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Evaluating shear bond strength of ceramic laminate veneers bonded to eroded teeth - an *in vitro* study

Ocena siły wiązania licówek ceramicznych z zębami z erozją – badanie *in vitro*

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Summary

Introduction. *Dental erosion is a debilitating condition that is commonly encountered in our everyday clinical practice due to the high consumption of acidic beverages, yet very little is known about the shear bond strength of these laminates bonded to eroded teeth.*

Aim of the study. *To evaluate the shear bond strength of ceramic laminate veneers bonded to eroded teeth.*

Material and methods. *This in vitro study was conducted in the Department of Prosthodontics on ceramic laminate veneers bonded to eroded teeth. The sample size was estimated using G power software. With 80% power of the study the sample size was estimated as a minimum of 23. Thirty extracted teeth specimens of premolars and incisors were collected, washed with saline and then immersed in 200 ml of soft drink beverage for a period of 14 days. To conduct necessary testing the samples were vertically embedded in acrylic resin (polymethyl methacrylate). Impressions of the specimens were taken and casts were prepared. Then, patterns of a uniform thickness of 0.5 mm, diameter of 2 mm and height*

Streszczenie

Wstęp. *Erozja zębów to wyniszczający stan, który jest powszechnie spotykany w codziennej praktyce klinicznej ze względu na duże spożycie kwaśnych napojów. Niewiele wiadomo na temat wytrzymałości wiązania na ścinanie tych laminatów połączonych z zerodowanymi zębami.*

Cel pracy. *Ocena wytrzymałości wiązania na ścinanie licówek z laminatu ceramicznego przytwierdzonych do zerodowanych zębów.*

Materiał i metody. *Niniejsze badanie in vitro przeprowadzono w Zakładzie Protetyki Stomatologicznej na licówkach z laminatu ceramicznego przyklejanych do zerodowanych zębów. Wielkość próby oszacowano za pomocą oprogramowania G power. Przy mocy badania 80% wielkość próby oszacowano na minimum 23. Pobrano 30 usuniętych zębów przedtrzonowych i siekaczy, przemyto solą fizjologiczną, a następnie zanurzono w 200 ml napoju bezalkoholowego na okres 14 dni. W celu przeprowadzenia niezbędnych badań próbki zatopiono pionowo w żywicy akrylowej (polimetakrylanie metylu). Pobrano wyciski i przygotowano odlewy otrzymując jednakową grubość 0,5 mm, średnicę 2 mm i wysokość 4 mm. Następnie*

of 4 mm were fabricated. The obtained samples were tested.

Results. *The mode of failure was checked for all the samples and it was found that 63% of the samples had adhesive failures, 26% had cohesive failures and 10% had mixed failures.*

Conclusions. *Shear bond strength of ceramic laminate veneers bonded to eroded teeth using carbonated beverages with no preparation was found to be low. which can be considered inadequate to withstand the loads occurring in natural dentition.*

próbki zostały poddane testom.

Wyniki. *Wszystkie próbki sprawdzono pod kątem defektów i stwierdzono, że 63% próbek miało uszkodzenia adhezyjne, 26% uszkodzenia kohezyjne, a 10% uszkodzenia mieszane.*

Wnioski. *Stwierdzono, że wytrzymałość wiązania na ścinanie licówek z laminatu ceramicznego mocowanych do zębów zerodowanych po ekspozycji na napoje gazowane bez opracowania jest niska, co można uznać za niewystarczające względem obciążeń występujących w uzębieniu naturalnym.*

Introduction

In recent years, there has been a lot of discussion and research on tooth wear, and dental erosion in particular. According to one research evaluating the prevalence of tooth wear in adults, it varies from 3% in those under 20 to 17% in those over 70 years old. According to another epidemiological survey, 29% of young individuals displayed symptoms of tooth wear, with 3% having significant wear. Since erosion and attrition frequently impact worn teeth, tooth wear is typically multifactorial, making the term "erosive tooth wear" (ETW) an adequate description in many clinical situations.[1]

One of the most common treatment options for younger patients reporting to the dental practitioner with erosive tooth wear is ceramic laminate veneers.

