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IMPACT OF DIFFERENT EROSIVE MEDIA ON SURFACE ROUGHNESS AND BOND STRENGTH OF REPAIRED LITHIUM DISILICATE CERAMIC USING TWO REPAIR SYSTEMS: AN IN VITRO STUDY

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ABSTRACT

Objectives: This study aims to evaluate the impact of various erosive media on the surface roughness and bond strength of repaired lithium disilicate ceramic using two repair systems.

Materials and Methods: Sixty-four discs of lithium disilicate (Amber Press) ceramic were prepared and divided into two main groups, each group was repaired using intra oral repair systems (Nanoksa Lab and Bisico Multi Repair). After that each main group was divided into four subgroups according to erosive media applied (Saliva, HCl, Red-Bull®, Coca-Cola®). The surface roughness (Ra) was measured before and after exposure to the erosive media using Mitutoyo profilometer, then shear bond strength (SBS) test was evaluated (MPa) using a universal testing machine Instron. Data were statistically analyzed using ANOVA and Tukey's post hoc test.

Results: The surface roughness was significantly different between different subgroups, where a high degree of Ra was recorded in the Coca-Cola® subgroups for both repair systems, while the saliva subgroups showed the lowest degree of surface roughness. The shear bond strength for "Nanoksa" was consistently higher across all erosive media compared to "Bisico." The mean shear bond strength for "Nanoksa" ranges from (3.559- 4.49 MPa), while for "Bisico," it ranges from (0.495- 2.322MPa).

Conclusions: This study found that the surface roughness and bond strength of repaired lithium disilicate ceramic are significantly influenced by the erosive media. The success of the repair is also greatly influenced by the system of repair that is selected.

KEYWORDS: Surface roughness, Bond strength, Lithium disilicate ceramic, Erosive media, Repair systems.

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INTRODUCTION

Over recent decades, dentistry has undergone a substantial evolution, largely due to advancements in materials and technology, particularly with the introduction of modern aesthetic materials aimed at enhancing dental and facial aesthetics.[1] The application of indirect ceramic restorations, as opposed to the aesthetically inferior metallic alternatives, is becoming increasingly prevalent. These consist of veneers, crowns, bridges, inlays, and onlays, which can now be crafted from industrial-grade prefabricated ceramic blocks utilizing CAD/CAM (computer-aided design and manufacturing) technology. These technologies offer numerous advantages such as consistent quality, superior mechanical properties, cost-efficiency, and shorter production times.[2]

There is a large range of ceramics that are utilized in these procedures, such as lithium disilicate glass ceramics, aluminum oxide, composite resins, nano-hybrid ceramics, and yttrium tetragonal zirconia polycrystals.[3] These materials are chosen based on their mechanical properties and their compatibility with various luting agents which are crucial for their adherence and overall performance in clinical settings. Despite their aesthetic and functional benefits, ceramic restorations are not without drawbacks; their brittle nature makes them prone to fractures from trauma or stress during use.[4]

When fractures occur, replacing the ceramic restoration entirely is often impractical due to the high costs and invasive nature of the procedure. Instead, direct restoration repair methods are preferred, involving surface treatments such as etching with hydrofluoric acid, bonding with silane coupling agents, air abrasion, or laser irradiation to enhance surface roughness and prepare it for adhesive bonding.[5]

This approach allows for the application of adhesive composite resin materials to repair the defect effectively. The success of such repairs depends on the careful consideration of the chemical compatibility between the ceramic material and the resin used. Research indicates that treatments like air-particle abrasion can significantly improves the surface energy and wettability of ceramics, enhancing the bond strength through micro-interlocking mechanisms.[6]

Furthermore, the durability of ceramic restorations can be compromised by exposure to erosive substances in the oral environment, such as HCl, Coca Cola®, Red Bull® and fruit juices. These substances can cause surface degradation through the leaching of alkali ions, leading to increased surface roughness, plaque accumulation, discoloration, and structural weakening, which in turn accelerates wear on both the ceramic restoration and opposing natural teeth. The challenge remains to ensure the longevity and aesthetic integrity of these ceramic restorations amidst these environmental factors.[7,8]

Due to the high erosive qualities of sugar and citric acid, which erode the tooth's surface surrounding brackets, soft beverages have a detrimental effect on the structure of enamel. Drinking soft drinks lowers the pH below 5.5, which can cause attrition of the teeth. Because healthy enamel is necessary for the retention of the restoration, dental erosion is a flaw on the surface of enamel caused by exposure to acids. This will weaken the binding between the repair material and the tooth.[9,10]

