Journal of Dentistry and Dental Practices
ISSN: 2689-5994

Academic Strive
Researcher's perception is our reality

Research Article *Volume 7 Issue 1*

Hydroquinone Levels in Radiographic Developer Solutions are Based on Concentration and Length of Time Oxidized in Free Air

Prasetyarini S, Supriyadi, Assary Aufa Wardhana R*

Department of Dental Radiology, Faculty of Dentistry, Jember University, Indonesia

***Corresponding author:** Raditya Assary Aufa Wardhana, Department of Dental Radiology, Faculty of Dentistry, University of Jember, Kalimantan Tegalboto Street No.37, Krajan Timur, Sumbersari 68121, Jember, Indonesia, Email: radityassary@gmail.com

Received Date: December 30, 2024; **Published Date:** January 08, 2025

Abstract

Radiographic examination in the field of dentistry is used as a supporting examination in determining a diagnosis and treatment plan. The development stage in processing radiographic film uses a developer solution. The developer solution contains the compound Hydroquinone which functions to create images. Hydroquinone is easily oxidized so it will reduce the developing ability of the developer solution. This study aims to determine differences in hydroquinone levels in radiographic developer solutions based on the length of time it oxidizes in free air. This laboratory experimental research uses a post test only control group design. The research samples consisted of 32 samples and were divided into 8 groups based on concentration and oxidization time in free air. Hydroquinone levels were measured using an HPLC instrument. The data obtained were analyzed using the Kruskal Wallis Test followed by the Post Hoc Test. The results of the study showed that there were differences in hydroquinone levels in developer solutions exposed to free air for 7, 14 and 30 days. The highest hydroquinone levels were in the group that was not exposed to free air and the lowest hydroquinone levels were in the group that was exposed to free air for 30 days. A developer solution with a concentration of 25% decreases hydroquinone levels more quickly than a developer solution with a concentration of 50%. The conclusion is that there was a decrease in hydroquinone levels in the developer solution with oxidization time in free air for 7, 14, and 30 days.

Keywords: Developer Solution; Film Developing; Hydroquinone Levels; Oxidation Time

Introduction

The radiographic examination has a vital role in the field of dentistry. Radiographic examinations in dentistry are carried out intraorally and extraorally; both are used based on their needs. Radiographic examination plays a role in helping determine the diagnosis and prognosis and monitor several treatment results, especially for diseases or disorders in the oral cavity [1]. In addition, recent research on radiography of the head and neck has increased attention to anatomical variations that may correlate with clinical disease [2]. The radiographic examination must go through several stages to be able to produce a good and accurate picture of the condition of the oral cavity, namely the preparation of X-ray aircraft and the tools needed, the selection of appropriate exposure factors, the patient's cooperative level, proper film processing, and other things that can affect the radiograph. Film processing involves several parts or stages, such as developing, rinsing, fixing, washing, and drying [3].

The first stage of film processing is developing. Developing functions in shaping latent shadows into visible images on

Copyright © 2025 Assary Aufa Wardhana R.

film [4]. In the developing stage, the film is immersed in a developer solution. The component in the developer solution that functions to form latent shadows into visible images on film is the developing agent. Materials included in the developing agent are phenidone and hydroquinone.

Hydroquinone is a material that oxidizes quickly in free air. Oxidation of hydroquinone in the developer solution will form hydrogen peroxide. The buildup of hydrogen peroxide in the developer solution will reduce the quality of radiographic images on film [5]. The developer solution should be used for 10 to 14 days, regardless of how many films are processed in a given time frame [6]. Meanwhile, other sources state that the developer solution can last for at least 3 to 4 weeks before it should be replaced [7].

Developer solutions must be treated according to the rules of the manufacturer. In this study, developer liquid was used under the Carestream brand, which has a law of a mixture of developer solutions of as much as 25% developer liquid and 75% water. Based on the description above, researchers wanted to find out whether there was a difference in Hydroquinone levels in the radiographic developer solution with the length of oxidized time in free air for 7, 14, and 30 days. Researchers also wanted to determine whether there was a difference in the speed of decreasing hydroquinone levels in developer solutions with different concentrations, namely as much as 25% and 50%.

Material and Methods

This research is an experimental research laboratory test and the posttest only control group design with 32 samples divided into eight groups (A = 50% concentration, B = 25% concentration, 1 = oxidized for 0 days, 2 = oxidized for seven days, 3 = oxidized for 14 days, 4 = oxidized for 30 days), the sample size is obtained from the Ferderer formula. The research was conducted at the Radiology Laboratory of the Faculty of Dentistry and the Analytical Chemistry Laboratory of the Faculty of Pharmacy, Jember University. The study was conducted using a radiographic developer solution made from the Carestream GBX Developer Replenisher developer brand, with a sample volume of 40 ml, placed in a glass container at room temperature and in a dark radiology room.

