



Exploring the Efficacy of Natural Remedies vs. Chemical Interventions in Dental Caries Management: A Comprehensive Meta-Analysis

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Abstract

Dental caries remains a major oral health problem, particularly in Indonesia, and requires effective preventive and therapeutic strategies. This meta-analysis compared natural remedies with chemical interventions for managing dental caries and reducing *Streptococcus mutans* populations. The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines and included randomized controlled trials published from 2018 to August 2023. Searches were conducted in PubMed, Cochrane, Scopus, and Epistemonikos using predefined PICO criteria. Eligible studies evaluated chemical interventions, including fluoride, chlorhexidine, and probiotics, or natural ingredients, including gum arabic, green tea, and miswak. Risk of bias was assessed using the Cochrane RoB 2 tool, while pooled effects were analyzed with Review Manager using fixed- or random-effects models according to heterogeneity. The findings showed that chemical interventions produced an overall significant reduction in dental caries incidence, with fluoride demonstrating the strongest and most consistent evidence. Probiotics significantly reduced *Streptococcus mutans* populations, whereas chlorhexidine showed favorable but less conclusive effects. Natural remedies also demonstrated preventive potential: gum arabic and green tea reduced caries incidence, while gum arabic and miswak significantly reduced *Streptococcus mutans* populations. Nevertheless, substantial heterogeneity and differences in intervention protocols limited direct comparison. A combined approach integrating evidence-based chemical therapy with promising natural remedies may provide comprehensive caries management. Larger, well-designed clinical trials are required to establish optimal dosages, application frequencies, long-term effectiveness, and safety.

Keywords: Natural Substances; Chemicals; Effectiveness; Dental Caries

1. Introduction

Tooth decay is a common issue that frequently occurs in humans, especially in Latin and Asian countries, with Indonesia being one of the countries facing serious oral health problems. More than 70% of the younger generation in Indonesia experiences tooth decay. The main causative organisms of tooth decay include various types of *Streptococcus* bacteria. Over the past few decades, the prevalence of tooth decay in Indonesia has increased due to limited dental healthcare facilities and a lack of public understanding of the importance of oral health. A household health survey in 2004 reported that a significant portion of the Indonesian population had lost all of their teeth, and the prevalence of tooth decay reached a very high level, far exceeding that of other developing countries (Shooriabi, 2021).

In an effort to address this issue of tooth decay, various therapies and approaches have been developed. The use of chemicals like fluoride has become the standard in preventing tooth decay for several decades, but herbal remedies continue to be a widely used option, especially in countries like Africa, India, and Iran. In advanced countries like China and the United States, there is a growing public interest in natural treatments, prompting research into alternative therapies using natural substances such as miswak and gum arabic. These therapies are considered to have the potential to be safer and more natural solutions in addressing tooth decay (Milgrom, 2018). In this context, this research aims to conduct a comprehensive meta-analysis to compare the effectiveness of therapy using natural substances and chemicals in managing tooth decay. Additionally, some probiotics have also been found to have the potential to reduce the levels of cariogenic *Streptococcus mutans*, which may have a positive effect on preventing tooth decay (Gafar, 2022).

This research will outline the existing scientific evidence and explore whether therapy using natural substances can be an effective alternative in the prevention and treatment of tooth decay. With a better understanding of the comparison between these two approaches, we can develop a clearer insight into which therapy is most suitable for patients' needs, and this can guide the selection of the best approach in clinical practice.

2. Method

In this meta-analysis study, we followed the Preferred Reporting Items for Meta-Analyses (PRISMA) guidelines to ensure clear and comprehensive reporting of methods and results. When gathering references, we specifically

included relevant previously published studies. This meticulous approach enhances the reliability and transparency of our research.

We focused this study specifically on randomized controlled trials (RCTs) as the qualifying study design. In this meta-analysis, only studies investigating interventions were considered. To meet the eligibility criteria, interventions had to be compared to a control group that either did not receive any intervention or received a different type of intervention or placebo.

