

Research Article

Association Between Salivary Enzyme Composition and the Surface Degradation of Contemporary Resin Composite Restorative Materials

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ABSTRACT

Background: Resin composite materials are widely used for direct dental restorations because of their favorable esthetics, adhesive properties, and conservative preparation requirements. Despite continuous improvements in resin chemistry and filler technology, these materials remain susceptible to degradation in the oral environment. Saliva contains several enzymes capable of interacting with resin matrices and potentially accelerating hydrolytic and proteolytic deterioration. The extent to which salivary enzyme composition is associated with clinically detectable surface degradation of contemporary resin composite restorations remains an important area of investigation.

Objective: To determine the association between salivary enzyme composition and surface degradation of contemporary resin composite restorative materials, with particular emphasis on salivary esterase activity, surface roughness, microhardness, and microscopic surface changes.

Methodology: This analytical cross-sectional study was conducted at Rashid Latif Dental College from January 2025 to June 2025 and included 78 participants with resin composite restorations. After obtaining written informed consent, the selected resin composite restorations were carefully retrieved from the oral cavity, labeled, and transferred to the laboratory for analysis. Unstimulated whole saliva was collected under standardized conditions, and salivary flow rate, pH, esterase activity, amylase, protease, matrix metalloproteinase-8 (MMP-8), and matrix metalloproteinase-9 (MMP-9) were measured. All 78 retrieved restoration specimens were evaluated for surface roughness and Vickers microhardness, and all underwent scanning electron microscopy (SEM) for assessment of microscopic surface degradation, including surface pits, filler exposure, resin matrix erosion, and microcracks. Correlations between salivary and surface parameters, group comparisons, and multivariable regression analysis were performed. A p-value <0.05 was considered statistically significant.

Results: The mean age of participants was 34.7 ± 9.2 years, and 42 (53.8%) were females. All 78 retrieved resin composite restoration specimens were successfully evaluated for surface roughness, Vickers microhardness, and SEM-based microscopic degradation. Mean salivary esterase activity was 18.6 ± 6.1 U/mL, while mean surface roughness was 0.39 ± 0.14 μ m and mean Vickers microhardness was 67.8 ± 8.9 VHN. SEM assessment demonstrated mild, moderate, and marked surface degradation in 33 (42.3%), 27 (34.6%), and 18 (23.1%) specimens, respectively. Salivary esterase activity showed a significant positive correlation with surface roughness ($r = 0.56$, $p < 0.001$) and an inverse correlation with microhardness ($r = -0.48$, $p < 0.001$). Specimens from participants with high esterase activity demonstrated greater surface roughness than those with low esterase activity (0.46 ± 0.13 vs. 0.32 ± 0.11 μ m, $p < 0.001$) and lower microhardness (63.9 ± 8.4 vs. 71.7 ± 7.5 VHN, $p < 0.001$). Lower salivary pH and longer restoration duration were also independently associated with greater surface deterioration.

Conclusion: Higher salivary esterase activity was significantly associated with greater surface roughness, reduced microhardness, and more pronounced microscopic degradation of contemporary resin composite restorations. Salivary pH, restoration duration, and composite material type also influenced surface integrity. These findings suggest that patient-specific salivary biochemical

characteristics may contribute to variation in the long-term clinical performance of resin-based restorative materials.

Keywords: Salivary Enzymes, Esterase, Resin Composite, Surface Roughness, Microhardness, Biodegradation, Restorative Dentistry.

INTRODUCTION

Resin composite restorative materials have become an integral component of contemporary restorative dentistry because they combine favorable esthetic properties with adhesive bonding and the ability to preserve sound tooth structure. As filler technology, resin chemistry, polymerization systems and handling characteristics have improved, their use in both anterior and posterior restorations has significantly grown. Nanofilled, nanohybrid and microhybrid composites are modern materials that offer superior strength, wear resistance, polishability and optical properties. However, even resin composites are vulnerable to physical, chemical and biological degradation during extended periods of exposure to the oral cavity (1, 2).

