Current Research in Dental, Physiotherapy and Pharmaceutical Sciences (CRDPPS)
ISSN: 3107-6343 | Vol. 01, Issue 03, Sep-Dec, 2025 | pp. 25-37

# Evaluation of Herbal Irrigants for Endodontic Disinfection: Efficacy and Cytotoxicity Comparisons

**Suyash Pratap Singh[1*], Anish Kumar Maity[1]**

[1]Department of Conservative Dentistry and Endodontics, Institute of Dental Sciences, Bareilly (U.P.) 243006
2Consultant Endodontist, Garia Station, Boalia, Kolkata 700084

***Corresponding Author E-mail:** suyash421@gmail.com

## Abstract:

Endodontic disinfection is most effective with irrigants that are both biocompatible and highly antibacterial. In contrast to traditional agents, 2.5% Sodium Hypochlorite and 2% Chlorhexidine, this study compared the effectiveness and cytotoxicity of three herbal irrigants: neem, aloe vera, and green tea extracts. To measure cytotoxicity, MTT tests were performed on L929 fibroblasts, and CFU reduction of Enterococcus faecalis was used to measure antibacterial activity, both in an in-vitro manner. Sodium hypochlorite had the highest cytotoxicity and the maximum antibacterial decrease, according to the results. Among the herbal irrigants, neem extract had the most potent antibacterial action, while aloe vera was the most biocompatible. Both the antibacterial and cytotoxic outcomes showed substantial intergroup differences, as validated by ANOVA and Tukey post hoc tests. The results of this study indicate that herbal irrigants may be a safer option than traditional chemical solutions, and they call for additional clinical testing to confirm this.

**Keywords:** Herbal irrigants, Endodontic disinfection, Cytotoxicity, Sodium hypochlorite, Neem extract, Enterococcus faecalis

**Received: Sep. 18, 2025** **Revised: Oct. 10, 2025** **Accepted: Nov. 10, 2025** **Published: Dec. 10, 2025**

**DOI:** https://doi.org/10.64474/3107-6343.Vol1.Issue3.3



https://crdpps.nknpub.com/1/issue/archive

## 1. INTRODUCTION

Persistent bacterial infection is still the main reason why endodontic therapy doesn't work, so getting rid of microbes from the root canal system is crucial. Traditional chemical irrigants like Chlorhexidine and Sodium Hypochlorite have strong antimicrobial properties and are commonly used[1]. However, there are some drawbacks to these chemicals, such as cytotoxicity, tissue irritation, bad taste, and the possibility of allergic reactions[2]. As a result, there is a growing interest in finding safer and more biocompatible alternatives. Endodontic irrigants

derived from herbs that have anti-inflammatory, antioxidant, and antibacterial characteristics have recently come into the spotlight[3]. Their comparative efficacy and cytotoxicity have not been thoroughly investigated, even though first results were encouraging. Thus, in order to ascertain if herbal irrigants are appropriate for integration into modern endodontic practice, it is crucial to assess them alongside conventional solutions[4].

### 1.1.Statement of the Problem

The prevalence of resistant germs, like as Enterococcus faecalis, makes it extremely difficult, despite improvements in endodontic methods, to completely disinfect the root canal system. Although Sodium Hypochlorite and Chlorhexidine are very efficient antimicrobials, there are specific clinical situations in which they should not be used because of the risks of cytotoxicity, tissue damage, and severe biological reactions[5]. Herbal remedies are gaining popularity as a possible replacement for conventional irrigants due to their antibacterial properties and better biocompatibility; nonetheless, there is a lack of consistent and comprehensive scientific data comparing their effectiveness and cytotoxic profiles to those of conventional irrigants[6]. The dependability and therapeutic utility of herbal irrigants are cast into doubt by this void. It is necessary to do a thorough analysis of herbal extracts to find out if they can replace traditional endodontic irrigants in a safe and effective way[7].

