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Original Research Article

The Influence of the Cervical Finish Line Designs on the Fracture Resistance of CAD/CAM Monolithic Zirconia Crowns, an in Vitro Study

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ABSTRACT

Background: One of the most common problems of all ceramic restoration is their fracture tendency under occlusal and lateral forces. The effect of different margin designs on the fracture resistance of monolithic fully contoured zirconia crowns has not been widely investigated.
Objective: This study conducted to compare the effect of two marginal designs namely Deepchamfer and Shoulder finish lines on the fracture resistance of Monolithic zirconia crowns.
Materials and methods: An experimental study done by preparing two identical acrylic first maxillary premolars, one with deep chamfer margin (Group I) and the other acrylic tooth prepared with shoulder finish line design (Group II) then taking ten impressions using Polyvinyl siloxane impression for each group followed by pouring the impressions to construct 20 epoxy resin dies. Scanning each epoxy resin die, scanned data transferred to CAD/CAM machine (Laserdenta, Germany) to fabricate the crowns. Checking of seating and marginal adaptation of each crown on its corresponding die then each epoxy resin die was seated in an acrylic base to facilitate fracture resistance testing and cementation of the crowns to their corresponding epoxy resin dies using self-adhesive resin cement then fracture resistance testing was done using Universal testing machine (Instron, USA) and the load was applied at the center of each crown. Data were collected, tabulated and statistically analyzed.
Results: Results showed that the highest fracture resistance values were recorded with Deep chamfer finish line.
Conclusion: Within the limitation of our study the following conclusion were drawn: Finish line design has a significant effect on the fracture resistance of all ceramic crowns. Deep chamfer finish line has a significant effect on increasing the fracture resistance of Monolithic zirconia crowns.

Key word: CAD/CAM, Fracture resistance, Deep chamfer finish line, shoulder finish line, all ceramic crowns, monolithic zirconia, fully contoured zirconia.

INTRODUCTION

Dental ceramics are materials that are used in construction of prostheses for damaged tooth structures or missing teeth. (Rosenblum & Schulman,1997)

In 1903, after many trials to improve the strength of feldspathic porcelain by addingAL2O3 by McLean make metal-free ceramics evolve and spread very quickly (McLean JW, 1903). Since 1965 many types of full ceramic systems have been improved and developed to meet the desires of both dentists and patients with high aesthetic characteristics and to be look like the natural teeth. However, because of some mechanical properties of these materials, such as brittleness, cracking, fracture resistance, wear resistance, low tensile

strength, and accuracy of the margin and repair difficulty, make them more limited in clinical use. (Sjogren G et.al 1999).

All Ceramic crowns offer the potential for excellent esthetics and biocompatibility which is more preferable for patients than restorations contains metal which bring more toxic chemicals and allergic reaction. In the past years this type of restorations has been used in there storations of premolars and molars. (Ferrance, 1992). Computer-aided design / computeraided manufacturing (CAD/CAM) technology improve the dental esthetic needs in the posterior area of the mouth by changing the designs. (Kassem & Atta, 2012)

The Possibility to fracture of all ceramic restoration in response to occlusal and lateral force is one of the most common problems in addition to the difference of color between the natural tooth and the ceramic restoration. (Cunningham.2005). Some of crown fractures happened due to the relatively low mechanical resistance of ceramic crowns may be due to increase of the biting forces which applied on the premolar and molar teeth and the inherent brittleness of ceramics. (Etemadi et.al. 2012) (Mclaren et.al. 2000)

All ceramic crowns fabricated by pressed ceramic technique showed better fracture resistance than the conventional porcelain veneering technique.

Pure zirconia is monoclinic structure at room temperature, and converted to a tetragonal structure during sintering at high temperatures. It transited from tetragonal to monoclinic phase during cooling. (Subbarao EC,1981) (Kisi & Howard, 1998)

This manner will cause a volume expansion, which lead to produce high compression stresses that make the material brittle. To have more stable crystalline phase add smallamounts of yttria (Y2O3), magnesia (MgO), calcia (CaO) or ceria (CeO). Addition of the seoxides can eliminate the transformation completely or partially from the tetragonal to the monoclinic structure during cooling after sintering and can prevent formation of any crack. (Garvie & Nicholson,1972) (Heuer AH et.al. 1986)

