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Relationship of X-ray Radiation Exposure from *Cephalometric* Radiography to Saliva pH

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ABSTRACT

X-ray imaging involves the interaction of ionizing radiation with biological tissues, potentially inducing cellular and physiological changes. Exposure to X-rays during cephalometric radiography may affect oral homeostasis, including salivary function and pH. This study aimed to determine whether salivary pH changed significantly before and after exposure to X-ray radiation during cephalometric radiography. A quantitative, quasi-experimental study using a one-group pretest–posttest design was conducted at the Radiology Laboratory of Dirgahayu Hospital, Samarinda, Indonesia, from October to December 2023. The study included 21 patients undergoing orthodontic treatment who had been referred for cephalometric radiographic examinations. Salivary pH was measured using a digital pH meter at three time points: before exposure, immediately after exposure, and 24 hours after exposure. The mean salivary pH was 6.9929 before exposure, decreased to 6.8786 immediately after exposure, and further declined to 6.8276 at 24 hours after exposure. The Friedman test revealed a statistically significant difference in salivary pH across the three measurement time points ($p < 0.05$). These findings indicated a significant change in salivary pH following cephalometric radiographic exposure, with a progressive decrease observed over the 24-hour measurement period. However, the study design did not establish that X-ray exposure directly caused the observed changes.

INTRODUCTION

Radiology is a medical discipline that uses imaging techniques, including X-ray imaging, to visualize internal anatomical structures and support clinical diagnosis and treatment planning. Radiological examinations play an essential role in identifying pathological conditions, guiding therapeutic decisions, and monitoring treatment outcomes. Accordingly, radiology services are widely available in healthcare facilities throughout Indonesia, including community health centers, private clinics, and hospitals (Rahmaddian et al., 2019).

Dental and maxillofacial radiology is a specialized field that supports the diagnosis, treatment planning, and evaluation of dental and craniofacial conditions. Dental radiographic examinations are generally classified into intraoral and extraoral techniques according to the positioning of the image receptor (Mallya & Ahmad, 2024). Intraoral radiography involves placing the image receptor inside the oral cavity to visualize the teeth and surrounding structures, whereas extraoral radiography uses a receptor positioned outside the oral cavity. Cephalometric radiography is an extraoral imaging technique commonly used to assess craniofacial relationships, particularly in orthodontic treatment planning (White & Pharoah, 2014).

Cephalometric radiography involves standardized imaging of the skull using a cephalostat to stabilize the patient's head and maintain consistent positioning during image acquisition. This standardization facilitates comparisons between radiographs obtained at different stages of treatment. Although lateral cephalometric radiography is the most commonly used projection, other craniofacial projections include posteroanterior (PA) and submentovertex (SMV) views. Lateral cephalometric radiographs provide information about skeletal, dental, and soft tissue relationships, allowing clinicians to assess craniofacial morphology through standardized anatomical landmarks, measurements, and angular relationships (Rozylo-Kalinowska, 2020).

Dental radiography uses X-rays, a form of ionizing electromagnetic radiation, to produce diagnostic images through differential attenuation as radiation passes through biological tissues. X-ray interactions with matter may produce ionization and secondary electrons, which can induce biological changes depending on the absorbed dose and tissue characteristics. In dentistry, X-rays are primarily used for diagnostic imaging, whereas substantially higher radiation doses are administered during radiotherapy for certain head and neck malignancies (Susanti et al., 2016).

Salivary function is essential for maintaining oral homeostasis, including lubrication, antimicrobial protection, buffering capacity, and enamel remineralization. Reduced salivary flow may decrease bicarbonate availability and buffering capacity, potentially contributing to lower salivary pH and an increased risk of enamel demineralization and dental caries (Aulia et al., 2021). Ionizing radiation can generate reactive chemical species through interactions with cellular components and water molecules, potentially damaging salivary gland tissues at sufficiently high doses. Radiation-related salivary gland dysfunction may alter salivary flow, pH, buffering capacity, and viscosity (Amatulhaq et al., 2023). However, these effects are primarily established in the context of therapeutic radiation exposure and should not be assumed to occur to the same extent following low-dose diagnostic radiography.

Susanti et al. (2016) reported a statistically significant difference in salivary pH before and after panoramic radiographic examinations, suggesting that potential short-term changes in salivary characteristics following dental X-ray exposure warranted further investigation. However, evidence specifically addressing salivary pH changes following cephalometric radiography remained limited. Therefore, this study aimed to compare salivary pH before, immediately after, and 24 hours after cephalometric radiographic exposure. The findings were expected to contribute to the understanding of short-term salivary pH variations associated with dental radiographic examinations and provide additional evidence relevant to radiation protection and clinical practice.