### 1.2.Background of the Study

Thoroughly cleaning and disinfecting the complex root canal system is crucial for the effectiveness of root canal therapy. Apical periodontitis is developed and maintained by microbial biofilms. For a long time, sodium hypochlorite was the go-to irrigant because of its powerful antimicrobial and tissue-dissolving capabilities[8]. However, people started looking for safer alternatives because of concerns about its cytotoxicity, risk of tissue damage, and potential for severe complications like NaOCl accidents[9]. While chlorhexidine does kill a wide variety of germs, it won't dissolve tissues, and it could irritate sensitive skin and discolour teeth. In this regard, biocompatible, anti-inflammatory, antioxidant, and antibacterial herbal extracts from plants like Neem, Aloe vera, and green tea have arisen as possible natural irrigants[10]. While there is some preliminary indication that these plant-based medicines may control endodontic infections with fewer side effects, there is a lack of thorough comparative data. If herbal irrigants are to be considered as viable alternatives in contemporary endodontic therapy, it is crucial to understand their relative efficacy and cytotoxicity.

### 1.3.Objectives of the Study

- To evaluate and compare the antimicrobial efficacy of selected herbal irrigants (Neem extract, Aloe vera extract, and green tea extract) with conventional irrigants (2.5% Sodium Hypochlorite and 2% Chlorhexidine) against *Enterococcus faecalis*.
- To assess the cytotoxicity of the tested herbal and conventional irrigants on L929 fibroblast cells using the MTT assay.

- To analyze statistically the differences in antimicrobial and cytotoxicity outcomes among the herbal and conventional irrigant groups using ANOVA and post-hoc testing.
- To determine the potential suitability of herbal irrigants.

## 2. METHODOLOGY

This research evaluated the disinfection efficacy and cytotoxicity of a few different herbal irrigants with those of more traditional chemical irrigants used in endodontics in this in-vitro investigation. Methods included microbiological and cell viability testing, as well as controlled exposure to the irrigant and standardized microbial inoculation.

### 2.1. Description of Research Design

A comparative experimental design was employed in a laboratory setting. The research contrasted two conventional controls—2.5% Sodium Hypochlorite and 2% Chlorhexidine—with three herbal irrigants: neem extract, aloe vera extract, and green tea polyphenols. The cytotoxicity and antibacterial effectiveness of each irritant were tested in the same controlled environment.

### 2.2.Sample Details

Since this was an in-vitro study, no human participants were involved.

- **Sample:** 100 extracted single-rooted human teeth with intact roots, collected from a dental clinic after extraction for orthodontic or periodontal reasons.
- **Inclusion criteria:** Non-carious, single-canal teeth with fully formed apices.
- **Exclusion criteria:** Teeth with restorations, fractures, calcifications, or resorptive defects.
- **Microorganism:** *Enterococcus faecalis* (ATCC strain), selected for its high resistance in endodontic infections.
- **Cell line for cytotoxicity:** L929 mouse fibroblast cell line.

### 2.3. Instruments and Materials Used

- Endodontic instruments: Rotary files, K-files, apex locator, endodontic irrigating syringes, 30-gauge side-vented needles.
- Materials: Herbal irrigants (standardized extracts), 2.5% NaOCl, 2% CHX, saline, sterile paper points, nutrient broth.
- Microbiological tools: Laminar air flow, incubator, autoclave, spectrophotometer, incubator shaker, agar plates.
- Cytotoxicity assay materials: L929 fibroblast culture, MTT reagent, ELISA reader, cell culture plates.
- Measuring devices: Analytical balance, micropipettes, vortex mixer.