Coloration of monolithic zirconia restorations by applying three-zone coloring system. First zone, un-sintered restoration and only the cervical area of the crown brushed with the desired final color. After that the body of the crown is brushed with the desired body shade. Finally, the 3rd, characterization the occlusal area of the crown by effects shades. **(**Curran DJet.al. 2010)

After adjustment the shade of the milled crown, it is sintered in an oven for 6.5 hours at 1,560ºC. (Sato K et.al. 2010). Sintering converts the zirconia from tetragonal to monolithic phase which make the milled crown a great fracture resistance and breakage resistance.(Curran DJ et.al. 2010)

The liability to fracture of an all ceramic restorations depends on the fracture resistance of the material, finish line design and proper material thickness. (Devaud, 2005) It was suggested that shoulder, chamfer and deep chamfer finishing line designs are considered to be adequate for the fracture strength of all-ceramic restorations. (Roh et.al. 2013)

Some studies suggested radial shoulder preparation with fully Monolithic zirconia crowns and some others recommend deep chamfer margin for improving the fracture resistance.

Ezatollah et.al. 2011 evaluated the effects of two margins designs namely chamfer and deep chamfer finish line designs of zirconia core restorations and the results showed that two finish line designs have a strong fracture resistance that is more than biting forces so we could use both designs. But because of the more resistance to fracture tendency of chamfer margin, this finish line is recommended because its efficiency in biomechanical characteristic of posterior single all-ceramic restorations.

Jalali et.al 2015 compared the fracture resistance and adaptation of the margin in two preparation designs chamfer

and shoulder of zirconia based all ceramic restoration and the results showed that less aggressive finish line design and tooth preservation in all-ceramic restorations does not adversely affect the adaptation of margin and fracture strength of the restoration with shoulder or chamfer finish line designs.

Jalalian et.al. 2011 declared that shoulder margin has lower fracture resistance than chamfer finish line in all ceramic restorations. Jalalian et al. 2011 In another research study showed high fracture resistance of CAD/CAM zirconia posterior crowns with chamfer finish line compared to shoulder.

Cho et al. 2004 evaluated the effectiveness of different finish line designs on fitting margin and the resistance to fracture of composite reinforced ceramic restorations and the results showed that although marginal gap in shoulder finish line was lesser than in chamfer finish line but the resistance to fracture with chamfer finish line was significantly higher.

Di Lorio et.al. 2008 approved the fracture resistance of shoulder finish line design of the core of Procera all ceramic crowns are higher than that with chamfer finishes line design.

De Jager et al. 2005 fined that metal collar in posterior crowns with chamfer finish line design is more convenient than in all ceramic restorations. Rammersberg et al. 2000approved that chamfer finish line preparation (0.5mm) has the greatest stability for posterior all ceramic crowns.

Ahmadzadeh et.al 2015 approved that the two marginal designs chamfer and shoulder marginal have almost equal fracture resistance in of IPS e.max all Ceramic Restorations posterior single crowns.

Nina R et.al 2014 evaluate the effect of shoulder and deep chamfer finish lines on marginal Fitness of electroformed P.F.M. Restorations and find less gap in deep chamfer design than shoulder design and results approved using the deep chamfer design and electroforming for metal ceramic restorations lead to long term success of restorations.

Potikel et.al. 2004 Estimated the fracture resistance of restored teeth with many different types of all ceramic restorations and showed no significant difference among groups. They present that the fracture resistance of natural teeth restored with all ceramic restorations with shoulder finish line with one-millimeter depth and a round internal angle was similar to the other restoration types.

A Five-year clinical results of zirconia frameworks for posterior FPD, the over- all survival rate was found to be 73.9% with problems of marginal integrity, leading to secondary caries (21.7%) and de-bonding of ceramic (15.2%) being major causes of failure. (Sailer et.al. 2007)

Zirconia as a material has many advantages such as low bacterial adhesion to its surface, biocompatible to the patient, cementation technique is simple and good mechanical characteristic. However, increase durability of dental restoration is not only depends on mechanical properties of the restoration. Fitting of margin is highly important in the longevity of restoration; gaps in the margin can cause carious, resolution of cement, defected margins, changing of sub gingival microflora, periodontal destruction and periapical lesions leading to pulpal effect all these. (Tinschert et.al. 2001) (Beuer et.al. 2009)