RCTs published between 2018 and the present (year of publication) were included. Selecting a time frame for study inclusion is an important step in ensuring the relevance and completeness of this meta-analysis.

2.1 Search Strategy and Qualified Study

In this study, two reviewers (Ghani and Josse) conducted a thorough search using online search engines, including PubMed, Cochrane, Scopus, and Epistemonikos. We carefully performed separate searches for each outcome on caries prevention and treatment management, using identical Boolean System and Medical Subject Headings (MeSH) search strings as in previous reviews. Our search was conducted in English, and we included studies published in both English and Indonesian. In addition, we performed a manual search of the references of all included studies.

Table 1. PICO Inclusion Criteria

Sub-PICO	
Patient/ Population	Patients with healthy teeth up to caries based on a reliable clinical diagnosis
Intervention	Treatment based on chemical compounds
Comparison	Treatment based on natural ingredients
Outcome	Reducing the incidence of caries and reducing the number of Streptococcus mutans bacteria

2.2 Study Selection

The following steps were carried out carefully according to established protocols: (1) Initial Identification, ensuring the removal of duplicate and non-original research articles; (2) Careful selection of titles and abstracts, with special emphasis on studies that use research designs; (3) Comprehensive Full Text Assessment, ensuring the availability of complete research texts; and (4) Rigorous Full Text Screening guided by PICO criteria, increasing the precision of study selection.

2.3 Assessment of the Risk of Bias

Assessment of potential bias in included studies was performed using the Risk of Bias Assessment Tool for Randomized Clinical Trials of Interventions (RoB 2). RoB 2, the second version of the Cochrane risk of bias assessment tool for randomized clinical trials, has been recognized as the recommended instrument for assessing the risk of bias in randomized clinical trials included in the Cochrane Review. RoB 2 uses a structured framework that covers different bias domains focusing on different aspects of test design, execution, and reporting

2.4 Statistic Analysis

Statistical analysis was performed using Review Manager 5.4 software, a well-established tool developed by the Cochrane Collaboration based in Oxford, England. The clinical implications of dichotomous data are presented in the form of odds ratios (OR) using fixed effects analysis models and statistical variance methodology. Additionally, 95% confidence intervals were used to account for study variation and total confidence assessments. In cases where significant statistical heterogeneity was observed in the meta-analysis, additional analyzes were performed using a random effects model, as proposed by DerSimonian and Laird, which offers a more careful analysis approach. In all cases of meta-analysis, forest plots are created to visually present the results in a comprehensive manner

3. Result and Discussion

The process of selecting studies from four trusted international health databases resulted in a total of 5637 articles as of August 16 2023, as outlined in Figure 1. Using Rayyan AI as an automatic tool, 211 articles were identified which were duplicates, 2566 articles were deemed ineligible because did not match the desired study design outlined by the authors, and 685 articles were excluded based on language and year of publication criteria. Furthermore, 2175 articles were ready for initial viewing based on their titles and abstracts. These findings revealed that 1232 articles had incorrect intervention or outcome information, along with 744 articles that had inaccuracies in the population studied. Of the 200 articles that were initially inaccessible, none were found later. The final selection and inclusion of articles is determined by a third examiner (supervisor). A total of 50 studies were included in this review, while other studies were inaccessible due to limited access (subscription-based), incomplete data presentation, and too high risk of bias. Further details are available in the PRISMA flowchart.