The earliest description of porcelain laminate veneer bonded to enamel dates back to the early 1980s.[2] Porcelain laminate veneers (PLV's) have evolved into a routine procedure in the treatment of the anterior teeth due to its aesthetic appeal, durability and biocompatibility. The traumatised and broken teeth can also be restored with ceramic veneers.[3]

The tooth surface and morphology, ceramic thickness, the kind of cement used and preparation geometry all have an impact on the long-term prognosis of ceramic veneers.[4] Numerous problems, including marginal discoloration, postoperative sensitivity, fracture and debonding, might make porcelain veneers less likely to succeed.[5]

Window preparation, butt joint incisal preparation, and incisal lapping preparation are three different typical preparation designs for a laminate veneer. Most commonly used designs are incisal and incisal lapping preparations.[6] With the advancement of dental ceramic methods, veneers can now be made with a thickness of 0.3 to 0.5 mm, minimizing the amount of tooth reduction.[7] Patients only become aware of their dental problem (aesthetic awareness) when the labial tooth structure, which has been undermined by the destructive combination of erosion and the focal attrition of the antagonistic teeth, fractures off and the clinical crowns suddenly appear extremely reduced in length. As a result, people only seek out therapy on their own after severe damage has already occurred and expensive restoration procedures are necessary. One patient in the famous study conducted in the University of Geneva by *Francesca* et al, studying the use of no prep and minimal prep veneers for patients with dental erosion in the year 2013, showed a facial veneer break at the mesial surface level of a central incisor.

At the one-week follow-up, the fracture was found after the restoration was delivered. The reason stated for the failure was that due to the present trend of minimal tooth preparation, the corresponding veneer was incredibly thin. Critical stress concentrations between the adhesive interface and the ceramic subsurface may have occurred as a result of polymerization shrinkage of the luting composite, necessitating expensive restorative procedures.[8]

Even until now, there is an insufficient number of studies discussing the direct implications of acidic erosion and its subsequent effects on the bond strength of the ceramic veneers used. Although there are many studies such as the "Geneva study" that discuss the use of minimally invasive or no-prep options for the treatment of such cases with extensive erosion, these studies do not give the clinician an exact value to determine the shear bond strength of the teeth subjected to erosive tooth wear since they are *in vivo* studies. Although there are a few *in vitro* studies reporting the values of shear bond strength of laminates bonded to teeth after minimal preparation, there are no studies reporting these values after the teeth have been subjected to erosion. No-prep veneers are repeatedly discussed in literature, especially for teeth that have undergone damage due to dental erosion as it would conserve the existing tooth structure, but the cost borne by the patients for these laminates is quite high. Hence the knowledge of shear bond strength of ceramic laminate veneers bonded to eroded teeth is of paramount importance. Thus this *in vitro* study was conducted to find out the value of shear bond strength of no-prep ceramic laminate veneers bonded to eroded natural teeth.

Aims and objectives of the study

To evaluate the shear bond strength of ceramic laminate veneers bonded to eroded teeth.

To determine the type of failure mode – cohesive, adhesive or mixed.

Null hypothesis: Erosion of teeth has no effect on the shear bond strength of ceramic laminate veneers.

Alternative hypothesis: Erosion of teeth has a significant effect on the shear bond strength of ceramic laminate veneers.

Materials and methods

This *in vitro* study was conducted in the Department of Prosthodontics.

Methodology

Sample size estimation: the sample size was estimated using G power software. With 80% power of the study the sample size was estimated as a minimum of 23.

Preparation of the sample

Thirty extracted specimens of premolars and incisors were collected, washed with saline and then immersed in 200 ml of soft drink beverage for a period of 14 days, after which time they were cleaned and washed thoroughly. Then they were patted dry and prepared for further analysis. To conduct necessary testing the samples were vertically embedded in acrylic resin (polymethyl methacrylate) (Fig.1).

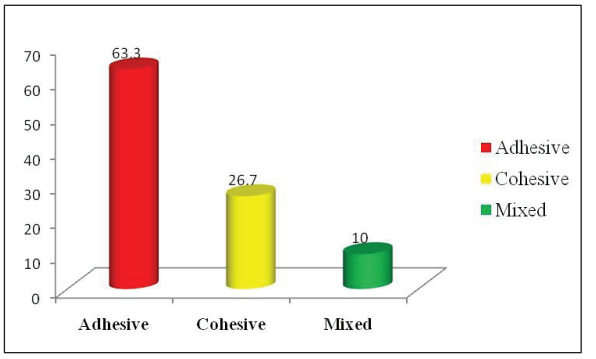

Fig. 1. Samples embedded in acrylic resin for testing.