The study began by making a developer solution by mixing developer liquid with water, where group A consisted of 20 ml of developer fluid and 20 ml of water. In comparison, group B consisted of 10 ml of developer fluid and 30 ml of water. The sample can stand in an unsealed container for the time corresponding to the sample group. The sample was prepared by dissolving aqudest and filtered using 0.2 μm millipore. Samples from the preparation were measured hydroquinone using the HPLC (High-Performance Liquid Chromatography) method. The solution was injected at HPLC with a wavelength of 295 nm, a flow rate of 1.0 ml/min and an injection volume of 20 μl. The results of sample measurements in the chromatogram area are carried out, and a standard injection of hydroquinone at HPLC is carried out, which produces a standard curve to convert the sample area results into ppm units. Standard hydroquinone is injected with several grade variations, and two standard curve equations are obtained.

The data obtained were analyzed using statistical analysis of Statistical Product and Service Solutions (SPSS) software. Data were analyzed using the Shapiro-Wilk normality test and Levene homogeneity test. Furthermore, the Two Way Anova parametric tests were carried out if the data were normally distributed ($p > 0.05$) and homogeneous. If the data is abnormal, a non-parametric test is carried out using the Kruskal Wallis test.

Results

Measurement of standard levels of Hydroquinone obtained two different standard curve equations. The first measurement has the equation y = 23034x + 1E+06, where $r^2 = 0.994$. Meanwhile, for the second measurement has the equation y = 24858x + 20813, with $r^2 = 0.9987$. The standard standard curve equation of Hydroquinone can be seen in Figures 4.1 and 4.2. Furthermore, to calculate the level of hydroquinone in the sample, the first equation is used for high levels, and the second is used for low levels (Figures 1 & 2).

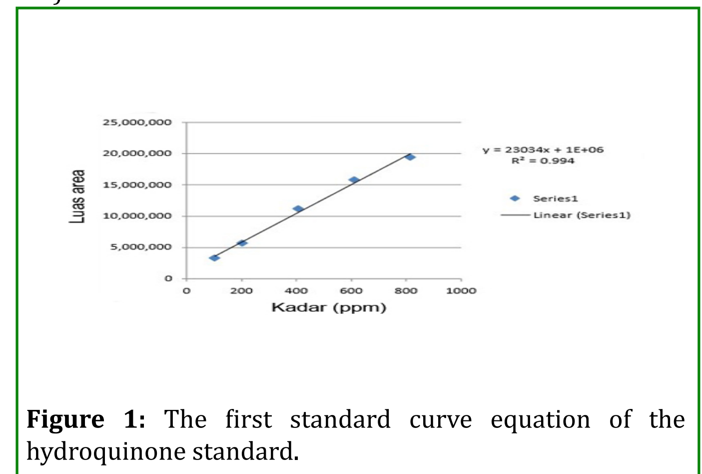

Figure 1: The first standard curve equation of the hydroquinone standard.

Calculation of Hydroquinone levels in the sample using both equations. After the sample is injected into the HPLC device, it will produce an area. If the result is an area between 3,306,856 and 19,423,496, the first equation is used to calculate the level of Hydroquinone. Meanwhile, if the result is an area between 45,772 and 275,948, the second equation is used to calculate Hydroquinone levels. After calculating

levels with both equations, the results of measuring Hydroquinone levels in ppm units were obtained and can be seen in Table 1.

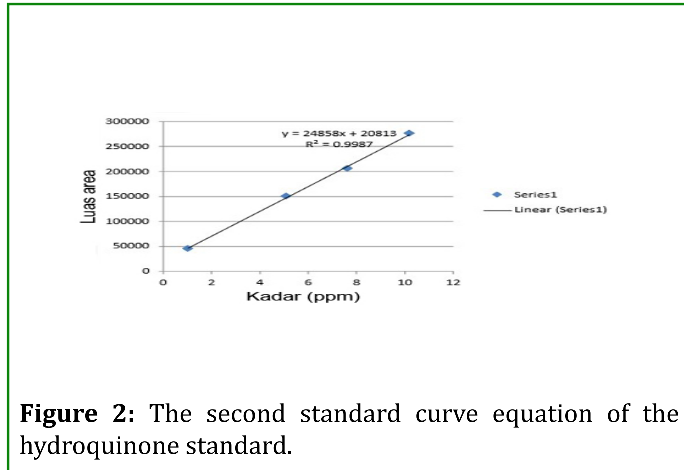

Figure 2: The second standard curve equation of the hydroquinone standard.

