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Restorative Materials Exposed to Acid Challenge: Systematic Review and Meta-Analysis

Saeed Ateeq Kh. Al Zahrani[1], Yousef Saleh Alanazi[1], Mshari Suliman Al Mutairi[1], Nasser Tayeb Marir[1], Mohammed Saeed Alasiri[1], Nasser Mohammed Almutairi[1], Saeed Ali Alqahtani[2], Abdullah Alrafee[3], Turki Abdullah Alqarni[1], Bashayer Alosaimi[4]

[1]Dentist ,MOH / RC2
[2]Consultant In Endodontics ,MOH/ RC2
[3]Consultant , King Fahad Medical City
[4]Dentist (GP), Ministry Of Health

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ABSTRACT
Background: Hard tissue that is found in the teeth may be destroyed by erosion if acidic solutions are exposed to them for an extended period. The intake of non-alcoholic beverages, for instance soft drinks, is therefore the key factor that contributes to the development of tooth erosion in young people.
Aim: To evaluate restorative materials exposed to acid challenge.
Materials and methods: Following the criteria outlined in the Cochrane Handbook for systematic reviews of interventions and the PRISMA statement, this systematic review was conducted. The database searches were done in the following: the Cochrane Library, Web of Science, and MEDLINE (PubMed). Furthermore, the literature search employed the following search terms and their combinations: "fruit juice" OR "chemical degradation") AND ("Computer-Aided Design / Computer-Aided Manufacturing material" OR " ceramic " OR " porcelain " OR " ceramic/polymer material " OR " resin-ceramic "). Criteria for eligibility include in vitro and in vivo trails, investigations that investigate indirect restorative materials, as well as trails that assess the impact of erosion on the surface roughness or surface microhardness of restorative materials.
Main findings and conclusion: A total of 1097 articles were found by electronic databases. Finally, five RCTs were selected. Our pooled meta-analysis for SR showed that, MD and 95% CI: 0.01[0.00, 0.02]. Weighted by fixed effect I2 and chi-p= 46% and <0.1. A mean change under 0 shows that the SR (surface roughness) is larger in the erosion group. Our pooled meta-analysis shows that the SMH (surface micro-hardness) is lesser in the erosion group with MD and 95% CI: 24.6[43.2, 6.01]. Weighted by random effects I2 and chi-p= 96% and <0.00001.

Keywords: Restorative materials, acid challenge, dental composites, CAD/CAM

INTRODUCTION

Hard tissue in the teeth can be eroded if they are exposed to acidic solutions for an extended period of time. It is the intake of non-alcoholic beverages, particularly soft drinks, that is the leading etiology of tooth erosion in children under the age of 18. After being submerged in a variety of soft beverages, such as fruit juices, orange juice, and Coca-Cola, enamel hardness has been shown to decrease significantly, according to a number of studies. Citric acid or hydrochloric acid might be incorporated into the examinations, which would allow for a major expansion of the breadth of research that is being conducted on this topic. The polyvalent acid known as citric acid is classed as an acid that ranges from medium-strong to weak, and it is usually used as a substitute for beverages that are acidic **(1).**

Hydrochloric acid was chosen for its presence in the gastric secretions. Citric acid has a substantial potential for the further separation of H+ protons and their delivery when contrasted with hydrochloric acid, as evidenced by published in vitro research. Additionally, it has been found that citric acid possesses chelating characteristics for the calcium ions that are present in enamel, which helps in the separation of these calcium ions further. Consequently, the acid erosion of enamel is a multifaceted process that is influenced by a variety of chemical mechanisms, including the chelating ability of the acid solution, the pH, the type of acid, as well as the quantity of tithable acid. The erosivity of any beverage is entirely determined by the presence of calcium and phosphate **(2).**

Physical elements can influence the erosive potential of acidic beverages; nevertheless, there is a lack of published research concerning the solution's adhesion to the surface of enamel, the beverage's flow and agitation, and temperature. In clinical environments utilizing acidic beverages as a medium for enamel samples, these compelling theoretical implications may be relevant to the situation**(3).**

