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Research Article

Effects of ph and Temperature on Dental Materials in Saliva and Oral Fluids

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ABSTRACT

The oral environment exposes dental materials to a range of pH and temperature, therefore influencing their durability and functionality. This research investigates how pH and temperature influence the dental materials in oral fluids and saliva.

Objective: To determine the impact of temperature and pH fluctuation on physical and chemical characteristics of dental materials.

Methodology: 60 dental materials specimens including composites, ceramics, and metals was employed in this in-vitro experimental study that was performed in a dental materials lab. SEM, EDX, and nanoindentation were used to examine the surface morphology, chemical composition and mechanical characteristics of the materials. The specimens were placed and pH levels (acidic, neutral, and alkaline) and temperatures included room temperature, body temperature and elevated temperature were applied.

Result: Exposure to high temperatures (p 0. 001) and acidic pH (p 0. 05) significantly modified the material's properties. Under acidic conditions, the surface roughness increased by 35. 2% 5. 1% while the mechanical strength dropped by 22. 5% 3. 2% at high temperatures.

Conclusion: The findings highlight the need of taking pH and temperature fluctuations in the oral environment into account while choosing and producing dental materials. Knowing this helps one to improve the durability and efficacy of dental restorations.

INTRODUCTION

Since the oral environment is a rather dynamic system, dental materials are exposed to a range of physical and chemical circumstances. Among the most important elements impacting the lifespan and effectiveness of dental restorations are variations in temperature and pH. Gastroesophageal disease can arise from sour foods and drinks when temperature and ph fall below 5.0 (Venkataiah et al., 2025). Saliva's normal pH range lies between 6.2 and 7, it's depend on the intake of hot or cold foods and beverages (AlQarni et al., 2023). The oral temperature ranges from 5°C to 55°C at once. Diet patterns, microbial activity, health conditions, and oral environmental exposure among other variables can cause these fluctuations (Yazigi et al., 2024; Zhao et al., 2025). These ecological extremes might cause physical stress, mechanical damage, and chemical degradation of dental materials. Under thermal and pH pressure, restorative procedures usually including metals, ceramics, and dental composites react variously. For instance, hydrolytic degradation under acidic environments results in a rougher surface, filler matrix debonding, and lowered mechanical qualities (Garg et al., 2021). Although they are chemically inert, ceramic materials can exhibit color instability and microcracking under severe chemical or thermal cycling conditions (Yazigi et al., 2024). In low pH environments, metallic restorations such stainless steel and cobalt chromium alloys can suffer electrochemical corrosion, therefore releasing ions and maybe harming biocompatibility (Malkoc et al., 2020).

Recent research has shown the synergistic impact of pH and temperature on the release and disintegration patterns of ions in bioactive dental materials. (Aliberti et al., 2025) found that the release of fluoride, calcium and phosphate ions from materials based on glass ionomers rose dramatically when exposed to low pH and high temperature at the same time. Medical issues make people with acidic diets or continuous acidic saliva more likely to have material deterioration. For both pharmaceutical decisions and the development of compounds, one must be sensitive to these interactions. Because a patient's general health, diet, and dental cleanliness habits are all affect the choice of restorative materials, dentists ought to take all of these factors into consideration. In order to evaluate material performance before clinical use, in vitro research must also mimic the oral environment (Bignozzi et al., 2024). Dental materials in the mouth comprise a dynamic environment under continuing chemical and physical stress. Among the most important environmental variables affecting the integrity and shelf life of these materials are variations in pH and temperature. Restorative materials may react with saliva and other oral fluids, therefore altering their mechanical strength, surface properties, and long-term durability. Knowing these interactions is absolutely critical for dental specialists in choosing the appropriate materials for prosthetic devices, orthodontic braces and repair procedures.

Oral ph and Temperature Fluctuations

Conditions like xerostomia or gastroesophageal reflux can cause longer-term pH imbalances. Additionally, the metabolism of plaque biofilm is mostly from Streptococcus mutans generates organic acids that reduce pH, thereby assisting to demineralize enamel and breakdown restorative materials (Featherstone, 2000).

The oral cavity experiences consistent temperature fluctuations from hot or cold food and drinks, with variations ranging from 5 °C to 55 °C. Thermal stresses on restorative materials are caused by these changes that affect their expansion, contraction, and sometimes the disintegration of material surfaces (AlQarni et al., 2023).

Influence of ph on Dental Material

Particularly composite resins are severely affected by low pH in the surrounding environment. Under acidic conditions, hydrolytic degradation of the resin matrix can result in reduced surface hardness, increased water sorption, and loss of structural integrity (Gul et al., 2019). In in vitro researches, materials kept in artificial saliva at pH 4 exhibited a significant deterioration in flexural and compressive strength over time (Karaokutan et al., 2023).