The oral cavity is a very dynamic environment where restorative materials are constantly subjected to moisture, temperature and pH changes, food components, bacteria, masticatory forces and components of saliva. Sorption of water and hydrolysis can gradually degrade the polymer matrix and the bond between the resin and inorganic filler particles. Multiple mechanical actions can lead to additional surface fatigue, microcracks, filler loss and surface roughness. These changes can cause changes in the surface properties of composite restorations, reduce the mechanical integrity of the restoration, and contribute to the development of plaque formation, staining, marginal breakdown and secondary caries (3, 4).

Salivary enzymes have gained more interest as potential contributors to resin composite biodegradation among the biological factors involved in this process. Typical dental composites are based on methacrylate monomers as the link of the ester structure is prone to hydrolysis. The ester-containing bonds can be acted upon by salivary esterases, which can help to break down the organic resin matrix. Breakdown of resin-based dental materials has been especially related with cholesterol esterase-like and pseudocholinesterase-like activities. Hydrolysis of resin can give rise to products from the resin degradation, reducing the polymer network, disrupting the surface integrity and altering the mechanical properties over time (5, 6).

Other salivary and host-derived enzymes can also play a direct or indirect role in degradation at the restoration surface and bonded area. Proteolytic enzymes and matrix metalloproteinases, such as MMP-8 and MMP-9, are in charge of degradation of the ECM and have a potential involvement in degradation of the hybrid layer and resin-dentin interface. Salivary amylase is a hydrolase with the main function of carbohydrate digestion but may also be an indicator of the biochemical properties of the oral environment and have a relationship with the microbial colonization of restorative surfaces. Thus, saliva enzymatic content could be a significant biological factor that may affect the long-term performance of resin composite restorations (7, 8).

Surface roughness and microhardness may be valuable parameters to assess the deterioration of restorative materials. Surface roughness increases could be a sign of matrix erosion, exposure of filler particles, loss of filler particles, and lead to the retention of plaque and increased bacterial adherence. Lower microhardness means that the resin matrix has become softer and weaker and could be a sign of a failure in mechanical properties of the resin matrix. Structural changes (e.g. surface pits, cracks, erosion of resin matrix, exposure of filler particles) can be further identified by microscopic assessment. It may be possible to gain insight into the possible relationship between the biochemical oral environment and degradation of restorative materials by evaluating these surface characteristics in conjunction with salivary enzyme measurements (9, 10).

The differences in the characteristics of saliva among individuals may also account for the lability of apparently identical resin composite restorations that deteriorate at different rates among the patients. Salivary enzyme levels, pH, flow rate are inter-individually different and may be affected by age, diet, oral hygiene, systemic disease and local oral disease. Salivary pH may have a negative effect on hydrolytic instability, and decreased salivary flow may affect buffering capacity and clearance of acid. Concurrently, the chemical structure of the composite itself, such as resin monomers, and the properties and coupling of the resin with the

filler, influence the biodegradability of the composite (11, 12).

Although laboratory studies have demonstrated the ability of salivary enzymes to degrade resin-based dental materials, relatively limited clinical information is available regarding the relationship between naturally occurring salivary enzyme levels and measurable surface deterioration of restorations functioning in the oral cavity. The majority of investigations have been conducted under controlled laboratory conditions with simulated enzymes versus a few studies that have considered patient specific salivary biochemical profiles in relation to clinical restoration surface properties. This restricts the knowledge of inter-individual differences related to the duration of restoration, and how this can affect the durability of restoration in everyday dentistry (13).

Therefore, the present study was conducted to investigate the association between salivary enzyme composition and surface degradation of contemporary resin composite restorative materials. Particular emphasis was placed on the relationship of salivary esterase activity, amylase, protease, MMP-8, and MMP-9 with surface roughness, microhardness, and microscopic degradation characteristics. The study also evaluated whether salivary pH, salivary flow rate, restoration duration, and composite material type contributed to differences in surface integrity. It was hypothesized that increased salivary enzymatic activity, particularly esterase activity, would be associated with greater surface deterioration of resin composite restorations.