Quality measures of zirconia dental crowns are limited compared to partial fixed dental prostheses which provide that both fractures of core and adhesive fractures (chipping) are clinical problems of zirconia. (Larsson & Wennerberg 2014) (Takeichi et.al. 2013) (Beuer et.al 2012)

Monolithic, fully anatomic contoured zirconia crowns have been considered as substitutional to porcelain veneered crowns to increase resistance to fracture and eliminate the incidence of the adhesive fractures. (Beuer et.al 2012) (Zhang et.al. 2013) (Guess et.al. 2013) (Bonfante et.al 2009) (Baladhandayutham et.al. 2015)

The occlusal thickness of CAD-CAM monolithic zirconia crowns not affect the risk of fracture resistance and the king of failure restoration; the occlusal thickness of CAD-CAM monolithic zirconia crowns can be minimum to 0.5mm with a sufficient strength to tolerate occlusal forces; CAD-CAM monolithic zirconia crowns can be used in molars with appropriate fracture resistance even in a thin thickness (0.5mm). (Sorrentino et.al.2016)

Conventional dual-cure resin cement indicated to be used in luting procedures because it is low soluble material with high mechanical and adhesive proprieties and before using dual cure cements pretreatment of the tooth root with an adhesive system is required. (Pedreira et.al 2009)

Pretreatment of the dentin not required with the recently developed self-adhesive resin cements because no need to use an adhesive system with these cement, they reduce the number of application steps, decreasing clinical treatment time and less technique sensitivity because it restricts procedural errors in the treatment steps. (Goracci et.al 2006) (Viotti et.al 2009)

Potiket et. al. 2004 found that using natural teeth in research have difficulties in standardization because of presence of large variations such as age of patient, anatomical variation and after extraction storage medium and time.

Nurdan et. al 2016 evaluate the effect of different die material on The fracture strength of CAD/CAM monolithic crowns using three types of die materials, the highest fracture resistant values showed with Ni-Cr alloy, dentin dies were the lowest and epoxy resin dissimilar fracture resistance with CAD/CAM crowns on dentin dies.

This study will be performed to compare the effect of finish line designs (deep chamfer finish line, shoulder finish line) on fracture resistance which can improve the mechanical performance of monolithic zirconia crowns clinically.

Aim of the study:

This study conducted to compare the effect of two marginal designs namely Deep chamfer and Shoulder finish lines on the fracture resistance of Monolithic zirconia crowns.

MATERIALS AND METHODS

Study design is experimental study conducted to compare the effect of finish line designs (deep chamfer finish line, shoulder finish line) on the fracture resistance of fully contoured monolithic zirconia crowns. This in vitro study conducted in Makkah UQU Dent lab by using two identical acrylic first maxillary premolars.

1. Materials used in this study:1. Monolithic zirconia blocks shade A2 (WHITEPEAKS/Germany), Self-adhesive resin Cement (Glass reinforced composite) (Colten/Whaledent), Epoxy resin material for construction of the dies CMB/Egypt (Kemapoxy 150 Solvent free transparent epoxy),

2- Methods:

On two identical acrylic first maxillary premolars, two different finish line designs were prepared. The first acrylic tooth was prepared with deep chamfer margin (1 mm depth) (Figure1)using a high speed contra angle with torpedo diamond bur degree of taper 10 degree axial reduction 1mm and occlusal reduction 1.5mm. Ten impressions were made using a Vinyl polyvinyl siloxane (Hannover, Germany). The impressions were poured using Epoxy resin (KEMAPOXY 150, Egypt) to create ten identical resin dies with deep chamfer margin (1mm). The second acrylic tooth was prepared with shoulder margin (1.3 mm depth) (Figure2)using a high speed contra angle with cylindrical diamond bur and degree of taper 10-degreeaxial reduction 1.5 mm and occlusal reduction 1.5mm, amount and uniformity of reduction was checked by putty index which was taken before preparation**.** Again Vinyl polyvinyl siloxane impressions were made and ten epoxy resin dies were created from these impressions. Each epoxy dies was

scanned and the data transferred to CAD/CAM machine. (Laserdenta, Germany) to fabricate the crowns. Three-dimensional laser scanning of each epoxy resin which then transferred into digital models.

