclusion: The shear bond strength between gingiva coloured composite resin and PEEK was stronger when PEEK was surface treated with airborne particle abrasion and 98% sulfuric acid. Hence, combination of airborne particle abrasion and 98% sulfuric acid results in a durable bond between PEEK and gingival coloured composite resin.

Keywords: PEEK, Zirconia, Gingiva coloured composite resin, 10 MDP containing primer, 98% sulfuric acid.

Introduction

Bone resorption following extraction of a tooth leads to loss of hard and soft tissues both in vertical and horizontal directions, compromising the esthetics and oral hygiene maintenance of the future prosthesis.

Regeneration of hard and soft tissue defects has been achieved through various surgical reconstructive procedures which includes, bone grafting and soft tissue grafting etc., However, these procedures are invasive, irreversible, technique-sensitive, and expensive and may not be feasible for all patients. Additionally, in severely resorbed ridges with severe bone loss in the labial site of the alveolar crest, restoration with implant supported fixed prosthesis results in an unesthetic long clinical crown.

Prosthetic restorations that replace both hard and soft tissue defects can be considered as an effective alternative to overcome the limitations of surgical reconstructive procedures. This approach can avoid additional surgical procedures and yield aesthetically and functionally pleasing outcomes. They can easily reestablish natural crown ratios and natural gingival profiles in complex environments. They include prosthetic restorations veneered with gingiva-coloured materials. Denture base acrylic resins, feldspathic porcelain, and indirect composite materials have been used as gingiva-coloured materials in prosthetic gingival restorations.

Gingiva-coloured porcelain has been widely used for reconstruction of extensive hard and soft-tissue defects, owing to its superior esthetics and ability to maintain continuity of materials within the prosthesis. However, gingiva-coloured porcelain-layered zirconia-based, implant-supported prostheses have several limitations, which includes, fracture of layering porcelain, bulk of the prosthesis, limited reparability and unsatisfactory long-term clinical outcomes. In recent years, a gingiva-coloured indirect composite material has been used to replace lost tissue architecture. Indirect composite materials have several advantages such as, chairside repairability, absence of distortion during firing, and predictable clinical outcomes.[1]

Zirconium dioxide ceramics are considered one of the most attractive materials for the framework of implant-supported prostheses, owing to their superior physical properties, excellent biocompatibility, and inherently aesthetic properties. Zirconia based implant supported fixed dental prosthesis are expected to provide aesthetically pleasing outcomes, due to the natural shade of the substrate, eliminating the problems caused by the grey effect of metal substrates. Technological improvements in design and manufacture have led to the development and fabrication of one-piece zirconia-based frameworks for implant-supported prostheses.[2]

PEEK is a high-performance thermoplastic polymer with good chemical, thermal, and mechanical properties, as well as excellent biocompatibility. A modified PEEK with 20% inorganic fillers has been used in dentistry for implants, temporary abutments for implant supported prosthesis, healing abutment, implant supported bars, clasp materials, or frameworks for removable and fixed partial prosthesis.[3]

A strong bond between gingiva-coloured materials and framework material is essential for the stability of gingiva-coloured prostheses. Hence, the purpose of this study is to evaluate and compare the bond strength of gingiva-coloured indirect composite resin to zirconia and PEEK framework materials.

Materials and Methodology

The sample size was established using G*power, version 3.0.1(Franz Faul universitat, Kiel, Germany). Considering the effect size of 0.5, significance level at 0.05 and to yield a power of 80% to detect significant differences, the total sample size needed was 42. Three groups of 14 samples each (14 samples× 3 groups = 45 samples).

Fourteen Zirconia discs measuring 10 mm diameter and 2mm thickness (Group 1) were fabricated by CAD-CAM milling. Twenty-eight PEEK discs measuring 10 mm diameter and 2mm thickness were fabricated by CAD-CAM milling (Group 2A & Group 2B) and all of them were mounted in an auto polymerizing acrylic resin before various surface treatments. [Figure 1]