METHODOLOGY

This analytical cross-sectional study was conducted at Rashid Latif Dental College from January 2025 to June 2025. The study was designed to investigate the association between salivary enzyme composition and the surface degradation of contemporary resin composite restorative materials. The principal exposure variables were salivary enzymatic parameters, particularly esterase activity, amylase, protease, matrix metalloproteinase-8 (MMP-8), and matrix metalloproteinase-9 (MMP-9), while the principal outcome measures were surface roughness, surface microhardness, and microscopic features of resin composite degradation.

The study included 78 participants whose resin composite restorations were clinically functional. The study participants were selected

from the outpatient dental clinics of Rashid Latif Dental College during the study period. The sampling technique employed was non-probability consecutive sampling, which is the method of enrolling the patients who met the eligibility criteria until the desired sample size was obtained. To achieve independence of observations, only one eligible restoration was evaluated for each participant. If more than one restoration was suitable, a random selection procedure was predefined and one restoration was selected.

Patients were selected if they were adult (18 years or older) and received at least one permanent tooth restoration with a modern resin composite. Restorations were also required to have been in functional service for a long enough period to allow them to be exposed to the oral environment and the influence of the saliva. Participants were only included if they were willing to give an unstimulated saliva sample and have the selected restoration clinically examined. Patients with severe active periodontal disease, extensive untreated caries, acute oral infection, xerostomia, known systemic disease that significantly affects salivary secretion and history of head and neck radiotherapy were excluded. Additionally, patients taking medications that have a significant effect on the composition of saliva or salivary flow were excluded where clinically relevant. Gross fracture, complete loss, recurrent caries that needed immediate replacement and extensive structural damage that did not allow reliable surface assessment were not included.

Demographic data such as age and sex was collected after enrolment, using a structured data collection form. Oral characteristics that could affect the restoration, such as tooth type, anterior or posterior location, type of resin composite, duration of the restoration in the mouth, plaque status, and gingival condition were documented. The material used determined the classification of restorative material as nanohybrid, nanofilled or microhybrid composite, where available. Appropriate clinical indices were used to evaluate oral hygiene and gingival status under standardized clinical conditions. For each of the selected restorations, changes in surface appearance, including loss of surface gloss, surface irregularity, marginal deterioration, pits, exposed filler particles, cracks and evidence of resin matrix erosion were examined. After obtaining written informed consent from each participant, the selected

resin composite restoration was carefully removed from the oral cavity using appropriate rotary instruments under water cooling, taking care to minimize any additional mechanical damage to the restoration surface. The retrieved restoration was gently cleaned to remove adherent debris without altering its surface characteristics, labeled with the participant's study identification number, and transferred to the laboratory for further analysis. The retrieved specimen was subsequently prepared for scanning electron microscopy (SEM) and Vickers microhardness testing according to standard laboratory procedures.

The unstimulated whole saliva was collected to minimize the variations caused by foods consumed, oral hygiene, circadian rhythm and recent physical activity. Advices were given to the participants to refrain from eating, drinking other than water, smoking and all oral hygiene procedures for 1-2 hours prior to sampling. Participants rested for about 5 minutes prior to collection in a seated position. The participants were asked to collect their saliva passively in the floor of their mouth for a total of approximately 5 minutes, then to spit it into a sterile labeled collection cup every 30 seconds or so. Total volume of saliva collected was recorded and unstimulated salivary flow rate was determined (in mL/min) by dividing total volume by the collection time.

The pH of the saliva was measured by a calibrated digital pH meter or a pH measurement system used in a laboratory immediately after it was collected. The saliva samples were then put into sterile tubes and sent to the laboratory for processing in line with laboratory procedure. The samples were centrifuged to remove cellular debris and particulate material and the supernatant was collected for biochemical analyses. Aliquots were placed under appropriate low-temperature laboratory conditions to maintain the enzymatic activities if analysis was not conducted immediately, and to avoid repeated freezing and thawing.

The biochemical evaluation was mainly directed to enzymes of the saliva which might be implicated in hydrolytic and proteolytic degradation of resin-based restorative materials. Salivary esterase activity was presumed to be the main enzymatic exposure since enzymes with esterase activity could be responsible for hydrolysis of ester containing bonds in resin matrices. The activity of esterase was determined spectrophotometrically or by

enzyme assay, and expressed as U/mL. Activities of salivary amylase and proteases were measured by using the biochemical assay kits purchased from commercially available sources following the manufacturers' instructions. If present in the laboratory protocol, concentrations of MMP-8 and MMP-9 were measured by enzyme-linked immunosorbent assay (ELISA) kits and reported in ng/mL. Each assay was performed under standard laboratory conditions and samples were submitted for analysis following recommended calibration and quality assurance procedures.