Dental radiography enables clinicians to identify anatomical structures and pathological changes that may not be adequately detected through clinical examination alone. It supports the diagnosis and evaluation of dental caries, periodontal disease, developmental abnormalities, and other oral and maxillofacial conditions. Accurate interpretation of radiographic images complements clinical findings and contributes to appropriate treatment planning and monitoring (Sukmana, 2019).

Intraoral radiographic techniques include periapical, bitewing, and occlusal radiography (Sukmana, 2019). Periapical radiographs depict the entire tooth, including its root and surrounding periapical structures, whereas bitewing radiographs primarily visualize the crowns

of the maxillary and mandibular teeth and adjacent alveolar bone crests. Occlusal radiographs provide a broader view of dental and supporting structures (White & Pharoah, 2014). Periapical imaging commonly employs the paralleling or bisecting-angle technique. The paralleling technique is generally preferred because it minimizes geometric distortion, while the bisecting-angle technique may be used when anatomical limitations prevent appropriate receptor positioning (Anggara et al., 2018; White & Pharoah, 2014).

Extraoral radiography provides broader visualization of the craniofacial structures, with the image receptor positioned outside the oral cavity. Common techniques include panoramic, lateral jaw, cephalometric, posteroanterior, anteroposterior, Waters, reverse Towne, and submentovertex projections (Sukmana, 2019). Panoramic radiography is particularly useful for evaluating the jaws, dentition, and certain pathological abnormalities (Gunawan et al., 2020). Extraoral examinations may also assist in assessing craniofacial trauma, developmental abnormalities, and skeletal relationships. Cephalometric radiography is especially valuable for evaluating dental and skeletal relationships, facial growth, and orthodontic treatment outcomes (White & Pharoah, 2014). Extraoral techniques may be appropriate when patients cannot tolerate intraoral receptor placement because of discomfort, swelling, or other clinical limitations (Iannucci & Howerton, 2016).

Cephalometric radiography is a standardized skull imaging technique widely used in orthodontics and orthognathic surgery to assess dental, skeletal, and soft tissue relationships. Cephalometric measurements are obtained using established anatomical landmarks, including sella (S), nasion (N), point A, and gnathion (Gn), depending on the analytical method employed (Whaites & Drage, 2021). These measurements support the evaluation of craniofacial growth, skeletal discrepancies, and treatment outcomes. Lateral cephalometric radiographs also provide information about the facial soft tissue profile, which may be enhanced through appropriate imaging techniques and exposure settings (Iannucci & Howerton, 2016). Both direct and indirect digital cephalometric imaging techniques generally involve relatively low radiation doses compared with therapeutic radiation procedures (Gijbels et al., 2004).

The primary clinical applications of cephalometric radiography include orthodontic assessment and orthognathic surgical planning (Boel, 2019). During lateral cephalometric imaging, a cephalostat maintains standardized head positioning relative to the X-ray source and image receptor, facilitating reproducible measurements of craniofacial structures (White & Pharoah, 2014). In orthodontics, cephalometric radiography supports diagnosis, assessment of skeletal and soft tissue abnormalities, treatment planning, and evaluation of treatment progress (Rozylo-Kalinowska, 2020). In orthognathic surgery, it assists with preoperative assessment, surgical planning, postoperative evaluation, and long-term monitoring of skeletal and soft tissue changes (Boel, 2019).

X-rays are ionizing electromagnetic radiation capable of removing electrons from atoms and molecules, thereby generating ions and secondary electrons. Ionizing radiation can damage biological tissues through direct interactions with cellular macromolecules or indirect mechanisms involving water radiolysis and the formation of reactive oxygen species. Radiotherapy uses these biological effects to treat malignant conditions, including head and neck cancers, but therapeutic radiation may also affect surrounding healthy tissues. Salivary glands are particularly vulnerable to radiation-induced dysfunction at sufficiently high doses,

potentially resulting in reduced salivary secretion and adverse oral health outcomes (Susanti et al., 2016).

Although dental radiographic examinations provide substantial diagnostic benefits, exposure to ionizing radiation requires appropriate justification and optimization. Diagnostic dental radiography generally involves low radiation doses, but X-rays can still interact with biological tissues and produce ionization (Iannucci & Howerton, 2016). Absorbed dose represents the energy deposited by ionizing radiation per unit mass and is expressed in grays (Gy), equivalent to joules per kilogram (Whaites & Drage, 2021). Equivalent dose accounts for the type of radiation and is expressed in sieverts (Sv), whereas effective dose additionally incorporates tissue-specific radiation weighting factors to estimate the overall stochastic radiation risk (Iannucci & Howerton, 2016).