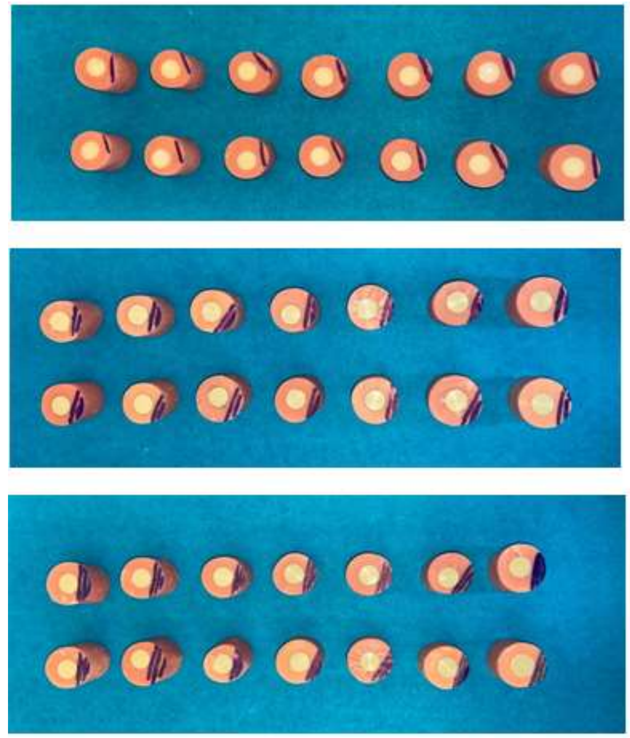

Figure 1: Group 1, Group 2a and Group 2b Samples Mounted In Autopolymerizing Acrylic Resin

Group1 (n=14): Surface treated zirconia discs bonded to gingiva-coloured indirect composite resin

Fourteen Zirconia discs were airborne particle abraded with 50 µm Al2O3 particles and the air abraded surface was coated with 10 MDP containing primer. [FIGURE 2]

Group2A (n=14): Surface treated PEEK discs bonded to gingiva-coloured indirect composite resin (only airborne particle abraded)

Fourteen PEEK discs were airborne particle abraded with 110 µm Al_2O_3 particles and the air abraded surface was coated with 10 MDP containing primer. [FIGURE 2]

Group 2B (n=14): Surface treated PEEK discs bonded to gingiva-coloured indirect composite resin (airborne particle abrasion & acid etching)

Fourteen PEEK discs were airborne particle abraded with 110 µm Al_2O_3 particles and the air abraded surface was treated with 98% sulfuric acid and was coated with 10 MDP containing primer. [Figure 2]

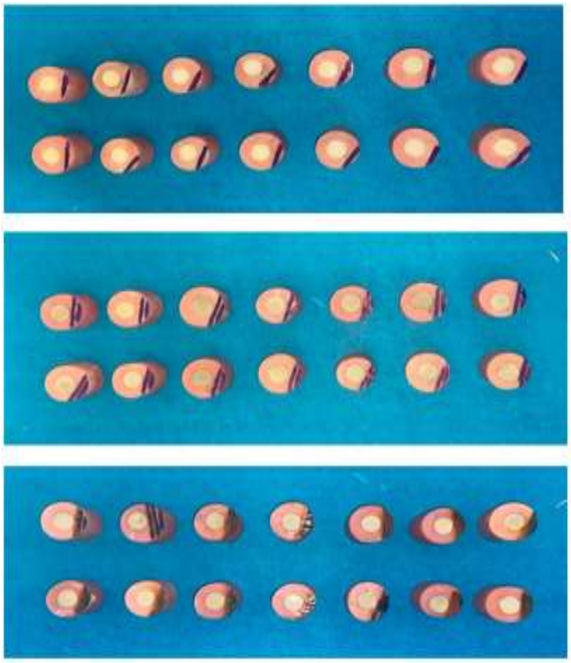

Figure 2: Group 1, Group 2a and Group 2b Samples after Surface Treatment

After the specimens were surface treated, a ring was made out of wax with inner diameter of 5mm and height 1mm into which the opaque material was thinly applied to specimens and light-polymerized for 60 seconds and an additional opaque material was applied on the primary material and light-polymerized for 3 minutes. [Figure 3]

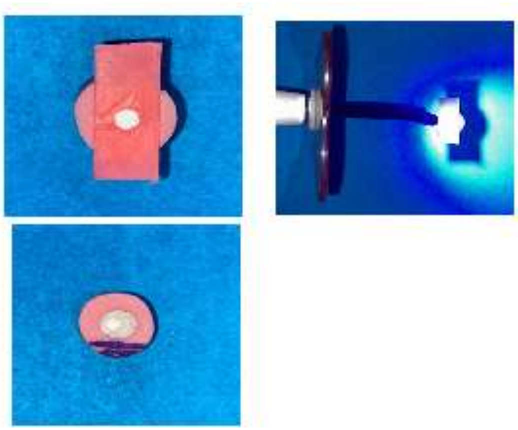

Figure 3: Opaque Material Loaded Into the Wax Ring and Light Cured

A ring made of wax with inner diameter 6.0 mm and height 2mm was mounted to surround the opaque material. The indirect material was then packed into the ring with a load of 5 N. The specimens were then light-polymerized for 5 minutes. [Figure 4]