One of the three most well-known drinks is Coca-Cola®, which is also the most popular soft drink.[11] The energy drink that people drink the most frequently is Red Bull®. Because of the drink's effects on mental and physical performance due to its high caffeine level, "Red Bull gives you wings" is one of the most well-known slogans in the United States. They may also affect the behavior and color of the dental material because of the acid action at body temperature.[10,12] Acidic ingredients in the soft drinks listed above may also have an impact on the growth of dental plaque on the bonding layer.[13]

An important factor in the aesthetic appearance of composite resin restorations is surface roughness. In addition to decreasing plaque buildup and stain attachment, a smooth surface improves the visual compatibility of tooth tissue. As a result, surface roughness has been a useful criterion in the study of composite resin color, serving as a benchmark for the assessment of aesthetic effect.[14]

The ability of a material to tolerate forces that could force its internal structure to move against itself is known as shear bond strength (SBS). Due to adhesives' high SBS, tests pertaining to them are frequently used to assess both the adhesives that are now available to dental professionals and the development of new resin adhesives. Regretfully, there is no correlation between these, and research conducted in vivo. Evidence suggests that SBS analysis processes could have problems.[15] The propriety of comparing the findings of other studies and the interpretation of the measurements obtained have drawn criticism. Therefore, it was recommended that a standardized SBS test methodology be used.[16]

This study aims to explore the impact of various erosive media on lithium disilicate ceramic's surface roughness and bond strength and compare the effectiveness of two different repair systems.

The null hypotheses of presented study were that there would be no significant difference in values of surface roughness and shear bond strength when two ceramic repair systems were used and that the artificial aging approach with four erosive media including saliva, HCL, Red Bull®, and Coca Cola® had no effect on its values.

Ethical consideration:

This study had the Scientific Research Ethics Committee's approval from Faculty of Dentistry, Mansoura University (approval number: A0104023FP).

MATERIALS AND METHODS

Specimen Preparation.

Sixty-four lithium disilicate ceramic discs were fabricated (6 mm diameter * 3 mm thickness)[17] and randomly divided into two main groups (n=32) based on the type of repair system:

Group 1: Nanoksa Lab repair kit.

Group 2: Bisico Multi Repair kit.

Repair Procedures.

All ceramic samples were treated by Sandblasting using 50 μm aluminum oxide particles from a distance of 10 mm perpendicular to samples surfaces, the pressure was 2.8 bar for 20 seconds.[18] After that, they were ultrasonically cleaned using an ultrasonic bath containing 96% ethanol for 5 minutes.[19] then these samples were repaired using two repair systems. All procedures were performed according to manufacturer's recommendations as the following:

Nanoksa Lab repair kit.

- **Ceramic acid etch:** The ceramic surfaces were etched with hydrofluoric acid (10%) for 2 minutes.
- **Composite Primer:** Thin layer of primer was applied to the bonding surface of the ceramic discs using a Micro-tip applicator then light cure for 20 seconds.
- **Ceramic conditioner:** Etching solution was added to the ceramic discs for 60 to 90 seconds and rinse thoroughly.
- **Nanoksa Lab:** A composite resin was incrementally applied and light-cured to repair the ceramic surface for 40 seconds.

Bisico Multi Repair kit.

- **Multi Repair Primer:** Thin layer was applied using a special brush (white shank) and allowed to air dry for approximately 1 minute.

- **Multi Repair Bond:** thin coat of repair bond was applied using another special brush (red shank) the processing time of Multi Repair Bond ranges between 30-60 seconds.
- **Nanofill®n Composite:** A composite resin was applied incrementally and light-cured to repair the ceramic surface for 20 seconds.

Then according to used type erosive media each main group was subdivided into four subgroups (n=8):

1. **Subgroup 1:** Control (saliva).
2. **Subgroup 2:** HCl.
3. **Subgroup 3:** Red Bull®.
4. **Subgroup 4:** Coca Cola®.

Surface Roughness Measurement.

For every specimen, surface roughness (Ra) was assessed, each specimen had at least three readings that were taken at several random locations. Using a profilometer (a Mitutoyo Instrument, Dental Biomaterial Department, Mansura University), the mean value was determined and expressed as a numerical value (in micrometers) before and after immersion of the repair material in 5 ml of the erosive media for four days at 37°C with change the erosive every 24 hour.[20] Scanning Electron Microscope was used to evaluated the effect of different erosive media on two repair systems.

Shear Bond Strength Testing.