The biological effects of ionizing radiation are commonly classified as stochastic effects and tissue reactions, historically termed deterministic effects. Stochastic effects involve a probability of occurrence that increases with radiation dose, while their severity is not determined by dose. These effects include radiation-induced malignancies and certain hereditary effects (Benn & Vig, 2021; Iannucci & Howerton, 2016). In contrast, tissue reactions generally occur when radiation exposure exceeds a tissue-specific threshold, with severity increasing as the dose rises. Oral complications associated with high-dose head and neck radiotherapy may include mucositis, epithelial damage, ulceration, and increased susceptibility to secondary infections.

The oral mucosa contains rapidly proliferating basal epithelial cells that are sensitive to therapeutic radiation exposure. During head and neck radiotherapy, radiation-induced epithelial damage may produce erythema, inflammation, and oral mucositis. As treatment continues, epithelial breakdown may progress to ulceration and more severe mucosal injury. Following radiotherapy, mucosal healing generally occurs over time, although persistent tissue changes, including fibrosis, atrophy, and reduced vascularity, may develop in some patients (White & Pharoah, 2014). These complications are associated with therapeutic radiation doses and are not characteristic of routine diagnostic cephalometric examinations.

Taste disturbances are another recognized complication of head and neck radiotherapy. Patients may experience reduced taste sensitivity within the first several weeks of treatment because of radiation-related injury to taste receptor cells and surrounding tissues (Iannucci & Howerton, 2016). The severity and pattern of taste impairment depend on the irradiated anatomical regions, radiation dose, and treatment characteristics. Partial or substantial recovery may occur within approximately 60–120 days after treatment, although recovery varies among patients (White & Pharoah, 2014).

Salivary glands are susceptible to radiation-induced injury, particularly during head and neck radiotherapy. The parotid glands, which contain predominantly serous acinar cells, are especially sensitive to radiation exposure. Radiation-related tissue changes may include acinar cell loss, vascular alterations, fibrosis, and progressive glandular dysfunction. These changes can reduce salivary flow and contribute to xerostomia, impaired oral lubrication, and increased susceptibility to dental demineralization (Iannucci & Howerton, 2016). Severe salivary gland dysfunction may occur following high cumulative therapeutic doses, including exposures approaching 60 Gy. Histopathological changes can include acute inflammatory responses,

acinar cell degeneration, ductal alterations, and progressive fibrosis (White & Pharoah, 2014; Yunus & Praja, 2016).

Patients receiving head and neck radiotherapy may experience alterations in the oral microbiota, including increased colonization by cariogenic microorganisms such as Streptococcus mutans and Lactobacillus species, as well as opportunistic fungi such as Candida species (De Ryck et al., 2015; White & Pharoah, 2014). Radiation-associated salivary gland dysfunction can contribute to dental caries through reduced salivary flow, lower pH, diminished buffering capacity, and increased viscosity. Changes in the availability of calcium and phosphate ions may further compromise enamel remineralization and increase susceptibility to tooth demineralization (White & Pharoah, 2014).

Susanti et al. (2016) reported a reduction in salivary pH following panoramic radiography and discussed the potential involvement of major and minor salivary glands within the irradiated region. The parotid glands contain predominantly serous acinar cells, whereas the submandibular glands contain both serous and mucous acinar cells. Serous acinar cells are particularly sensitive to high-dose radiation injury, although the biological significance of exposure during routine diagnostic radiography remains uncertain. Reduced salivary flow may decrease bicarbonate availability and buffering capacity, potentially contributing to lower salivary pH (Khoerunnisa et al., 2017). Nevertheless, the mechanisms established for therapeutic radiation exposure should not be directly extrapolated to low-dose panoramic or cephalometric examinations.

Interactions between ionizing radiation and intracellular water can initiate radiolysis, producing reactive species such as hydroxyl radicals (•OH), hydrated electrons, and hydrogen peroxide (H_2O_2). These reactive products may interact with cellular proteins, lipids, and nucleic acids, potentially causing oxidative damage. At sufficiently high radiation doses, injury to salivary gland cells may impair secretion and alter salivary composition, including bicarbonate concentrations and buffering capacity (Amatulhaq et al., 2023). However, whether the substantially lower radiation doses associated with cephalometric radiography produce measurable changes in salivary gland function requires empirical investigation.

Saliva is an exocrine secretion produced primarily by the parotid, submandibular, and sublingual glands, together with numerous minor salivary glands distributed throughout the oral mucosa. Whole saliva contains secretions from these glands and additional components derived from gingival crevicular fluid, oral microorganisms, epithelial cells, and other oral sources. Salivary secretion may be classified as unstimulated or stimulated, depending on the presence of mechanical, gustatory, olfactory, or pharmacological stimuli. The relative contributions of individual salivary glands vary according to the level and type of stimulation. Under resting conditions, the submandibular glands generally contribute the largest proportion of whole saliva, whereas the parotid glands become increasingly important during stimulated secretion (Kasuma, 2015).