Fabrication of ceramic laminate veneers

For all groups an impression was taken for each prepared tooth with vinyl polysiloxane

impression material (Panasil A-silicon; Germany) according to the manufacturer's instructions. The impression procedure involved first placing a wax spacer with a tissue stop and then constructing a tray for each individual tooth using self-curing acrylic with vent holes created on the tray. The double mix single impression technique was adopted with a type IV dental stone for pouring. Two coats of different colored die spacers were applied on the stone cast: one was master silver (13µ) and the other master gold (13 µ) since two coats are the recommended thickness of die spacer for laminate veneers.[9] Porcelain veneer wax patterns were fabricated for all the groups. The wax patterns were fabricated using Geo Crowax, Renfert, beige, opaque at a uniform thickness of 0.5 mm and diameter of 2 mm and height of 4 mm. Thickness was verified at three locations: cervical, middle and incisal using a wax gauge. Then invested using ivoclar pressvest investment powder. Placed in the burnout furnace at 845°C for 45 minutes. The investment and an ingot of IPS e.max press was transferred to the furnace and automatically pressed (press programme Emax press LT).

Tooth surface treatment

All the teeth were cleaned with pumice slurry, rinsed, and dried. Scotchbond™ Etchant gel was applied to the tooth surface for 15 seconds and then rinsed for 10 seconds. Excess water was blotted leaving tooth moist. Using a fully saturated brush tip for each coat, two consecutive coats of Adper Single Bond Plus Adhesive were applied, then dried gently for 2-5 seconds.

Veneer treatment

Bonding surface of the veneer was etched by applying Scotchbond™ Etchant for 15 seconds, then rinsed and dried. A single coat of the RelyX™ Ceramic Primer was applied to the bonding surface of the veneer for 60 seconds and dried. One coat of adhesive was applied to the bonding surface of the veneer. Gently dried for 2-5 seconds. RelyX Veneer Cement was applied, the excess cement was "tack-cured" for easier clean-up. Each area and margin of the veneer was light-cured for 30 seconds. All the samples were cured with the same protocol as mentioned and prepared for testing (Fig. 2).

Testing shear bond strength

Each specimen was mounted on a metal holder in the Zwick Roell universal testing machine. All the specimens were tightened and stabilized to ensure the loading pin was positioned properly on the ceramic veneer, i.e. 1 mm from the incisal edge and at 90° angle to the palatal surface of the teeth. The load was applied at a crosshead speed of 0.5 mm/min until the failure occurred. The ultimate load leading to failure was recorded in Newton (N) (Fig. 3).

Testing the mode of failure. The mode of failure was ascertained using stereomicroscope

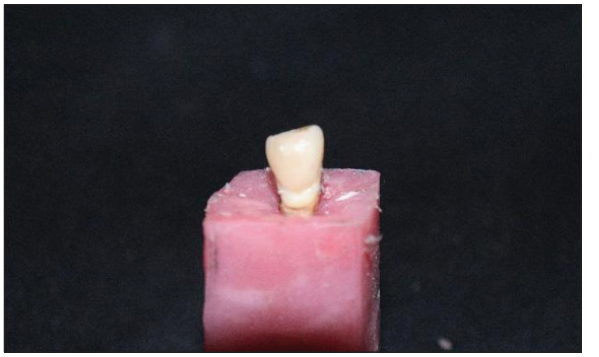

Fig. 2. Sample with bonded veneer.

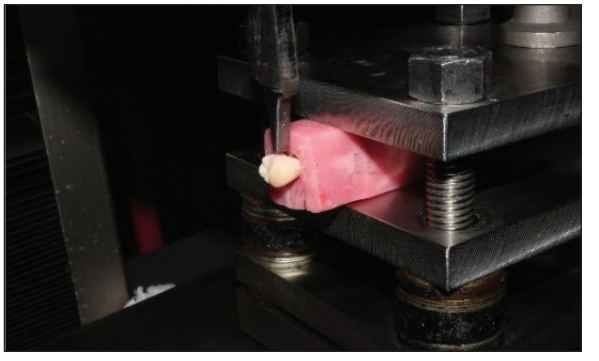

Fig. 3. Shear bond testing using universal testing machine.