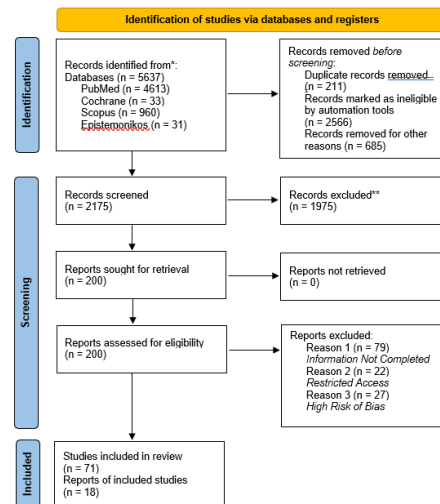


Figure 1. PRISMA 2020 Flowchart

3.1 Risk of Bias Assessment

The results of Review Manager 5.3 for risk of bias assessment are shown in Figure 2 and Figure 3. It can be seen in the figure that all included studies show a predominantly low risk of bias. Although articles were identified with a maximum of one domain categorized as having a high risk of bias in the risk of bias assessment, it should be noted that these articles involved a relatively limited study population, thereby minimizing their potential impact on the overall analysis results.

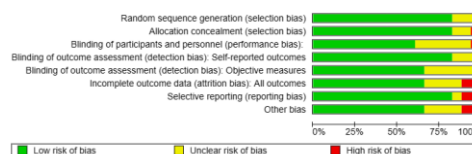


Figure 2. Accumulated Risk of Bias Graph of Inclusive Studies

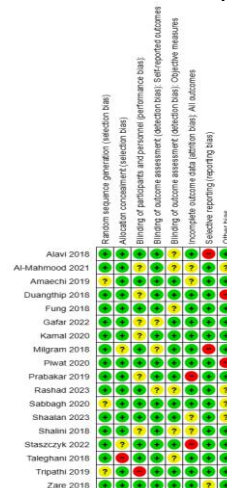


Figure 3. Summary of Risk of Bias Assessment in 18 Included Articles

3.2 Study Analysis

Preliminary results of selection in the meta-analysis revealed that the studies included in each intervention group showed substantial heterogeneity in their results. Therefore, the analysis model for this study was adjusted to use a random effects approach.

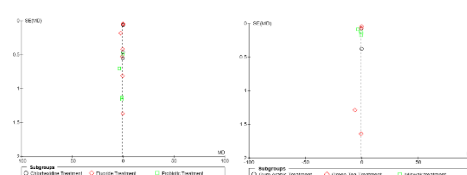


Figure 4. Funnel Diagram of Potential Bias Results

3.3 Therapeutic Management With Chemicals

The Forest Plot results in this analysis reveal the impact of various chemical therapies, such as chlorhexidine, fluoride, and probiotics, on the incidence of dental caries.

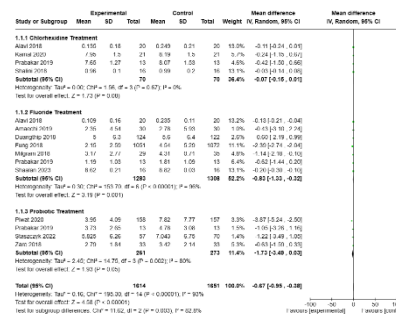


Figure 5. Forrest plot results of the effect of various chemical therapies on the incidence of dental caries

In this study, the effectiveness of chlorhexidine in reducing the incidence of dental caries was evaluated through four RCTs, with the results showing low heterogeneity values ($\text{Tau}^2 = 0$), as well as no significant heterogeneity between these studies ($\text{Chi}^2 = 1.56$, $df = 3$, $P = 0.67$, $I^2 = 0\%$). These results indicate that chlorhexidine has a positive influence in reducing the incidence of dental caries, although not significantly ($P = 0.08$).

In contrast, the evaluation of fluoride effectiveness involved seven RCT studies, with results reflecting high heterogeneity ($\text{Tau}^2 = 0.30$) and significant variation between study results ($\text{Chi}^2 = 153.70$, $df = 6$, $P < 0.00001$, $I^2 = 96\%$). However, the effect of fluoride on reducing dental caries remained statistically significant ($P < 0.00001$). These results indicate that while fluoride has a strong positive impact, differences between studies need to be considered.

Research on probiotics involved four RCT studies, with results showing considerable heterogeneity ($\text{Tau}^2 = 2.45$) and significant variation ($\text{Chi}^2 = 14.75$, $df = 3$, $P = 0.002$, $I^2 = 80\%$). These results illustrate that probiotics may have a positive influence in reducing dental caries ($P = 0.05$), although not statistically significant.

