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ORIGINAL RESEARCH **OPEN ACCESS**

Chemotherapy and salivary pH in adults with cancer: an analytical cross-sectional study at a hospital in Cajamarca, Peru

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ABSTRACT

Background: Provisional restorations must maintain adequate mechanical integrity during treatment, particularly when subjected to bending and occlusal forces. **Objective:** To compare the flexural and compressive strengths of a bis-acryl resin, an autopolymerizing polymethyl methacrylate (PMMA) resin, and a 3D-printed provisional resin. **Methods:** A comparative experimental in vitro study was conducted using 54 specimens, with 18 specimens assigned to each material. For each group, nine specimens were evaluated for flexural strength and nine for compressive strength. After storage in distilled water at 37 °C for 24 hours, flexural strength was assessed using a three-point bending test and compressive strength by axial loading in a universal testing machine. **Results:** Significant differences were found among the materials for flexural strength ($F = 6.104$; $p = 0.007$) and compressive strength ($F = 20.750$; $p = 0.000$). The bis-acryl resin showed the highest mean flexural strength (69.46 ± 7.70 MPa), followed by the 3D-printed resin (60.92 ± 3.54 MPa) and PMMA (57.04 ± 10.36 MPa). It also showed the highest mean compressive strength (82.25 ± 14.79 MPa), followed by the 3D-printed resin (75.96 ± 5.62 MPa) and PMMA (51.30 ± 9.89 MPa). Flexural strength differed significantly between the bis-acryl resin and both PMMA and the 3D-printed resin, whereas compressive strength differed significantly between PMMA and the other two materials. **Conclusion:** Under the conditions of this study, the bis-acryl resin demonstrated the most favorable overall mechanical performance, while the 3D-printed resin showed compressive strength comparable to that of the bis-acryl resin.

Keywords: Dental Materials; Polymethyl Methacrylate; Composite Resins; Flexural Strength; Compressive Strength.

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Introduction

Cancer remains one of the leading causes of morbidity and mortality worldwide and represents a growing challenge for healthcare systems. In 2022, approximately 20 million new cancer cases and 9.7 million cancer-related deaths were estimated globally, and this burden is expected to increase substantially over the coming decades [1,2]. Chemotherapy remains a fundamental component of treatment for numerous hematological and solid malignancies because of its ability to inhibit the growth and division of cancer cells [3]. However, its cytotoxic activity is not limited to malignant tissues and may affect rapidly renewing healthy cells, including those of the oral mucosa and salivary glands [4]. Saliva contributes to lubrication, antimicrobial defense, mucosal integrity, dental remineralization, and regulation of the oral acid–base balance [5]. Therefore, alterations in salivary flow, composition, buffering capacity, or pH may compromise oral homeostasis and increase susceptibility to dental and mucosal complications [4,6].

Previous evidence suggests that chemotherapy may modify salivary characteristics, although the direction and magnitude of these changes remain inconsistent. Najafi et al. observed reductions in unstimulated salivary flow, pH, and bicarbonate concentrations after chemotherapy in adults with acute myeloid leukemia [7]. Similarly, longitudinal changes in salivary flow and pH have been reported in women receiving chemotherapy for breast cancer [8] and in children with acute lymphoblastic leukemia evaluated at different stages of treatment [9]. Studies involving patients receiving chemoradiotherapy or mixed oncological treatments have also reported changes in salivary composition and lower pH values compared with pretreatment measurements or healthy controls [10,11]. In contrast, Ramya et al. found that patients with untreated cancer had lower salivary pH values, whereas those undergoing treatment exhibited a shift toward more alkaline levels [12]. These discrepancies may be explained by differences in cancer type, chemotherapy regimen, concomitant radiotherapy, timing of saliva collection, type of saliva evaluated, and measurement method.

In Peru, Chaupe Huaripata reported that most patients with head and neck cancer undergoing chemotherapy had salivary pH values between 5.5 and 6.5, with acidic values occurring more frequently among women and individuals aged 41 to 63 years [13]. Nevertheless, that investigation was descriptive, focused on a specific oncological population, and did not analytically evaluate the relationship between chemotherapy duration and salivary pH. Furthermore, no published analytical studies addressing this relationship in adult cancer patients from Cajamarca were identified. This knowledge gap is clinically relevant because salivary acidification and reduced buffering capacity may favor dental demineralization, caries development, microbial imbalance, oral candidiasis, and mucosal discomfort, potentially affecting nutrition, treatment tolerance, and quality of life [4-6]. Current clinical guidance also emphasizes the importance of objectively assessing salivary gland dysfunction and oral dryness in patients receiving cancer treatment [14]. Salivary pH measurement may therefore constitute a rapid, minimally invasive, and accessible complementary assessment in oncological dental care.

