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Research Article

Degree of Wear of Human Enamel Caused by Three Different Types of Crown and Bridge Materials-A Comparative Evaluation

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Abstract

Purpose: The purpose of this in vitro study was to evaluate and compare the degree of wear of human enamel caused by metal ceramic, lithium disilicate glass ceramic and polyether ether ketone (PEEK).

Materials and Methods: Thirty test specimens (antagonists), 10 each of metal ceramic, lithium disilicate glass ceramic and PEEK were fabricated in the form of discs of 20mm diameter and 3mm thickness. Enamel specimens were prepared from 30 extracted human permanent premolars. Enamel specimens were abraded against each type of antagonists on a pin on disk wear tester under a constant load of 5kg (49N) at 30rpm for 4800cycles.

The mean loss of height of all the enamel specimens were measured at baseline and after 4800 cycles of wear with a profilometer. All the data was statistically analysed. The comparison between three groups was done by one-way ANOVO test for continuous data and followed by post-hoc multiple comparison test. All p-values less thsn 0.05 were considered statistically significant. The wear of both enamel specimens and antagonists was evaluated quantitatively with scanning electron microscopic images.

Results: Significant differences were found in loss of height among the three groups. The mean loss of height was found to be 1.177mm and standard deviation of 0.471 for metal ceramic group. The mean loss of height was found to be 0.927mm and standard deviation of 0.326 for lithium disilicate group. The mean loss of height was found to be 0.131mm and standard deviation of 0.074 for PEEK group. Statistically

significant differences were found when the enamel wear caused by PEEK was compared with metal ceramic and lithium disilicate glass ceramic. No significant difference was found when the enamel wear caused by metal ceramic was compared with lithium disilicate glass ceramic.

Conclusion: Within the limitations of this in vitro study, PEEK resulted in less wear of enamel when compared to metal ceramic and lithium disilicate glass ceramic. Metal ceramic and lithium disilicate increased the enamel surface roughness after wear testing.

Keywords: Human Enamel; Crown; Bridge; Evaluation

Introduction

Wear is an unavoidable aspect of restorative dentistry [1]. Wear of tooth structure is a natural and unavoidable consequence of tooth-on-tooth or tooth-on-restoration contact. However, this natural process may be hastened by the use of restorations whose wear qualities differ from those of the tooth structure against which they slide [2]. The mechanism of tooth wear involves the interaction of a number of elements, including mechanical stress resulting from compression, flexion, and tension, friction, and chemical impacts. Rarely do these elements operate alone; hence, the term multifactorial nature of hard dental tissue wear is most often employed [3].

Restoration of missing decayed or Disfigured dentition has been one of the major tasks of dentists all over the world. The materials chosen for tooth restoration must meet the fundamental criteria of durability, biocompatibility, and aesthetics. Metals were extensively employed in the past due to their unparalleled strength, but their aesthetic limitations led to the development of porcelain. In recent years, a paradigm change has been characterised by a greater emphasis on higher aesthetics, with ceramic being the prevalent trend [4]. Porcelain occlusal surfaces have exploded in popularity due to the need for aesthetics in dental restorative materials. This can have severe repercussions if the porcelain restoration opposes an enamel surface, as *in vitro* studies have consistently demonstrated enamel's accelerated wear against porcelain [5]. With the development of newer metal-free ceramics, the brittleness of ceramics was eliminated, but the enhanced strength remained a cause for worry because it contributed to the deterioration of opposing natural dentition. Despite the ongoing advancement of restorative materials, their abrasive effect on opposing natural dentition has never been entirely eliminated and remains a therapeutic problem. Ideally, a restorative material that replaces or opposes enamel should have comparable functional properties to enamel [6]. However, the search for a superior material has never ceased. Polyether ether ketone is one such substance that has recently made its way into the field of dentistry (PEEK). It is the most significant reflective of poly aryl ether ketone (PAEK). This substance is semi-crystalline thermoplastic. PEEK offers good chemical resistance and thermally stable mechanical characteristics.

Clinical testing is necessary for evaluating the complexity of oral wear, but they are costly and time-consuming. In addition, they do not permit the control of variables such as masticatory forces and oral conditions. Consequently, *in-vitro* mastication appears to be a viable method for evaluating the wear performance of emerging novel materials [7]. Using a two-body wear mechanism, the goal of this *in vitro* study is to examine and compare the wear behaviour of human tooth enamel against three different types of materials: metal ceramic, lithium disilicate glass ceramic, and polyether ether ketone.