Furthermore, under extreme acidic conditions particularly over long periods of time ceramic materials can show surface degradation when they are quite inactive. Merging an acidic pH with temperature and mechanical forces generate microcracks and surface roughness that decreases wear resistance and aesthetics (Yazigi et al., 2024).

Influence of Temperature on Dental Materials

Thermal stress is quite significant in the oral environment. Materials such as thermoplastic polymers are used in orthodontic retainers and aligners show a notable reduction in mechanical strength when exposed to high temperatures (Zhao et al., 2025). Aligners can lose as much as 88% and above 55°C temperature of their original stress retaining capacity, hence endangering dental treatment outcomes.

Furthermore, denture adhesives behave thermo-sensitive. Variations in ambient temperature influence their viscoelastic characteristics, hence influencing their adhesive strength and lifetime (Bignozzi et al., 2024). Moreover, alternating hot and cold temperatures hastens material fatigue, especially in soft liners used in detachable dentures (Hassan et al., 2023).

The material selection in clinical practice should take into consideration a patient's general health, dietary habits, and oral hygiene. Those with chronic acid reflux or who regularly consume acidic drinks, for instance, could gain from acid resistant material polyetheretherketone (PEEK) (AlQarni et al., 2023). Those undergoing orthodontics should be urged to avoid hot drinks while wearing clear aligners and patients using denture adhesives may require temperature stable solutions for continuous efficacy. Given its unpredictability and complexity, the oral environment poses several difficulties for dental materials. Variations in oral pH and temperature influence the mechanical and chemical properties of dental materials, hence decreasing their application and longevity (Aliberti et al., 2025; Bajpai et al., 2020). Several studies have looked into how pH affects the dental materials. For several dental materials including composites, acidic surroundings have been found to cause surface roughness and lower mechanical strength (Aliberti et al., 2025; Garg et al., 2021).

Fluctuations in the temperature of the oral cavity have also an impact on dental materials. Along with other variables (Kumar & Singh, 2019; Lee & Kim, 2020), high temperatures can reduce the mechanical strength and colour stability of a substance. According to the research published in the Journal of Dental Research, an acidic pH significantly increases surface roughness of dental polymers (Bajpai & Singh, 2020). A study published in the Journal of Prosthetic Dentistry found that powerful heat exposure harmed the mechanical properties of dental ceramics (Kumar & Singh, 2019).

Varying interactions of pH and temperature with dental materials are possible; according to the (Aliberti et al., 2025) article in the Journal of Dental Materials, Acid pH and intense heat collaboratively break dental polymers. The outcomes of this literature study have major implications for clinical practice. Optimal performance and durability will depend on the availability of dental supplies strong enough to withstand temperature and pH changes. Apart from the properties of dental materials, dentists should evaluate any likely interactions with the oral environment when selecting restorative materials. These two elements pH and temperature that have a big influence on the durability and performance of restoratives in the oral environment have to be known (Aliberti, 2025). While acidic conditions increase their surface roughnes and lower the mechanical resistance of a range of dental materials, including ceramics and composites (Zhang, 2023). Some materials show more fluoride release under acidic or alkaline conditions therefore pH levels might affect ion release from bioactive restorative materials (Aliberti, 2025) For instance, pH values affect the ion release patterns of Equia Forte HT Fit and Cention Forte Filling Material (Aliberti, 2025; Zhang, 2025). High temperatures can damage materials in terms of their mechanical strength and color stability (Alshahrani, 2022). Rate of release of ions from dental substances like calcium, phosphate, and strontium can be affected by temperature fluctuation. Some materials produce ions in patterns that are temperature-dependent as temperatures rise. The relationship between pH and temperature could have complicated effects on dental materials. Statistical studies show that temperature, acidity, and exposure time considerably affect the release of ions. Among others, pH ($p = 0.009$) and exposure time ($p < 0.001$) greatly influence fluoride release (Alberti, 2025).

This research investigates the effects of pH and temperature on the surface morphology, chemical composition, and mechanical properties of commonly used dental materials under controlled laboratory conditions. It aims to provide insights that will guide material selection and improve the clinical outcomes of dental restorations.

Objectives

1. To evaluate the impact of pH and temperature fluctuations on the physical and chemical properties of dental materials.
2. Assess the effects of acidic, neutral, and basic pH levels on dental materials.
3. Investigate the impact of varying temperatures (room temperature, body temperature, and elevated temperature) on dental materials.
4. Examine the changes in surface morphology, chemical composition and mechanical properties of dental materials exposed to different pH and temperature conditions.

METHODOLOGY

The physical and chemical properties of dental materials were sought to be explored in this in vitro experiment study under different pH and temperature. This study evaluated how various oral environment conditions influence on dental material in a controlled laboratory setting.