Surface roughness of each retrieved resin composite specimen was measured using a calibrated surface profilometer and expressed as average surface roughness (R_a , μm). Measurements were obtained from multiple representative areas of the specimen, avoiding restoration margins and areas visibly damaged during retrieval. The mean of the repeated measurements was used as the final R_a value for analysis. Higher R_a values represented greater surface irregularity and degradation.

Surface microhardness of the retrieved resin composite specimens was evaluated using a Vickers microhardness tester and expressed as Vickers hardness number (VHN). Multiple indentations were made at predetermined points on each specimen with adequate spacing between indentation sites. The mean VHN obtained from the repeated measurements was used for statistical analysis. Lower VHN values were interpreted as greater softening and degradation of the resin matrix.

Surface morphology of the retrieved resin composite specimens was evaluated using scanning electron microscopy (SEM). The specimens were prepared according to standard SEM procedures and examined for evidence of surface pits, exposed filler particles, filler loss, microcracks, resin matrix erosion, and irregular surface architecture. Based on the overall microscopic appearance, degradation was categorized as mild, moderate, or marked. Mild degradation represented limited surface irregularity or minimal defects; moderate degradation represented evident surface erosion or filler exposure; and marked degradation represented extensive roughening, cracking, matrix disruption, or substantial filler loss.

To compare, the participants were also divided into low and high salivary esterase activity groups. The study population median esterase value was used as the cut-off point when no

validated clinical threshold was available. This classification enabled the surface roughness of the glasses, their microhardness and the behavior of their microdegradations to be compared in the two groups, with different enzymatic activity.

The main result of this was the degradation of the resin composite surface, mainly in the form of surface roughness. Surface microhardness and surface degradation characteristics, at the microscopic level, were considered secondary outcomes. Salivary esterase activity was used as the independent variable and other potential predictors such as amylase activity, protease activity, MMP-8 activity, MMP-9 activity, salivary pH, salivary flow rate, restoration duration, and type of composite material were included. A structured proforma was used for all data collection, which was created for the purpose of the study. A study ID number was used to ensure the confidentiality of each participant. Standardized procedures were used to perform clinical evaluations and laboratory measurements. Laboratory equipment was calibrated prior to analysis and biochemical assays performed as per standard operating procedure. The averaged data for repeated measurements was added to the final data set to increase the reliability of the measurement. The data were entered and analyzed with IBM SPSS Statistics software. The distribution of continuous variables was assessed, and those that were approximately normally distributed were summarized as mean $\pm$ standard deviation, those that were skewed were summarized as median and interquartile range. Frequencies and percentages were reported for categorical variables. Independent-samples t-test was used to compare the mean surface roughness and mean microhardness between

two groups when both groups met parametric assumptions and Mann-Whitney U test was used when both groups did not meet parametric assumptions. One-way analysis of variance (ANOVA) and a post hoc test as needed was used to compare the three categories of composite materials. The chi-square test or Fisher's exact test were used to compare the frequencies of the various categorical variables (microscopic degradation categories or surface defects). Pearson correlation coefficient was used for normally distributed variables, and Spearman's rank correlation was used for non-parametric variables to examine the correlation between the concentration of the enzymes and the continuous surface properties. The magnitude and direction of correlation coefficient were interpreted. A multivariable linear regression model was created to assess if salivary enzyme activity was independent predictor of surface roughness after adjustment for potential confounding variables such as age, salivary pH, salivary flow rate, duration of restoration and composite material type. The results were represented by regression coefficients, 95% confidence interval and p value. The values of $p < 0.05$ were considered statistically significant.

RESULTS

The mean age of the participants was 34.7 ± 9.2 years (range 19–55 years). Of the total participants, 42 (53.8%) were females and 36 (46.2%) were males. The mean pH of the saliva was 6.74 ± 0.41 and the mean unstimulated salivary flow rate was 0.46 ± 0.17 mL/min. The median time for the composite restorations evaluated was 18 months (IQR 11 – 30 months).