The objective of this study was to determine the association between chemotherapy duration and salivary pH in adults with cancer treated at the Hospital Regional de Cajamarca, Peru, and to examine this relationship according to sex and age. This research is scientifically and clinically justified by the need to generate local evidence regarding salivary alterations during cancer treatment, clarify whether longer chemotherapy exposure is associated with greater salivary acidification, and support the incorporation of preventive oral monitoring into multidisciplinary oncology care. The findings may contribute to identifying patient groups at increased risk of oral complications and to developing evidence-based dental strategies during chemotherapy.

Materials and methods

Study design and setting

An observational, analytical, cross-sectional study with prospective data collection was conducted among adult patients receiving chemotherapy at the Oncology Department of the Hospital Regional Docente de Cajamarca, Peru, during 2025. Each participant was evaluated at a single time point, without intervention or modification of the prescribed oncological treatment. The study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cross-sectional studies [15].

Population and sample

The study population comprised 81 adult patients with cancer treated at the Oncology Department during the study period. The minimum sample size was calculated

using the finite-population formula, considering a 95% confidence level, an expected proportion of 50%, and a maximum allowable error of 5%. The resulting sample consisted of 68 participants.

Participants were recruited through nonprobability convenience sampling until the required sample size was reached. The inclusion criteria were age between 18 and 50 years, confirmed cancer diagnosis, current chemotherapy treatment, availability of a complete oncology medical record, and acceptance to participate through written informed consent.

Patients were excluded when they presented systemic or local conditions that could substantially alter salivary secretion or pH, used concomitant medications known to affect salivary gland function apart from their oncological treatment, had consumed food or beverages within 60 to 90 minutes before saliva collection, or had incomplete information regarding the study variables.

Study variables

The exposure variable was chemotherapy duration, obtained from the oncology medical record and classified as up to 1 month, 2 to 3 months, 4 to 5 months, and 6 months or longer.

The outcome variable was salivary pH, initially recorded as a quantitative measurement and subsequently categorized according to the operational criteria established in the study protocol as acidic (0.0–6.9), neutral (7.0–7.9), or alkaline (8.0–14.0). Sex and age were considered covariates. Age was categorized into 18 to 35 years and 36 to 50 years.

Instruments and data collection

An ad hoc data collection form was used to record sex, age, cancer diagnosis, chemotherapy duration, and salivary pH. Information related to oncological treatment was transcribed directly from the participants' medical records.

Salivary pH was measured using an AKSO digital pH meter, model AK90, with a measurement range of 0.0 to 14.0 pH units, a resolution of 0.1 units, and an accuracy of ±0.1 units. Before each measurement session, the device was calibrated using standard buffer solutions of pH 4.01, 7.00, and 10.01, according to the manufacturer's instructions [17]. Measurement reliability was ensured through three-point calibration, standardized sample collection, uniform electrode handling, and use of the same equipment and procedure for all participants.

Saliva collection and pH measurement

Unstimulated whole saliva was collected under standardized clinical conditions, following established recommendations for salivary sample collection [16]. Participants attended their chemotherapy sessions in the morning and were instructed not to consume food or beverages for at least 60 to 90 minutes before sample collection.

Each participant was seated with the back upright and the head tilted approximately 45° forward. Participants were instructed to remain relaxed, avoid speaking, and refrain from swallowing for 5 minutes to allow saliva to accumulate naturally in the floor of the mouth.

The accumulated saliva was aspirated using a sterile disposable syringe, and a minimum volume of 5 mL was transferred to a sterile 10-mL glass beaker identified with the participant's numerical code. When the initial volume was insufficient, the collection procedure was repeated.

Before each measurement, the pH-meter electrode was rinsed with distilled water and carefully dried with lint-free paper. The electrode was immersed directly in the saliva sample, and the pH value was recorded after the reading stabilized. Between measurements, the electrode was rinsed with distilled water to prevent cross-contamination. The same operator performed all measurements.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics, version 27. Categorical variables were summarized using absolute frequencies and percentages.