The main goals of these therapies will consistently be the survivability, durability, and optimal clinical efficacy of restorations. Nonetheless, the deterioration of restorative materials may be triggered by intrinsic factors (like., eating complaints) as well as extrinsic factors (e.g., food, medicine, oral hygiene, and smoking), in addition to regular wear and exposure to the environment of oral cavity. Thus, the functional durability of rehabilitations is not assured by all restorative materials, underscoring the need to regulate these restorations to avert failure **(4).**

A number of studies have extensively examined the performance of dental composites and various restorative materials in a standard oral environment. The studies simulated typical oral conditions by submerging samples in fake saliva, also all indicated alterations in the restorative materials surface, notably a reduction in microhardness in addition an elevation in SR **(5).**

This is well-documented; nonetheless, certain individuals encounter more difficult oral conditions, particularly with increased intake of acidic beverages. Therefore, it is essential to perform additional research on the impact of this on restorative materials. Nonetheless, the global use of acidic beverages and the consequent erosive effects are escalating, leading to heightened tooth wear, significant material degradation, and an increased chance of restorative failure **(6).**

Thus, this systematic review and meta-analysis evaluated restorative materials exposed to acid challenge.

Patients and Methods

The protocol for this review followed the guidelines laid out in the Cochrane Handbook for intervention systematic reviews as well as the Preferred Reporting Items for Systematic Reviews as well as Meta-Analyses (PRISMA) statement.

PICOs: The population, intervention, comparison, and outcomes (PICOs) approach were employed to structure a specific query. The following were the distinct populations studied, interventions performed, comparisons made, and outcomes recorded: Population: supplies for indirect restorative procedures; Intervention: acidic solutions used on restorative materials; Restorative materials that have not been subjected to acidic solutions are being compared. Results: the SR or SMH of supplementary medicinal substances; Design of the trail: in vitro as well as in vivo trials. To determine how acidic solutions influence the surface roughness or surface microhardness of restoration materials, this comprehensive review has been conducted.

Search strategy: Databases that were searched included the Cochrane Library, Web of Science, and MEDLINE (PubMed). In addition, the following terms & combinations were utilized in the literature search: "chemical degradation"OR “fruit juice" as well as ("Computer-Aided Design (CAD)/ Computer-Aided Manufacturing (CAM) material" OR “resin-ceramic" OR "porcelain" OR " ceramic/polymer material " OR " ceramic ").

Eligibility criteria: (a) research evaluating restorative materials in vitro or in vivo, (b) research examining indirect restorative materials, & (c) research assessing the effect of erosion on the surface roughness or shear modulus of restorative materials. Research that met all but one of these requirements was not considered. (a) studies that do not test indirect restorative materials with acid; (b) studies that assess these materials according to established methods or criteria; and (c) studies that assess these materials in relation to their obsolescence. Assessing and choosing Two reviewers independently duplicated the statistics extraction process utilizing a standardized form in Microsoft Excel.

Data extraction: The subsequent information has been obtained from the whole texts of the included articles: materials analyzed, authors & year of publication, erosion methods, sample size, trial design, in addition to acidic solutions employed.

Risk of bias assessment

The bias risk valuation utilized ROB1, encompassing multiple characteristics. These factors encompassed the examination of performance bias, selection bias, attrition bias, reporting bias, detection bias, and additional potential causes of bias.

Data synthesis

In our meta-analysis, we employed the inverse variance method specifically for continuous outcomes. This procedure entailed consolidating the mean differences (M.D.) between the two groups with their corresponding standard deviations (S.D.). In contrast, categorical outcomes were aggregated as a relative risk (R.R.) between the two groups under comparison, accompanied with a 95% confidence interval (C.I.) for the two-arm meta-analysis. We examined the statistical heterogeneity among studies utilizing the I^2 statistic chi-squared test, where chi²-p values of 0.1 indicated heterogeneity, and I^2 values of 50% or greater suggested substantial heterogeneity. Rev-Man software version 5.4 was utilized for double-arm meta-analysis, whilst Open-Meta Analyst program was employed for single-arm meta-analysis.

RESULTS

The initial database search identified 1,097 possibly relevant studies, and 32 complete texts were evaluated for eligibility. Ultimately, five studies were incorporated into the systematic review. Figure 1 illustrates the Preferred Reporting Items for Systematic Reviews as well as Meta-Analyses flow diagram.