Overall, the meta-analysis showed that interventions with various chemicals to prevent dental caries had an overall statistically significant positive effect ($P < 0.00001$). However, significant heterogeneity was found between these studies ($I^2 = 93\%$), which suggests variations in the effectiveness of this therapy. These findings provide a strong basis for recommendations for the use of chemicals as part of dental caries prevention efforts, although it is important to consider variations between studies in clinical decision making. These results also inspire further research to better understand the impact and optimize the use of this therapy in clinical practice.

In a meta-analysis conducted to evaluate the effect of various chemical therapies (chlorhexidine, fluoride, and probiotics) on the population of *Streptococcus mutans*, the bacteria that causes dental caries, several important findings were found.

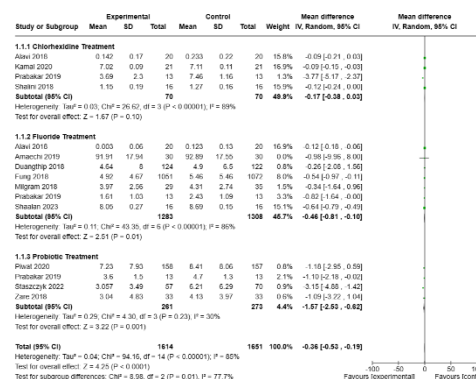


Figure 6. Forest Plot Results of the Effect of Various Chemical Therapies on Streptococcus mutans Populations

Evaluation of the effectiveness of chlorhexidine against *Streptococcus mutans* populations involved four RCTs, and the results showed a low degree of heterogeneity ($\text{Tau}^2 = 0.03$) and no significant heterogeneity between the studies ($\text{Chi}^2 = 26.62$, $df = 3$, $P < 0.00001$, $I^2 = 89\%$). The test for overall effect results show a Z value of 1.67 with $P = 0.10$, which, although not reaching a high level of statistical significance, shows a tendency that chlorhexidine may have a positive influence in reducing the population of *Streptococcus mutans*.

In contrast, evaluation of the effectiveness of fluoride against *Streptococcus mutans* populations showed a moderate level of heterogeneity ($\text{Tau}^2 = 0.11$) with a significant level of heterogeneity ($\text{Chi}^2 = 43.35$, $df = 6$, $P < 0.00001$).

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0.00001, $I^2 = 86\%$). The overall effect test results showed a Z value of 2.51 with $P = 0.01$, reaching a level of statistical significance indicating that fluoride has a positive and significant effect in reducing the population of *Streptococcus mutans*. Although there is noteworthy variation between studies, this effect remains statistically significant.

Meanwhile, evaluation of the effectiveness of probiotics showed a low level of heterogeneity ($\text{Tau}^2 = 0.29$) with no significant heterogeneity ($\text{Chi}^2 = 4.30$, $\text{df} = 3$, $P = 0.23$, $I^2 = 30\%$). The overall effect test results showed a Z value of 3.22 with $P = 0.001$, reaching a level of statistical significance indicating that probiotics have a significant effect in reducing the population of *Streptococcus mutans*.

Overall, the meta-analysis illustrates that the use of chemicals, especially fluoride and probiotics, can be effective in reducing *Streptococcus mutans* populations in a statistically significant manner ($P < 0.00001$). However, variations between studies should be noted, and the selection of the most appropriate therapy may need to be tailored to the specific clinical context. This analysis also identified significant differences between the three chemical therapies evaluated ($P = 0.01$) and a relevant degree of heterogeneity (77.7%). These results provide an important basis for further development in research and clinical application of chemical therapy in the prevention of dental caries.

3.4 Therapeutic Management With Natural Ingredients

In a meta-analysis conducted to evaluate the effect of various natural ingredient therapies (gum arabic, green tea, and miswak) on caries incidence rates, several important findings were found. This Forest Plot provides a comprehensive view of the effectiveness of these three types of natural ingredients in reducing the incidence of caries, although the level of significance is not always the same.