Table 1. Demographic, Oral and Restoration Characteristics of Participants (N = 78)

Variable	Result
Age, years	34.7 ± 9.2
Male	36 (46.2%)
Female	42 (53.8%)
Salivary pH	6.74 ± 0.41
Salivary flow rate, mL/min	0.46 ± 0.17
Plaque index	1.21 ± 0.48
Gingival index	0.93 ± 0.39
Restoration duration, months, median (IQR)	18 (11–30)
Posterior restorations	56 (71.8%)
Anterior restorations	22 (28.2%)
Nanohybrid composite	31 (39.7%)
Nanofilled composite	26 (33.3%)
Microhybrid composite	21 (26.9%)

Values are presented as mean $\pm$ standard deviation, n (%), or median (interquartile range), as appropriate.

Measurable variation among the study population was shown by salivary enzyme analysis. The mean salivary esterase activity was 18.6 ± 6.1 U/mL and mean amylase activity was 92.4 ± 28.7 U/mL. Mean MMP-8

and MMP-9 concentrations were 23.8 ± 9.6 ng/mL and 41.7 ± 14.3 ng/mL, respectively. The biochemical variables with the highest relative variation were esterase activity.

Table 2. Salivary Biochemical and Enzyme Profile of Study Participants

Salivary parameter	Mean $\pm$ SD
Esterase activity, U/mL	18.6 ± 6.1
Amylase activity, U/mL	92.4 ± 28.7
Protease activity, U/mL	13.9 ± 4.8
MMP-8, ng/mL	23.8 ± 9.6
MMP-9, ng/mL	41.7 ± 14.3
Salivary pH	6.74 ± 0.41
Salivary flow rate, mL/min	0.46 ± 0.17

All retrieved resin composite restoration specimens were successfully prepared and evaluated for surface characteristics. The mean surface roughness was 0.39 ± 0.14 μ m, while the mean Vickers microhardness was 67.8 ± 8.9 VHN. Scanning electron microscopy (SEM) demonstrated mild surface degradation in 33

(42.3%) specimens, moderate degradation in 27 (34.6%), and marked degradation in 18 (23.1%). Surface pits were observed in 29 (37.2%) specimens, filler particle exposure in 25 (32.1%), resin matrix erosion in 21 (26.9%), and microcracks in 17 (21.8%).

Table 3. Surface Characteristics and Microscopic Degradation of Retrieved Resin Composite Restoration Specimens

Surface parameter	Result
Surface roughness (Ra), μ m	0.39 ± 0.14
Surface microhardness, VHN	67.8 ± 8.9
Mild surface degradation	33 (42.3%)
Moderate surface degradation	27 (34.6%)
Marked surface degradation	18 (23.1%)
Surface pits	29 (37.2%)
Filler particle exposure	25 (32.1%)
Resin matrix erosion	21 (26.9%)
Surface microcracks	17 (21.8%)

Significant differences were found between the various categories of contemporary resin composites in terms of surface degradation. The surface roughness was found to be the highest for the microhybrid composites (0.46 ± 0.13 μ m), followed by the nanohybrid composites (0.38 ± 0.12 μ m) and nanofilled

composites (0.34 ± 0.11 μ m). The difference was statistically significant ($p = 0.006$). The microhardness of the surface of the restorations was, in turn, highest for the nanofilled group (71.6 ± 7.5 VHN) and lowest for the microhybrid group (63.4 ± 9.1 VHN; $p = 0.004$).