The association between chemotherapy duration and salivary pH category was evaluated using Pearson's chi-square test. Fisher's exact test was applied when the expected cell frequencies did not meet the assumptions of the chi-square test. Analyses were conducted for the total sample and subsequently stratified by sex and age group.

All statistical tests were two-sided, and statistical significance was established at $p < 0.05$. Analyses were performed using complete cases, without statistical imputation of missing data.

Ethical considerations

The study was approved by the Bioethics Committee of Universidad Privada Antenor Orrego and authorized by the Hospital Regional Docente de Cajamarca. All participants provided written informed consent before data collection. The study followed the principles of the Declaration of Helsinki, and participants' anonymity and confidentiality were protected through numerical coding of the records. The authors declared no conflicts of interest.

Results

A total of 68 adults with cancer were included in the analysis. Acidic salivary pH was recorded in 40 participants (58.8%), neutral pH in 24 (35.3%), and alkaline pH in 4 (5.9%). A statistically significant association was found between chemotherapy duration and salivary pH (p = 0.002). Among participants who had received chemotherapy for 6 months or longer, 26 of 35 (74.3%) had acidic salivary pH. In contrast, 11 of the 13 patients (84.6%) who had received chemotherapy for up to 1 month had neutral salivary pH (Table 1).

Table 1. Association between chemotherapy duration and salivary pH among adults with cancer at a hospital in Cajamarca, Peru, 2025.

Chemotherapy duration	pH salival								p	X^2
	Acidic		Neutral		Alkaline		Total			
	f	%	f	%	f	%	f	%		
Up to 1 month	2	2,9	11	16,2	0	0,0	13	19,1	0,002	132,348
2–3 months	8	11,8	5	7,4	0	0,0	13	19,1		
4–5 months	4	5,9	2	2,9	1	1,5	7	10,3		
6 months or longer	26	38,2	6	8,8	3	4,4	35	51,5		
Total	40	58,8	24	35,3	4	5,9	68	100,0		

Note: f = absolute frequency; % = relative frequency; p = probability value obtained using the chi-square test.

Acidic salivary pH was observed in 15 of 27 men (55.6%) and 25 of 41 women (61.0%). Neutral pH was identified in 44.4% of men and 29.3% of women, whereas alkaline pH was recorded exclusively among women (Table 2).

Among participants aged 18–35 years, acidic and neutral salivary pH were recorded in 42.9% and 57.1%, respectively. Among those aged 36–50 years, 60.7% had acidic pH, 32.8% had neutral pH, and 6.6% had alkaline pH (Table 3).

In the sex-stratified analysis, chemotherapy duration was significantly associated with salivary pH among women (p = 0.001), whereas no statistically significant association was observed among men (p = 0.356). In the overall sample, the association between chemotherapy duration and salivary pH remained statistically significant (p = 0.002) (Table 4).

In the age-stratified analysis, no statistically significant association between chemotherapy duration and salivary pH was found among participants aged 18–35 years (p = 0.907). A statistically significant association was observed among those aged 36–50 years (p = 0.002) and in the overall sample (p = 0.002) (Table 5).

Discussion

The main finding of this study was the significant association between chemotherapy duration and salivary pH. Acidic salivary pH was markedly more frequent among patients treated for 6 months or longer than among those treated for up to 1 month. However, the distribution did not show a strictly progressive increase across every treatment interval; therefore, the findings should be interpreted as an association between longer chemotherapy exposure and salivary acidification rather than as a uniform dose–response pattern. These results are consistent with studies reporting reductions in salivary pH, flow rate, or bicarbonate concentration during chemotherapy and chemoradiotherapy [7,8,10,11]. Mazzeo et al. also observed salivary gland dysfunction and acidification of stimulated saliva during chemotherapy with fluorouracil and leucovorin, while Jensen et al. documented temporary salivary hypofunction in patients receiving adjuvant chemotherapy for breast cancer [18,19]. Collectively, this evidence suggests that systemic antineoplastic treatment may disrupt salivary homeostasis through functional and compositional alterations of the salivary glands.

Table 2. Distribution of salivary pH by sex among adults with cancer at a hospital in Cajamarca, Peru, 2025.