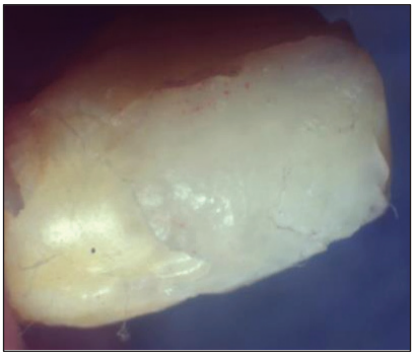

Fig. 4. Cohesive failure.

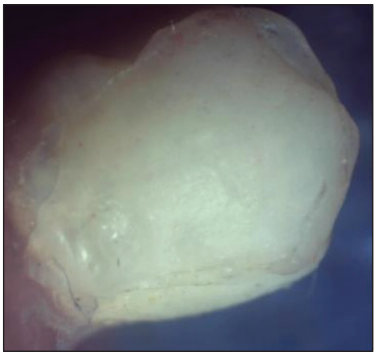

Fig. 5. Adhesive failure.

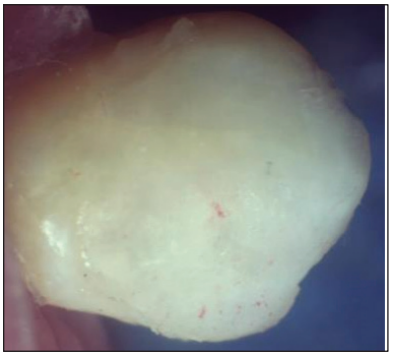

Fig. 6. Mixed failure.

at 30X magnification. The mode of failure was classified as adhesive, cohesive or mixed (<40% of interface), according to the classification by *Scherrer* et al.[10] The area of fracture was determined using an imaging software.

Statistical method for analysis

The data was analysed using the G power software version 3.1. The numerical data is presented by mean and standard deviation. The mean of the samples was found to be 13.5 MPa.

Results

The statistical analysis as depicted in Table 1 revealed an average mean shear bond strength of 13.5 MPa with a standard deviation of 0.59 MPa a maximum value of up to 22.9 MPa and minimum of 7 MPa in the samples tested.

The mode of failure was checked for all the samples and it was found that 63% of the samples had adhesive failures (Fig. 5), 26% had cohesive failures (Fig. 4) and 10% had mixed failures (Fig. 6) (Graph 1).

Discussion

Dental erosion is a debilitating condition that affects the second-largest microbiome in the body, but one thing that sets it apart from dental caries is that it is described as having no bacterial involvement. G.V. Black predicted that tooth degradation was less common than 0.1% as early as 1908. Although he cited several potential aetiologies of developmental, systemic or extrinsic origins, he hypothesised that the origin may be inherited. The situation has undergone a substantial change now as recent epidemiological research conducted in the past 20 years has revealed that a significant portion of young people exhibit symptoms of tooth erosion. Erosive tooth wear is nevertheless more common than it used to be, particularly in younger age groups. The primary reason for this phenomenon is a shift in dietary practices and lifestyle; but, what about variables like taste preference modifications, greater prosperity, and the addition of acids to confectionery items that may have affected these dietary practises and lifestyles.[11]

Table 1. Shear bond strength of ceramic laminate veneers bonded to eroded teeth

	N	Range	Min.	Max	Mean	Mean Std. Error	Std. Deviation	Variance
Shear bond strength (MPa)	30	15.9000	7.0000	22.9000	13.556667	0.5926695	3.2461843	10.538

