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The Effect of Mechanical Agitation Duration on Root Canal Irrigation Techniques (on the cleanliness of dentinal tubules in the middle third of the root canal)

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ABSTRACT
This study aimed to evaluate the effectiveness of irrigation solution application time duration in cleaning dentinal tubuli in the middle third of the root canal through Passive Ultrasonic Irrigation (PUI) and manual agitation irrigation techniques. This study was a laboratory experiment with posttest-only control group, involving 16 extracted mandibular premolars and divided into four treatment groups according to the duration of irrigation application (15 and 30 seconds) and the irrigation technique used. Evaluation of detine tubuli clearance was performed by Scanning Electron Microscope (SEM), and statistical analysis was performed by Kruskal-Wallis test. The results showed no significant difference in dentinal tubule clearance between treatment groups ($p = 0.120$; $p > 0.05$). Thus, 15 and 30 seconds of irrigation solution application time duration in the mechanical agitation technique had no significant effect on the cleanliness of dentinal tubules in the middle third of the root canal.

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INTRODUCTION

Root canal treatment refers to the endodontic triad concept which includes *access cavity, cleaning shaping* , and *obturation* [1] . The success of this procedure depends on the instrumentation technique, the type of irrigation solution, and the method used during the root canal cleaning process. One widely applied technique is ultrasonic irrigation, which works by generating vibrations and heat to improve the distribution of the solution to hard-to-reach areas, including dentinal tubules [2]. This study aims to determine whether ultrasonic irrigation can remove debris more effectively than conventional methods because it increases the flow rate of the irrigation solution and facilitates more optimal cleaning.

Ultrasonic irrigation is divided into two main types, namely *Ultrasonic Irrigation* (IU) which uses simultaneous instrumentation and *Passive Ultrasonic Irrigation* (PUI) which works without direct contact with the instrument [3]. PUI is superior in removing pulp tissue and debris compared to conventional irrigation methods with needles and syringes, because it creates a faster and more even flow of solution in the root canal [4]. However, ultrasonic irrigation still has limitations, especially when overcoming *apical vapor lock* , namely the

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formation of air bubbles that inhibit the penetration of the irrigation solution to certain areas in the root canal, so that the effectiveness of cleaning can be reduced [5].

Various types of irrigation solutions are used to support the root canal cleaning process, including *Sodium Hypochlorite* (NaOCl) and *Ethlene Diamine Tetraacetic Acid* (EDTA) [6]. NaOCl is one of the most frequently used solutions because it has strong antibacterial properties and the ability to dissolve necrotic and vital tissue. The commonly used concentration is 2.5% because at this level, the solution's toxicity is still within safe limits while its antimicrobial activity and tissue-dissolving ability remain optimal [7].

A standard irrigation protocol typically involves the use of 2.5% NaOCl for 1 minute, followed by 17% EDTA for 1 minute to help lubricate the root canal and remove bacteria and inorganic tissue debris [6,8]. Afterward, NaOCl is reapplied for 30 seconds to allow deeper penetration into the opened dentinal tubules, thereby inhibiting further bacterial growth and increasing cleaning effectiveness [9]. The effectiveness of NaOCl is influenced by its concentration and duration of application, while the hypochlorite anion in the solution also has the potential to cause collagen degradation in the root canal, which can impact the condition of the surrounding tissue.

Some literature shows that the middle to apical 1/3 of the tooth has an irregular surface profile, the presence of accessory canals and ramifications, so that the use of adequate irrigation materials and intervention using ultrasonic activation is recommended to maximize the level of root canal cleanliness [10].

Various studies have been conducted on the effect of root canal irrigation duration, but the results obtained still vary because they are influenced by the concentration and application time of the solution [11.] The effectiveness and efficiency of irrigation time are important aspects for dentists in performing root canal treatment. Therefore, this study aims to analyze the effect of mechanical agitation duration in irrigation techniques on the cleanliness of dentinal tubules in the middle third of the root canal, which will be carried out at the RSGMP UNJANI and the SEM Laboratory of Bandung Polytechnic.

METHOD

This study was an experimental study with *a posttest-only* control group design. The subjects were the duration of root canal irrigation solution application using mechanical agitation techniques such *as Passive Ultrasonic Irrigation* (PUI) and manual agitation. The sample in this study was extracted mandibular first premolars. The sample size was calculated using a paired categorical analytical formula, resulting in a minimum sample size of 4 for each group, resulting in a total sample size of 16.