Specimens were checked before testing with a light stereomicroscope (Nikon MA100 Japan) at 30× magnification to discard specimens with presence of air bubbles or gaps at the interface. The specimen was attached to the lower fixed head of the universal testing machine (Instron model 3345 England). Unibeveled chisel with 0.5 mm width blade was attached to the upper movable head of the testing machine, compression mode of force applied via the chisel blade which was placed as close as possible to the composite interface at a crosshead speed of 1.0 mm/min up to specimen failure. The force required for failure (Newton) was divided by the surface area (mm^2) to calculate the shear bond strength in MPa by machine software (BlueHill 3 Instron England). Mode of failure of specimen of each subgroup was examined using Scanning Electron Microscope (SEM).

Statistical Analysis.

The data were tabulated, processed, and analyzed using the IBM SPSS Statistics 26 computer programs to find and describe the (Mean and standard deviation) of Ra quantitatively. Three-way ANOVA and post hoc Tukey tests were used to determine the significance of differences among different groups ($p<0.05$).

RESULTS

Surface Roughness

This study compared the effect of four different erosive media on composite repair materials after storage in saliva (control group), HCL, Coca Cola®, and Red Bull® for four days at 37°C. The data were tabulated, processed, and analyzed using the IBM SPSS Statistics 26 computer programs to find and describe the (Mean and standard deviation) of Ra quantitatively, as showed in table (1) and figure (1).

Nanoksa Lab Repair System

The results of Nanoksa Repair system showed that specimens of saliva subgroup remained relatively stable. Regarding to subgroups 2 and 3 (HCl, Red Bull®) there was significant increase in surface roughness (0.5448250, 0.5204625) respectively, while the highest values of surface roughness were recorded for Coca Cola® subgroup (0.5947000).

Bisico Multi Repair System:

The result of Bisico Multi Repair system showed that specimens of saliva subgroup remained

TABLE (1) Surface Roughness (Ra) Values Before and After Exposure to Erosive Media

	Repair Material	Erosive	N	Mean	Std. Deviation
Before	**Nanoksa**	**Saliva**	8	0.5146125	0.15473759
		HCl	8	0.4622500	0.13852637
		Red Bull	8	0.4525000	0.03652385
		Coca Cola	8	0.4299375	0.07636734
	Bisico	**Saliva**	8	0.4790500	0.03322675
		HCl	8	0.4967625	0.07536862
		Red Bull	8	0.4488875	0.07031843
		Coca Cola	8	0.4296625	0.08425365
After	**Nanoksa**	**Saliva**	8	0.4933750	0.04103872
		HCl	8	0.5448250	0.06254335
		Red Bull	8	0.5204625	0.13127733
		Coca Cola	8	0.5947000	0.16347985
	Bisico	**Saliva**	8	0.4894500	0.05665878
		HCl	8	0.6696750	0.12648542
		Red Bull	8	0.4843000	0.08746021
		Coca Cola	8	0.5977125	0.10226254

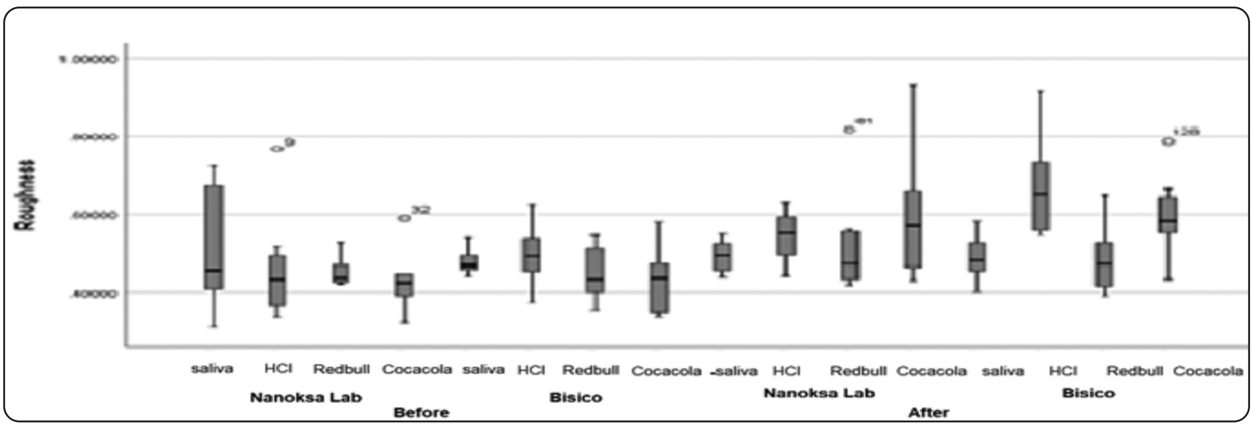

Fig. (1) Surface Roughness (Ra) Values Before and After Exposure to Erosive Media

relatively stable. Regarding to subgroups 3 and 4 (Red Bull®, Coca Cola®) there was significant increase in surface roughness (0.484300, 0.5977125) respectively, while the highest values of surface roughness were recorded for HCl subgroup (0.6696750).