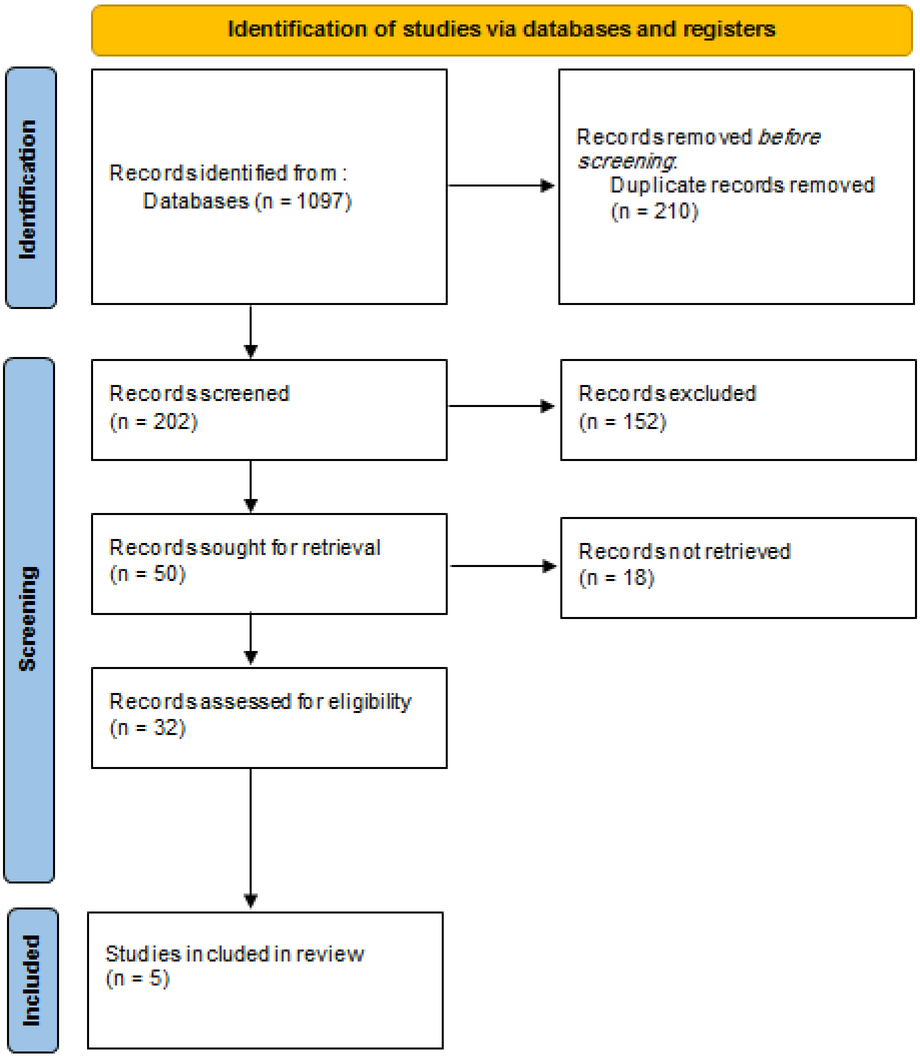


Figure 1: The PRISMA flow diagram for included studies.

Table 1: Summary of baseline characteristics of our involved studies.

	Study ID	Site	Study design	Sample size	Material tested	Acidic solutions	Erosion protocol
1	Alencar-Silva et al., (7)	Brazil	in vitro	8	PS e.max Computer-Aided Design (IvoclarVivadent AG)	cola (pH=2.3)	immersion in acidic solution at thirty-seven degrees Celsius for Ninety days
2	Backer et al., (8)	USA	in vitro	10	Lava Ultimate (3M ESPE) & Paradigm MZ100 (3M ESPE)	simulated gastric juice (pH equal 1.2)	immersion in acidic solution at Twenty-five degrees Celsius for twenty-four hours
3	Colombo et al., (9)	Italy	in vitro	15	Cerasmart (GC Corporation), Lava Ultimate (3M ESPE), Grandio blocs (VOCO GmbH), & Vita Suprinity (Vita	cola (pH=2.5) simulated gastric	immersion in acidic solution for twenty-four hours