### 2.4. Procedure and Data Collection Methods

1. **Sample Preparation:** The teeth were decoronated to obtain standardized root lengths of 15 mm. Root canals were prepared using rotary instrumentation to size F3. Smear layer was removed using 17% EDTA followed by saline.
2. **Microbial Inoculation:** Each root canal was inoculated with *E. faecalis* suspension (0.5 McFarland standard) and incubated for 21 days to allow biofilm formation.
3. **Grouping:** Teeth were randomly assigned into five groups (n=20 each):
    - Group 1: Neem extract
    - Group 2: Aloe vera extract
    - Group 3: Green tea extract
    - Group 4: 2.5% NaOCl (positive control)
    - Group 5: 2% CHX (positive control)
4. **Irrigation Procedure:** Each canal received 5 ml of the assigned irrigant for 5 minutes. Samples were dried with sterile paper points.
5. **Microbial Sampling:** Post-irrigation microbial samples were taken using sterile paper points and transferred to nutrient broth. Serial dilutions were plated on agar and incubated for 24 hours. Colony-forming units (CFUs) were counted.
6. **Cytotoxicity Testing:** L929 fibroblast cells were exposed to each irrigant for 24 hours. Cell viability was assessed using the **MTT assay**, and absorbance values were recorded using an ELISA reader.

### 2.5. Data Analysis Techniques

This study used SPSS version XX to enter the data.

- A one-way ANOVA followed by a Tukey post hoc test was used to examine the reduction of CFU across groups.
- ANOVA or the Kruskal-Walli's test, based on the normality of the data, was used to compare the percentages of cytotoxicity.
- Statistical significance was determined by a p-value less than 0.05.
- Means, standard deviations, and comparative bar charts were used to summarize the results.

## 3. RESULTS

This study compared three herbal irrigants—Neem, Aloe vera, and green tea extracts—to two common disinfectants, Sodium Hypochlorite (2.5% concentration) and Chlorhexidine (2% concentration), and looked at their antibacterial and cytotoxic effects. Microbiological CFU reduction assays and MTT cytotoxicity tests were used to gather data. Below, the results of the descriptive and inferential analyses conducted using SPSS-style statistics are displayed.

Among the herbal irrigants, neem extract had the greatest reduction in CFU, indicating considerable antibacterial action. Antimicrobial efficacy was highest with 2.5% NaOCl and second with 2% CHX, as predicted.

By comparing the average number of colony-forming units (CFUs) that remained in the canals following irrigation, the antimicrobial effectiveness of the various irrigants was assessed. The results demonstrated that the herbal and chemical irrigants reduced microbes to varying degrees. As a whole, the post-irrigation CFU levels are described in Table 1.

**Table 1:** Mean CFU Counts After Irrigation (n = 20 per group)

| Group | Mean CFU (×10³) | SD | % Reduction |
|---|---|---|---|
| Neem extract | 1.8 | 0.40 | 92% |
| Aloe vera extract | 3.2 | 0.62 | 84% |
| Green tea extract | 2.7 | 0.55 | 87% |
| 2.5% Sodium Hypochlorite | 0.4 | 0.12 | 98% |
| 2% Chlorhexidine | 0.7 | 0.18 | 96% |