Then Scanning Electron Microscope at 500x magnification was used to evaluate the effect of erosive media on the repair material as shown in figures (2,3) for both types of repair material.

Bond Strength

After surface roughness evaluation, shear bond strength test was performed (MPa) to compare the effect of four different erosive media on composite repair material.

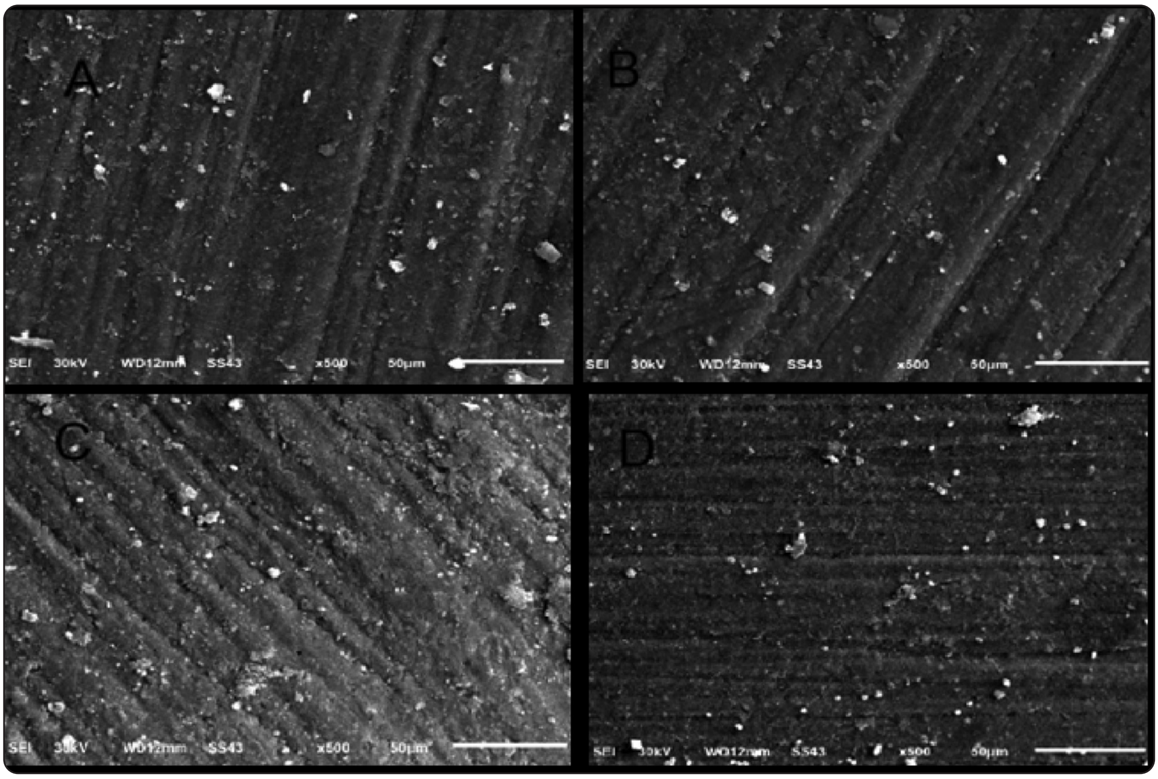

Fig. (2) SEM image showing surface roughness for Nanoksa Lab group: A) Saliva. B) HCl. C) Red Bull®. D) Coca Cola®.

