Journal of Neonatal Surgery
ISSN(Online): 2226-0439
Vol. 14, Issue 7s (2025)
https://www.jneonatalsurg.com

OPEN ACCESS

Antibacterial Efficacy of Chitosan Nanoparticle Based Intracanal Medicament Compared with Conventional Intracanal Medicament for Root Canal Disinfection - A Systematic Review

Dr. Atluri Manoj[1], Dr. Manish Ranjan[2], Dr. Sanyukta Singh[3], Dr. C. Ragavendran[4]

[1]Department of Conservative Dentistry and Endodontics, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences (SIMATS), Saveetha University, Chennai-600077, Tamil Nadu, India.

Email ID: 152206004.sdc@saveetha.com

[2]Department of Conservative Dentistry and Endodontics, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences (SIMATS), Saveetha University, Chennai-600077.Tamil Nadu. India.

Email ID: manish@saveetha.com

[3]Department of Conservative Dentistry and Endodontics, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences (SIMATS), Saveetha University, Chennai-600077.Tamil Nadu. India.

Email ID: sanyuktasingh.sdc@gmail.com

[4]Department of Conservative Dentistry and Endodontics, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences (SIMATS), Saveetha University, Chennai-600077.Tamil Nadu, India.

Email ID: ragavan889@gmail.com

Cite this paper as: Dr. Atluri Manoj, Dr. Manish Ranjan, Dr. Sanyukta Singh, Dr. C. Ragavendran, (2025) Antibacterial Efficacy of Chitosan Nanoparticle Based Intracanal Medicament Compared with Conventional Intracanal Medicament for Root Canal Disinfection - A Systematic Review. *Journal of Neonatal Surgery*, 14 (7s), 366-372.

ABSTRACT

Background: Root canal disinfection is crucial for the success of endodontic treatment, with intracanal medicaments playing a significant role in eliminating microbial infections. Conventional medicaments such as calcium hydroxide and chlorhexidine are widely used, but their limitations have led to the exploration of novel formulations. Chitosan nanoparticles, due to their antimicrobial properties and biocompatibility, have emerged as promising alternatives.

Objective: This systematic review aims to evaluate the antibacterial efficacy of chitosan nanoparticle-based intracanal medicaments in comparison to conventional intracanal medicaments for root canal disinfection.

Methods: A comprehensive literature search was conducted in PubMed, SCOPUS, and Web of Science databases, following PRISMA guidelines. Studies assessing the antibacterial effectiveness of chitosan nanoparticle-based intracanal medicaments against Enterococcus faecalis and other endodontic pathogens were included. Data extraction and risk of bias assessment were performed independently by two reviewers.

Results: Seven in vitro studies met the inclusion criteria. The reviewed studies utilized various formulations of chitosan nanoparticles, including combinations with calcium hydroxide, chlorhexidine, and propolis. Antimicrobial assessments were conducted using colony-forming unit (CFU) analysis, scanning electron microscopy (SEM), and spectrophotometry. Five studies demonstrated enhanced antibacterial efficacy with chitosan nanoparticle-based medicaments compared to conventional agents, while two studies showed comparable but not superior effects.

Conclusion: Chitosan nanoparticle-based intracanal medicaments exhibit significant antibacterial potential and may serve as effective alternatives to conventional medicaments. Their ability to enhance antimicrobial activity and provide controlled drug release suggests promising clinical applications. However, further standardized in vivo studies are required to validate their efficacy and long-term benefits.

Keywords: *Chitosan nanoparticles, intracanal medicament, root canal disinfection, antibacterial efficacy, endodontics*

1. INTRODUCTION

The use of intracanal medicaments plays a crucial role in the success of root canal treatments, aiming to eliminate or suppress microbial infections within the root canal system. The efficacy of these medicaments, particularly in terms of their antibacterial properties, is paramount in achieving favorable treatment outcomes. Root canal infections are primarily caused by bacteria, and addressing their presence is essential for the prevention of persistent or recurrent infections.

The intracanal medicaments employed in root canal therapy are designed to target and eliminate bacteria within the intricate root canal system. These medicaments are introduced into the root canal space during various stages of the treatment process, such as during instrumentation or as an inter-appointment dressing between treatment sessions. The antibacterial efficacy of these medicaments is a critical factor in controlling and eradicating microbial populations, thereby promoting the overall success of the root canal procedure.

The microbial flora within the root canal system primarily consists of bacteria. Pathogenic bacteria, such as *Enterococcus faecalis, Prevotella intermedia, Porphyromonas gingivalis,* and other anaerobic organisms, are commonly associated with persistent infections in root canals. Intracanal medicaments serve multiple purposes, including disinfection, reduction of microbial load, prevention of reinfection, and facilitation of periapical healing. Antibacterial properties are crucial for achieving these objectives.