Figure 1: Maxillary first premolar with deep chamfer finish line.
Figure 2: Maxillary first premolar with shoulder finish line.

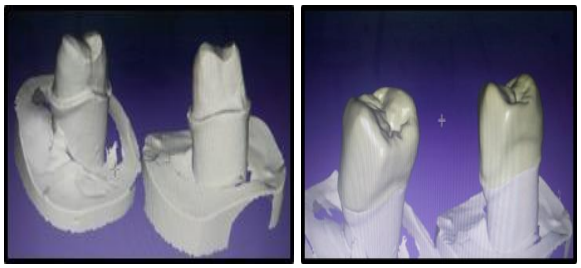

Figure 3: CAD/CAM Digital die.
Figure 4: CAD/CAM design.

Computer aided designing of the three dimensional image from the receptor unities carried out. CAD/CAM Software designed a full anatomical crown of maxillary first premolar (Figure3-4-5), The design produced with the CAD software are converted into milling strips for the CAM-processing and finally send to the 3-axis milling device which has degrees of movement in the three spatial directions. In X, Y and Z planes. The milling was done using dry milling technique. (Figure6)

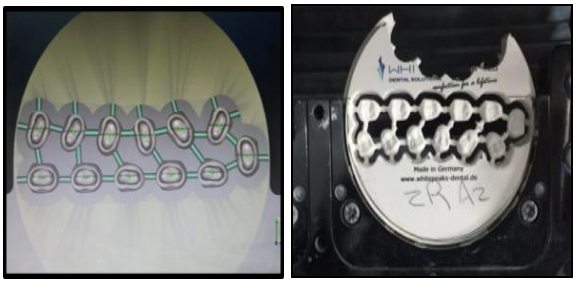

Figure 5: CAD/CAM Digital dies in zirconia block.
Figure 6: Crowns after milling.

Figure 7: TABEO sintering machine.
Figure 8: Checking of seating of each crown on its corresponding epoxy resin die.
Figure 9: Epoxy resin die fixed in acrylic base.

After milling fabricated crowns were finished by sintering and glazing using TABEO glaze material (NV mihmvogt, Germany) (Figure7) Checking of seating and marginal adaptation of each crown on its corresponding die (Figure8) Then each epoxy resin die was seated in an acrylic base to facilitate fracture resistance testing (Figure9) and cementation of the crowns to their corresponding epoxy resin dies using self-adhesive resin cement (Figure10) and pressing with even force by cementation device with one Kg load for 20 seconds then curing by LED curing light device 20 seconds (OSKADENTAL, Osaka) (Figure11) Then fracture resistance testing were done using Universal testing machine (Instron, USA), athin rubber sheet was applied on the occlusal surface to prevent slippage of the testing machine tip and the

load was applied at the center of each crown (Figure12). Data were collected, tabulated and statistically analyzed.

Statistical Analysis

Statistical analysis was performed by Microsoft office 2013 (Excel) and Statistical package for social science (SPSS) Version 20.

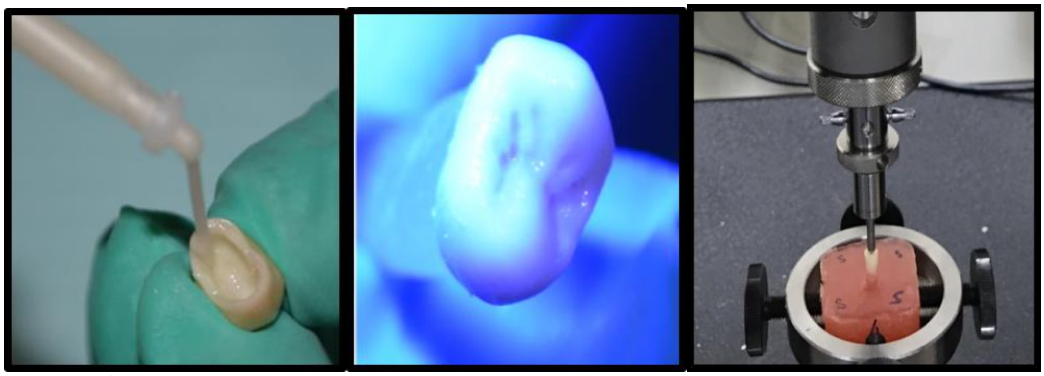

Figure 10: Apply self-adhesive resin cement.
Figure 11: Curing cement by LED curing light device.
Figure 12: Universal testing machine.