The research sample was obtained through a non-probability sampling technique with a purposive sampling method, namely selectively selecting samples from a population that is in accordance with the research objectives. Therefore, the mandibular first premolar teeth were collected based on predetermined and considered criteria. This study was conducted from October 2024 to January 2025 at the RSGMP UNJANI Laboratory, LKGT Faculty of Dentistry, Jenderal Achmad Yani University, and the SEM (*Scanning Electron Microscope*) Laboratory of Bandung Polytechnic.

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This study involved 16 mandibular first premolars, which were cleaned, soaked, and crown-trimmed before root canal preparation. Working length was measured with a #10 K-file, and preparation was performed using *a Rotary Instrument File* with irrigation and recapitulation at each file change.

The samples were divided into four groups with variations in irrigation techniques, namely using 17% EDTA and 2.5% NaOCl, both with and without Ultra-X Activator activation. After preparation was complete, the samples were dried and analyzed using *a Scanning Electron Microscope* (SEM) to assess the cleanliness of the dentinal tubules in the middle third of the root canal, by scoring the presence of *a smear layer* .

RESULT

Study This aim For evaluate effectiveness duration use solution irrigation in clean dentinal tubules in one third middle channel root teeth . Data analysis was performed through processing statistics use appropriate test method For ensure accuracy results study .

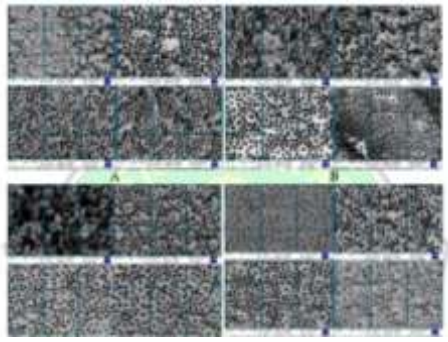

Figure 1. Scanning Electron Microscope (SEM) results at 1000x magnification and scoring determination.

a. Irrigation with 17% EDTA for 15 seconds and 2.5% NaOCl for 15 seconds (Manual agitation)
b. Irrigation with EDTA 17% for 30 seconds and NaOCl 2.5% for 30 seconds (Manual agitation)
c. Irrigation with 17% EDTA for 15 seconds and 2.5% NaOCl for 15 seconds (PUI)
d. Irrigation with EDTA 17% for 30 seconds and NaOCl 2.5% for 30 seconds (PUI)

The image above shows the results of a scan using *a Scanning Electron Microscope* (SEM). Scoring was performed using a 3x3 grid to improve evaluation accuracy. Each square in the grid was assessed using a predetermined scoring method, and the results were then expressed as a percentage of the total number of squares in each sample.

Table 1. Scoring Determination

	Group A	Group B	Group C	Group D
	Irrigation with 17% EDTA for 15 seconds and 2.5% NaOCl for 15 seconds (No ultrasonic)	Irrigation with 17% EDTA for 30 seconds and 2.5% NaOCl for 30 seconds (No ultrasonic)	Irrigation with 17% EDTA for 15 seconds and 2.5% NaOCl for 15 seconds (Ultrasonic)	Irrigation with 17% EDTA for 30 seconds and 2.5% NaOCl for 30 seconds (Ultrasonic)

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Samples	A1, A2, A3, A4	B1, B2, B3, B4	C1, C2, C3, C4	D1, D2, D3, D4
Scores	3, 2, 2, 2	2, 1, 1, 4	2, 2, 1, 2	1, 2, 2, 3

The scoring results were then subjected to statistical testing to see whether or not there was a difference in *the smear layer* in the middle 1/3 of the root canal.

Table 2. Shapiro-Wilk normality test

Group	P-value	Description
A	0.001	Not Normal
B	0.001	Not Normal
C	0.001	Not Normal
D	0.272	Normal

Note: P-value > 0.05 = Normal

The results of the data normality test show that there is only 1 group that has a significance value greater than 0.05, namely group D, so that the dominant data is not normally distributed.

Table 3. Homogeneity Test.

Levene's Test	P-value	Description
	0.295	Homogeneous

Note: P-value > 0.05 = Homogeneous

The homogeneity test results revealed a significance value of 0.295. This significance value is greater than 0.05, thus concluding that the data for all groups used is homogeneous. However, because there are groups whose data is predominantly not normally distributed, further analysis will be conducted using the non-parametric Kruskal-Wallis test.