					Zahnfabrik)	juice (pH=1.2) simulated gastric juice (pH=2.0)	
4	Egilmez et al., (10)	Turkey	in vitro	15	Cerasmart (GC Corporation), Lava Ultimate (3M ESPE), as well as Vita Enamic (Vita Zahnfabrik)	simulated gastric juice (pH equal 1.2)	immersion in acidic solution at thirty-seven degrees Celsius for 24 h
5	Kukiattrakoon et al., (11)	Thailand	in vitro	5	Vita VMK 95 (Vita Zahnfabrik), IPS Empress (IvoclarVivadent AG), Vitadur Alpha (Vita Zahnfabrik),and IPS e.maxceram (IvoclarVivadent AG)	green mango juice (pH equal 2.4) & pineapple juice (pH equal 3.7)	immersion in acidic solutions at thirty-seven degrees Celsius for 168 h

Risk of bias evaluation:
Most of our involved trails were judged low risk regarding most parameters except for detection and performance biases were judged high risk.

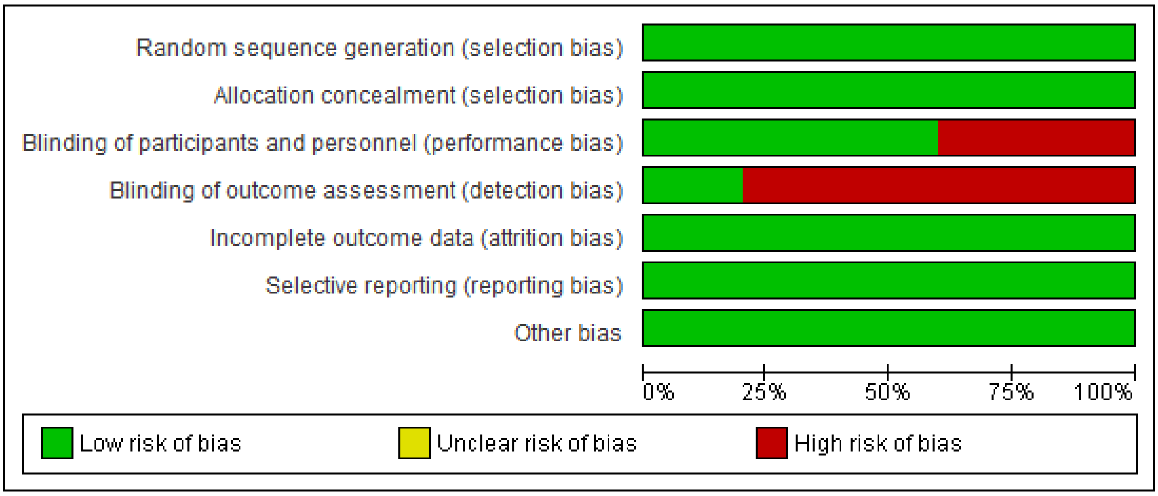


Figure 2: Risk of bias graph.