Materials and Methods

Methodology

Fabrication of enamel specimens

This study used 30 non-caries, non-restored premolars with complete root formation. Teeth were then sterilised with thymol, cleansed with an ultrasonic scaler, and stored in a saline solution to prevent dehydration. A 15 mm x 10 mm x 10mm block of wax was made. From this wax block, a putty index was made. The teeth were im- mersed in self-curing acrylic resin so the occlusal surface was 5 mm above the resin. To create a single point of contact with the antagonists, the lingual cusp tips were shortened. Cusp points were reduced with a fine-grit diamond polishing bur. Polishing enamel samples using 400-grit SiC abrasive sheets. Tooth samples were randomly divided into three groups of 10 for abrasion vs antagonistic groupings

- **Group I:** To abrasively oppose PEEK
- **Group II:** Abrasive for lithium disilicate ceramic glass
- **Group III:** To abrade metal fused with porcelain.

Using a profilometer, the height of each enamel specimen was assessed prior to testing.

Specimen preparation

A stainless-steel die of dimensions 20mm in diameter and 3mm thickness was fabricated to form circular disc. Using the die, addition silicon mould was made. This mould was used to make wax patterns to fabricate metal ceramic and lithium disilicate specimens.

Test procedure

Wear tests were conducted on a pin on disc wear and friction test rig. It has a size-variable upper pin holder that is fixed. For this investigation, a 10mm to 12mm pin holder was utilised. The specimens of enamel were placed in the upper specimen holder. A screw within the slot was used to alter the vertical position of the specimen. The enamel specimen protruded at least 3mm from the holder's opening.

The lower part is equipped with a disc that rotates at the specified speed. For this study, a 165mm in diameter and 5mm thick metal disc was manufactured. To retain the test specimens, a 20mm-diameter, 3-mm-thick hole was drilled in the centre of a disc so that the test specimens could be securely seated in the revolving disc. The test samples were af- fixed to the disc, which was capable of rotational movement. Both specimens' contacting surfaces were made parallel to one another. With a load of 5kg (49N) and 30 cycles per minute for 4800 cycles, wear tests were conducted. In order to minimise friction during testing, the specimens were tested in distilled water. The water was replaced after each test to clear the wear track of debris.

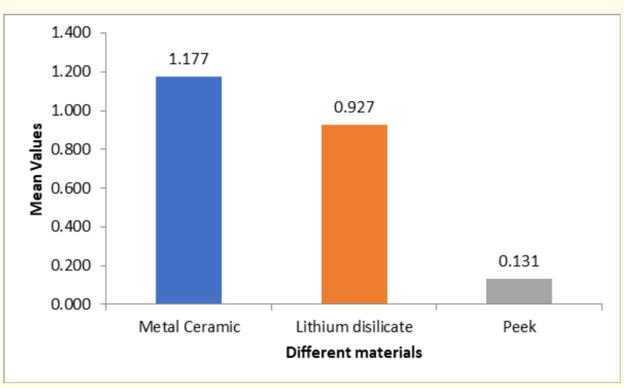
Using a profilometer, the height loss of each enamel specimen after testing was determined. The tooth samples were then put on the profilometer's work surface in the same orientation as the initial measurement. Adjusting the axis and remeasuring the height up to the base of the tooth, where it was lodged in the acrylic, allowed the reduction in height to be computed. For the qualitative evaluation of wear patterns, specimens of test materials and enamel were analysed using a scanning electron microscope.

A statistical analysis was performed on the results collected. Using Microsoft Excel and graph pad prism, data was evaluated. Mean SD was used to summarise continuous data. Three groups were compared using the one-way ANOVA/Kruskal-Wallis test for continuous data, followed by the post-hoc multiple comparisons test. All p-values less than 0.05 were deemed statistically significant.

Results

The height of teeth after 4,800 cycles of enamel wear were analysed with a profilometer. In all study groups, the height of tooth significantly reduced when compared to its initial height.

