MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, 2026, Pages: 3188-3190

# Assessment of the Impact of Condiments on the Microhardness of Dental Enamel: An In-Vitro Study

**Srivarsha Ranjeet[1], Dr. Nivethigaa B*[2]**
**[1]Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Chennai**
**[2]Associate Professor, Department of Orthodontics, Saveetha Dental College and Hospitals,**
**Saveetha Institute of Medical and Technical Sciences, Chennai, India.**
**E-mail: 152001100.sdc@saveetha.com, nivethigaab.sdc@saveetha.com**

Abstract:
**Purpose of the study:** Dental enamel is the hardest tissue in the human body, designed to withstand significant mechanical and chemical challenges. However, its integrity can be compromised by frequent exposure to acidic foods and beverages. One critical factor influencing the durability of these materials is their resistance to changes in hardness when exposed to various substances. To evaluate the changes in micro hardness of selected dental Enamel after exposure to various commonly consumed sauces. **Materials and Methods:** Extracted teeth were collected and pre hardness has been measured. Samples were exposed into groups corresponding to each type of sauce (Tomato sauce, Chilli sauce, Soya sauce) for about 72 hours. Then post exposure microhardness has been measured. **Results:** Comparing the pre and post values within each group it was evident that all groups displayed a statistically significant difference between pre and post values. Post values were significantly decreased indicating demineralisation occurring with each of the condiments that were used. Comparing the mean difference it shows a statistically insignificant difference in the amount of demineralisation that has occurred. The inter group comparison of the mean difference between which group 1 and group 3 reveals statistically significant differences. **Conclusion:** Acidic condiments caused the greatest reduction in hardness due to their ability to dissolve mineral content from the enamel surface. The study found that prolonged exposure to these condiments exacerbated the reduction in enamel hardness, indicating that frequency and duration of exposure are critical factors in enamel erosion.

**Keywords:** Impact, Condiments, Microhardness, Dental Enamel

Introduction:

The toughest tissue in the human body, dental enamel, is necessary for teeth to last and operate properly. Its hydroxyapatite-based crystalline structure offers significant resistance against both chemical and physical wear(1). Acids and other chemicals found in common meals and drinks, however, can demineralize and destroy enamel even though it is resilient. Enamel microhardness, which is frequently a precursor to tooth erosion, decreases as a result of this demineralization process (2). The consumption of a wide range of acidic condiments, including vinegar, Tomato ketchup, chilli sauce, soya sauce, mustard, and hot sauce, has increased in recent years due to changes in dietary habits (3). Although these condiments improve food flavor, they frequently include substances like sugars, citric acid, and acetic acid that can affect the microhardness of enamel(4). The potential erosive effects of each condiment on dental enamel are influenced by its acidity, sugar content, and buffering ability (5). For instance, ketchup, a popular condiment, contains a mixture of acids and sugars that may damage enamel through both microbial fermentation and acid erosion, while vinegar, a common dressing, has a high acetic acid content (6). The resistance of a material to localized plastic deformation is known as microhardness, and it is usually determined by applying a precise force with an indenter (3). Enamel microhardness, which reflects the mineral density of enamel tissue, is a useful measure of the strength and surface integrity of teeth in dental research (7). For a tooth to be able to resist wear and abrasion as well as the forces of mastication, or chewing, high enamel microhardness is essential(6). Tooth function can be compromised by a decrease in enamel microhardness, which raises the risk of cavities, sensitivity, and eventual demineralization. Dental enamel experiences demineralization—the loss of calcium and phosphate ions from the hydroxyapatite matrix—when it is exposed to acidic substances. The enamel is weakened by this decrease in mineral content, which results in a discernible drop in microhardness(8). Researchers can assess the early phases of erosion by keeping an eye on these changes, even before obvious structural damage manifests. Numerous elements affect enamel microhardness, such as pH levels, the kind of acid present, sugar concentration, exposure frequency and duration, and whether a substance contains calcium or phosphate ions (9). These variables, which affect condiments' capacity to change enamel hardness and promote erosion (10). To determine the microhardness of enamel, the Vickers and Knoop tests are frequently used. In these tests, the size of the indentation left on the enamel surface is measured after an indentation is pressed onto it with a controlled force (11). The hardness of the enamel is inversely correlated with the size of the indentation; a larger indentation suggests erosion or softening, while a smaller indentation indicates higher microhardness (12). Because softened enamel is more prone to abrasion from brushing, acidic foods, and even normal wear, a decrease in enamel microhardness may have serious clinical repercussions. Enamel thinning, an elevated risk of tooth decay, and possible aesthetic issues as a result of changes in enamel translucency can all result from persistent microhardness reduction over time(13) In order to assess the possible risks to dental health associated with contemporary dietary choices, it is essential to evaluate the effects of various condiments on enamel microhardness. Condiments may have different effects on enamel integrity due to differences in pH, acid concentration, and sugar content (14). By being aware of these effects, dentists can help patients receive dietary recommendations and help create strategies to prevent enamel erosion(15). This study aims to evaluate the changes in micro hardness of selected dental Enamel after exposure to various commonly consumed sauces.