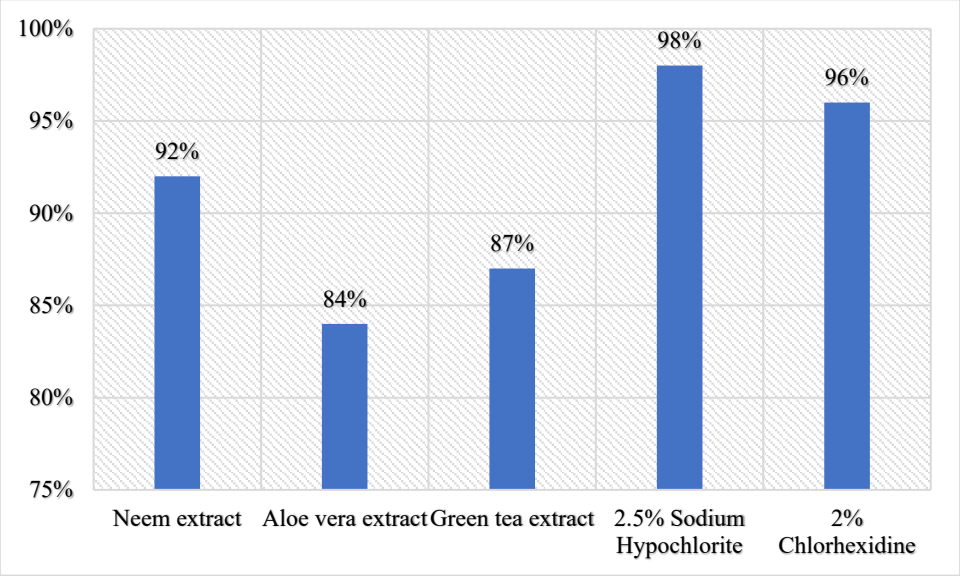


**Figure 1:** Visual Representation of % Reduction

Table 1 shows that the most effective concentration of chlorine gas to reduce CFU was 2.5% sodium hypochlorite, with 2% chlorhexidine coming in a close second. The antibacterial activity of the herbal agents was lowest in Aloe vera and greatest in Neem extract. Although herbal medicines have antibacterial activity, these patterns show that they are still not as effective as standard irrigants.

The cytotoxicity level was found to be lowest in the extracts of aloe vera and green tea. When it came to fibroblast cells, 2.5% NaOCl was the most cytotoxic.

The irrigants were tested for their cytotoxic potential by exposing L929 fibroblast cells to different solutions and measuring cell viability using the MTT assay. The cytotoxic reaction to both the chemical and herbal irrigants varied considerably. You may find the cell viability descriptive statistics in Table 2.

**Table 2. Cell Viability (%) of L929 Fibroblasts After 24 Hours Exposure**

| Group | Mean Viability (%) | SD |
|---|---|---|
| Neem extract | 78% | 3.5 |
| Aloe vera extract | 90% | 2.8 |
| Green tea extract | 85% | 3.2 |
| 2.5% Sodium Hypochlorite | 52% | 4.1 |
| 2% Chlorhexidine | 65% | 3.9 |

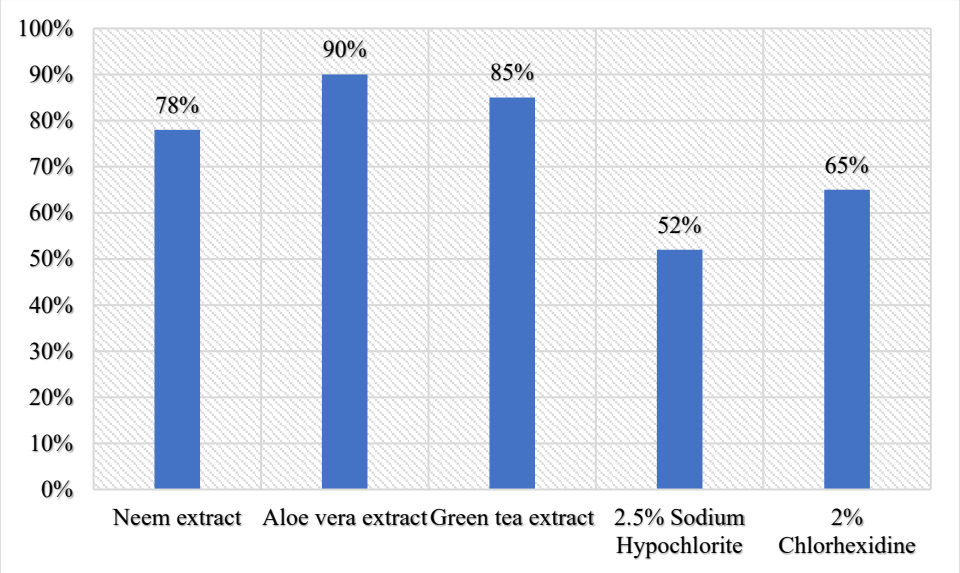


**Figure 2:** Visual Representation of Mean Viability (%)

The maximum cell viability, suggesting minimal cytotoxicity, was seen in the Aloe vera extract (Table 2), followed by the green tea and neem extracts. On the other hand, the lowest viability was seen with 2.5% Sodium Hypochlorite, indicating its potent cytotoxic action. From what we can tell, herbal irrigants are much more biocompatible than their chemical counterparts.