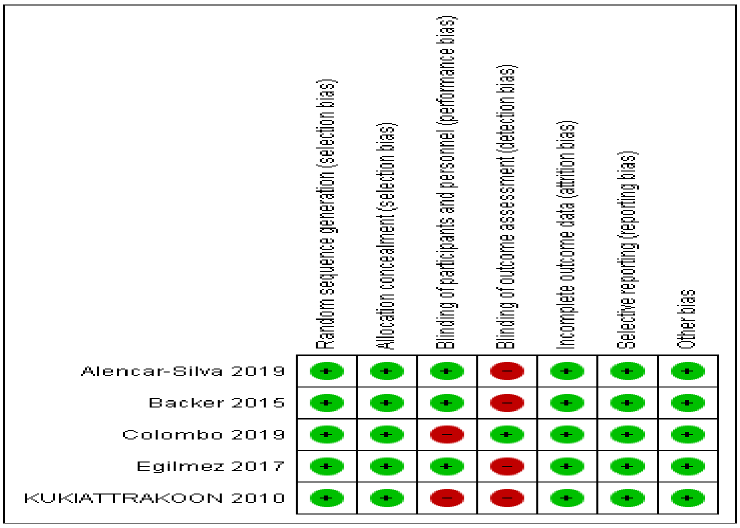
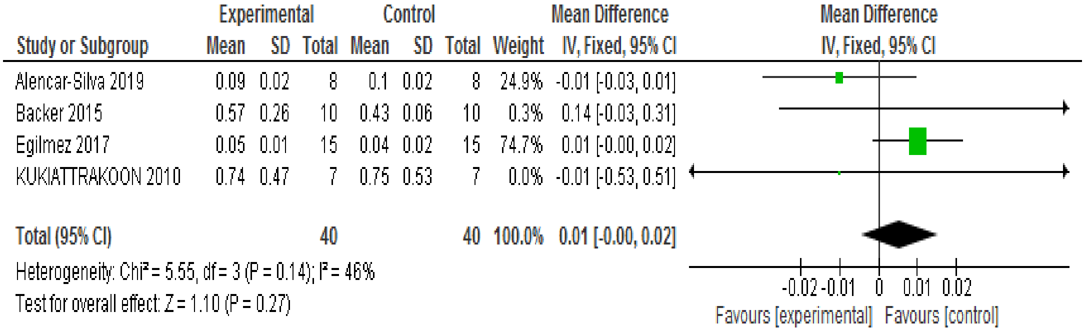


Figure 3: Risk of bias summary.

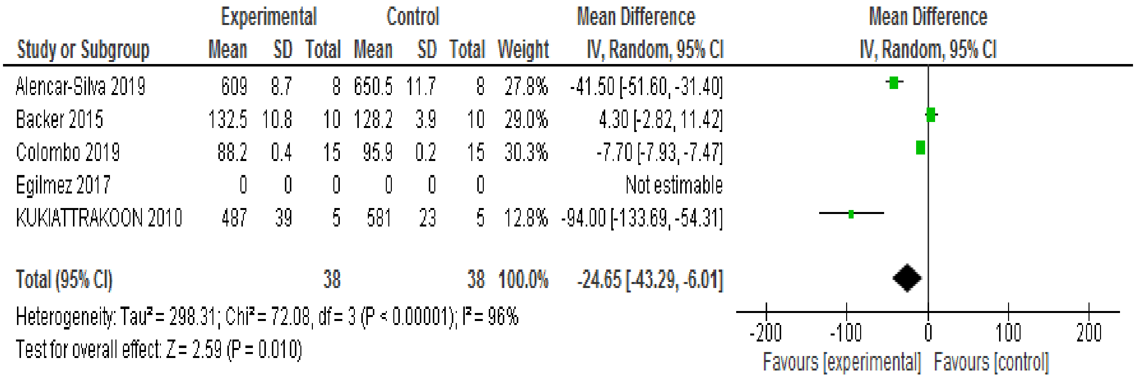
Outcomes

1. SR:



Our pooled meta-analysis for this outcome showed that, MD and 95% CI: 0.01[0.00, 0.02]. Weighted by fixed effect I^2 and chi-p= 46% and <0.1. A mean difference below zero demonstrates that the surface roughness is elevated in the erosion group.

2. SMH



Our pooled meta-analysis shows that the surface microhardness is lower in the erosion group with MD and 95% CI: 24.6[43.2, 6.01]. Weighted by random effects I^2 and chi-p= 96% and <0.00001.

DISCUSSION

This systematic review and meta-analysis evaluated restorative materials exposed to acid challenge. Our pooled analysis indicated that SR was greater in the erosion group. While our results showed that SMH was lower in the erosion group compared to control.

Colombo et al., (9) after being subjected to a carbonated acidic beverage, a meta-analysis was carried out in order to analyze the changes that occurred in the SMH of various restorative Computer-Aided Design / Computer-Aided Manufacturing materials. Following the immersion of each material in Coca-Cola, there were discernible changes in the micro-hardness of each respective substance. After being exposed to acid, the nanohybrid composite exhibited the highest percentage loss and showed a rise in its initial micro-hardness. The resin nano ceramic & the hybrid ceramic demonstrated similar percentages of micro-although the latter initially presented greater values, the hardness value has been decreasing. As well as exhibiting the lowest percentage reduction in micro-hardness, the zirconia-reinforced lithium silicate glass ceramic was discovered to have the highest starting values. Both before and after being subjected to acid treatment, the various Computer-Aided Design / Computer-Aided Manufacturing materials displayed micro-hardness values that were significantly distinct from one another.