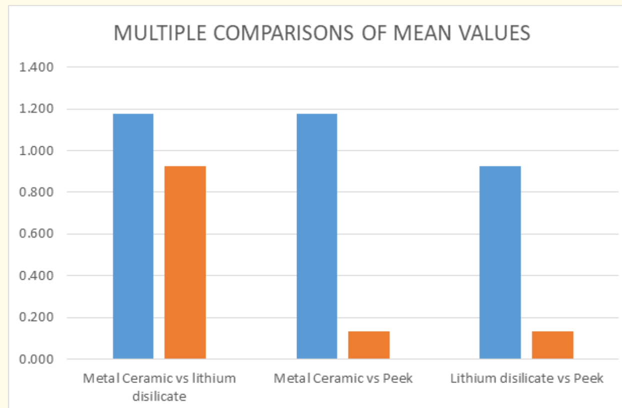
The minimum loss of height for glazed metal ceramic group was 0.616 and maximum was 1.705 while the minimum loss of height for mechanically polished lithium disilicate group was 0.528 and maximum was 1.683. The minimum loss of height for PEEK group was 0.05 and maximum was 0.297. Graph 1 depicts that metal ceramic group showed maximum loss of height followed by lithium disilicate group and PEEK showing the minimum loss of height.



Graph 1: Graphical bar diagram representation showing mean loss of height after 4800 cycles.

The mean loss of height was found to be 1.177 ± 0.471 for metal ceramic group. The mean loss of height was found to be 0.927 ± 0.326 for lithium disilicate group. The mean loss of height was found to be 0.131 ± 0.074 for PEEK group. Statistically significant difference was found between the groups with $p \leq 0.001$.

Post Hoc analysis was carried out to know which groups differed It revealed a significant difference between metal ceramic and PEEK groups ($P < 0.0001$). There was also significant difference observed between Lithium disilicate and PEEK groups ($P < 0.0001$). Graph 2 depicts the multiple comparisons of mean values. Metal ceramic and lithium disilicate shows no significant difference, metal ceramic and PEEK shows significant difference, and lithium disilicate and PEEK shows significant difference in their mean values. For the characterization of wear patterns, the test specimens and enamel specimens were evaluated by SEM at a magnification of 1.00 K X at 8.00 kV.



Graph 2: Graphical bar diagram representation showing multiple comparisons of mean values.

Figure 1 and 2 shows the SEM images of Metal ceramic at baseline and after 4800 cycles of wear testing. Figure 2 shows the roughened porcelain surface, varying wear depths and ploughed surface.

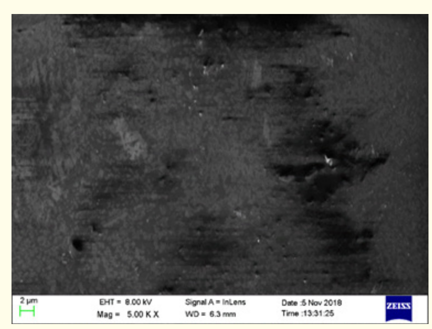


Figure 1: At baseline.
SEM images of metal ceramic

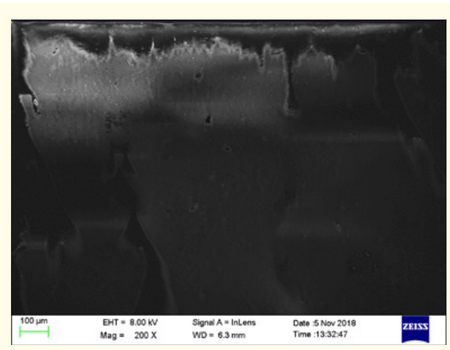


Figure 2: After 4800 cycles.
SEM images of lithium disilicate glass ceramic

Figure 3 and 4 shows the SEM images of lithium disilicate at baseline and after 4800 cycles of wear testing. Figure 4 shows loss of polished surface with crack propagation. The wear track region appeared smoother than the original surface. Figure 5 and 6 shows SEM images of PEEK at baseline and after 4800 cycles of wear testing. Figure 6 shows a comparatively intact surface with roughening of the surface.

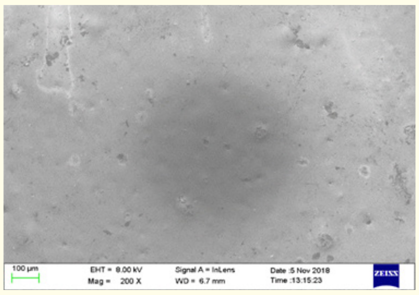


Figure 3: At baseline.