Sample Group	n	Hydroquinone Levels (ppm)		Average	Standard Deviation
		Lowest	Highest		
A1	3	578	617	594,75	17,211
A2	3	426	460	443,25	16,76
A3	3	240	275	259,25	16,194
A4	3	0,74	0,86	0,79	0,0505
B1	3	239	271	256,5	13,576
B2	3	6,00	7,1	6,71	0,489
B3	3	1,36	1,98	1,70	0,306
B4	3	0,46	0,62	0,54	0,073

A1 : Non-oxidized developer solution in free air with 50% developer solution concentration
A2 : Oxidized developer solution in free air for 7 days with 50% developer solution concentration
A3 : Oxidized developer solution in free air for 14 days with 50% developer solution concentration
A4 : Oxidized developer solution in free air for 30 days with 50% developer solution concentration
B1 : Non-oxidized developer solution in free air with 25% developer solution concentration
B2 : Oxidized developer solution in free air for 7 days with 25% developer solution concentration
B3 : Oxidized developer solution in free air for 14 days with 25% developer solution concentration
B4 : Oxidized developer solution in free air for 30 days with 25% developer solution concentration

Table 1: Results of measuring hydroquinone levels in eight sample groups.

The lowest hydroquinone levels were found in the sample group with a developer fluid composition of 25% and exposed to free air for 30 days, with an average of 0.54 ppm. Meanwhile, the highest hydroquinone levels were found in the sample group with a developer fluid composition of 50% and were not exposed to free air, with an average of 594.75 ppm. Two groups of samples based on different developer fluid compositions had different rates of decreasing hydroquinone levels. The sample group with a developer fluid composition was 25% faster to experience a decrease in hydroquinone levels than the developer fluid composition of 50%. An overview of the speed of decreasing hydroquinone levels can be seen in Figure 3.

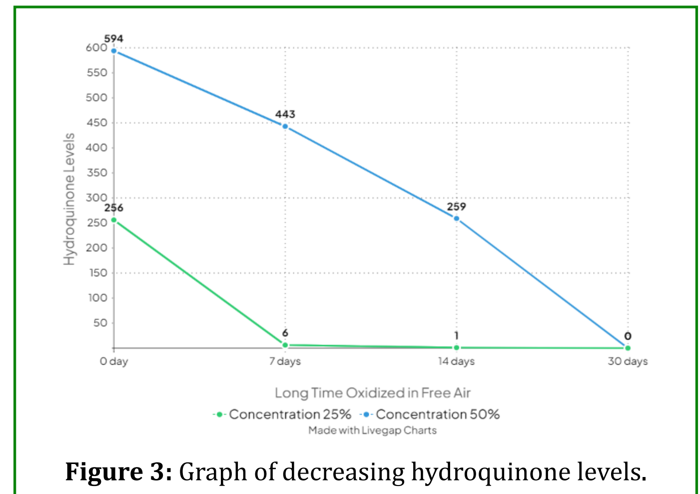

Figure 3: Graph of decreasing hydroquinone levels.

Data on hydroquinone levels were statistically analyzed. The result of the normality test with the Shapiro-Wilk test is obtained (Sig) 0.01 ($p<0.05$), meaning that the data is not normally distributed. The results of the Levene homogeneity test obtained a significance value (Sig) of 0.00 or $p < 0.05$, so the data were not homogeneous. The data was not normally distributed, so a non-parametric test of Kruskal Wallis was carried out. The Kruskal Wallis test calculation results obtained a significance value (Sig) of 0.002 or $p < 0.05$, meaning there are significant differences between groups.

Discussion

Measurement of Hydroquinone levels in this study using the High-Performance Liquid Chromatography (HPLC) method. HPLC instruments are used because of their fast analysis time, have good separation power so that compounds can be analyzed selectively without being affected by the presence of other compounds, and are sensitive to determine compound levels in small concentrations [8]. HPLC is a widely accepted separation technique for analyzing and purifying certain compounds in a sample in several fields, including pharmaceutical, environmental, biotechnological, polymer, and food industries. This method has the advantage of high separation power, so it will not give false negative results and can analyze compounds with small levels. The working

principle of HPLC is the separation of solutes (solutes) by differences in the elution speed of solute-solute substances passing through a chromatographic column. The separation process occurs with the help of a liquid mobile phase pump flowing through the column to the detector [9].