RESULTS

Quantitative Data were presented as mean, standard deviation (SD) range and 95%Confidence Interval (95% CI) values. All Fracture resistance data showed parametric distribution using student's t-test to compare between the two means of finish line designs.

The significance level was set at $P \leq 0.05$.

Descriptive statistics

Table (1): Descriptive statistics (Range, minimum, maximum mean and standard deviation) data of two finish line designs:

	N	Range	Minimum	Maximum	Mean	Std. Deviation
Deep chamfer finish line	10	1396.70	2121.32	3518.02	3070.7240	415.17818
Shoulder finish line	10	443.38	2020.35	2463.73	2287.5730	144.49961
Valid N (listwise)	10					

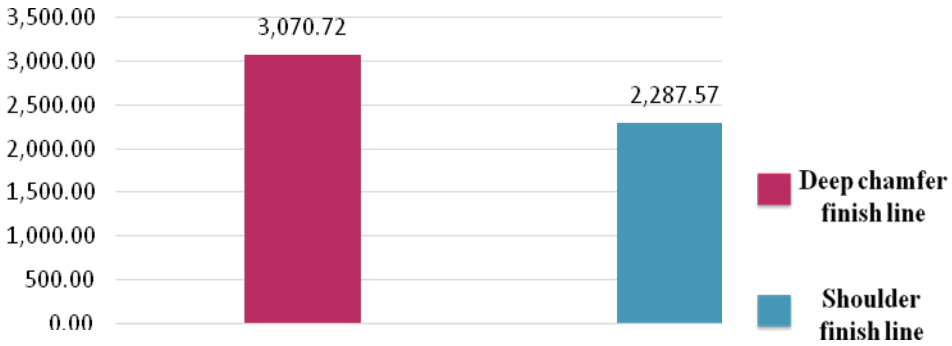

Figure 13: Bar-chart showing Mean values for Fracture resistance of Deep chamfer and Shoulder finish lines:

The highest mean fracture resistance value was with deep chamfer finish line .The lowest fracture resistance value was with shoulder finish line.

Table (2): Mean, Standard deviation (SD), Std. Error Mean and 95% Confidence Intervaldata of the fracture resistance of paired data.

		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference	
					Lower	Upper
Pair 1	Deep chamfer finish line – Shoulder finish line	783.15100	495.21707	156.60139	428.89405	1137.40795

Table (3): Student t-test between monolithic zirconia crowns with two different finish line design:

Deep chamfer finish line - Shoulder finish line	t	Degree of Freedom	P Value Sig. (2-tailed)
	5.001	9	(.001)*

(*) Related to significant difference that's mean the p-value <0.05 in correlation between two groups.

DISCUSSION

All Ceramic crown had esthetics and biocompatibility advantages which made them more favorable by patients than metal crowns as they had color and biological risk and in the past years had been used in the restorations of premolars and molars. (Ferrance, 1992). Liability to fracture of all ceramic restoration under occlusal and lateral forces was one of the most common problems. (Cunningham.2005). The introduction of computer-aided design/ computer-aided manufacturing (CAD/ CAM) technology improved the esthetic needs in dental restorations by modifications of the designs and used in new treatment modalities. (Kassem & Atta, 2012)