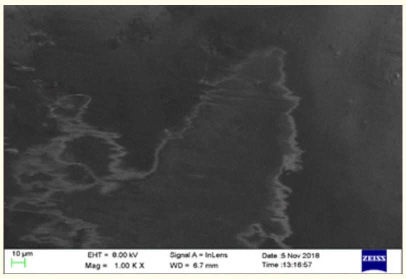


Figure 4: After 4800 cycles.

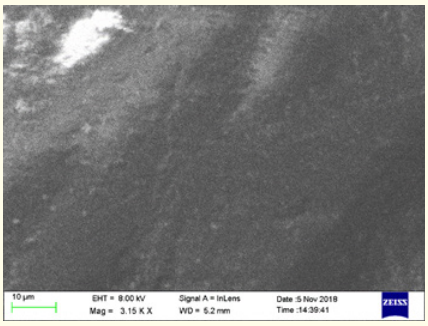


Figure 5: At baseline.
SEM images of PEEK

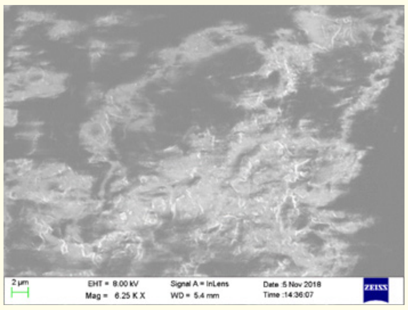


Figure 6: After 4800 cycles.

Figure 7 shows SEM of enamel antagonist to metal ceramic surface. The enamel surface shows cracks, ploughed surfaces with variable wear depths. Figure 8 shows SEM of enamel antagonist to lithium disilicate glass ceramic. The enamel surface shows a polished surface with microfracture. Figure 9 shows SEM of enamel antagonist to PEEK. Here the enamel surface hardly shows any wear, cracks or ploughed surface. There is an intact enamel surface.

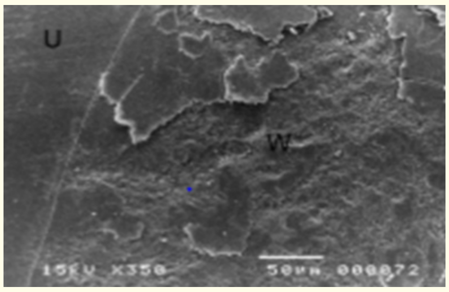


Figure 7: Enamel against Metal ceramic.
SEM images of enamel specimens

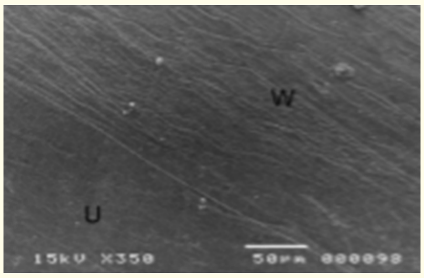


Figure 8: Enamel against Lithium disilicate.

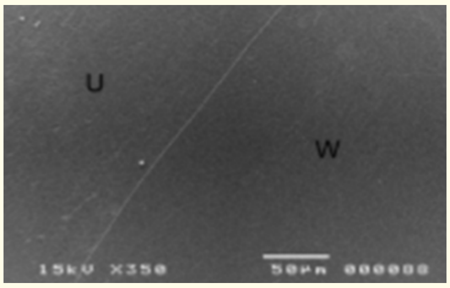


Figure 9: Enamel against PEEK.

Discussion

Physiological wear is the progressive, but slow decrease of cusp convexity, manifesting as flattening of posterior cusp tips and anterior mammelons. Restorations with different wear qualities than the replacement of tooth structure may affect wear rate. Dentists control whether restorative materials sustain physiologic or pathologic wear. Group function with a porcelain occlusion can cause greater wear than canine-guided mutually protected occlusion [1]. Consequently, it is necessary to evaluate the wear qualities of restorative materials and their possible abrasive effects on the opposing natural teeth. The patient must understand the long-term implications of the materials employed and viable alternatives before choosing a treatment regimen.