Hydroquinone levels were measured after the developer solution was treated in the form of exposure to free air for 7, 14, and 30 days. This study's results of measuring hydroquinone levels decreased from the initial levels. Hydroquinone is one type of chemical compound that falls into the phenol group. Phenol is a chemical compound that can be easily oxidized and undergo an evaporation process in the air or oxidized [10]. Oxidation is a chemical reaction involving removing electrons from a molecule, atom, or ion. Oxidation can be alternatively defined as the incorporation of a substance with oxygen. Oxidation and reduction must always occur together; such reactions are called oxidation-reduction or redox reactions [11].

Oxidation is a chemical reaction involving the transfer of electrons from one substance to another. These reactions can cause changes in the chemical structure of substances, including changes in chemical bonds, functional groups, and physical and chemical properties of substances [12]. Changes in the chemical structure of substances in the most common oxidation reactions are combination, decomposition, combustion, and displacement [12]. The chemical structure of hydroquinone undergoes decomposition when subjected to oxidation. A decomposition reaction is decomposing a compound into two or more components. Hydroquinone will become quinone by the chemical reaction $C_6H_6O_2 \rightarrow C_6H_4O_2 + 2H+$. This oxidation can occur spontaneously or with the help of oxidizing agents, such as oxygen, sulfur dioxide, or potassium permanganate [13,14].

Changes in chemical structure can affect the properties of substances, such as solubility, catalytic activity, thermal stability, toxicity, and reactivity. Changes in properties that occur in hydroquinone are solubility and reactivity. Changes in solubility occur due to changes in the chemical structure of hydroquinone. Hydroquinone has a more polar structure than quinone, which makes hydroquinone more soluble in water, while quinone is difficult to dissolve in water. Changes in reactivity occur due to changes in the chemical structure of hydroquinone. Quinones have carbonyl groups that are more reactive than hydroxyl groups, so quinones are more reactive to other substances than hydroquinones [13]. Changes in these properties can affect hydroquinone levels in solution [11]. Therefore, there was a decrease in hydroquinone levels in the sample groups exposed to free air, such as the sample groups A2, A3, A4, B2, B3, and B4.

Measuring hydroquinone levels with different developer fluid concentrations shows different reduction speeds. The difference can be seen in the decrease in hydroquinone levels from A1 to A2 and from B1 to B2. The calculation of the speed of decreasing levels can use the formula $v = \Delta C / \Delta t$. Group B1-2 had a speed of decreasing Hydroquinone levels by 35.8 ppm/day, while group A1-2 had a speed of 22.91 ppm/day. The difference in the rate of decrease in Hydroquinone levels is based on different oxidation speeds of Hydroquinone. Factors that can affect the oxidation speed of Hydroquinone are the pH of the initial solution and the initial content of Hydroquinone [15]. Hydroquinone oxidation is faster under acid than in alkaline conditions [16]. In this study, the pH of the initial solution in Sample Group B with a developer liquid concentration of 25% was lower than in Sample Group A with a developer liquid concentration of 50%. The initial Hydroquinone levels in the two sample groups were also different, where the sample group with a 50% developer fluid concentration contained more Hydroquinone than the sample group with a liquid concentration of 25%. These two factors affect the speed of decreasing Hydroquinone levels in both sample groups. Another factor affecting the speed of oxidation of Hydroquinone is temperature. The higher the temperature, the faster the hydroquinone oxidation process. The oxidation process will be faster at room temperature than cold temperature [17].

Oxidation of hydroquinone in water can produce a byproduct, namely Hydrogen Peroxide. The chemical reaction is $C_6H_6O_2 + O_2 \rightarrow C_6H_4O_2 + H_2O_2$. Hydrogen Peroxide has acidic properties, and the developer solution tends to be alkaline. Excessive production of hydrogen peroxide will lead to a decrease in the quality of radiographic images [5]. Hydrogen peroxide production can be minimized by reducing agents, such as sodium sulfite (Na_2SO_3). The function of sodium sulfite in the developer solution is to protect the developer solution by slowing down the rapid oxidation rate of hydroquinone so that the developer solution will last longer [18].

This research uses liquid developers with the brand Carestream GBX Developer. According to the manufacturer, the recommendation for making developer solutions is to mix developer liquid and water in a ratio of 1:4 or equivalent to 25% developer liquid. This study showed a drastic decrease in hydroquinone levels and a change in colour to brown within seven days with a developer fluid composition of 25%. It can lead to a decrease in developing ability—using a weak developer solution when processing film will reduce the quality of radiographic images. Therefore, the developer solution is recommended to be used in less than seven days.