Saliva contributes to oral health by lubricating oral tissues, facilitating mastication and swallowing, supporting speech, providing antimicrobial protection, and maintaining acid–base balance. Salivary flow also promotes oral clearance by removing food debris and reducing the retention of fermentable carbohydrates, thereby limiting conditions favorable to bacterial acid production (Kasuma, 2015). In addition, salivary calcium, phosphate, and fluoride ions support

enamel remineralization, while bicarbonate and other buffering components help neutralize acids generated by oral microorganisms (Kasuma, 2015).

Salivary pH reflects the acidity or alkalinity of saliva and is influenced by salivary flow rate, electrolyte composition, buffering capacity, and microbial activity. Under physiological conditions, salivary pH varies considerably, with commonly reported values ranging from approximately 5.6 to 7.0 and an average near 6.7 (Bolla et al., 2017). Bicarbonate is a major component of the salivary buffering system, and its concentration generally increases with salivary flow. Reduced buffering capacity may contribute to prolonged acidic conditions in the oral cavity, increasing the risk of enamel demineralization. Acidogenic and aciduric microorganisms, including Streptococcus mutans and Lactobacillus species, can contribute to dental caries by producing acids and tolerating low-pH environments (Bolla et al., 2017). Consequently, evaluating salivary pH before and after cephalometric radiography may provide preliminary evidence of short-term changes in the oral environment, although observed differences cannot independently establish radiation-induced salivary gland damage.

METHOD

Design, Location, and Research Time

This study employed a quantitative, quasi-experimental approach using a one-group pretest–posttest design with repeated measurements. Participants who met the inclusion criteria underwent salivary pH measurements at three time points: before, immediately after, and 24 hours after X-ray exposure during cephalometric radiography. The study was conducted at the Radiology Laboratory of Dirgahayu Hospital, Samarinda, Indonesia, from October to December 2023. The alternative hypothesis (H_1) proposed that salivary pH differed significantly across the three measurement time points, whereas the null hypothesis (H_0) proposed that no significant differences existed. The conceptual framework of the study is presented in Figure 1.

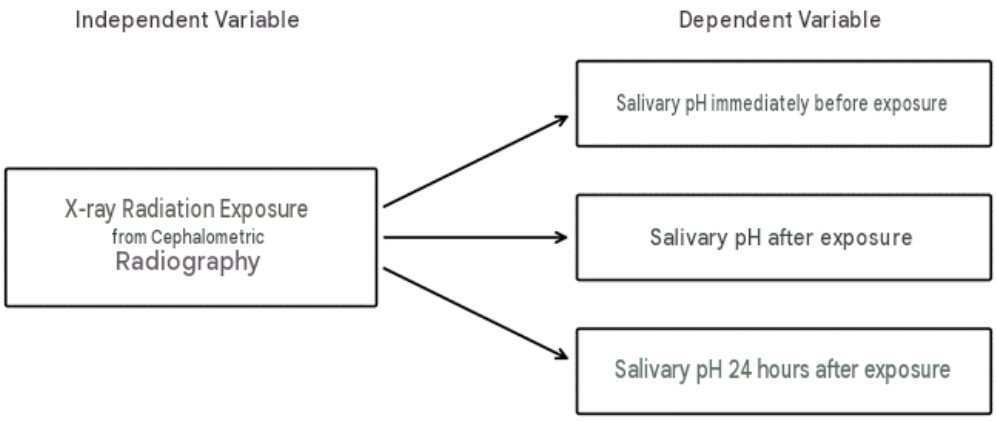


Figure 1. Research Concept Framework

Population and Sample

The study population was orthodontic treatment patients who received referrals to undergo *cephalometric* radiography examinations in the October–December 2023 period from three orthodontic dentist practices, namely the practice of drg. Saiful Rokhim, Sp.Ort., drg.

Dame Rimauli Simbolon, Sp.Ort., and drg. Rina Wahyu W., Sp.Ort. The sample size was estimated using *the Lemeshow* formula for an unknown population, namely $n = (Z\alpha^2 \times S^2) / d^2$, with $Z\alpha = 1.96$ (95% confidence), $S = 0.0354$ as the standard deviation (Susanti et al., 2016), and $d = 0.015$ as the desired degree of deviation, resulting in a minimum sample number of 21 people.