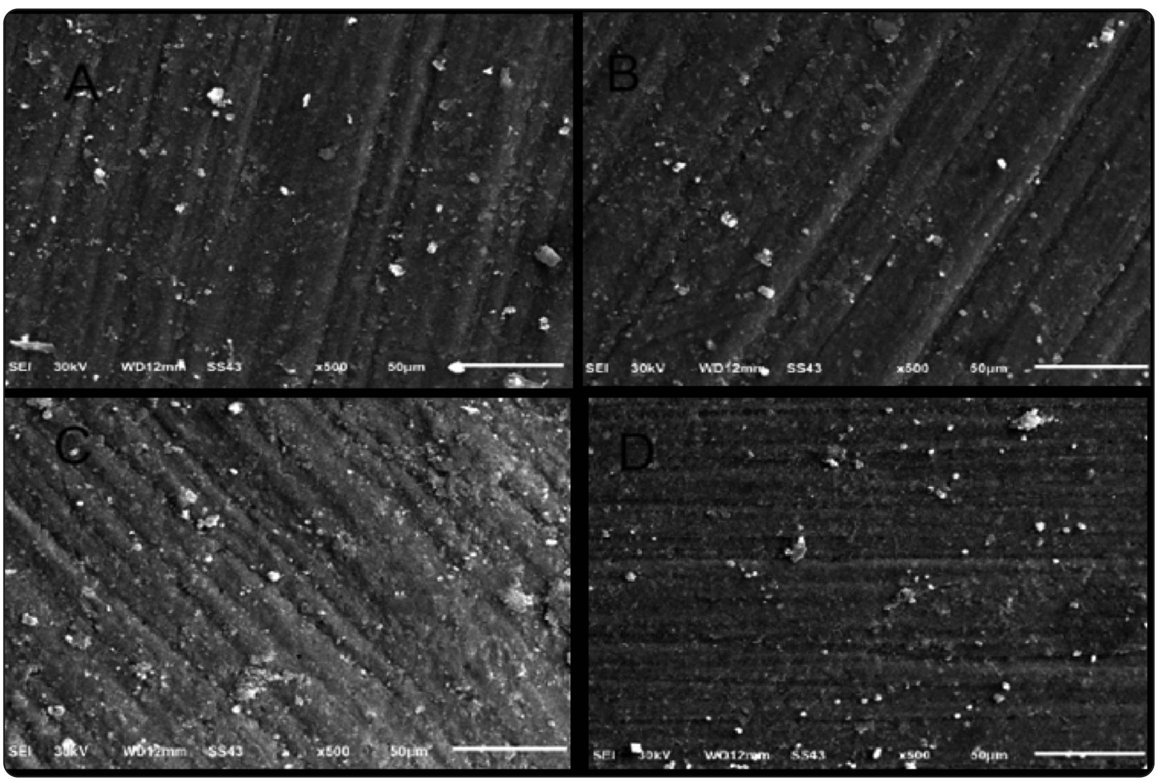

Fig. (3) SEM image showing surface roughness for Bisico group: A) Saliva. B) HCl. C) Red Bull®. D) Coca Cola®.

The data were tabulated, processed, and analyzed using the IBM SPSS Statistics 26 computer programs to find and describe the (Mean and standard deviation) of SBS quantitatively. As shown in table (2) and figure (4).

The result of Nanoksa Lab Repair system showed that the highest bond strength specimens of subgroup 3 (Red Bull®) with mean was (4.4961763 MPa) recorded value, then the subgroup 2 (HCl) with mean was (4.3210350 MPa) while the subgroup 4 (Coca Cola®) mean was (4.1440775 MPa) and the lowest mean recorded value was for saliva subgroup (3.5589675 MPa).

The result of Bisico Multi Repair system showed that the highest bond strength specimens of subgroup 4 (Coca Cola®) with mean was (2.3221906 MPa) recorded value, then the subgroup 3 (Red Bull®) with mean was (2.0105393 MPa) while the subgroup 2 (HCl) mean was (1.7318525 MPa) and the lowest mean recorded value was for subgroup 3 (saliva) (0.4949586 MPa).

Scanning Electron Microscope (SEM).

Representative samples for both types of repair material system of each failure pattern (cohesive, adhesive, and mixed) were studied by Scanning Electron Microscope at 150x, 500x magnification to evaluate the mode of failure of the repair material as shown in table (3) and figures (5,6).

TABLE (2) Shear Bond Strength (SBS) Values for Different Groups of Repair Systems.