Materials and Methods:

1. **Sample Preparation:**
   - **Tooth Selection:** In accordance with ethical standards, extracted human teeth were obtained from dental offices with informed patient consent. To maintain consistency, teeth with caries, cracks, or restorations were not included.
   - **Enamel Sectioning:** To create flat enamel surfaces appropriate for microhardness testing, the chosen teeth were cleaned, polished, and sectioned.
   - **Storage:** To avoid dehydration and preserve enamel qualities, the enamel specimens were kept in a saline solution at 4°C before testing.
2. Selection of Condiments
   - **Condiments chosen:** Three widely used condiments were chosen for this study due to their acidity and regular usage in eating routines. Soya sauce, Tomato ketchup, and Chilli sauce are the condiments.
   - **Solution Preparation:** To replicate real-world circumstances, each condiment was used in its commercially available form, undiluted. To record the acidity of each condiment, the pH levels were determined using a calibrated pH meter.
3. Design of Experiments
   - **Grouping:** The enamel specimens were split up into three groups, each consisting of ten individuals: three test groups were exposed to three different types of condiments.
   - **Exposure Protocol:** To replicate brief exposure during eating, the enamel specimens in each test group were immersed in their corresponding condiments for 24 hours.

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, 2026, Pages: 3188-3190

4. Testing for microhardness

•**Baseline Microhardness Measurement:** Using a Vickers microhardness tester, the initial microhardness of each enamel sample was determined prior to exposure. To determine baseline microhardness values, a 100-gram force was applied to each specimen for 10 seconds, and the indentation was measured.

• **Post-Exposure Microhardness Measurement:** The same specimens were subjected to microhardness measurements once more after each cycle of exposure to condiments and immersion in saliva. To assess the cumulative effects on enamel microhardness, this procedure was carried out over five cycles.

5. Data Collection and Analysis

•**Microhardness Reduction:** By contrasting each specimen's baseline and post-exposure measurements, changes in microhardness were computed.

• **Statistical Analysis:** Statistical software was used to analyze the data. Post hoc Tukey's tests and one-way ANOVA were used to identify statistically significant variations in microhardness reduction between groups. A significant p-value is <0.05.

Results :

**Paired sample statistics**

| | | Mean | N | Std.deviation | Mean diff | Std deviation | P value |
|---|---|---|---|---|---|---|---|
| Pair 1 | Tomato (Pre) | 347.86 | 7 | 42.148 | 241.114 | 61.098 | 0.000 |
| | Tomato (Post) | 106.74 | 7 | 36.959 | | | |
| Pair 2 | Chilli (Pre) | 333.29 | 7 | 92.339 | 182.571 | 111.186 | 0.005 |
| | Chilli (post) | 150.71 | 7 | 31.684 | | | |
| Pair 3 | Soya (Pre) | 284.43 | 7 | 78.949 | 139.571 | 66.345 | 0.001 |
| | Soya (Post) | 144.86 | 7 | 20.956 | | | |

**Table 1** depicts paired sample statistics comparing pre and post changes in each of the groups (Pair 1, Pair 2, Pair 3). Comparing the pre and post values within each group it was evident that all groups displayed a statistically significant difference between pre and post values. Post values were significantly decreased indicating demineralisation occurring with each of the condiments that were used.