Regular consumption of soft drinks or sports drinks intensifies tooth caries and enamel eroding activities. Carbonated beverages weaken the surface hardness of enamel, dentine, and composite restorations, while soft drinks are said to have lower pH values and diminished buffering capabilities.[12] In the present study, teeth were submerged for 14 days since it is challenging to estimate the degree of oral exposure to soft drinks, with the exception of individuals who consume them continually. But there are certain predictions that can be made. The overall exposure time to beverages is 22,750 seconds (380 minutes or 6.3 hours) per year based on an average daily soft drink consumption of 25 ounces and a residence time in the mouth of five seconds. Before salivary clearance occurs, the length of a beverage's contact to the dentition is more likely to be around 20 seconds, so that the annual exposure to dental enamel to soft drinks is roughly 90,000 seconds (1,500 minutes or 25 hours). A fair time frame for assessing the potential enamel assault is 336 hours of testing, which corresponds to around 13 years of typical beverage intake.[13]

An *in vivo* study by *Beier US* et al. which evaluated the failures of PLV's for up to 20 years reported that failure rate for laminate restorations on non-vital teeth was substantially higher.[14]

Hence the use of this minimally invasive option for severely eroded teeth can be considered questionable. The first objective of our study was evaluating the mean shear bond strength of ceramic laminate veneers bonded to eroded teeth and the value obtained is 13.5 MPa. It has been reported that shear bond strength of adhesives to enamel should be at least 20 MPa to adequately compensate for the stresses caused by polymerization shrinkage of composite resin. *Öztürk E* et al. in the year 2011 studied the shear bond strength of ceramic laminates bonded to varied levels of enamel and dentine and reported values as low as 5.5 MPa when the veneers were bonded to dentine and upon bonding to enamel it was as high as 24.76 MPa.[15] The parameters used in the study conducted by *Öztürk E* et al. were similar to our study in terms of the type of adhesive used but they did not study the effects of dental erosion. With dental erosion the SBS was 13.5 MPa, which implies that the null hypothesis can be rejected and alternative hypothesis is accepted as after being exposed to dental erosion the value of shear bond strength went to 13.5 MPa in comparison to 20-22 MPa in the relyx veneer cement group upon bonding to dentine and enamel-dentine complex respectively. This decrease is thought to result from the tubular occlusion by mineral salts, preventing resin tag formation. In an *in vitro* study conducted in 2022, it was reported that the highest SBS 19.93 for 100% enamel, 19.03 MPa followed by 80% enamel, 18.44 for 60% enamel, 18.18 for 50% enamel, 17.83 for 40% enamel and 11.3 MPa for 20% enamel group. The lowest SBS (9.63 ± 3.46 MPa) was detected in 0% enamel group, but they did not study the effects of dental erosion. The values reported in the study conducted by *Zhu J* et al. cannot be clinically correlated in cases of patients with erosive tooth wear as it is not possible to know the amount of enamel or dentine remaining in a patient affected by this condition.[16] The second objective was determining the mode of failure and it was found to be predominantly adhesive; this occurs when the bond strength of the adhesive to the surface of the tooth is lower resulting in the failure of the adhesive interface but the laminate as well as the tooth are intact. This shows that once the tooth is subjected to dental erosion the bond strength of the adhesive to the tooth becomes lower. This is in accordance with both *Öztürk E* et al. and *Zhu J* et al.[15,16] They reported a greater number of adhesive failures in <50% enamel group here it can be inferred that since most

of the samples underwent adhesive failure, the percentage of preserved enamel in patients with dental erosion can be as low as 50% and thus it would not be advisable to go ahead with a no-prep veneer rather than a full coverage option.

Hence the present study would help the clinician get an idea of the bond strength to be expected in an individual with erosive tooth wear since it evaluates the effect of erosion of enamel on the shear bond strength of ceramic laminates. There are few case reports in the recent literature such as the one published by *Ioannis Papadopoulos* et al. in the year 2020 which discusses techniques to restore teeth affected by erosive tooth wear with a combination of materials depending upon the erosive status of the individual tooth. Przypis [1]? This type of approach to treatment planning should be propagated rather than opting for ceramic veneers for patients who seek an aesthetic treatment option; it might serve the short-term goal of providing aesthetics but the long-term success may be questionable. The treatment rendered to patients with eroded teeth should depend upon the extent of wear and not only rely on adhesive dentistry. In the case of extreme erosive wear of teeth, full coverage restorations may be more beneficial to the patient than minimally invasive options as they would benefit from the adhesion protocol as well as retention and resistance form of the tooth.