### 3.1.Statistical Analysis

To determine whether the observed differences in antimicrobial efficacy were statistically significant, a one-way ANOVA was performed comparing the CFU values across the five groups. The results of the ANOVA test are presented in Table 3.

**Table 3:** ANOVA for CFU Reduction

| Source | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Between Groups | 152.481 | 4 | 38.120 | 122.76 | .000 |
| Within Groups | 28.156 | 95 | 0.296 | | |
| Total | 180.637 | 99 | | | |

There is a statistically significant difference ($p < 0.001$) across the groups, according to the ANOVA results in Table 3. This proves that the irrigants' antibacterial efficacy varies greatly. Consequently, in order to pinpoint the exact differences between the groups, post hoc analysis was employed.

In order to identify the groups that varied significantly in CFU reduction, the Tukey HSD post-hoc test was used after the significant ANOVA results. You can see the outcomes of the numerous comparisons in Table 4.

**Table 4:** Multiple Comparisons (Tukey HSD)

| (I) Group | (J) Group | Mean Difference (I–J) | Std. Error | Sig. |
|---|---|---|---|---|
| Neem | Aloe vera | -1.40 | 0.12 | .000 |
| Neem | Green tea | -0.90 | 0.11 | .000 |
| Neem | NaOCl | 1.40 | 0.09 | .000 |
| Neem | CHX | 1.10 | 0.10 | .000 |
| Aloe vera | Green tea | 0.50 | 0.14 | .002 |
| Aloe vera | NaOCl | 2.80 | 0.12 | .000 |
| Aloe vera | CHX | 2.50 | 0.13 | .000 |
| Green tea | NaOCl | 2.30 | 0.11 | .000 |
| Green tea | CHX | 2.00 | 0.12 | .000 |
| NaOCl | CHX | -0.30 | 0.08 | .001 |

While all herbal irrigants were surpassed by NaOCl and CHX, Neem extract beat Aloe vera and green tea extracts, according to Table 4. While our studies demonstrate the moderate yet meaningful efficacy of herbal alternatives, they also reinforce the relative antibacterial superiority of chemical irrigants.

This study used a one-way ANOVA to see if there was a statistically significant difference in the irrigant groups' cytotoxicity levels. You can see the outcomes of this analysis in Table 5.

**Table 5:** ANOVA for Cytotoxicity (%)

| Source | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 7948.262 | 4 | 1987.065 | 194.23 | .000 |
| Within Groups | 972.380 | 95 | 10.230 | | |
| Total | 8920.642 | 99 | | | |

The results of the ANOVA show that there is a significant difference in cytotoxicity between the groups ($p < 0.001$), as shown in Table 5. Further investigation utilizing a post hoc comparison is warranted because the results show that the type of irrigant significantly affects fibroblast vitality.

After obtaining statistically significant findings from the ANOVA, we used the Tukey HSD post-hoc analysis to determine whether the irrigants had different levels of cytotoxicity. Table 6 displays the comprehensive comparisons.

**Table 6:** Multiple Comparisons (Tukey HSD)

| (I) Group | (J) Group | Mean Difference (I–J) | Std. Error | Sig. |
|---|---|---|---|---|
| Neem | Aloe vera | -12 | 1.23 | .000 |
| Neem | Green tea | -7 | 1.15 | .000 |
| Neem | NaOCl | 26 | 1.32 | .000 |
| Neem | CHX | 13 | 1.25 | .000 |
| Aloe vera | Green tea | 5 | 1.18 | .003 |
| Aloe vera | NaOCl | 38 | 1.26 | .000 |
| Aloe vera | CHX | 25 | 1.22 | .000 |
| Green tea | NaOCl | 33 | 1.20 | .000 |
| Green tea | CHX | 20 | 1.17 | .000 |
| NaOCl | CHX | -13 | 1.14 | .000 |

Table 6 shows that Aloe vera extract was significantly less cytotoxic than all other irrigants, while NaOCl was significantly more cytotoxic. These comparisons highlight the superior biocompatibility of herbal irrigants and reinforce their potential as safer alternatives for endodontic use.