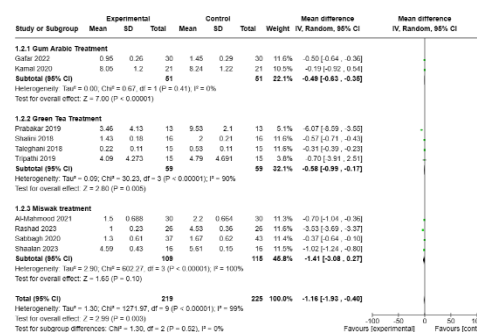


Figure 7. Forest Plot Results of the Effect of Various Natural Ingredients Therapy on the Incidence of Dental Carie

First, when we consider the use of gum arabic as a caries prevention therapy, it is found that the effect is highly significant ($P < 0.00001$). This analysis included two studies with very low levels of heterogeneity ($\text{Tau}^2 = 0$, $\text{Chi}^2 = 0.67$, $\text{df} = 1$, $P = 0.41$, $I^2 = 0\%$). These results suggest that gum arabic may have potential in reducing the incidence of dental caries.

Second, in the case of green tea, the results showed a statistically significant effect in reducing the caries incidence rate ($P = 0.005$). This evaluation consisted of four studies with a fairly high degree of heterogeneity ($\text{Tau}^2 = 0.09$, $\text{Chi}^2 = 30.23$, $\text{df} = 3$, $P < 0.00001$, $I^2 = 90\%$). Despite the high degree of heterogeneity, these results indicate that green tea has positive potential in the prevention of dental caries.

However, when we evaluated the effectiveness of miswak, the results showed statistical insignificance ($P = 0.10$) in reducing the incidence rate of caries. This analysis included four studies with a very high degree of heterogeneity ($\text{Tau}^2 = 2.90$, $\text{Chi}^2 = 602.27$, $\text{df} = 3$, $P < 0.00001$, $I^2 = 100\%$). This shows that although miswak is a natural ingredient that is often used to clean teeth, the existing scientific evidence is not strong enough to support its effectiveness in reducing dental caries.

Overall, when these results are combined, there are indications that natural substances, particularly gum arabic and green tea, have potential in reducing the incidence of dental caries. These results were supported by the overall analysis showing statistical significance ($P = 0.003$). Despite the high degree of heterogeneity in some analyses, the overall analysis showed a low degree of heterogeneity ($I^2 = 0\%$), indicating that the positive effect on caries incidence rate is generally accepted.

A meta-analysis conducted to evaluate the effect of various natural ingredient therapies (gum arabic, green tea, and miswak) on the population of *Streptococcus mutans*, a bacterium that causes dental caries, revealed important findings in the context of dental caries prevention. These Forest Plot results provide a comprehensive picture of the effectiveness of these three natural ingredients, although some of them did not reach high statistical significance.

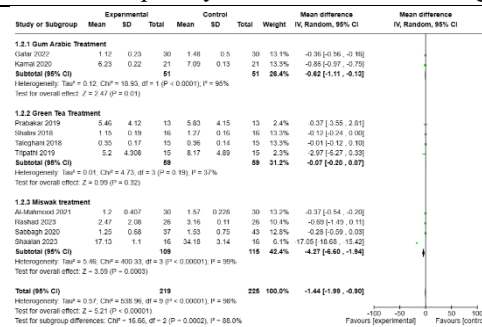


Figure 8. Forest Plot Results of the Effect of Various Natural Ingredients Therapies on Streptococcus mutans Populations

The use of gum arabic showed a statistically significant effect in reducing the population of Streptococcus mutans ($P < 0.00001$). This analysis involved two studies with a very high level of heterogeneity ($\text{Tau}^2 = 0.12$), although the results of the test for overall effect showed a Z value of 2.47 with $P = 0.01$. This indicates that gum arabic may have the potential to reduce the population of bacteria that cause dental caries.