Table 4. Comparison of Surface Characteristics According to Resin Composite Type

Variable	Nanohybrid (n = 31)	Nanofilled (n = 26)	Microhybrid (n = 21)	p-value
Surface roughness, μ m	0.38 ± 0.12	0.34 ± 0.11	0.46 ± 0.13	0.006
Microhardness, VHN	68.1 ± 8.0	71.6 ± 7.5	63.4 ± 9.1	0.004
Moderate/marked degradation	16 (51.6%)	11 (42.3%)	18 (85.7%)	0.008
Surface pits	10 (32.3%)	7 (26.9%)	12 (57.1%)	0.071
Matrix erosion	7 (22.6%)	5 (19.2%)	9 (42.9%)	0.138

Correlation analysis revealed that the surface microhardness and surface roughness were negatively ($r = -0.48$, $p < 0.001$) and positively ($r = 0.56$, $p < 0.001$) correlated with the salivary esterase activity. Additionally, there were strong positive correlations between

MMP-8 and MMP-9 and surface roughness. The pH of the saliva was inversely related to the surface roughness, which showed that the oral environment of lower pH had surface deterioration.

Table 5. Correlation Between Salivary Factors and Resin Composite Surface Characteristics

Salivary variable	Surface roughness, r	p-value	Microhardness, r	p-value
Esterase activity	0.56	<0.001	-0.48	<0.001
Amylase activity	0.21	0.064	-0.18	0.116
Protease activity	0.31	0.006	-0.27	0.018
MMP-8	0.42	<0.001	-0.34	0.002
MMP-9	0.39	<0.001	-0.31	0.006
Salivary pH	-0.37	0.001	0.30	0.008
Salivary flow rate	-0.25	0.029	0.22	0.054

The participants are then classified into two groups: "low esterase" and "high esterase", based on the median value of the enzyme activity. Retrieved restoration specimens from participants with higher salivary esterase activity showed significantly greater surface roughness (0.46 ± 0.13 versus 0.32 ± 0.11 μm ,

$p < 0.001$) and lower microhardness (63.9 ± 8.4 versus 71.7 ± 7.5 VHN, $p < 0.001$). Twenty-nine (74.4%) of the restorations in the high esterase group exhibited moderate-to-marked SEM degradation, whereas 16 (41.0%) of the restorations in the low esterase group did ($p = 0.003$).

Table 6. Surface Degradation According to Salivary Esterase Activity

Surface parameter	Low esterase activity (n = 39)	High esterase activity (n = 39)	p-value
Surface roughness, μm	0.32 ± 0.11	0.46 ± 0.13	<0.001
Microhardness, VHN	71.7 ± 7.5	63.9 ± 8.4	<0.001
Moderate/marked degradation	16 (41.0%)	29 (74.4%)	0.003
Surface pits	9 (23.1%)	20 (51.3%)	0.010
Filler exposure	8 (20.5%)	17 (43.6%)	0.029
Matrix erosion	6 (15.4%)	15 (38.5%)	0.021

Salivary esterase activity remained an independent predictor of increased surface roughness after controlling for age, salivary pH, restoration duration, and composite type and salivary flow rate ($\beta = 0.41$, $p < 0.001$) in a multivariable regression analysis. Higher restoration duration ($\beta = 0.28$, $p = 0.009$) and

lower salivary pH ($\beta = -0.24$, $p = 0.018$) were also found to be associated with the amount of surface degradation independently. The nanofilled composite material had a relatively protective association with surface degradation, but a weaker one than with regard to enzymatic activity.

Table 7. Multivariable Linear Regression for Predictors of Surface Roughness

Predictor	Standardized β	95% CI for B	p-value
Salivary esterase activity	0.41	0.005 to 0.014	<0.001
MMP-8 level	0.18	0.001 to 0.005	0.074
Salivary pH	-0.24	-0.132 to -0.012	0.018
Salivary flow rate	-0.14	-0.191 to 0.022	0.117
Restoration duration	0.28	0.001 to 0.005	0.009
Composite type	-0.19	-0.071 to -0.002	0.039

Figure 1. Mean Surface Roughness According to Salivary Esterase Activity

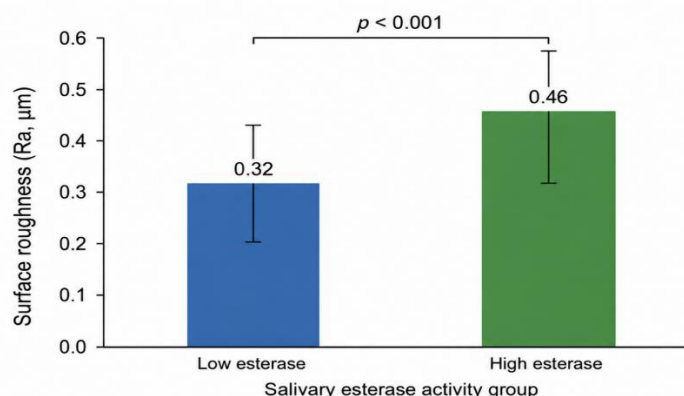


Figure 1. Comparison of mean surface roughness of resin composite restorations between low and high salivary esterase activity groups.