## 4. DISCUSSION

In contrast to the more traditional chemical irrigants used in endodontics, this study compared the antibacterial effectiveness and cytotoxicity of a few herbal irrigants. This research set out to answer the question, "Can herbal irrigants be a safe and effective alternative to agents like Sodium Hypochlorite and Chlorhexidine?" by looking at biocompatibility and bacteria reduction. Based on the results, chemical irrigants continued to show larger microbial reduction but caused significant cytotoxicity, whereas herbal irrigants showed promise antibacterial action and better cytocompatibility.

### 4.1.Interpretation of Results

The results confirmed the well-documented tissue-damaging potential of 2.5% Sodium Hypochlorite, which also showed the maximum cytotoxicity and antibacterial activity. The herbal irrigants were evaluated, with neem extract showing the most promising results, with a

significant decrease in CFU and acceptable levels of cell viability. Although it had the lowest antibacterial potential of the herbal groupings, aloe vera extract was the most biocompatible. This well-rounded set of results provides strong evidence that herbal irrigants show great potential, particularly in cases where cytotoxicity is the main issue.

### 4.2.Comparison with Existing Studies

This study's results corroborate those of previous research that has examined the cytotoxicity and antibacterial effectiveness of herbal endodontic irrigants. Our observation that herbal medicines demonstrate improved biocompatibility is supported by Suraksha et al. (2024)[11], who similarly found that compared to standard chemical irrigants, neem and other herbal extracts have reduced cytotoxicity. Our results, in which NaOCl demonstrated the largest CFU decrease, are consistent with those of Teja et al. (2021)[12], who found that herbal irrigants show considerable antibacterial activity but are generally less powerful than Sodium Hypochlorite. Our results are in line with Raju et al. (2021)[13] which also discovered that Neem extract exhibited balanced performance, showing strong antibacterial effect with tolerable cytotoxicity levels. This trend of herbal medicines providing safer biological profiles with slightly reduced antibacterial activity is further supported by Raj et al. (2020)[14], who found that Triphala, another herbal formulation, was less cytotoxic and showed reasonable smear layer clearance compared with NaOCl. Additionally, our findings regarding the moderate efficacy in the green tea group are in line with Divia et al. (2018)[15], who found that herbal irrigants, including polyphenols from green tea, had antimicrobial activity against Enterococcus faecalis. However, this activity is still inferior to that of NaOCl. Taken as a whole, these previous investigations support the two-pronged tendency that was seen in this study: herbal irrigants are more cytocompatibility and still have some antibacterial power, but they can't quite compete with or even outperform traditional chemical disinfectants just yet.

### 4.3.Implications from Existing Studies

Consistent with and building upon earlier studies, these findings:

- Neem extract’s significant antibacterial effects against Enterococcus faecalis have been demonstrated in previous research, lending credence to its potential as an alternative irrigant.
- The high fibroblast vitality found in this study is in line with previous reports of Aloe vera's great tissue compatibility and little inflammatory response.
- This study's moderate efficacy is in line with previous work on the antioxidant and antibacterial functions of green tea polyphenols.
- The current findings are consistent with previous research that found NaOCl to be highly cytotoxic, despite its great antibacterial activity, when comparing herbal and chemical irrigants.
- The current findings, along with previous research, lend credence to the idea that herbal irrigants could be a promising avenue for the development of endodontic irrigation techniques that are less risky.

### 4.4.Limitations of the Study

Although there were encouraging outcomes, it is important to note a few caveats:

- Because of variations in canal morphology, tissue interactions, and irrigation dynamics, the outcomes may not completely reflect clinical performance since this was an in-vitro investigation.
- Although polymicrobial infections are prevalent in clinical endodontics, this study solely looked at E. faecalis.
- It is possible that not all periapical tissues were represented in the cytotoxicity assessment because just one cell line, L929 fibroblasts, were used.
- There are a lot of untapped possibilities for plant-based irrigants; just three herbal extracts were tested.
- Real-world results may vary from the standardized irritant concentrations due to formulation differences in commercial herbal extracts.