In evaluating the effectiveness of green tea against Streptococcus mutans populations, the results showed that the effect was not statistically significant ($P = 0.32$). This analysis involved four studies with a low level of heterogeneity ($\text{Tau}^2 = 0.01$), and the overall effect test results showed a Z value of 0.99. This suggests that, although green tea may have potential in caries prevention, existing evidence has not yet reached high statistical significance.

However, when we evaluated the effectiveness of miswak, the results showed a statistically significant effect in reducing the population of Streptococcus mutans ($P = 0.0003$). This analysis involved four studies with a very high degree of heterogeneity ($\text{Tau}^2 = 5.46$), and the overall effect test results showed a Z value of 3.59. This indicates that miswak can be an effective natural ingredient in reducing the population of bacteria that cause dental caries.

Overall, when these results are combined, there are indications that the use of natural ingredients, especially gum arabic and miswak, has the potential to significantly reduce Streptococcus mutans populations. These results were supported by the overall analysis showing a high level of statistical significance ($P < 0.00001$). Although there was heterogeneity between studies, the overall analysis showed a relatively low level of heterogeneity ($I^2 = 88\%$), indicating a generally acceptable positive effect. Further research is needed to better understand the potential and mechanism of action of this natural substance in the prevention of dental caries and to determine the optimal dose and frequency for its use in clinical practice.

3.5 Comparison of the Effectiveness of Chemicals and Natural Ingredients in Caries Management

Effectiveness of Chemicals

In the chemical therapy group, particularly chlorhexidine and fluoride, the results showed several important findings. Chlorhexidine, although not reaching a high level of statistical significance in reducing the incidence of dental caries, showed a positive trend. This indicates that chlorhexidine may have potential in reducing dental caries, although further research is needed to understand its effects in more depth.

Meanwhile, fluoride shows clear and significant effects in reducing dental caries. Although there are variations between studies, the existing scientific evidence is strong enough to support the use of fluoride as an effective preventive approach in reducing the risk of dental caries.

Effectiveness of Natural Ingredients

In the natural product therapy group, we evaluated gum arabic, green tea, and miswak. The results showed that gum arabic had a significant effect in reducing the S. mutans population. This is an interesting finding because gum arabic is a natural substance that is perhaps less well known in caries prevention. These results provide encouragement for further research regarding the potential of gum arabic in reducing the risk of dental caries.

Green tea, although it has a positive effect in reducing the S. mutans population, has not reached a high level of statistical significance in reducing dental caries. This indicates that while green tea may provide benefits in maintaining dental health, more research is needed to confirm its clinical effectiveness.

On the other hand, miswak showed significant effects in reducing S. mutans populations and dental caries. This is an interesting finding because miswak is a natural ingredient that has long been used in dental care in several cultures. These results highlight the potential of miswak as an effective natural ingredient in the prevention of dental caries.

4. Conclusion

This meta-analysis indicates that chemical interventions, particularly fluoride, have the strongest evidence for reducing dental caries risk, while probiotics may significantly decrease Streptococcus mutans populations. Natural remedies also demonstrate useful potential: gum arabic and miswak can reduce cariogenic bacteria, and green tea may help prevent caries. Nevertheless,

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each approach has specific advantages, limitations, and varying levels of evidence. Chemical treatments are easier to incorporate into routine care, whereas natural ingredients require further investigation regarding mechanisms, dosage, and application frequency. Combining proven chemical interventions with promising natural remedies may support holistic caries management, although clinical trials remain necessary to guide practice.

5. Suggestion

In the context of holistic dental care, it may be wise to consider a combination of both approaches, using chemicals that have been proven to be effective and natural ingredients that show positive potential. This can provide a more comprehensive solution in preventing dental caries. In this context, further research and larger clinical trials are urgently needed to validate these findings and guide optimal clinical practice in the prevention of dental caries.

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