Conclusion

Shear bond strength of ceramic laminate veneers bonded to teeth that have been eroded by carbonated beverages without any surface treatment was found to be low, which can be considered inadequate when it comes to withstanding the loads that occur in natural dentition. Hence we can consider proceeding with restorations that rely on retention and resistance form of the tooth rather than singularly trust the adhesive bonding protocol. The treatment protocol should be specific to each tooth rather than following the blanket approach, for the ease and quick delivery of the prosthesis. Patient education using evidence-based reports is of utmost relevance as this approach could significantly alter the lifespan of the treatment rendered.

References

1. *Papadopoulos I, Fuller J:* Restoration of localised erosive wear using a combination of dental materials: a conservative approach. Br Dent J 2021; 230(5): 294-300. doi: 10.1038/s41415-021-2697-5
2. *McLaren EA, LeSage B:* Feldspathic veneers: what are their indications? Compend Contin Educ Dent 2011; 32(3): 44-49.
3. *Fradeani M, Redemagni M, Corrado M:* Porcelain laminate veneers: 6- to 12-year clinical evaluation – a retrospective study. Int J Periodontics Restorative Dent 2005; 25(1): 9-17.
4. *Peumans M, Van Meerbeek B, Lambrechts P, Vanherle G:* Porcelain veneers: a review of the literature. J Dent 2000; 28(3): 163-177. doi: 10.1016/s0300-5712(99)00066-4
5. *JB S, Roobins JW, Hilton TJ, Schwartz R:* Porcelain veneer In: Grisham B, editor. Fundamentals of operative dentistry: a contemporary approach. 4th ed. Quintessence publishing Co, inc: China; 2013. pp. 463–487.
6. *Oheymann H, Edward J, Swift J, Vritter A:* Art and science operative dentistry. 6th ed. Elsevier Mosbey: Canada; 2013. pp. 316–319.
7. *Layton DM, Clarke M:* A systematic review and meta-analysis of the survival of non-feldspathic porcelain veneers over 5 and 10 years. Int J Prosthodont 2013; 26(2): 111-124. doi: 10.11607/ijp.3202
8. *Vailati F, Gruetter L, Belser UC:* Adhesively restored anterior maxillary dentitions affected

by severe erosion: up to 6-year results of a prospective clinical study. Eur J Esthet Dent 2013; 8(4): 506-530.
9. *Cho SH, Chang WG, Lim BS, Lee YK:* Effect of die spacer thickness on shear bond strength of porcelain laminate veneers. J Prosthet Dent 2006; 95(3): 201-208. doi: 10.1016/j.prosdent.2005.12.011
10. *Scherrer SS, Cesar PF, Swain MV:* Direct comparison of the bond strength results of the different test methods: a critical literature review. Dent Mater 2010; 26(2): e78-93. doi: 10.1016/j.dental.2009.12.002
11. *Gambon DL, Brand HS, Veerman EC:* Dental erosion in the 21st century: what is happening to nutritional habits and lifestyle in our society? Br Dent J 2012; 213(2): 55-57. doi: 10.1038/sj.bdj.2012.613
12. *Cheng R, Yang H, Shao MY, Hu T, Zhou XD:* Dental erosion and severe tooth decay related to soft drinks: a case report and literature review. J Zhejiang Univ Sci B 2009; 10(5): 395-399. doi: 10.1631/jzus.B0820245
13. *von Fraunhofer JA, Rogers MM:* Dissolution of dental enamel in soft drinks. Gen Dent 2004; 52(4): 308-312.
14. *Beier US, Kapferer I, Burtscher D, Dumfahrt H:* Clinical performance of porcelain laminate veneers for up to 20 years. Int J Prosthodont 2012; 25(1).
15. *Öztürk E, Bolay Ş, Hickel R, Ilie N:* Shear bond strength of porcelain laminate veneers to enamel, dentine and enamel-dentine complex bonded with different adhesive luting systems. J Dent 2013; 41(2): 97-105. doi: 10.1016/j.jdent.2012.04.005
16. *Zhu J, Gao J, Jia L, Tan X, Xie C, Yu H:* Shear bond strength of ceramic laminate veneers to finishing surfaces with different percentages of preserved enamel under a digital guided method. BMC Oral Health 2022; 22(1): 1-1.

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