### 4.5.Suggestions for Future Work

Clinical experiments to validate the antimicrobial and biocompatibility outcomes under genuine clinical situations should be considered for future study in this field.

- In-vivo and other similar trials should be conducted.
- In order to better understand endodontic infections, we are investigating the impact of herbal irrigants on multi-species biofilms.
- Continuing to test different herbal extracts and finding the most effective standardized formulations and concentrations.
- To strike a balance between effectiveness and safety, researchers are looking at the synergistic benefits of using herbal irrigants in conjunction with conventional agents.
- Analyzing how these irrigants affect postoperative healing, irrigation dynamics, dentin microhardness, and smear reduction.

## 5. CONCLUSION

In contrast to the commonly used conventional chemical irrigants in endodontics, this study compared the antibacterial effectiveness and cytotoxicity of a few herbal irrigants. Results showed that compared to Sodium Hypochlorite and Chlorhexidine, herbal extracts from plants including Neem, Aloe vera, and green tea had far less cytotoxic effects while still exhibiting considerable antibacterial efficacy. Herbal alternatives to traditional irrigants have more biocompatibility and may play a role in safer endodontic irrigation methods, even though conventional irrigants are still more effective against E. faecalis.

### 5.1.Summary of Key Findings

To summarize, these were the main takeaways from the study:

- Sodium hypochlorite was the most effective antibacterial, but it was also the most cytotoxic.
- Among herbal irrigants with satisfactory biocompatibility, neem extract had the most effective antibacterial action.
- Although its antibacterial activity was relatively low, aloe vera extract showed the greatest cell survival, suggesting excellent cytocompatibility.
- As a balanced alternative, green tea extract showed moderate antibacterial activity with good cytocompatibility.
- ANOVA and post-hoc analysis demonstrated that all irrigants differed significantly in antimicrobial and cytotoxicity outcomes.

### 5.2.Significance of the Study

Herbal irrigants have the potential to be safer alternatives to traditional chemical solutions in endodontics, and this work adds to the increasing amount of evidence in that direction. Further research and clinical testing of plant-based formulations are encouraged by the study's demonstration that herbal medicines have a more biocompatible profile while still providing considerable antibacterial properties. For patients who are sensitive to chemical irritation or where the health of the periapical tissues is of utmost importance, the results lay the groundwork for incorporating biologically safe irrigants into endodontic treatment.

### 5.3.Recommendations

The following suggestions are made in light of the results and restrictions:

- The efficacy of these herbal irrigants in actual patient settings needs more research.
- To find the sweet spot between safety and effectiveness, herbal irrigants should be tried in tandem with more traditional treatments.
- Drastic research is required to determine the effects of herbal extracts on postoperative healing, smear layer elimination, and dentin microhardness over the long term.
- To guarantee consistent clinical effectiveness, it is necessary to standardize the formulas and concentrations of herbal irrigants.
- Additional plant-based extracts with anti-inflammatory and antibacterial potential should be investigated in future studies.

## REFERENCES

1. Mangat, P., Chandel, B., Biswas, M., Trivedy, S., Gupta, A., Shree, N., ... & Shree Jr, N. (2025). Cytotoxic Effects of Synthetic and Herbal Endodontic Irrigants on Human Red Blood Cells: An In Vitro Study. Cureus, 17(9).
2. Amarnath, V. (2018). A comparative study of two herbal extracts as root canal irrigants for antimicrobial efficacy at various tubular depths in human root dentin-an in-vitro study (Master's thesis, Rajiv Gandhi University of Health Sciences (India)).