Salivary pH	Sex					
	Male		Female		Total	
	f	%	f	%	f	%
Acidic	15	22,1	25	36,8	40	58,8
Neutral	12	17,6	12	17,6	24	35,3
Alkaline	0	0,0	4	5,9	4	5,9
Total	27	39,7	41	60,3	68	100,0

Note: f = absolute frequency; % = relative frequency.

Table 3. Distribution of salivary pH by age group among adults with cancer at a hospital in Cajamarca, Peru, 2025.

Salivary pH	Age					
	18 a 35 years		36 a 50 years		Total	
	f	%	f	%	f	%
Acidic	3	4,4	37	54,4	40	58,8
Neutral	4	5,9	20	29,4	24	35,3
Alkaline	0	0,0	4	5,9	4	5,9
Total	7	10,3	61	89,7	68	100,0

Note: f = absolute frequency; % = relative frequency.

The biological plausibility of this association involves direct and indirect effects of cytotoxic therapy. Chemotherapy may affect glandular tissue, reduce salivary secretion, modify electrolyte and bicarbonate concentrations, and weaken buffering capacity, thereby facilitating a more acidic oral environment [4,20]. Nevertheless, previous findings are not entirely consistent. Ramya et al. found lower salivary pH before cancer treatment and a shift toward more alkaline values after therapy [12], indicating that salivary pH may also be influenced by the underlying malignancy, treatment regimen, timing of measurement, hydration, diet, oral microbiota, and concurrent therapies. Evidence from patients receiving head and neck radiotherapy additionally shows that lower oral pH is associated with a higher occurrence of treatment-related caries [21]. Although radiotherapy and chemotherapy are not directly interchangeable, these findings reinforce the clinical relevance of maintaining oral acid–base balance during cancer treatment.

In the stratified analyses, the association between chemotherapy duration and salivary pH was significant among women but not among men, and among participants aged 36–50 years but not among those aged 18–35 years. These findings are compatible with the national study by Chaupe Huaripata, which reported a predominance of acidic salivary values among women and patients older than 40 years undergoing chemotherapy [13]. Differences in salivary flow and biochemical composition between sexes have also been documented in healthy populations [22,23]. However, evidence regarding age is heterogeneous: some studies have reported reductions in resting salivary secretion with age, whereas others found no independent effect of age on stimulated salivary pH [23,24]. Moreover, the present study did not formally test interactions between chemotherapy duration and sex or age. Therefore, significance within one subgroup and non-significance within another should not be interpreted as definitive evidence that the association differs biologically by sex or age. The small number of younger participants and the absence of alkaline values in some strata may also have reduced the stability of these estimates.

From a clinical perspective, the high frequency of acidic salivary pH supports incorporating oral assessment into multidisciplinary cancer care. An acidic oral environment, particularly when accompanied by reduced flow or buffering capacity, may contribute to dental demineralization, caries, candidiasis, mucosal discomfort, dysgeusia, and other oral toxicities associated with chemotherapy [14,20,25]. Salivary pH measurement is rapid, minimally invasive, and inexpensive and may be useful as a complementary screening procedure, particularly in patients receiving prolonged chemotherapy. Nevertheless, an isolated pH value should not be considered a diagnostic test by itself. It should be interpreted together with salivary flow, xerostomia symptoms, oral hygiene, dietary exposure, medication use, mucosal status, and caries risk. Patients with persistent acidification may benefit from closer dental surveillance, individualized oral hygiene instruction, dietary counseling, professional fluoride measures, and timely management of salivary gland dysfunction.

Table 4. Association between chemotherapy duration and salivary pH stratified by sex among adults with cancer at a hospital in Cajamarca, Peru, 2025.

		Chemotherapy duration										
		Up to 1 month		2–3 months		4–5 months		6 months or longer		Total		p
Sex	Salivary pH	f	%	f	%	f	%	f	%	f	%	
Male	Acidic	1	1,5	3	4,4	3	4,4	8	11,8	15	22,1	0,356
	Neutral	4	5,9	2	2,9	2	2,9	4	5,9	12	17,6	
	Alkaline	0	0,0	0	0,0	0	0,0	0	0,0	0	0,0	
	Total	5	7,4	5	7,4	5	7,4	12	17,6	27	39,7	
Female	Acidic	1	1,5	5	7,4	1	1,5	18	26,5	25	36,8	0,001
	Neutral	7	10,3	3	4,4	0	0,0	2	2,9	12	17,6	
	Alkaline	0	0,0	0	0,0	1	1,5	3	4,4	4	5,9	
	Total	8	11,8	8	11,8	2	2,9	23	33,8	41	60,3	
Total	Acidic	2	2,9	8	11,8	4	5,9	26	38,2	40	58,8	0,002
	Neutral	11	16,2	5	7,4	2	2,9	6	8,8	24	35,3	
	Alkaline	0	0,0	0	0,0	1	1,5	3	4,4	4	5,9	
	Total	13	19,1	13	19,1	7	10,3	35	51,5	68	100,0	