Figure 1. Comparison of mean surface roughness (R_a , μm) of resin composite restorations between participants with low and high salivary esterase activity. Higher esterase activity was associated with significantly greater surface roughness ($p < 0.001$).

DISCUSSION

The present study demonstrated a meaningful association between salivary enzyme composition and degradation of retrieved contemporary resin composite restoration specimens. The most prominent finding was that greater salivary esterase activity was associated with increased surface roughness, reduced Vickers microhardness, and more pronounced SEM-detected microscopic surface deterioration. Retrieved specimens from participants in the high-esterase group showed a mean surface roughness of $0.46 \pm 0.13 \mu\text{m}$, compared with $0.32 \pm 0.11 \mu\text{m}$ in specimens from participants with lower esterase activity. Moreover, salivary esterase activity showed a moderate positive correlation with surface roughness ($r = 0.56$, $p < 0.001$) and a negative correlation with microhardness ($r = -0.48$, $p < 0.001$). These findings indicate that restorations exposed to different salivary biochemical environments during their clinical service may exhibit varying degrees of surface degradation, supporting the concept that biologically active components of the oral environment can contribute to the gradual deterioration of resin-based restorative materials (14, 15).

The relationship between esterase activity and composite deterioration is biologically plausible because commonly used methacrylate-based restorative materials contain ester bonds that are susceptible to enzymatic hydrolysis. Salivary esterases (cholesterol esterase-like,

pseudocholinesterase), which are also present in resin matrices, may release degradation products by degrading the ester containing components. Experimental studies have previously shown varying levels of degradation of resin monomers and cured composite materials by the esterase fraction of saliva in humans. Research also found that esterases from saliva and bacteria in the mouth are significant components in biodegrading resin-based restorations, which may have significant impacts on their mechanical properties and durability. The mechanisms account for the enhanced roughness and lessened hardness found with increasing esterase activity in the present study (16, 17).

One of the other interesting findings was the correlation between MMP-8, MMP-9 and protease activity with surface deterioration. Increased surface roughness was positively correlated with MMP-8 and MMP-9, and increased protease activity was associated with increased surface roughness and decreased microhardness. The MMPs are not considered to be involved in direct degradation of the bulk composite matrix but are important in degradation of the collagen component of the resin-dentin interface, and therefore may be markers of a more proteolytically active oral environment. Biodegradation of resin restoration has been the subject of reviews that report on an intricate interplay between salivary esterases, bacterial esterases, MMPs, enzymes produced by inflammatory cells and oral microorganisms with respect to resin restoration deterioration and bonded interfaces. It has also been demonstrated that the activity of esterase in saliva can contribute to increased degradation of the interfacial integrity of resin-dentin and promote more

bacterial penetration and biofilm formation. In this sense the failure of composite is expected to be a result of a series of biochemical and mechanical processes, not the effect of one enzyme (18, 19).

The present results also indicated a negative correlation between flow and a slight deterioration in surface and a positive correlation between pH and surface roughness. Acidic conditions can improve water sorption and hydrolytic instability of matrices of resin and can also activate the proteolytic enzymes that are present in the host. Previous studies have suggested that the effects of saliva, acids, and enzymes have a synergistic effect on resin composites. The studies included in the investigation showed a change in surface roughness after exposure to simulated salivary, acidic and enzymatic degradation and specifically evaluated changes in surface roughness after these oral challenges are applied to resin composites. The present results thus highlight the possible significance of the oral environment of the individual patient, especially the pH of the saliva and enzyme profile, in the clinical durability of resin-based restorations (20).