Zhang et al. found that monolithic zirconia ceramics were more superior in chipping and resistance to fracture in comparison to glass-infiltrated zirconia, lithium disilicate and veneering porcelain. In this study the effect of deep chamfer add shoulder finish line designs in CAD/CAM Monolithic fully contoured zirconia crowns was investigated. Preparation of finish line design done on two identical acrylic teeth representing upper first premolar, the extracted natural teeth was not chosen because they have more chipping tendency during preparation, the absence of identical natural teeth. After preparation of the two finish line design impressions were made using a Vinyl polyvinyl siloxane it has long working time and high accuracy and recording fine details then pouring these impressions by Epoxy resin to create identical resin dies. Using Epoxy resindies helped to control and standardize the accuracy of the preparation and the results of fracture resistance as it has approximately similar modulus of elasticity to dentin. Theim pressions were poured ten with deep chamfer and ten with shoulder finish line. Followed by fabrication of the crowns using The CAD/CAM software which aid to increasing the designs accuracy starting by accurate Laser scan digital impression drawn exact dimensions of preparation into a computer then designing anatomical features of fully contoured upper first premolar. The CAD/CAM software display 3D image of the crown, and using 3-axis for milling the crowns by dry milling technique of Monolithic zirconia blocks shade A2 to fabricate the fully contoured crowns. Monolithic zirconia blocks were used because of their high resistance to chipping and fracture in comparison with veneered zirconia. And drymilling provides short milling time, minimal material costs and no moisture absorption by the monolithic zirconia so no initial drying times prior to sintering of the crowns and the last steps sintering and glazing of the crowns using TABEO high-quality technology. After completing the construction of the crowns. Checking of seating and marginal adaptation of each crown on its corresponding die then each epoxy resin die was seated in an acrylic base to facilitate holding a small die in position during fracture resistance testing on universal testing machine. Cementation of the crowns to their corresponding epoxy resin dies using self-adhesive resin cement as it has less bonding steps than total etch. Cementing device with one Kg load was used to ensure uniform seating for all crowns on their corresponding dies. To ensure complete setting of the cement light cure device was used for20 seconds for each surface. Then fracture resistance testing was carried out using Universal testing machine. To avoid slipping of the crown during testing a small piece of rubber placed on the top of the occlusal surface of each crown during testing. Regarding the finish line design there was a statistically significant difference between Deep chamfer and Shoulder finish line (p-value<0.05) of fully contoured monolithic zirconia crowns. In agreement with the results, Jalalian et.al.

2011 which declared that shoulder margin has lower fracture resistance than chamfer finish line in all ceramic restorations in comparison with chamfer. Jalalian et al. 2011. In another research study showed high fracture resistance of CAD/CAM zirconia posterior crowns with chamfer finish line compared to shoulder. De Jager et al. 2005 find that metal collar in posterior crowns with chamfer finish line design is more convenient in all ceramic restorations. Rammersberg et al. 2000 approved that chamfer finish line preparation (0.5mm) has the greatest stability for posterior all ceramic crowns. Cho et al. 2004 evaluated the effectiveness of different finish line designs on fitting margin and the resistance to fracture of composite reinforced ceramic restorations and the results showed that although marginal gap in shoulder finish line was lesser than in chamfer finish line but the resistance to fracture with chamfer finish line was significantly higher.

On the other hand, Di Lorio et.al. 2008 approved the fracture resistances of shoulder finish line design of the core of Procera all ceramic crowns is higher than that with chamfer finish line design. Potikel et.al. 2004 Estimated the fracture resistance of restored teeth with many different types of all ceramic restorations and showed no significant difference among groups. They proved that the fracture resistance of natural teeth restored with all ceramic restorations with shoulder finish line with one-millimeter depth and a round internal angle was similar to the other restoration types. Jalali et.al 2015 compared the fracture resistance and adaptation of the margin in two preparation designs chamfer and shoulder of zirconia based all ceramic restoration and the results showed that less aggressive finish line design and tooth preservation in all-ceramic restorations does not adversely affect the adaptation of margin and fracture strength of the restoration with shoulder or chamfer finish line designs.

Ahmadzadeh et.al 2015 approved that the two marginal designs chamfer and shoulder marginal have almost equal fracture resistance in of IPS e.max all Ceramic Restorations posterior single crowns. A Five-year clinical results of zirconia frameworks for posterior FPD, the over- all survival rate was found to be 73.9% with problems of marginal integrity, leading to secondary caries (21.7%) and de-bonding of ceramic (15.2%) being major causes of failure. (Sailer I et.al. 2007)

Further studies will be needed to test the effect of different margin design on the marginal adaptation of different all ceramic crowns and its effect on fracture resistance.

CONCLUSION

Within the limitation of our study the following conclusions were drawn:

1. Finish line design has a significant effect on the fracture resistance of all ceramic crowns.
2. Deep chamfer finish line has a significant effect on increasing the fracture resistance of Monolithic zirconia crowns.

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