Clinical testing is the best way to estimate restorative materials' wear performance. *In-vivo* studies are time-consuming and expensive. Even great variation among subjects is unavoidable [8]. Laboratory examinations of wear behaviour using chewing simulators allow for comparable results with different materials under standardised conditions [9].

Phillips RW (1982) stated enamel's properties vary by tooth position and histological structure [10]. Because the enamel crystals in the head of the enamel rod are aligned parallel to the long axis of the rod, cuspal enamel is stronger and more resistant to forces in the direction parallel to the enamel rods. Since the purpose of this study was to evaluate the wear behaviour of enamel in a clinical context, only the cuspal points of the enamel specimens were retained in contact with the specimens.

According to Li and Zhou lubrication has an important effect during the wear process of enamel in the oral environment. Hence, distilled water was used and was renewed after each test which would aid in lubricating the contact surface, wash away debris, and reduce heat generation from abrasion, some wear debris may still stay in the wear track and influence contact stresses and wear, according to Fischer., *et al*. [11].

There is ample literature to describe how different ceramics affect enamel wear. Additionally, different polishing methods affect enamel wear in different ways [12]. Mechanical polishing of ceramic surfaces has been recommended by various studies as it results in less enamel wear than glazed surfaces. According to the previous research, the lithium disilicate group in the current study was mechanically polished using diamond burs, silicone polishing wheels, and polishing paste [13-19].

However, some ceramic particles are destined to gradually disappear from the contact area of the crown's surface due to antagonistic occlusal contacts [20]. The mechanical qualities and structural integrity of the ceramic layer, which makes up the load-bearing portion of the restoration, might be negatively impacted by wear behaviour in the oral environment [21]. Any wear factor, such as clenching or chewing, can result in surface and subsurface flaws. These defects may be the source of crack nucleation and propagation due to stress [22] and that this porcelain may become penetrated by these cracks, ultimately leading to the clinical failure of the restoration [23].

But there is always room for improvement, and PEEK is one such material that has entered the dental field. PEEK has advantages include strong polishing capabilities, minimal plaque affinity, and good wear resistance [24]. PEEK material has enhanced colour stability over PMMA and composites and exhibits less surface roughness when compared to composites [25]. The aforementioned factors led to the selection of polyether ether ketone (PEEK) as the present study's material of choice.

Etman., *et al*. (2008) [26] reported that the enamel wear against glass ceramic crowns was more (184.24μm) than that of feldspathic porcelain layering (149.70μm). Similar findings were found in the present study. The reason for more wear against glass ceramic was attributed to microfractures occurring in the core matrix.

In a study conducted by Silva NR., *et al*. (2011) [27], lithium disilicate glass-ceramic restorations showed that they were wear-resistant and wear-friendly to the opposite enamel in a manner similar to that of the feldspathic ceramics typically used for veneering metal-ceramic or ceramic crowns where as in the present study, feldspathic porcelain (metal ceramic) caused more enamel wear than glass ceramic.

In the study conducted by Rupawala., *et al*. (2017) [28] lithium disilicate showed greater wear with a mean of 0.23mm than the metal ceramic group, which showed a mean of 0.15mm, the results of which were in contradiction to the present study where metal ceramic showed greater wear than lithium disilicate glass-ceramic. The reason for more abrasion by Lithium disilicate was attributed to its higher crystalline content (70% volume), which may be a contributing factor to the increased abrasiveness of antagonistic tooth enamel.

However, scientific studies have demonstrated a poor correlation between material's hardness and the abrasive potential of ceramic materials on human enamel. Different surface treatments also play important roles in wear performance[14] for the same kind of material. According to many authors, after subjecting different specimens for the same duration of wear testing, glazed ceramic specimens exhibit much more enamel wear than those mechanically polished ones. Various studies reported [14,29] glazed surfaces caused more enamel wear than polished surfaces. Similar results were obtained in this study, where in polished lithium disilicate comparatively showed less enamel wear than glazed metal ceramic.

A possible explanation is that the glazed surface is quickly worn away to reveal the rough surface of ceramic beneath. This may occur due to chairside adjustments that are made before the cementation of the prosthesis or may also occur within a short period of function. The surfaces of all materials are rough at a microscopic level with sharp, rugged projections called asperities, which have a surface profile of peaks and valleys. The ceramic underneath the glaze has high asperities and owing to its high hardness value (1378-1354 Hv), tends to abrade the comparatively softer enamel opposite to it [28].