Sampling uses *a nonprobability sampling* technique of *purposive sampling*, where samples are taken based on considerations or criteria that have been determined by the researcher to be representative of the population. Inclusion criteria include: (1) patients who receive referrals from the SAP Dental Care clinic, the Kimia Farma Agus Salim clinic, and the private clinic drg. Rina Wahyu W., Sp.Ort for *a cephalometric* radiography examination at the Radiology Laboratory of Dirgahayu Hospital Samarinda; (2) aged 17–55 years; and (3) willing to be a respondent and sign an *informed consent*. Exclusion criteria included respondents with systemic diseases and respondents who withdrew during the study.

Variables, Instruments, and Operational Definitions

The independent variable of this study was X-ray radiation exposure from *cephalometric* radiography, while the bound variable was saliva pH before, after, and 24 hours after exposure. The research instrument consisted of a digital pH meter (*Onemed*) to measure saliva pH, a pH 7 buffer solution to calibrate the pH meter, and *a spittoon* (saliva storage pot). The operational definition of the research variables is presented in Table 1.

Table 1. Operational Definition

Variable	Operational Definition	Criteria & Scores	Scale of Measurement
Saliva pH before exposure to X-ray radiation from *cephalometric radiography*	The pH value of the respondent's saliva was measured using a digital pH meter before the respondent was exposed	Scale 0.0–14	Ratio
Exposure to X-ray radiation from *cephalometric radiography*	X-ray radiation dose values from *cephalometric radiography aircraft*	0–3.4 μSv	Ratio
pH of saliva after radiation exposure	Saliva pH value after exposure to X-ray radiation from *cephalometric* radiography measured using a digital pH meter	Scale 0.0–14	Ratio
Saliva pH 24 hours after radiation exposure	Saliva pH value 24 hours after exposure to X-ray radiation from *cephalometric* radiography measured using a digital pH meter	Scale 0.0–14	Ratio

Research Procedure

The data used are primary data obtained directly from the respondents. The research procedure includes: (1) contacting prospective respondents to coordinate the X-ray schedule; (2) explaining the sampling procedures to the respondents; (3) filling out the identity sheet and signing the *informed consent*; (4) taking the first saliva sample shortly before the *cephalometric* X-ray examination by instructing the respondent to spit into the saliva storage

pot, then measuring the pH; (5) taking and measuring the second saliva sample immediately after *the cephalometric* X-ray examination; (6) coordinating the place and time of taking the third sample; and (7) taking and measuring the third saliva sample 24 hours after the X-ray. The flow of the research is shown in Figure 2.