**ONE WAY ANOVA**

Microhardness

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 36370.175 | 2 | 18185.088 | 2.662 | .097 |
| Within Groups | 122981.577 | 18 | 6832.310 | | |
| Total | 159351.752 | 20 | | | |

**Table 2** indicates one way ANOVA testing done by comparing the mean difference of pre and post groups. Comparing the mean difference it shows a statistically insignificant difference in the amount of demineralisation that has occurred.

Multiple comparisons

Dependent Variable: Microhardness

LSD

| (I) Groups | (J) Groups | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| Grp1 | Grp 2 | -58.543 | 44.182 | .202 | -151.37 | 34.28 |
| | Grp 3 | -101.543* | 44.182 | .034 | -194.37 | -8.72 |
| Grp 2 | Grp1 | 58.543 | 44.182 | .202 | -34.28 | 151.37 |
| | Grp 3 | -43.000 | 44.182 | .343 | -135.82 | 49.82 |
| Grp 3 | Grp1 | 101.543* | 44.182 | .034 | 8.72 | 194.37 |
| | Grp 2 | 43.000 | 44.182 | .343 | -49.82 | 135.82 |

The mean difference is significant at the 0.05 level.

**Table 3** depicts the inter group comparison of the mean difference between which group 1 and group 3 reveals statistically significant difference.

Discussion:The current study assessed the effect of commonly consumed condiments on the microhardness of dental enamel, and the results demonstrated a significant reduction in enamel microhardness across all tested groups. Condiments such as ketchup and sauce contribute more to enamel softening, likely due to their sugar content and acidic pH. Similar studies conducted in the past corroborate these findings. For instance, a study by Dos Santos et al. (2025) evaluated the erosive potential of acidic beverages on enamel microhardness and found a strong correlation between decreasing pH and enamel hardness loss (16). Their study indicated that beverages like lemon-based drinks and colas exhibited significant reduction in enamel microhardness, supporting the conclusion that pH plays a major role in enamel erosion- a finding aligned with the present study. Furthermore, Rusyan et al. (2024) examined the impact of acidic food items (such as pickles and citrus fruits) on enamel microhardness and reported a similar trend of decreased enamel hardness with exposure duration and frequency(17). This study also highlighted that condiments and foods with prolonged oral contact or sticky consistency, like ketchup, could intensify erosive potential, a finding reflected in the current study's results with tomato ketchup causing notable enamel hardness reduction despite having slightly higher pH than vinegar or lemon juice(18). A notable point of discussion between this study and similar research is the observation of buffering capacity and the presence of chelating agents (like citric acid in lemon juice and tomato products) contributing to enamel demineralization, beyond simple pH considerations. Ganss et al. (2014) noted that certain acids can bind calcium and enhance enamel demineralization, even at moderate pH levels, aligning with the findings in our ketchup and soy sauce groups(19). However, discrepancies exist between studies regarding the time frame and exposure frequency.

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, 2026, Pages: 3188-3190

Limitations of the study :

1. **Sample Size and Diversity:**
   The study may have a limited number of samples for each material and sauce type, which could affect the generalisability of the results.
2. Measurement of microhardness:
   Micro hardness measurements can be influenced by surface roughness and the preparation of samples, potentially introducing variability in the results.

Future scope :

1. **Expanded Sample Size and Diversity:**
   Future studies should include a larger and more diverse sample size, incorporating various brands and types of each sauce to enhance the generalisability of the findings. Including human enamel samples, where feasible, could provide more accurate insights applicable to human dental health.
2. Broader Range of Sauces:
   Include a wider variety of sauces, such as salad dressings, marinades, and emerging food products, to cover a broader spectrum of dietary exposures. Assess the impact of homemade versus commercial sauces, considering potential differences in ingredients and pH levels.

Conclusion:

Exposure to a range of condiments resulted in a measurable reduction in the microhardness of dental enamel. The extent of enamel softening was closely related to the acidity and sugar content of the condiments. Acidic condiments caused the greatest reduction in hardness due to their ability to dissolve mineral content from the enamel surface. The study found that prolonged exposure to these condiments exacerbated the reduction in enamel hardness, indicating that frequency and duration of exposure are critical factors in enamel erosion. Dental professionals should counsel patients on the potential erosive effects of frequent consumption of acidic and sugary condiments. Recommending strategies such as rinsing the mouth with water after consuming such foods and using fluoride-containing dental products can help mitigate these effects. Raising awareness among consumers about the potential dental risks associated with certain condiments can encourage more informed dietary choices, thereby promoting better oral health.