Figure 4: Gingival Coloured Composite Resin Packed Surrounding Opaque Material and Light Cured

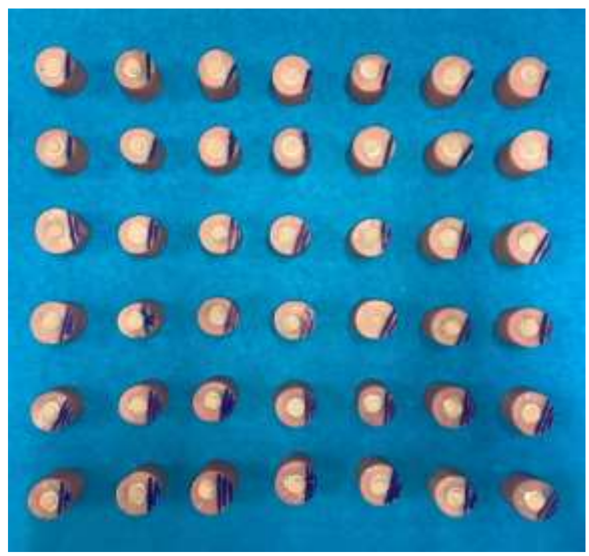

Figure 5: Bonded Specimens

A universal testing machine (Mecmesin Multi Test 10-i) [Figure 6] was used with a 10 kN load cell and a 1 mm/min crosshead speed to test the shear bond strength. [Figure 7]

Figure 6: Universal Testing Machine

Figure 7: Shear Bond Strength Testing of Group 1, Group 2a and Group 2b Specimens

Results

SPSS (Statistical Package for Social Sciences) version 20. (IBM SPASS statistics [IBM corp. released 2011] was used to perform the statistical analysis. The values obtained were subjected to ANOVA test to compare the shear bond strength among the groups with post hoc Bonferroni test for inter group comparison and the level of significance is set at 5%. Mean shear bond strength was high in Group 1- 243.55 ± 99.10 followed by Group 2B- 145.29 ± 34.16 and Group 2A- 127.78 ± 33.18. ANOVA test was applied to compare the shear bond strength among the groups. ANOVA test showed statistically significant difference among the groups (p=0.001).

Post-hoc Bonferroni test was applied for inter-group comparison. Statistically significant difference with respect to shear bond strength was seen between Group 1 and Group 2A; Group 1 and Group 2B (p=0.001) whereas, there was no significant difference seen between Group 2A and Group 2B (p=1.00)

Table 1: Comparison of the Mean Shear Bond Strength among the Groups Using Anova

Groups	N	Minimum	Maximum	Mean	S.D	p value
Group 1	14	128.1	421.8	243.55	99.10	0.001*
Group 2A	14	60.5	184.3	127.78	33.18	
Group 2B	14	89.7	201.3	145.29	34.16	

*Significant

Graph 1:

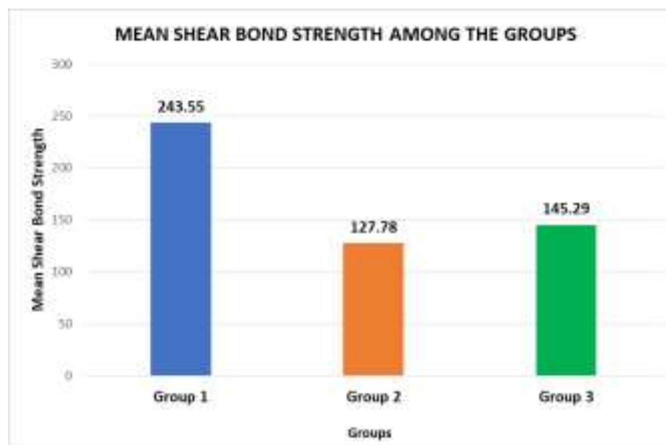

Table 2: Inter Group Comparison of the Shear Bond Strength Using Post-Hoc Bonferroni

	Mean Difference	p value	95% Confidence Interval	
			Lower Bound	Upper Bound
Group 1 Vs Group 2A	115.771	.001*	55.748	175.795
Group 1 Vs Group 2B	98.257	.001*	38.234	158.281