Differences also were found between the composite categories studied. The surface roughness of the microhybrid composites was higher than that of the nanofilled composites, while the hardness was higher for the nanofilled composite. These differences might be due to differences in filler size and distribution, composition of resin matrix, filler-matrix coupling, degree of polymerization, and the ability of the individual monomers to undergo hydrolysis. Restorative materials can vary in their chemical makeup and structures, and therefore, do not necessarily react in the same way to biological degradation. Experimental studies have also demonstrated that resin restorations and their interfaces can deteriorate, in part, due to the properties of the restorative material. Recent publications also emphasize that residual or incompletely polymerized methacrylate monomers (Bis-GMA, TEGDMA and UDMA) are susceptible to enzymatic degradation and may generate lower molecular weight degradation products that can lead to an increasingly compromised surface and structural integrity (1).

The multivariable analysis helped confirm the main finding as salivary esterase activity remained independently associated with surface roughness even after the other potential confounding factors were accounted

for. The time of restoration was also found to be a contributor to deterioration, as was the low pH of saliva, indicating that both time dependent and biochemical factors of saliva have a role in the condition of resin composite restorations. The greater the duration of service time, the more the restorative material will be subjected to temperature variation, moisture, food acids, mechanical stresses, microorganisms, and salivary enzymes. With time, these cumulative stresses can lead to hydrolysis of the polymer matrix, compromise the filler-matrix interface, release of filler particles, and surface pits and cracks. These surface alterations can then help to trap plaque and may help to set-up conditions that can further contribute to the deterioration of the restorations. Existing literature validates a bi-directional interaction between biological degradation, which weakens the restoration interface and possibly allows for microbial penetration and biofilm formation (6).

The clinical implications of the results are that the biochemical properties of saliva may be a contributing factor to the varying degrees of deterioration that may be seen in resin composite restorations following apparently identical restorative procedures. Patients with high salivary esterase activity or persistently acidic saliva may have an oral environment that promotes degradation of susceptible resin matrices, potentially increasing the risk of restoration deterioration.

This does not mean that salivary enzyme testing is a screening test that should be used in routine clinical practice today but it is a suggestion for continuing to develop resin formulations that are more resistant to biological hydrolysis. These strategies being explored involve modifying the chemistry of the resins, creating an ester resistant or free resin monomer, adding antimicrobial ingredients or blocking esterase or MMP. Better knowledge of biochemical factors in the oral cavity of a patient may one day lead to more personalized choice of the restorative material.

Several limitations should be acknowledged. This study included a relatively small sample size of 78 participants from one dental institution that may not be representative of the general population. It is also cross-sectional and shows associations but does not show a direct causal relationship between the activity of the enzymes produced by the salivary glands and progressive restoration degradation. Other factors, such as diet, brushing habits, parafunctional loading, polishing methods,

original restoration quality, and composite formulation variations, might also have affected the surface characteristics. In addition, the saliva sample obtained once might not accurately reflect the activity of an enzyme over time due to the change in saliva composition that occurs over time. Salivary esterases as well as other enzymes should be routinely measured over time in future prospective longitudinal and laboratory clinical studies and monitored over the course of several years for individual restorations. Comparisons of particular commercial resin formulations and the determination of biochemical degradation products would further define which composite chemistries are the most resistant to enzymatic degradation.

CONCLUSION

The study demonstrated a significant association between salivary enzymatic composition and surface degradation of contemporary resin composite restorations. Higher salivary esterase activity was associated with increased surface roughness, reduced microhardness, and a greater frequency of microscopic deterioration, including surface pits, filler exposure, and resin matrix erosion. MMP-8, MMP-9, protease activity, lower salivary pH, and longer restoration duration also showed relationships with surface degradation. Among the evaluated biochemical factors, salivary esterase activity emerged as the strongest independent predictor of surface roughness. Differences in degradation were also observed among resin composite categories, indicating that material composition may influence resistance to the biological oral environment. These findings highlight the importance of considering both restorative material characteristics and patient-related salivary factors when evaluating the long-term performance of resin composite restorations. Further longitudinal investigations are required to determine whether salivary enzyme profiling can assist in predicting restoration longevity and guide the development of more biologically stable restorative materials.

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