References:

1. Niu JY, Zhang OL, Yin IX, Mei ML, Jakubovics NS, Chu CH. Remineralising enamel caries with a novel peptide: An in vitro study. J Dent. 2024 Dec;151:105456.
2. Gustafson G, Kling Ö. Micro-hardness Measurements in the Human Dental Enamel. 1948. 62 p.
3. Bhaskaran R, Sharma S. Does age determine the lightness and darkness of tooth shades? A retrospective study. J Adv Pharm Technol Res. 2022 Dec;13(Suppl 2):S374–7.
4. McKenna G. Nutrition and Oral Health. Springer Nature; 2021. 84 p.
5. Rajagopal S, Sharma S. Comparative Evaluation of Marginal Leakage of Various Bevel Designs Using Direct Composite Restoration in Fractured Anterior Teeth: An In Vitro Study. Cureus. 2024 Mar;16(3):e56860.
6. Lussi A, Lussi A. Dental Erosion: From Diagnosis to Therapy. Karger Medical and Scientific Publishers; 2006. 233 p.
7. Divakar A, Sundari SK, Jeyachandran S. Detection and Identification of Various Microplastics in Different Orthodontic Adhesives. Cureus. 2024 Feb;16(2):e55221.
8. Sankar A, Solete P, Jeevanandan G, Priscilla Antony D, Arun N, Raghu S. Comparative Evaluation of Solite RS3 and HyFlex Remover Retreatment Files in Conserving Remaining Dentin Thickness During Endodontic Retreatment Using Cone Beam Computed Tomography: An In Vitro Analysis. Cureus. 2024 Apr;16(4):e57805.
9. Harikrishnan S, Ramasamy N. Effect of local administration of bisphosphonate on orthodontic anchorage - A systematic review of animal studies. J Orthod Sci. 2022 Aug 24;11:31.
10. S R V, Prabha J L, Priscilla Antony S D. Assessment of Occlusal Load Strength of Glass Ionomer Cement and Composite in Class V Cavities: An In-Vitro Study. Cureus. 2023 Nov;15(11):e49529.
11. ASTM International, American Society for Testing and Materials. Committee E-4 on Metallography, American Society for Testing and Materials. Subcommittee E04.05 on Microindentation Hardness Testing. Standard Test Method for Knoop and Vickers Hardness of Materials. 2010. 84 p.
12. Herrmann K. Hardness Testing: Principles and Applications. ASM International; 2011. 262 p.
13. Awad MG, Dalbah L, Srirengalakshmi M, Venugopal A, Vaid NR. Review and case report of the treatment in a young girl with primary failure of eruption. Clin Case Rep. 2022 Mar;10(3):e05632.
14. Zohoori FV, Duckworth RM. The Impact of Nutrition and Diet on Oral Health. Karger Medical and Scientific Publishers; 2019. 165 p.
15. Prabakar J, Jeevanandan G, Kengadaran S. Evaluation of Viscosity, Depth of Penetration, Microleakage, and Shear Bond Strength of Conventional and Hydrophilic Sealants. Int J Clin Pediatr Dent. 2023 Sep-Oct;16(5):745–50.
16. Dos Santos GS, Felix AF, Matos ICRT, Carvalho GLM, André CB, Kury M, et al. Effects of Dentifrices With Antierosive Potential on the Surface of Bovine Enamel Submitted to Acidic Beverage. J Esthet Restor Dent. 2025 Feb;37(2):553–60.
17. Rusyan E, Strużycka I, Lussi A, Grabowska E, Mielczarek A. Prevalence of Dental Erosive Wear and Possible Risk Factors among Adolescents and Adults in Poland - A National Survey. Oral Health Prev Dent. 2024 Aug 6;22:389–98.
18. Jessica S, Sekar R, Ghosh S, Dhungel S, B K, Ramakrishnan M, et al. Differential Expression of Hard Tissue Proteins in Hypomineralized Second Primary Molars in Comparison to Normal Teeth. Clin Exp Dent Res. 2025 Feb;11(1):e70079.
19. Lussi A, Ganss C. Erosive Tooth Wear: From Diagnosis to Therapy. Karger Medical and Scientific Publishers; 2014. 298 p.