Group 2 Vs Group 2B	-17.51	1.00	-77.538	42.509

*significant

Discussion

Implant-supported prostheses are considered one among the most common prosthetic options for reconstruction of completely or partially edentulous patients. Gold alloys, titanium, and cobalt-chromium (Co-Cr) alloy are the commonly used framework materials for implant supported prostheses and RDPs and are conventionally fabricated by casting procedures or produced using a computer-assisted design/computer-assisted manufacturing (CAD/CAM) system. CAD/CAM technology makes it possible to machine-mill even large frameworks from prefabricated homogeneous blanks made of different materials. Recently, it has become possible to fabricate even large and complex frameworks for tooth and implant-supported prostheses by machine-milling zirconium dioxide (zirconia) ceramic blocks. Owing to its excellent biocompatibility, increased strength and inherent aesthetic properties, zirconium dioxide (zirconia) ceramics are being successfully used as a framework material for implant-supported all-ceramic restorations and implant abutments.[1]

PEEK is a high-performance thermoplastic polymer with good chemical, thermal, and mechanical properties, as well as excellent biocompatibility. A modified PEEK with 20% inorganic fillers has been used in dentistry for implants, temporary abutments for implant supported prosthesis, healing abutment, implant supported bars, clasp materials, or frameworks for removable and fixed partial prosthesis. The chemical aromatic structure of PEEK, which includes ketone and other components, creates an inert surface, resulting in inadequate bonding. As a result, surface conditioning processes such as etching or abrasive treatments must be used. Creating a micro retentive surface texture and applying a primer is crucial.[3]

Restoration with implant-supported fixed prosthesis in severely resorbed ridges results in an unesthetic long clinical crowns. Alternatives for restoring such deficient tissues include prosthetic restorations veneered with gingival-coloured materials. Denture base acrylic resins, feldspathic porcelain, and indirect composite materials have been used as gingiva-coloured materials in prosthetic gingival restorations.

In recent years, a gingiva-coloured indirect composite material has been used to replace lost tissue architecture overcoming the shortcomings of Gingiva-coloured porcelain such as fracture of layering porcelain, bulk of the prosthesis, limited reparability and shrinkage during firing. Indirect composite materials have several advantages such as, chairside repairability, absence of distortion during firing, and predictable clinical outcomes.[2]

A study was conducted to evaluate the shear bond strengths of two gingiva-coloured materials - an indirect composite material and a denture base acrylic resin to zirconia ceramics and to determine the effects of surface treatment with various priming agents. A gingiva-coloured indirect composite material (CER) and denture base acrylic resin (PAL) were bonded to zirconia disks with unpriming (UP) or one of seven priming agents namely, Alloy Primer (ALP), Clearfil Photo Bond (CPB), Clearfil Photo Bond with Clearfil Porcelain Bond Activator (CPB + Act), Metal Link (MEL), Meta Fast Bonding Liner (MFB), MR. bond (MRB), and V-Primer (VPR). Shear bond strength was determined before and after 5000 thermocycles. According to the results, it was concluded from this study that, for the denture base acrylic resin (PAL) specimens, bond strengths were significantly lower after thermal cycling in all groups tested and that, the MDP functional monomer was found to provide improved bonding of a gingiva-coloured indirect composite material and denture base acrylic resin to zirconia ceramics.[1]

A study evaluated the effect of various surface treatment methods on the shear bond strength between PEEK and gingival composite resin. Thirty-two specimens of PEEK milled with dimensions of 5x5x2mm were divided into four groups based on surface treatment used as: Sand blasting, Aluminium nitride nano particles, Hydrofluoric acid, Sulfuric acid. The specimens were observed in scanning electron microscope (SEM) after different pretreatments. Composite resin was luted over each surface treated PEEK specimen after application of visio. link primer. The shear bond strength was tested using universal testing machine and failure mode analysed under stereomicroscope. The mean shear bond strength found in sulfuric acid group (8.18 ± 1.42 MPa) was statistically significant ($p<0.05$) than those observed in hydrofluoric acid (5.27 ± 1.97 MPa), air abrasion (4.58 ± 1.32 MPa) and aluminium nitride nanoparticles (2.93 ± 1.04 MPa) groups. Stereomicroscopic evaluation showed adhesive and mixed bond failures. The results of the study concluded that, the highest values of shear bond strength in the sulfuric acid group.[3]

A study was performed to evaluate and compare the shear bond strength of the gingiva-coloured composite resin and the tooth-coloured composite resin to porcelain, metal and zirconia. Sixty cylindrical specimens were fabricated and divided into 6 groups as (Group 1-W: tooth-coloured composite bonded to porcelain, Group 1-P: gingiva-coloured composite bonded to porcelain, Group 2-W: tooth-coloured composite bonded to base metal, Group 2-P: gingiva-coloured composite bonded to base metal, Group 3-W: tooth coloured composite bonded to zirconia, Group 3-P: gingiva-coloured composite bonded to zirconia). The shear bond strength was measured with a universal testing machine after thermocycling and the failure modes were noted. The results of the study concluded that, the shear bond strength of the gingiva-coloured composite was not less than that of the tooth-coloured composite.[4]