Repair Material	Erosive	N	Mean	Std. Deviation
Nanoksa Lab	**Saliva**	8	3.5589675	1.12741432
	HCl	8	4.3210350	1.13989366
	Red Bull	8	4.4961763	1.87056957
	Coca Cola	8	4.1440775	1.44216273
Bisico	**Saliva**	7	0.4949586	0.23901991
	HCl	8	1.7318525	1.41921872
	Red Bull	7	2.0105393	0.84815907
	Coca Cola	8	2.3221906	1.17027963

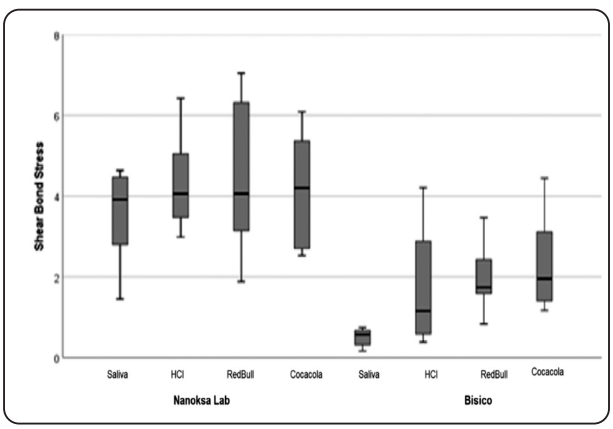

Fig. (4) Shear Bond Strength (SBS) Values for Different Groups and Repair Systems

TABLE (3) Failure mode of tested subgroups.

Repair Material	Erosive	Adhesive	Cohesive	Mix
Nanoksa Lab	**Saliva**	3	0	5
	HCl	4	3	1
	Red Bull	3	3	2
	Coca Cola	5	1	2
Bisico	**Saliva**	5	2	1
	HCl	7	0	1
	Red Bull	6	1	1
	Coca Cola	5	2	1

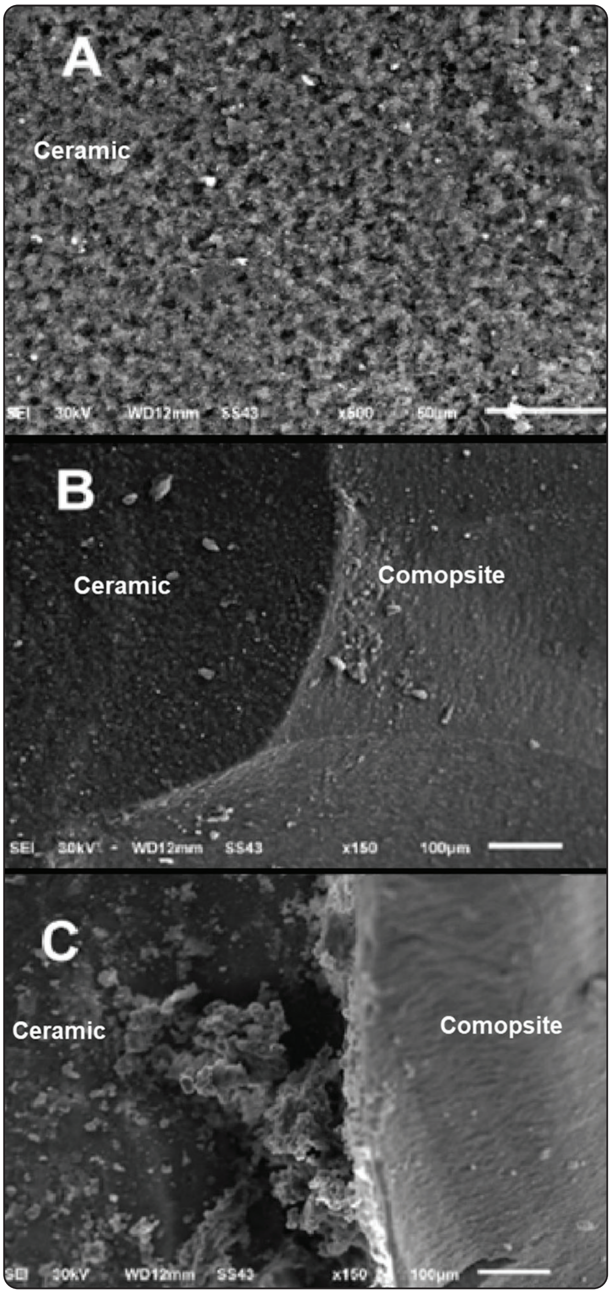

Fig. (5) SEM image showing failure mode for Nanoksa Lab group: A) Adhesive. B) Cohesive. C) Mix.