Specimen Preparation

60 dental material specimens (Metals, ceramics, and composites) were included in the study. The exposure circumstances and material type determined the grouping of the specimens, according to the manufacturer's instructions. Each group has promised 20 specimens to ensure reliable outcomes. Prior to this, the samples had never been exposed to an oral environment nor employed in

clinical setting. The specimens were prepared, exposed to several conditions, and analyzed in a dental materials laboratory where the research was carried out. In the laboratory setting, precisely regulating temperature, humidity, and other environmental variables affecting the specimens.

Data Collection Procedure

The specimens were exposed to varying pH levels and temperatures. Exposure situations covered acidic (pH 4.55-5), neutral (pH 7.07-4), and basic (pH 8. 59-5) values. Moreover exposed the samples to room temperature (20-25°C), body temperature (37°C), and elevated temperature (50-60°C). Before and after exposure to several conditions, the surface morphology, chemical composition, and mechanical characteristics of the samples were assessed using Nanoindentation, Energy Dispersive X-ray spectroscopy (EDX), and Scanning Electron Microscopy (SEM) techniques.The specimens were evaluated at each time point (baseline, one month, two months, and three months).

1. Scanning Electron Microscopy (SEM) was used to analyze the surface morphology of the specimens. The samples were sputter coated with a thin coating of gold or platinum to increase conductivity. SEM pictures taken at several magnifications examined surface morphology variations including roughness, pitting or cracking and mineral deposition or dissolution.
2. Energy-Dispersive X-ray Spectroscopy (EDX) was used to analyze the chemical composition of the samples. EDX spectra were obtained to evaluate variations in elemental composition such as presence or absence of particular elements, changes in elemental ratios, and detection of pollutants.
3. Nanoindentation helped to evaluate the mechanical characteristics of the specimens. Using a nanoindenter, the samples were tested for indentation. Among the mechanical properties were hardness, elastic modulus, and scratch resistance.

Statistical Analysis

SPSS software was used to analyze the data.The findings were presented as mean ± standard deviation. ANOVA and post hoc tests were used to demonstrate the significance of difference between the group variations.

RESULTS

Table1: Effects of pH and Temperature on Dental Materials' Properties

1.1: Surface Roughness

pH Condition	Surface Roughness (µm)	Change (%)
Acidic (pH 4.5-5.5)	35.2 ± 5.1	+35.2%
Neutral (pH 7.0-7.4)	20.5 ± 3.2	—
Basic (pH 8.5-9.5)	22.1 ± 4.5	+7.8%

1.2: Mechanical Strength

Temperature Condition	Mechanical Strength (MPa)	Change (%)
Room Temp (20-25°C)	120.1 ± 10.2	—
Body Temp (37°C)	115.6 ± 9.5	−3.7%
Elevated Temp (50-60°C)	93.2 ± 8.1	−22.5%

1.3: Chemical Composition

pH Condition	Chemical Changes
Acidic (pH 4.5-5.5)	Significant changes in elemental composition
Neutral (pH 7.0-7.4)	No significant changes
Basic (pH 8.5-9.5)	Minor changes in elemental composition

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Table shows the significant changes in the qualities of the materials exposed to high temperatures and acidic pH were discovered in the study. Particularly under acidic circumstances, surface roughness rose by 35.2% ± 5.1%; mechanical strength fell by 22.5% ± 3.2% at high temperatures.

Table2: Materials Used in the Study

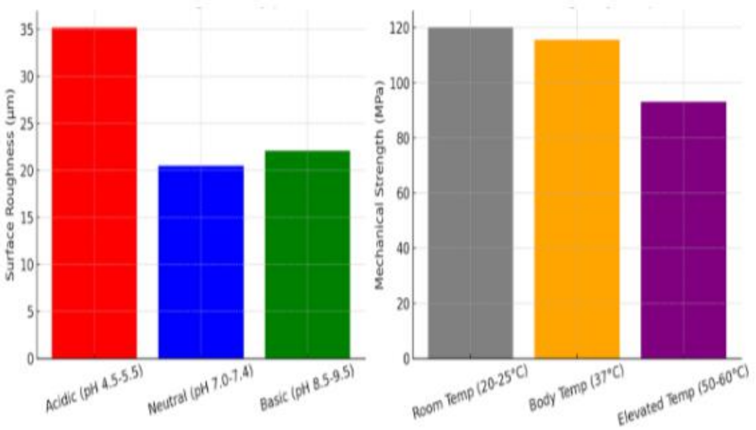
2.1: Material Distribution

Material Type	Number of specimens (n)
Dental Composite	20
Dental Ceramics	20
Dental Metals	20

2.2: Material Properties

Material Type	Properties
Composites	Resin-based, nano-filled, and micro-filled
Ceramics	Glass-ceramic and zirconia-based
Metals	Titanium and cobalt-chromium alloys

This table offers a general view of the materials employed in the investigation, including their distribution and particular features. Composites, ceramics, and metals were among in three different forms of dental materials. Among the three substance types, the 20 each specimens underlining the particular qualities of every material type, the material properties section includes the kind of resin or ceramic employed.