A study was conducted to evaluate the durability of bond strength between an indirect composite material and zirconia ceramics after thermocycling and to assess the effect of various priming agents for zirconia surface treatments. Ninety-six zirconia disks were fabricated using CAD/CAM mailing as a bonding substrate. The specimens were randomly divided into six groups with sixteen specimens in each group and were treated with one of the following acidic priming agents, Alloy Primer (ALP, Kuraray), Clearfil Ceramic Primer (CCP, Kuraray), Clearfil Photo Bond (CPB, Kuraray), Clearfil Photo Bond with Clearfil Porcelain Bond Activator (CPB + Activator, Kuraray), Estenia Opaque Primer (EOP, Kuraray) and Porcelain Liner M Liquid A (PLA, Sun Medical). The specimens were bonded with an indirect composite material (Estenia C&B Dentin, Kuraray). Shear bond strengths were tested before and after 100000 thermocycles. The results of the study concluded that, application of a combination of hydrophobic phosphate monomer (MDP) and initiator could result in a durable long-term bond between Katana zirconia and Estenia C&B composite material.[6]

A study was performed which determined the shear bond strength (SBS) between an indirect gingival composite resin and glazed gingival porcelain after various surface treatments. A total of 176 porcelain disks with natural glazing were used and assigned to one of four groups as, no surface treatment, airborne-particle abrasion, hydrofluoric acid etching, or a combination of airborne-particle abrasion followed by hydrofluoric acid etching. Each group was divided into two subgroups as, one subgroup was unprimed, and the other was silanized. An indirect composite resin was then bonded to the porcelain disks. Half of the specimens in each group were exposed to 5000 thermocycles. Shear bond strength of all the specimens were measured. The results of the study concluded that, among the silanized specimens, those treated with the combination of airborne-particle abrasion and hydrofluoric acid etching exhibited the highest bond strengths both before and after thermocycling. Also, Airborne-particle abrasion followed by hydrofluoric acid etching with silane application yielded stronger, more durable bonds between the indirect gingival composite resin and glazed gingival porcelain.[11]

The present study was conducted aiming to evaluate and compare the bond strength of gingiva-coloured indirect composite resin to zirconia and PEEK framework materials. Forty-two samples of dimensions 10mm diameter and 2mm thickness were divided into three groups: Group 1 (n=14): Surface treated zirconia discs bonded to gingiva-coloured indirect composite resin, Group 2A (n=14): Surface treated PEEK discs bonded to gingiva-coloured indirect composite resin (only airborne particle abraded), Group 2B (n=14): Surface treated PEEK discs bonded to gingiva-coloured indirect composite resin (airborne particle abrasion & acid etching). Following the respective surface treatments for the zirconia & PEEK discs, gingiva-coloured indirect composite resin was bonded to the specimens. During bonding, a constant pressure was applied to all the specimens. Samples were then subjected to shear testing in a universal testing machine.

The results of this study showed that, the mean shear bond strength was high in Group 1- 243.55 ± 99.10 followed by Group 2B- 145.29 ± 34.16 and Group 2A- 127.78 ± 33.18. Statistically significant difference with respect to shear bond strength was seen between Group 1 and Group 2A; Group 1 and Group 2B (p=0.001) whereas, there was no significant difference seen between Group 2A and Group 2B (p=1.00).

The in-vitro design of this study, which lacked full oral simulation, is one of its main limitations. To ascertain the impact on other mechanical qualities including flexural strength and fracture toughness, more investigation is needed. Researches can also be conducted to assess the effect of combination of various surface treatments to improve the strength of gingiva coloured composite resin to PEEK.

Conclusion

Within the limitations of this study, it was concluded that PEEK had improved shear bond strength with gingiva coloured composite resin when it was subjected to combined airborne particle abrasion along with 98% sulfuric acid followed by priming with 10 MDP than the currently used method of airborne particle abrasion and priming with 10 MDP Primer. Further, the shear bond strength between PEEK with gingiva coloured composite resin when subjected to combined airborne particle abrasion and 98% sulfuric acid followed by priming with 10 MDP primer was comparable with the bond strength between zirconia and gingiva coloured composite resin when zirconia was primed with 10 MDP primer.

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