Table 4. Kruskal-Wallis test

Kruskal-Wallis	P-value	Description
	0.120	No significant difference

Note: P-value > 0.05 = No significant difference

The test results above were conducted to determine whether there was a significant difference between all test groups in *smear layer removal* in the middle third of the root canal. The significance value obtained was 0.120, with a P-value >0.05. Therefore, it can be concluded that there was no significant difference between the test groups.

Discussion

The results of statistical analysis using the Kruskal-Wallis Test showed that there was no significant difference in the cleanliness of dentinal tubules in the middle third of the root canal between groups with irrigation solution application durations of 15 and 30 seconds, using either the PUI mechanical agitation technique or manual agitation . Several previous studies have stated that longer irrigation durations and the use of ultrasonic irrigation techniques can increase the effectiveness of cleaning the smear layer on the root canal walls . However, in this study, the time range set between 15 and 30 minutes didgua had too little variability, so it was not enough to produce a significant difference between the test groups .

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In addition, several other studies have also shown that the differences between ultrasonic and manual irrigation techniques are not always significant due to other factors such as the stages of solution application and uniform preparation procedures in each test group [14]. In this study, the only variable that was differentiated was the duration of solution application, while the irrigation technique and procedure stages remained the same, which most likely caused the results that did not show significant differences in dentinal tubule cleanliness. Therefore, further studies with a wider range of irrigation durations and variations in application techniques are needed to evaluate the optimal effectiveness in root canal treatment procedures.

The combination of irrigation solutions such as EDTA and NaOCl has become a common practice for root canal irrigation because it is considered a standard procedure for irrigation during root canal treatment and the effects of EDTA and NaOCl [15]. This can eliminate anaerobic and aerobic bacteria in *the smear layer*, so that the use of these solutions in all samples produces *smear layer scores* that are not much different from all test groups [16].

In a study conducted by Dua A, et al., it was explained that in general the ability of EDTA and *smear clear* in removing *the smear layer* can increase along with the length of application time of the irrigation solution, where in the 17% EDTA and *smear clear* test groups, the effectiveness depends on the root canal section . In the middle 1/3 section, the amount of debris in the dentinal tubules decreased significantly when the application time increased from 1 minute to 3 minutes. However, there was no statistically significant difference between the duration of 3 and 5 minutes. It can be concluded that increasing the application duration to 5 minutes did not provide a significant difference compared to 3 minutes, this indicates that the cleaning effectiveness reaches an optimal point at 3 minutes so that the extension of time does not provide significant additional benefits.

Another study stated that irrigation with EDTA followed by final irrigation with 6% NaOCl showed a significant difference in the cleaning of dentinal tubules [18]. This occurs because EDTA helps the demineralization process of inorganic components, while NaOCl supports the dissolution of the organic matrix. Factors that affect the demineralization capacity *of chelating agents* include contact time, pH, and the concentration of calcium ions remaining in the *chelating solution* after root canal irrigation, in order to evaluate the demineralization effect on root canal dentin [19].

Instrumentation techniques when performing irrigation affect the amount and distribution *of smear layers* produced and vary, and some literature states that ultrasonic irrigation techniques are more effective because of the mechanical factors they produce, but with other factors such as operator skills, tool use, or consistency of the application of irrigation methods affecting the test group, so that if a statistical data analysis test is carried out, there is a possibility that the results will show significant or insignificant differences. The use of tools such as *the Rotary Instrument File* used in this study is one of the effective and easily reproducible tools, with a general movement that is a continuous rotational movement [20]. Although the use of these instruments has many advantages, it can also increase the risk of fracture compared to *stainless steel files* .

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Furthermore, homogeneity in sample properties, such as the initial condition of the root canal, which may cause low variability in samples, can reduce differences between groups. Other factors that may influence the absence of significant differences include environmental conditions. The assessment method using *Scanning Electron Microscope* (SEM) analysis provides detailed visualization, but the assessment carried out in determining the *smear layer score* can affect the final results.

The type of irrigation solution with the concentration and technique commonly used and applied to all groups may also affect the effectiveness of smear layer cleaning so that effectiveness has reached its maximum limit and causes the duration of irrigation time to show no significant difference [18]. Therefore, a range of application duration times and stricter variable control are needed in subsequent research.

CONCLUSION

This study showed that mechanical agitation durations of 15 and 30 seconds in irrigation techniques did not significantly differ in effectiveness in improving dentinal tubule cleanliness in the middle third of the root canal. As a recommendation, further research is needed to explore the effect of irrigation solution application duration over a wider time range, so that it can provide a stronger basis for root canal treatment procedures.

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