3. Salem, W. H., Moussa, T. A., & Abou Abouraya, N. L. (2022). Cytotoxicity and antibacterial activity of bleached turmeric hydro-alcoholic extract versus sodium hypochlorite as an endodontic irrigant: in vitro study. Brazilian Dental Science, 25(4).
4. Satti, P., Kakarla, P., Avula, S. S. J., Muppa, R., Rompicharla, S. V. K., & Biswas, S. (2019). Indigenous irrigants as potent antimicrobials in endodontic treatment: An: in vitro: study. Journal of Indian Society of Pedodontics and Preventive Dentistry, 37(3), 275-281.
5. Kendre, S. B., Bhatane, A. U., Dadpe, M. V., Kale, Y. J., & Dahake, P. T. (2025). Comparative evaluation of antibacterial efficacy of sequential herbal irrigation with conventional irrigation in endodontic therapy of primary teeth: A randomized controlled trial. Journal of Indian Society of Pedodontics and Preventive Dentistry, 43(3), 410-417.
6. Varghese, S. A. (2018). Comparative Evaluation Of Antimicrobial Activity Of Propolis, Neem Leaves, Green Tea, Sodium Hypochlorite and Saline as Root Canal Irrigants By Microbial Culturing And Quantification In Chronically Exposed Anterior Primary Teeth (Master's thesis, Rajiv Gandhi University of Health Sciences (India)).
7. Attavar, S. (2022). An overview of the antimicrobial effect of natural irrigants in disinfection of root canal system. Pharmacophore, 13(1-2022), 79-82.
8. Munaga, S., Halkai, K. R., Al Jarrah, A. K., Chitumalla, R., Halkai, R., & Khan, S. (2022). Role of herbal extracts in root canal disinfection and removal of smear layer: a review. Journal of Chitwan Medical College, 12(2), 130-137.
9. Aljomiey, R. M., Basri, J. R., Alarnous, S. O., & Al Hamazani, A. D. (2024). TOXICITY OF VARIOUS ROOT CANAL IRRIGATION SOLUTIONS: A SYSTEMATIC REVIEW. CAHIERS MAGELLANES-NS, 6(2).
10. Aljarbou, F., Niazy, A. A., Lambarte, R. N. A., Mothana, R. A., Binrayes, A., Al-Obaida, M., & Alamri, H. M. (2022). Efficacy of Salvadora persica root extract as an endodontic irrigant–an in-vitro evaluation. Journal of Herbal Medicine, 34, 100564.
11. Suraksha, H., Shetty, S., Jayalakshmi, K. B., Sujatha, I., Harishma, S., & Choudhary, S. (2024). "Comparative evaluation of cytotoxicity of three herbal endodontic irrigants at three intervals of time"–An in vitro study. Journal of Conservative Dentistry and Endodontics, 27(11), 1126-1130.
12. Teja, K. V., Janani, K., Srivastava, K. C., Shrivastava, D., Jose, J., Marya, A., & Karobari, M. I. (2021). Comparison of herbal agents with sodium hypochlorite as root canal irrigant: a systematic review of in vitro studies. Evidence-Based Complementary and Alternative Medicine, 2021(1), 8967219.
13. Raju, V. G., Ahamed, A. S., Krishnamurthy, M., Selvendran, K. E., Alshawkani, H. A. A., Allayl, O. A. H., ... & Sumayli, M. A. A. (2021). Comparative evaluation of cytotoxicity of neem leaf extract, 2% chlorhexidine, nigella sativa extract and 3% sodium hypochlorite. World Journal of Dentistry, 13(1), 46-52.
14. Raj, V. R., Varma, R. B., Sureshkumar, J., Kumaran, P., Xavier, A. M., & Madhavan, M. (2020). Comparison of cytotoxicity and smear layer removal efficacy of triphala (an

Indian ayurvedic herbal formulation) and 5.25% sodium hypochlorite as root canal irrigants: An: in vitro: study. Journal of Indian Society of Pedodontics and Preventive Dentistry, 38(4), 343-349.

15. Divia, A. R., Nair, M. G., Varughese, J. M., & Kurien, S. (2018). A comparative evaluation of Morinda citrifolia, green tea polyphenols, and Triphala with 5% sodium hypochlorite as an endodontic irrigant against Enterococcus faecalis: An: in vitro: study. Dental research journal, 15(2), 117-122.