Common intracanal medicaments include calcium hydroxide, chlorhexidine, antibiotics, and a combination of these agents. Each medicament has its unique antibacterial spectrum and mechanism of action. Calcium hydroxide is widely used in endodontics due to its antimicrobial activity, which works by raising the pH of the root canal environment, creating an inhospitable condition for many bacteria. It is particularly effective against Gram-positive bacteria. Chlorhexidine is an antiseptic with broad-spectrum antibacterial properties. It is effective against both Gram-positive and Gram-negative bacteria, making it a valuable intracanal medicament.

In certain cases, antibiotics may be used as intracanal medicaments to target specific bacterial strains. However, their use is carefully considered to avoid antibiotic resistance and other potential side effects. Understanding the antibacterial efficacy of intracanal medicaments is crucial for clinicians to make informed decisions during root canal therapy, ultimately contributing to the long-term success of the treatment and the preservation of tooth structure.

Root canal therapy in endodontics involves several antimicrobial strategies, such as preparation, irrigation, and intracanal dressing, aimed at reducing the endodontic microbiota. Among the various intracanal medicaments, calcium hydroxide stands out due to its favorable antimicrobial action. The mechanism of action is attributed to its ability to dissociate into calcium and hydroxyl ions, leading to a localized increase in pH. In vitro studies have highlighted the importance of the type of vehicle used, with an aqueous vehicle promoting solubility and rapid resorption by macrophages. However, this may necessitate multiple redressings until the desired effect is achieved.

In the realm of pharmaceutical formulations, chitosan, a cationic polymer derived from crustacean exoskeletons, has emerged as an intriguing excipient. Comprising copolymers of glucosamine and N-acetyl glucosamine, chitosan exhibits antimicrobial and antifungal properties. Its ability to retain high water amounts makes it particularly valuable for slow-release formulations. This evolving understanding of intracanal medicaments and their mechanisms reflects the ongoing advancements in endodontic research and the exploration of innovative materials for enhanced therapeutic outcomes.

2. MATERIALS AND METHODS

The present systematic review was performed in accordance with PRISMA guidelines (2020) (Preferred reporting items for systematic reviews and meta analysis).

2.1 Protocol Registration

The protocol for this systematic review has been registered with the PROSPERO International prospective register of systematic reviews, registration No. CRD42024485758.

2.2 Search strategy

A systematic literature search was conducted in PubMed, SCOPUS, and Web of Science databases until December 2023, including articles published up to November 2023.The search utilized free terms and Medical Subject Headings (MeSH) in various combinations, including:Enterococcus faecalis, E. faecalis, dentin tubule disinfection, chitosan nanoparticle, chitosan microparticle, chitosan chlorhexidine nanoparticle, chitosan metal nanoparticles, chitosan calcium hydroxide, chitosan derivatives, chitosan agarose polysaccharide, chitosan gel, calcium hydroxide paste, calcium hydroxide gel, intracanal medicaments, calcium hydroxide medicament, antibacterial properties, antibacterial effectiveness, antimicrobial properties, root canal disinfection, root canal sterilization, antimicrobial efficacy.The research question of this systematic review is structured using the **PICO format**, as outlined below:

PICO	Description
Population (P)	Infected root canals.
Intervention (I)	Chitosan nanoparticle-based intracanal medicament.
Comparison (C)	Conventional intracanal medicaments.
Outcome (O)	Measurement of antibacterial efficacy.

Table 1: PICO and Study design.

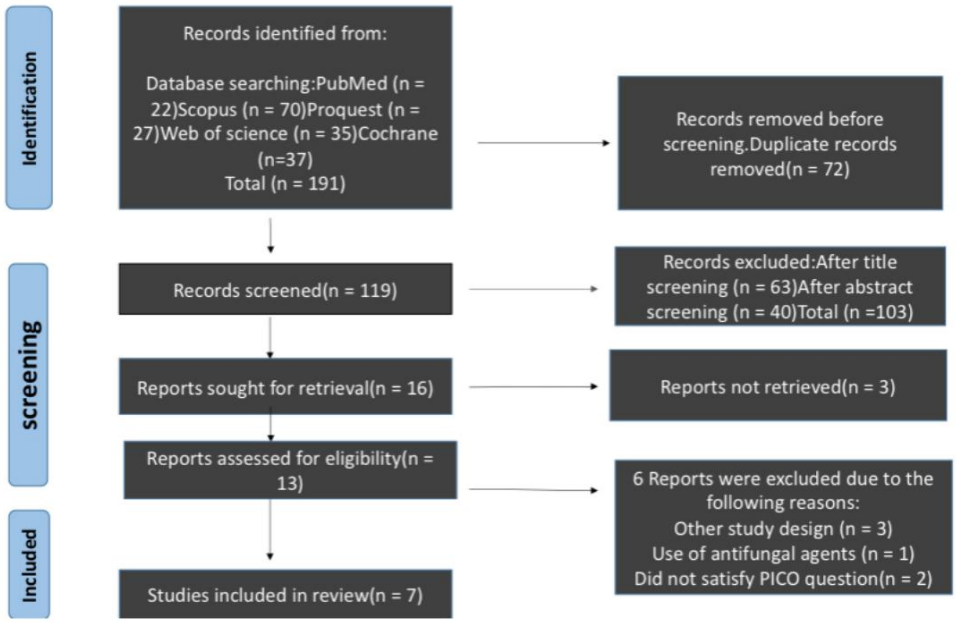
2.3 Selection Criteria

The criteria for inclusion and exclusion were structured in accordance with the study design, population, intervention, comparison, and outcome. In vitro and ex vivo studies conducted on extracted human or bovine permanent teeth or dentin slabs were included. Studies that evaluated the antibacterial efficacy of chitosan nanoparticle-based intracanal medicaments compared to conventional intracanal medicaments were considered. The studies had to include at least two experimental groups: one with calcium hydroxide and another with a chitosan nanoparticle-based medicament.