The weakness of this study is that the sample treatment is carried out in a different place from the measurement of hydroquinone levels, so it can have the opportunity to cause influence hydroquinone levels. Hydroquinone is a compound that is sensitive to light and air. Hydroquinone levels can

quickly change when the transfer process is not tightly closed and lightproof.

Conclusion

Based on the research that has been done, it can be concluded that there are differences in hydroquinone levels in radiography developer solutions that are oxidized in free air for 7, 14, and 30 days. Hydroquinone levels decrease with increasing oxidation time in free air for 7, 14 and 30 days. Developer solutions with a concentration of 25% experience a decrease in hydroquinone levels faster than developer solutions with a concentration of 50%.

Acknowledgment

The author would like to express his deepest gratitude to the Institute for Research and Community Service, University of Jember.

References

1. Saputra WH (2020) Keterampilan Interpretasi Radiografi Periapikal Sebagai Bagian Penting Dalam Keterampilan Diagnostik Di Kedokteran Gigi. Doctoral dissertation. Universitas Muhammadiyah Yogyakarta.

2. Alharbi Hazar S, Shaikha A, Sara M (2023) Incidental Findings in Digital Panoramic Radiographs among Dental School's Patients. Journal of International Dental & Medical Research 16: 4.

3. Afani ZA, Rupiasih NN (2017) Pengolahan Film Radiografi Secara Otomatis Menggunakan Automatic X-Ray Film Processor Model Jp- 33. Bulletin Fisika 18: 53-57.

4. Zusagka E, Sutanto H, Arifin Z (2014) Pengaruh Peningkatan pH Cairan Developer dengan Penambahan Antara NaOH dan Na_2CO_3 terhadap Densitas Citra. Youngster Physics Journal 3: 203208.

5. Nasehzadeh A, Khosravan A, Resa SH (1995) Kinetics And Mechanism Of Aerial Oxidation Of Hydroquinone In A Developer Solution and Determination Of Developer's Half-Life At 20 C. J Sci 6.

6. Whaites E, Drage N (2020) Essentials of Dental Radiography and Radiology E-Book. Elsevier Health Sciences.

7. Mallya S, Lam E (2019) Whitei and Pharoah's Oral radiology Ei-book: principleis and inteirpreitation: seicond South Asia Eidition Ei-Book. Eilseivieir India.

8. Lestari W, Prasasti D (2018)Analisis Hydroquinone Pada Bleaching Cream Yang Dijual Secara Online Dan Tidak Memiliki Izin Edar Dari BPOM. Media Farmasi 15: 43-51.

9. Soleha M (2021) Analisis Kadar Hydroquinone Pada Krim Pemutih Dengan Metode KCKT (Kromatografi Cair Kinerja Tinggi). Skripsi. STIKES Bhakti Husada Mulia Madiun.

10. Fertiasari R, Leni, Kristiandi K (2023) Analisis Hydroquinone Pada Kosmetik Cair Menggunakan Kromatografi Cair Kinerja Tinggi (KCKT). Media Ilmiah Kesehatan Indonesia 1: 6-11.

11. Atkins P, Jones L (2009) Chemical Principles: The Quest for Insight. In: 5th (Edn.),.

12. Chang R, Overby J (2022) Chemistry. In: 14th (Edn.), McGraw Hill.

13. McMurry J (2023) Organic Chemistry. In: 10th (Edn.), Rice University.

14. Atkins P, Paula J, Keeler J (2018) Atkins Physical Chemistry. In: 11th (Edn.), Oxford University Press, USA.

15. Zhang Z (2021) Electrochemical Oxidation Of Hydroquinone Using EuDoped Pbo2 Electrodes: Electrode Characterization, Influencing Factors And Degradation Pathways. Journal of Electroanalytical Chemistry.

16. Li T (2015) Factors Influencing Hydroquinone Degradation In Aqueous Solution Using A Modified Microelectrolysis Method. China: Water Science & Technology.

17. Putri AGS, Agustini TW, Rianingsih L (2014) Pengaruh Ekstrak Lidah Buaya (Aloe Vera) Sebagai Antioksidan Terhadap Oksidasi Lemak Fillet Ikan Bandeng (Chanos Chanos Forsk) Segar Selama Penyimpanan Dingin. Jurnal Pengolahan Dan Bioteknologi Hasil Perikanan 3: 11-16.

18. Thomson E, Johnson O (2014) Essentials of Dental Radiography. In: 9th (Edn.), Pearson.