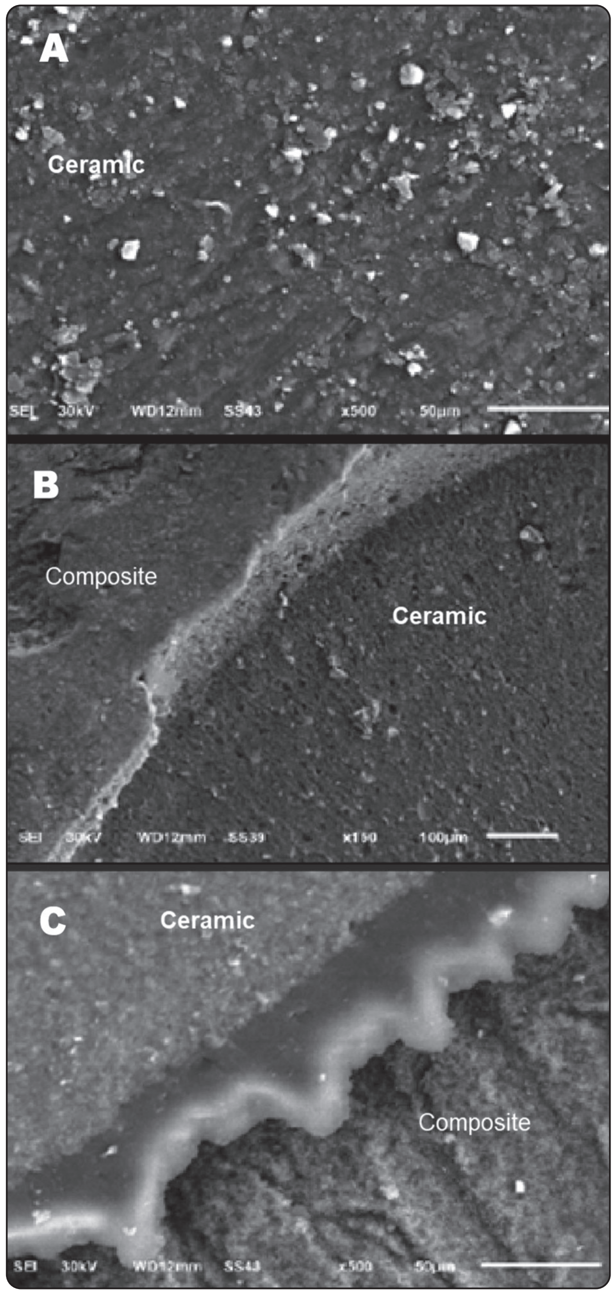

Fig. (6) SEM image showing failure mode for Bisico group: A) Adhesive. B) Cohesive. C) Mix.

DISCUSSION

This study utilized lithium disilicate ceramic as the core material for evaluating the effects of various erosive media on surface roughness and bond strength of two repair systems. This study showed that there were significant differences between different erosive media on surface roughness and shear bond strength at two used repair systems so, the null hypothesis of this study was rejected.

In the present study Lithium Disilicate Glass Ceramic (Amber® Press) was chosen due to its highly appreciated in restorative dentistry due to its aesthetic qualities and mechanical properties, including a high fracture resistance and chemical durability. These characteristics make it a preferred choice for both anterior and posterior restorations.[21]

Two repair systems were tested to compare their effectiveness in restoring the lithium disilicate ceramics after erosion. These systems were Nanoksa Lab Repair system and Bisico Multi Repair system, that were selected as novel repair materials. The Nanoksa LAB is a highly durable and aesthetically pleasing dental composite characterized by its combination of nano particle/Zirconium filler and a urethane dimethacrylate matrix. This unique chemistry enhances the composite's strength, wear resistance, and polishability, resulting in exceptional esthetic outcomes. The material's structure facilitates excellent grinding and polishing properties. Nanoksa LAB also includes Nanoksa Gingiva, designed for gingival build-up, which, when used with the main product, allows for finely balanced restorations of both teeth and gums ("white" and "red" asthetics). The shades and accessories of both products are fully harmonized, ensuring precise color matching across different ages and ethnicities.[22]

While the Bisico Multi repair system was characterized by harmonized products, which allows the immediate repair of fractured ceramic veneers in only one session, intraorally and without acid etching. The treatment can be carried out without any stress for the patient.[23]

The specimens were exposed to different erosive environments to simulate oral conditions these include artificial saliva, hydrochloric acid (HCl), Coca Cola®, and Red Bull®. These media were selected to assess the degradation and wear resistance of the materials under acidic conditions that are commonly encountered in the oral environment.[24,25]

This study used a profilometer (Mitutoyo Instrument) to measure surface roughness and a universal testing machine (Instron) to assess shear bond strength. These measurements were crucial for understanding how the surface integrity and mechanical properties of the ceramic were affected by the erosive treatments and repair procedures.[26,27]

The study design aimed to closely replicate clinical conditions to provide insights into the durability and performance of repaired ceramic materials in a simulated oral environment. The use of these specific materials and methods helped in quantitatively and qualitatively analyzing the impact of erosive media on dental ceramics, which is critical for developing effective repair techniques in restorative dentistry.[28]