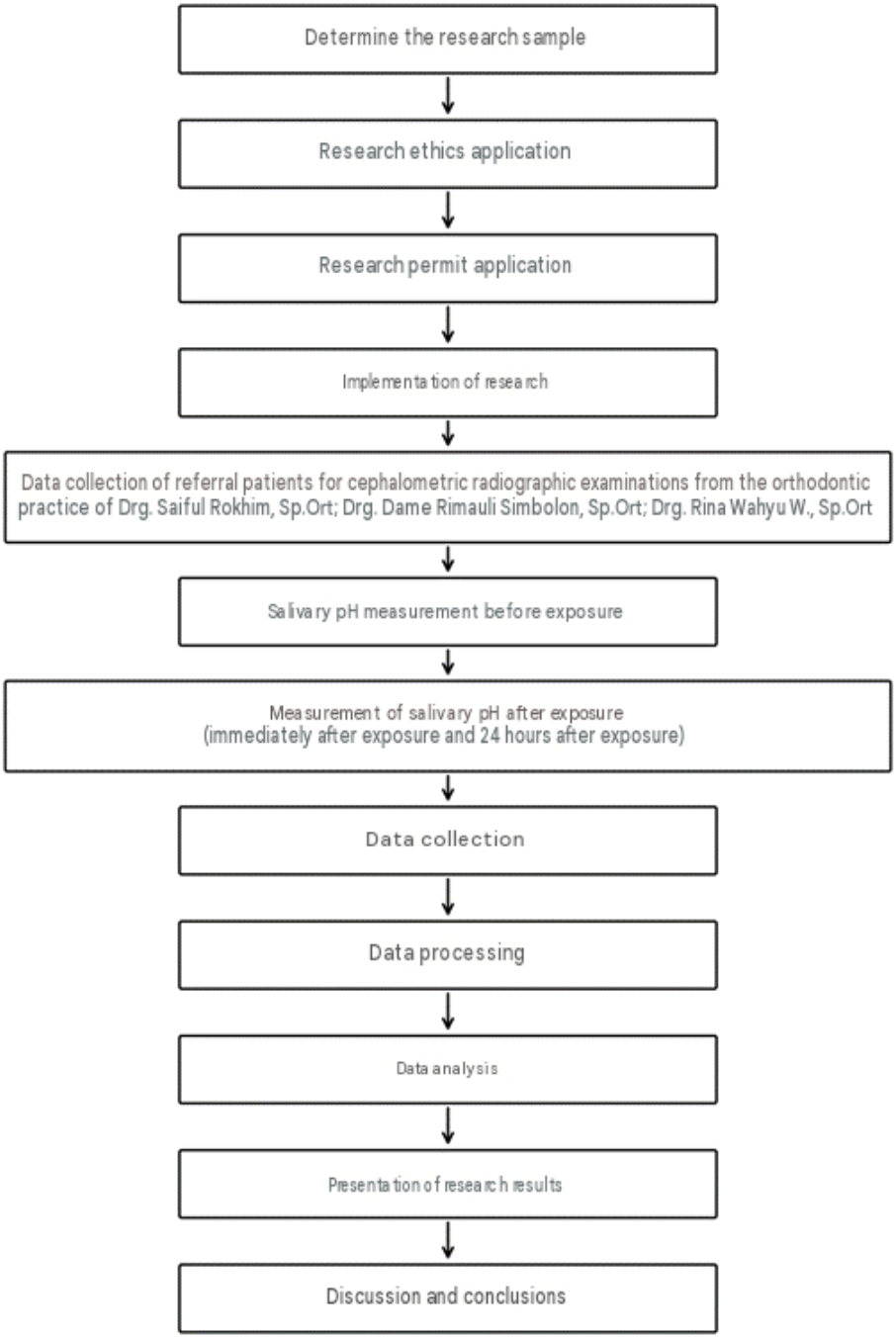


Figure 2. Research Flow

Data Processing and Analysis

Data were processed through *editing*, *coding*, *tabulating*, and *cleaning* stages using Microsoft Excel 2010 and SPSS Statistics version 29.0.0.0, then presented in the form of tables and narratives. Univariate analysis was used to describe the saliva pH of respondents before,

after, and 24 hours after exposure, with *Shapiro-Wilk* normality test due to the relatively small number of samples. Bivariate analysis used *the ANOVA Repeated Measures test* if the data were normally distributed, or the Friedman non-parametric test if the data was not normally distributed, followed by the *Bonferroni follow-up test* between groups. The difference was considered significant if $p < 0.05$. All subjects gave consent through *informed consent*, the identity of the respondents was kept confidential, and the research had obtained ethical *clearance* from the Research Ethics Commission of the Faculty of Medicine, Mulawarman University.

RESULTS AND DISCUSSION

Results

The study respondents were 21 people who were in accordance with the inclusion criteria and were willing to be involved by signing an *informed consent*. There were four patients who were not willing to be respondents and three patients who could not be reached for the third sampling due to the distance of domicile. Data were obtained through interviews, then saliva sampling was carried out before, after, and 24 hours after exposure which was directly measured using a digital pH meter (*Onemed*) that had been calibrated with a pH 7 buffer solution. The characteristics of the respondents were dominated by 19 women (90.5%), while men as many as 2 people (9.5%). Based on age, respondents aged 20–25 years were 8 people (38.1%), 26–30 years old as many as 7 people (33.3%), and 31–35 years old as many as 6 people (28.6%) (Table 2).

Table 2. Characteristics of Respondents

Characteristics	Categories	Quantity (n)	Percentage (%)
Gender	Male	2	9,5
	Women	19	90,5
	Total	**21**	**100**
Age (years)	20–25	8	38,1
	26–30	7	33,3
	31–35	6	28,6
	Total	**21**	**100**

Descriptive statistics of the respondents' saliva pH are presented in Table 3. The saliva pH data before exposure had an average of 6.9929 with a minimum value of 6.23 and a maximum of 7.44. The saliva pH data after exposure had an average of 6.8786 with a minimum value of 6.13 and a maximum of 7.24. The saliva pH data 24 hours after exposure had an average of 6.8276 with a minimum value of 6.10 and a maximum of 7.16.

Table 3. Descriptive Statistics of Saliva pH Before, After, and 24 Hours After Exposure

Saliva pH	N	Average	Std. Deviation	Minimum	Maximum
Before exposure	21	6,9929	0,27245	6,23	7,44
After exposure	21	6,8786	0,25017	6,13	7,24
24 hours after exposure	21	6,8276	0,23601	6,10	7,16

The Shapiro-Wilk *normality test* (Table 4) showed that saliva pH data before exposure were normally distributed (p = 0.263), while saliva pH data after exposure (p = 0.029) and 24 hours after exposure (p = 0.000) were not normally distributed.

Table 4. Shapiro-Wilk *Normality Test Results*

Saliva pH	Statistic	df	Sig.
Before exposure	0,944	21	0,263
After exposure	0,896	21	0,029
24 hours after exposure	0,788	21	0,000

Remarks: the data is declared to be normally distributed if the significance value (Sig.) > 0.05.