Note: f = absolute frequency; % = relative frequency; p = probability value obtained using the chi-square test.

Table 5. Association between chemotherapy duration and salivary pH stratified by age group among adults with cancer at a hospital in Cajamarca, Peru, 2025

		Chemotherapy duration										
Age	Salivary pH	Up to 1 month		2–3 months		4–5 months		6 months or longer		Total		p
		f	%	f	%	f	%	f	%	f	%	
18 - 35 years	Acidic	1	1,5	1	1,5	0	0,0	1	1,5	3	4,4	0,907
	Neutral	2	2,9	1	1,5	0	0,0	1	1,5	4	5,9	
	Alkaline	0	0,0	0	0,0	0	0,0	0	0,0	0	0,0	
	Total	3	4,4	2	2,9	0	0,0	2	2,9	7	10,3	
36 - 50 years	Acidic	1	1,5	7	10,3	4	5,9	25	36,8	37	54,4	0,002
	Neutral	9	13,2	4	5,9	2	2,9	5	7,4	20	29,4	
	Alkaline	0	0,0	0	0,0	1	1,5	3	4,4	4	5,9	
	Total	10	14,7	11	16,2	7	10,3	33	48,5	61	89,7	
Total	Acidic	2	2,9	8	11,8	4	5,9	26	38,2	40	58,8	0,002
	Neutral	11	16,2	5	7,4	2	2,9	6	8,8	24	35,3	
	Alkaline	0	0,0	0	0,0	1	1,5	3	4,4	4	5,9	
	Total	13	19,1	13	19,1	7	10,3	35	51,5	68	100,0	

Note: f = absolute frequency; % = relative frequency; p = probability value obtained using the chi-square

The strengths of this study include objective pH measurement using a calibrated digital device, standardized collection of unstimulated whole saliva, and analysis according to chemotherapy duration, sex, and age. It also provides locally relevant evidence from an adult oncology population in Cajamarca, where information on salivary changes during chemotherapy remains limited. However, several limitations must be acknowledged. The cross-sectional design does not establish temporality or causality, and the absence of pretreatment measurements prevented assessment of individual changes from baseline. Convenience sampling at a single hospital limits generalizability, while the relatively small sample and sparse observations in some categories may have reduced the reliability of stratified chi-square analyses. Potential confounders—including cancer type and stage, chemotherapy regimen and cumulative dose, hydration, oral hygiene, diet, medications, salivary flow, buffering capacity, and oral disease—were not incorporated into multivariable models. Future research should use multicenter longitudinal designs with measurements before, during, and after chemotherapy; retain pH as a continuous variable; evaluate salivary flow and buffering capacity; and apply adjusted models with formal interaction testing to clarify whether sex and age modify the association.

Conclusions

Chemotherapy duration was significantly associated with salivary pH, with acidic values occurring most frequently among patients who had received treatment for 6 months or longer. In the stratified analyses, this association was significant among women and participants aged 36–50 years, but not among men or those aged 18–35 years. These findings support monitoring salivary pH during prolonged chemotherapy, while acknowledging that the cross-sectional design does not allow causal conclusions.

Author Contributions Statement (CrediT)

FH: Conceptualization, Methodology, Writing – Original Draft, Supervision, Formal analysis, Data curation, Validation, Visualization, Resources, Project administration, Funding acquisition, Writing – Review & Editing.

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Conflict of Interest

The authors declare that they have no financial, professional, institutional, or personal relationships that could have influenced the design, conduct, analysis, interpretation, or publication of this study

Data Availability

The de-identified dataset and the corresponding variable coding used in this study are available from the corresponding author upon reasonable and justified request. Access will be provided in accordance with participant confidentiality, ethical approval conditions, and applicable institutional regulations

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