The erosive media significantly affected the surface roughness and bond strength of lithium disilicate ceramics, with the acidic solutions posing greater risks than neutral ones like artificial saliva.[29] Erosive wear on dental ceramics can occur due to a combination of chemical dissolution and mechanical abrasion, typically seen with acidic beverages and gastric acids.[30] Among the tested repair systems, the Nanoksa Lab Repair Kit provided the best results in terms of restoring bond strength and surface integrity. Future studies could explore the long-term effects of repeated exposure to erosive media and the efficacy of different protective treatments to mitigate these effects. The Coca Cola® subgroup showed the most pronounced effect, likely due to its strong acidity and higher capacity for chemical degradation of silicate networks in the ceramic.[31]

Both repair systems, the Nanoksa Lab Repair system and the Bisico Multi Repair system, were effective in restoring the surface integrity and bond strength of the damaged ceramics. However, the Nanoksa system showed slightly superior performance, which might be attributed to its chemical composition that may foster better bonding with the lithium disilicate matrix.[32] This finding is significant for clinical practice, as selecting an appropriate repair system can directly influence the longevity and durability of ceramic restorations.

The implications of this study extend beyond mere material selection, highlighting the necessity for patients to be aware of the potential erosive effects of common beverages on dental restorations. This awareness is crucial for preventive strategies that may help in extending the life span of ceramic restorations, thus ensuring better clinical outcomes and patient satisfaction.[33]

SEM micrographs and fracture type analyzes were used to evaluate the interface generated between the tested materials in the most of studies. Adhesive failure was associated with decreased SBS, while cohesive failure corresponded with improved SBS.[34] Adhesive failure type was mostly observed when glass ceramic was repaired with Bisico repair system that revealed the lowest SBS value between groups, On the other hand, the cohesive and mixed failure was mostly found with Nanoksa repair groups producing high value of SBS.

Both materials generally exhibit more cohesive failures in Saliva and Coca Cola, possibly due to the pH or the chemical composition of these substances affecting the material integrity.[35] HCl shows a diverse range of failures for both materials, which could be attributed to its strong erosive nature affecting both the material bonding and integrity.[36]

The presence of mixed failures in almost all groups indicates that neither type of repair material is completely resilient to any one type of erosive challenge, suggesting that both bonding and material integrity are compromised under different conditions.

Moreover, in clinical situations, the inner surface is luted to the underlying structure, whilst only the outside surface is exposed to external stimuli. Therefore, it might be incorrect to assume that the results of the present tests accurately reflect clinical reality. The use of just two types of resin composite was another restriction that might have limited how far the current results might be applied. Lastly, because insufficient research was done on the repair bond strength of resin composites to glass ceramic materials, there was no meaningful comparison of the current findings with those of earlier studies.

CONCLUSION

This study underscores the significant impact of various erosive media on both the surface roughness and bond strength of repaired lithium disilicate ceramics. It clearly demonstrates that the type of repair system plays a crucial role in the effectiveness of ceramic repairs under erosive conditions. Specifically, the Nanoksa Lab Repair System exhibited superior performance across all tested conditions, consistently maintaining higher bond strength and better surface integrity compared to the Bisico Multi Repair System. This difference can be attributed to the distinct chemical compositions of the repair materials, which may interact differently with the lithium disilicate ceramic matrix.

The findings from this research highlight the critical need for selecting appropriate repair systems that can withstand harsh environmental challenges, particularly acidic erosive media commonly encountered in the oral environment. By choosing the most effective repair system, the longevity and durability of ceramic restorations can be significantly enhanced, thereby improving clinical outcomes and patient satisfaction.

Limitations.

This study has outlined its limitations as follows:

- The research is an in-vitro study, meaning the results may not fully translate to in-vivo conditions where other variables can affect outcomes.
- The study specifically examines the impact of different erosive media on the surface roughness and bond strength of repaired lithium disilicate ceramics. Therefore, the conclusions drawn are limited to these specific conditions and materials.
- It is implied that further research might explore a broader range of materials and conditions to provide a more comprehensive understanding of the phenomena studied.

These limitations suggest that while the study provides valuable insights into the effects of erosive media on repaired ceramics, the applicability of the results may be restricted to similar laboratory conditions unless corroborated by additional research in more varied or in the clinic.

Conflict of Interest

Regarding this work, the authors have disclosed no conflicts of interest.

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Data Availability

The study's supporting data are accessible upon request and are included in the publication.

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