Since there were data groups that were not normally distributed, bivariate analysis was performed using Friedman's non-parametric test. The *results of the Friedman* test (Table 5) showed an *Asymp. Sig.* value of 0.000 (< 0.05), resulting in a significant difference between saliva pH before, after, and 24 hours after exposure to X-ray radiation from *cephalometric radiography*. The decrease in the mean salivary pH value at all three measurement times is shown in Figure 3.

Table 5. Results of *the Friedman Analysis Test*

Test Variables	Asymp. Sig.
pH before – pH after – pH 24 hours after exposure	0,000*

Remarks: *significant if the value of Asymp. Sig. < 0.05.

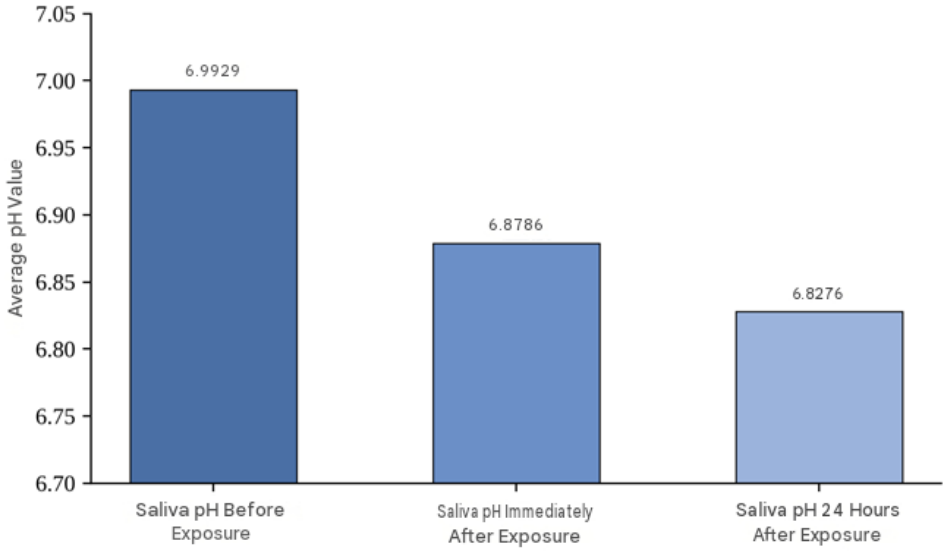


Figure 3. Graph of Respondents' Average Saliva pH Values Before, After, and 24 Hours After X-Ray Radiation Exposure from *Cephalometric Radiography*

Further analysis between groups was performed using *the Bonferroni* test by coding group 1 = pre-exposure saliva pH, 2 = post-exposure saliva pH, and 3 = saliva pH 24 hours post-exposure. The results of the follow-up test (Table 6) showed that there was a significant difference between pre- and post-exposure saliva pH (p = 0.000) and between saliva pH before and 24 hours after exposure (p = 0.004). Meanwhile, the comparison between saliva pH after exposure and 24 hours after exposure yielded a significance value of 0.402 (> 0.05), so there was no significant difference between the two.

Table 6. Results of *Bonferroni Advanced Test* Analysis (*Pairwise Comparisons*)

(I) Time	(J) Time	Sig.
1 (before exposure)	2 (after exposure)	0,000*
	3 (24 hours after exposure)	0,004*
2 (after exposure)	1 (before exposure)	0,000*
	3 (24 hours after exposure)	0,402
3 (24 hours after exposure)	1 (before exposure)	0,004*
	2 (after exposure)	0,402

Remarks: *there is a significant difference if the Sig. value < 0.05; 1 = Saliva pH before exposure, 2 = Saliva pH after exposure, 3 = Saliva pH 24 hours after exposure.

Discussion

X-rays are a clinical diagnostic support tool whose application is increasingly needed in supporting examinations in the health sector, especially dentistry. Although its diagnostic benefits are very helpful, the carcinogenic potential of low-dose X-ray examinations is still a concern (Benn & Vig, 2021). X-ray exposure is divided into high-dose radiotherapy and fluoroscopy, as well as low-dose diagnostic radiology, one of which is *cephalometric* radiography (Lurie, 2019). Exposure to low-dose X-ray radiation from oral radiography also has side effects on the salivary glands, where changes in *buffer capacity* and salivary viscosity will trigger changes in salivary pH which has an impact on the dental demineralization process (Lin et al., 2015).