When choosing ceramic crowns for restorations, the wear behaviour should be considered among the most important factor because it is an irreversible and unavoidable process [30]. An appropriate wear resistance or a mild wear regime is able to guarantee the long-term stability of the ceramic restorations, when they are subjected to repetitive masticatory force in the mouth. In contrast, the severe wear of ceramic restoration is regarded as a significant cause, which lead to the failure eventually (Ren and Zhang 2014) [31]. As a result, the wear properties of ceramic restorations have a great influence on therapeutic outcome.

Polyetherether ketone is a newer material recently introduced in dentistry. Unfortunately, there are limited studies evaluating the clinical behavior of this material. In literature, studies based on stain resistance, color stability and surface roughness of PEEK material are limited. In present study, the overall results suggest that the lowest enamel wear was caused by PEEK probably because of low hardness as stated by Zok F., *et al*. (2007) [32].

In a study conducted by Hahnel S., *et al*. (2014) [33] significantly lower surface roughness was identified for PEEK after polishing them to high gloss using silicon carbide paper. Probably because of its lower surface roughness it caused less enamel wear.

Gediminas Skirbutis., *et al*. (2017) [34] stated that BioHPP has a great potential as framework material. This was a good alternative to Chromium-Cobalt frames for the patients with high aesthetic requirements. But in clinical situations the results might be different. Nowadays, there are many combinations of PEEK with other materials such as fibres, carbon or ceramics. However, more clinical research is necessary to find out the situation, because most of the studies have been carried out *in vitro*.

For the qualitative characterization of the wear patterns, the test specimens and enamel specimens were subjected to SEM. After the wear test, flattening of the enamel surface was found against each material.

The metal ceramic surface showed roughened porcelain surface and ploughed surface. Lithium disilicate glass ceramic showed loss of polished surface with crack propagation. The wear track region appeared smoother than the original surface. PEEK surface showed a comparatively intact surface with roughening of the surface.

According to Sripetchdanond J (2014) [35] the fracture toughness of the material is a key to the prevention of cracking. In addition, the microfracture mechanism is considered to be the dominant mechanism responsible for the surface breakdown of ceramics and the subsequent damage that a roughened ceramic surface can cause to enamel surface.

In the present study, rough porcelain surface or asperities originated probably after the glazed surface was removed exposing the underlying rough porcelain surface. The enamel wear occurred through hard filler protruding from the abraded matrix. This could probably be the reason for more enamel wear with metal ceramic.

The enamel surface against PEEK did not show any major difference. As the surface roughness of PEEK is less, enamel wear caused was less. This finding was in conformity with the study done by Hahnel S., *et al*. (2014) [33] who stated that PEEK showed significantly lower surface roughness after polishing them with SiC paper.

Regarding the methods of wear testing, the amount and duration of load, as well as velocity are some of the factors that influence the amount of enamel wear [36]. The greater the velocity at which the abrasive moves along the surface of the substrate, the greater the rate of abrasion also the greater the pressure applied the more rapid the abrasion. The lack of standardization found in wear-related literature is a problem [37]. Dissimilarities in the testing method may lead to a different outcome in any individual study, so it is difficult to directly compare the present result with various previous investigations [35].

Limitations of the present study include

Tooth tissue may show varying geometry or thickness of enamel and it may become brittle due to storage conditions. As a result, standardization of enamel specimens was not achieved. Sliding forces along with rotational forces can simulate masticatory cycle. In the present study pin on disk wear tester was used which exerted only rotational forces. No sliding forces were exerted. So masticatory action was not replicated. In present study, only mean loss of height values were determined. Other values like maximum surface roughness and maximum wear depth were not determined.

Conclusion

Within the limitations of this *in vitro* study, following conclusions were drawn

- PEEK has shown less wear of enamel when compared to metal ceramic and lithium disilicate glass ceramic.
- Polished lithium disilicate has shown to cause less wear.
- Enamel has shown crack propagation against ceramic whereas a smooth surface against PEEK.
- Further studies with larger sample size have to be done to come to a definitive conclusion.

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