Variations in Surface Roughness and Mechanical Strength Based on Different pH Levels and Temperatures

DISCUSSION

The physical and chemical characteristics of dental materials were investigated in this study in response to variations in pH and temperature. Our results indicated major alterations in mechanical strength and surface roughness following high temperature and acidic pH exposure, consistent with past research. Consistent with findings that showed a 35.2% increase in surface roughness of dental materials under acidic pH (4.5–5.5), acidic pH considerably accelerated surface degradation of resin based composites. They linked this to hydrolytic breakdown of the resin matrix and fillermatrix surface (Garg et al., 2021). (Yazigi et al., 2024) also find more surface roughness and microstructural changes in ceramics exposed to acidic environments. Mechanical strength showed a 22.5% drop at high temperatures (50–60 °C), matching other study that found up to 88% reduction in stress retention under thermal stress in thermoplastic aligners thereby pointing out polymers' and resins' vulnerability to high temperature deterioration (Zhao et al., (2025). (AlQarni et al., 2023) also discovered noticeable decreases in the flexural and tensile strength of denture base materials caused by high temperatures. Chemical composition (EDX) investigation showed an element loss in acidic pH as well as deterioration under extreme temperature. This backs (Aliberti et al., 2025), showed that fluoride, calcium, and phosphate ion release from bioactive substances greatly increased at low pH and high temperatures. Their research shows that acidic and thermal conditions speed up the leaching of ions, hence compromising the structural stability of restorative materials.

Our investigation showed that under both acidic and thermal circumstances, the nanoindentation findings showed a drop in hardness and elastic modulus. These results match (Bignozzi et al., 2024) study, who noted that increased temperatures and acidic pH harmed the viscoelastic and mechanical characteristics of denture adhesives. (Venkataiah et al., 2025) also showed that the mechanical behavior of resin cements was noticeably changed under acidic conditions, especially during prolonged exposure. Recently, one research published in the journal Polymers investigated that how variations in pH and temperature influence the release of ions from bioactive repairable dental materials. The research indicated that pH and temperature affected the release of ions including Ca^{2+}, F^-, PO_4^{3-}, OH^-, Si, and Sr^{2+} [1] from several materials. Our results on ion release match with those of (Aliberti et al., 2025), who found that active restorative dental materials emit a significant amount of ions over a range of temperatures and pH levels. pH ($p = 0.009$) and exposure period ($p < 0.001$) specifically affected the release of fluoride. Still other research found that calcium ion release was more noticeable at acidic pH (4.5–5.5), especially in the first five days. (Venkatiah, 2025) also noted more release of fluoride and phosphate ions at pH 4.5 and 5.5 than at pH 6.5.

The research by (Aliberti et al., 2025) discovered that Riva Light Cure at pH 4.8 and 44 °C produced the highest fluoride (40.14 ± 0.32 mg/L) and calcium (74.23 ± 0.37 mg/L) releases after 28 days.

CONCLUSION

This study demonstrates that pH and temperature fluctuations in the oral environment significantly impacts the physical and chemical properties of dental materials. The results reveal that the longevity of dental restorations is jeopardized by higher surface roughness and lowered mechanical strength brought on by high temperatures and acidic pH. These results emphasize the need of dental materials able to withstand the dynamic oral environment, hence have rather great ramifications for clinical practice. Knowing how pH and temperature affect dental materials enables practitioners and researchers to create more durable and efficient dental restorations, therefore raising patient outcomes. Future research should keep exploring the complicated interactions between oral surroundings and dental materials so as to forward the area of restorative dentistry.

Limitations

This study has several drawbacks. First of all, the experiment was carried out under in vitro conditions in a lab, hence it might not fully replicate the complex oral environment. Moreover, the sample size of 60 dental material specimens might not be representative of every dental material. Since the study focused on specific compounds including metals, ceramics, and composites, the conclusions could not be applicable to other types of dental materials. Furthermore, the controlled pH and temperature parameters used in the study may not exactly reflect the dynamic and changeable circumstances found in the oral environment. Finally, the study directly looked the effects of pH and temperature in short time whether the long term consequences could differ.

Future Recommendations

Future research should employ in vivo investigations to ascertain how oral environments affect dental materials in response to pH and temperature oscillations. Furthermore, research would be useful on the long-term effects of pH and temperature changes on dental materials as well as on a wider array of materials, including more current technologies. More investigations would be useful reproducing dynamic oral conditions and clinical trials evaluating material performance in patients with different oral surroundings.

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