Saliva functions to maintain the balance of the oral cavity through its composition, viscosity, degree of acidity, and proteins. High viscosity of saliva triggers a low pH of saliva so that the condition of the oral cavity becomes more acidic. Saliva has a normal pH value ranging from 6–7, varying from 5.3 at a low flow rate to 7.8 at a high flow rate (Atqiya et al., 2021). In this study, the pH of the respondents' saliva before exposure had an average of 6.9929 with a range of 6.23–7.44 (Table 3), so that the pH distribution of the respondents' saliva before the intervention was still relatively normal.

Although the dose received from oral radiography is relatively low, it is possible that the radiation has side effects on exposed cells or living tissues, especially in the oral cavity (Susanti et al., 2016). Radiotherapy induces changes in the electrolyte and antibacterial function of saliva and reduces the *buffer capacity of* saliva by up to 67%, which has an impact on reducing the pH of saliva and the normal flora of the oral cavity (Pinna et al., 2015). Reduced saliva production due to decreased secretion will decrease buffer capacity which triggers an increase in viscosity and a decrease in saliva pH. In this study, the average pH of saliva shortly after exposure decreased to 6.8786 with a range of 6.13–7.24, or an average decrease of 0.1143 compared to before exposure, and this difference was statistically significant ($p = 0.000$; Table 6). These findings show that the use of low-dose radiation in *cephalometric* radiography does not mean that it does not cause side effects for exposed cells or tissues, especially in saliva.

One of the side effects of radiation in the head and neck area is a decrease in salivary secretion. Radiotherapy has a destructive effect on the salivary glands resulting in hyposalivation and dry mouth (*xerostomia*), which is a subjective state of dry oral cavity that occurs when the speed of saliva secretion is lower than the reduction of saliva due to

evaporation and absorption through the mucosa. *Xerostomia* has an impact on speech, swallowing, and dental and oral health due to decreased salivary *self-cleaning* function , and impaired salivary function tends to persist in the first 24 hours after radiation (Nasutianto, 2019). In this study, the average pH of saliva 24 hours after exposure was 6.8276 with a range of 6.10–7.16. This value was 0.1653 lower than before exposure and differed significantly (p = 0.004), while the decrease from shortly after exposure to 24 hours after exposure of 0.051 was not statistically significant (p = 0.402). This shows that the decrease in saliva pH due to exposure still persists until 24 hours after exposure.

Overall, the mean salivary pH values before, after, and 24 hours after exposure to X-ray radiation from *cephalometric* radiography showed consecutive decreases from 6.9929 to 6.8786 and 6.8276 (Figure 7), which was confirmed by *the Friedman* test with *the value of Asymp. Sig.* 0.000 (< 0.05). Thus, H1 was accepted, i.e. there was a significant difference between salivary pH before, after, and 24 hours after exposure to X-ray radiation from *cephalometric* radiography. This study is in line with Susanti et al. (2016) who obtained a significant decrease in saliva pH of 0.0638 between before and after exposure to X-ray radiation from panoramic radiography ($p < 0.05$). This is also reinforced by Ajani et al. (2019) who stated that the decrease in saliva pH after radiation exposure is caused by sperm cells that undergo apoptosis so that the rate of saliva flow decreases, the saliva buffer capacity decreases, and the condition of the oral cavity becomes more acidic. This mechanism is in accordance with the explanation that the ionization of water molecules in the cells that make up the salivary glands produces free radicals and hydrogen peroxide that damage the cell so that the concentration of bicarbonate ions as saliva buffers decreases (Amatulhaq et al., 2023; Aulia et al., 2021).

This study has several limitations. First, the data collection time is less effective because some of the respondents are workers who take advantage of the night time for consultation and immediately take X-rays afterwards, so it is not possible to contact the researcher first. Second, there is no quarantine for the respondents so that saliva pH sampling 24 hours after exposure is influenced by many confounding factors that can cause changes in saliva pH to be not too significant. Third, radiation exposure dose measurements from the equipment used are not carried out due to the unavailability of radiation dose measuring devices at the research site.

CONCLUSION

Based on the findings, the mean salivary pH decreased from 6.9929 (range: 6.23–7.44) before X-ray exposure during cephalometric radiography to 6.8786 (range: 6.13–7.24) immediately after exposure and further declined to 6.8276 (range: 6.10–7.16) at 24 hours after exposure. The Friedman test revealed statistically significant differences in salivary pH across the three measurement time points ($p < 0.05$), with significant differences observed between baseline and both post-exposure measurements. These findings indicated that cephalometric radiographic examinations were associated with short-term reductions in salivary pH, although a direct causal relationship with X-ray exposure could not be established. Future research should investigate salivary pH changes following different dental radiographic procedures, assess the duration of observed changes, and examine potential biological mechanisms. Further studies should also incorporate radiation dose measurements, appropriate control groups,

longer follow-up periods, and adjustments for potential confounding factors to better determine whether diagnostic X-ray exposure contributes to changes in salivary pH.

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