Earlier, the hybrid ceramic was evaluated for its mechanical properties (12), (13), and the results showed that it exhibited comparable indentation values of 67.30 ± 2.04. As an additional point of interest, the evaluation of color stability & micro-hardness following exposure to acidic substances like coffee & red wine has been carried out in the past(13). According to the findings, coffee had the potential to influence both the color and the micro-hardness of the types of materials that were examined.

In 2017, Backer et al., (8) investigated the effect that synthetic gastric juice had on the mechanical properties of a Computer-Aided Design / Computer-Aided Manufacturing resin composite, with a specific focus on the micro-hardness of the composite. The acidic exposure, which consisted of immersing them in an acidic solution for at least six and up to twenty-four hours, did not have any effect on the micro-hardness of the samples. These findings are in stark contrast to the studies that have been conducted up until this point. Although dental ceramics are believed to be chemically inert restorative materials, their durability and long-term stability may be compromised if they are subjected to chemicals that are acidic and erosive.

The trial directed by Kukiattrakoon et al., (11)analyzed the microhardness of ceramics that had been immersed in acidic liquid and the elemental compositions of their surfaces. A drop in the micro-hardness values of ceramics was proven by them. This loss can be related to the dissolution of materials, which occurs when ceramics are exposed to an acidic environment. Essential components like aluminum, silica, & potassium are liberated from the glass phase. It has also been observed that disintegration occurs in other dental materials that are utilized in conservative dentistry, (14) for instance fiber-reinforced composites and resin composites (15).

Alencar-Silva et al. (7) performed research on a vitreous Computer-Aided Design / Computer-Aided Manufacturing lithium disilicate ceramic that had a glazed or mechanically polished finish. They examined the impacts of popular drinks and toothbrushing on ceramic SR, microhardness, and color stainability. Immersion in the beverages changed the computer-Aided Design / Computer-Aided Manufacturing lithium disilicate ceramic's SR, microhardness, and color stainability. These alterations varied according to the surface treatment that was utilized.

Surface treatment had an effect on SR, which increased across the board, with the glazed groups showing the highest values. Surface treatment and solutions both have an impact on the microhardness reduction. On whatever measure, the use of a toothbrush had no significant effect.

Actually, the buccal cavity is a complex aqueous environment that is influenced by the daily consumption of a variety of substances. One illustration is that the pH values of saliva can be diminished by food and beverages. Through the utilization of this technology, it is possible to modify the physical and mechanical characteristics of restorative Computer-Aided Design / Computer-Aided Manufacturing materials (16). In this experiment, the degradation of mechanical qualities, like flexural strength, flexural modulus, and micro-hardness, is a consequence of factors such as acids, saliva, and bases (17). These factors played a role in the degradation of these properties. According to the findings of Colombo et al. (9), the outcomes achieved at T0 confirmed that Computer-Aided Design / Computer-Aided Manufacturing resin composites exhibit superior micro-hardness properties. This was in contrast to the other materials that were evaluated. Ceramic-based materials boast greater mechanical qualities and are often more robust than composite-containing materials. Ceramic-based materials also have a longer lifespan (18).

Egilmez et al., (10) evaluated the Weibull properties and flexural strength of a variety of CAD/CAM materials under a variety of in vitro aging conditions. Their results suggested that the flexural strength of newly developed restorative Computer-Aided Design / Computer-Aided Manufacturing materials was significantly reduced by artificial aging. The structural integrity and flexural strength of CerasmartTM as well as LavaTM Ultimate are not affected by HCl exposure or cyclic loading.

CONCLUSION

Restorative materials exposed to acid challenge exhibited higher SR and decreased micro-hardness, according to this systematic review and meta-analysis. Prior to and following acid exposure, the micro-hardness values of the various CAD/CAM materials varied.

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