Case reports, review articles, cross-sectional studies, animal studies, and in vivo studies were excluded. Studies with insufficient or incomplete data were also excluded. Additionally, studies that did not assess antimicrobial efficacy or lacked a proper control group were not considered for inclusion.

2.4 Screening Process

The search and screening process was carried out independently by two reviewers to ensure an unbiased selection of studies. After gathering all relevant information from electronic database searches, a structured screening process was followed to eliminate articles that did not meet the predefined inclusion and exclusion criteria.



Step 1: Removal of duplicate records and irrelevant publications based on the title and scope of the study. Any citations that did not align with the research focus were excluded at this stage.

Step 2: One reviewer screened the titles and abstracts of all identified studies, selecting those that were relevant to the antibacterial efficacy of chitosan nanoparticle-based intracanal medicaments. Studies lacking statistical data, results, or

antimicrobial assessment were immediately excluded. In cases of uncertainty, the full-text article was obtained and cross-checked by a second reviewer.

Step 3: Both reviewers independently assessed the selected full-text studies, ensuring that any incomplete publications or those with insufficient data were eliminated. Additionally, articles that did not match the study's PICOS criteria were excluded.

Step 4: A final thorough evaluation of the remaining articles was conducted, focusing specifically on their methodology, antimicrobial assessment, and comparison with conventional intracanal medicaments. Only studies meeting all inclusion criteria were selected for systematic review.

2.5 Data Extraction

The included studies were processed for data extraction by two independent reviewers. Key details recorded included the first author, year of publication, study type, sample size, study groups, antibacterial agents used, methodology, and antibacterial assessment criteria. Evaluation methods such as CFU analysis, SEM, spectrophotometry, and pH measurement were noted. Risk of bias assessment was also conducted, and discrepancies were resolved through discussion.

2.6 Assessment of Risk of Bias

The risk of bias in the included studies was evaluated using a modified Cochrane tool, specifically designed for in vitro studies. The assessment focused on various methodological parameters, including study design, sample selection, operator details, outcome measurement techniques, blinding, and statistical analysis. Each study was systematically reviewed to identify potential sources of bias that could affect the reliability of the results. The studies were classified based on their risk levels, considering factors such as incomplete data, inconsistencies in methodology, and lack of standardized evaluation criteria. The overall risk of bias was determined by summarizing these assessments, ensuring that only high-quality studies were included for analysis.

3. RESULTS

3.1 Search and Selection

A total of **191 studies** were identified from **PubMed, SCOPUS, and Web of Science**. After removing duplicates, **119 studies** remained. Screening of titles and abstracts led to the exclusion of **106 studies**, leaving **13 full-text articles** for eligibility assessment. Following detailed evaluation, **6 studies** were excluded due to insufficient data or lack of control groups. Finally, **7 studies** met the inclusion criteria and were selected for systematic review. The selection process followed **PRISMA guidelines.**

3.2 Description of included studies

The antibacterial efficacy of **chitosan nanoparticle-based intracanal medicaments** was examined in **seven in vitro studies** included in this systematic review, provides a detailed overview of the included studies, including their methodology and outcomes.

The selected studies featured different methodologies employed to incorporate **chitosan nanoparticles** with intracanal medicaments. Three studies evaluated the antibacterial effectiveness of **chitosan combined with calcium hydroxide**, while two studies assessed the efficacy of **chitosan-propolis nanoparticles.** Another study investigated the **synergistic effect of chitosan with chlorhexidine**, and one study explored the influence of **chitosan as a carrier for antibiotic pastes.**

Each study used distinct methodologies, including **colony-forming unit (CFU) counts, scanning electron microscopy (SEM), and spectrophotometric analysis** to assess bacterial reduction. The **variation in formulations and evaluation techniques highlighted the innovation** in enhancing the antimicrobial performance of intracanal medicaments. The summary of study characteristics and findings is presented in [**Table 2**].

Using the **modified Cochrane tool**, five studies showed a **medium risk of bias,** while two exhibited a **low risk of bias**. Variability in **study design, sample size, and outcome assessment** prevented a **meta-analysis**. The lack of standardized techniques further limited statistical evaluation, but the findings provide valuable insights into the **antibacterial efficacy of chitosan nanoparticle-based intracanal medicaments.**

AUTHOR	YEAR	JOURNAL	SPECIMEN	STUDY DESIGN	N	INTERVENTION	COMPARISON	PERIOD OF PLACEMENT OF ICM	BIOFILM FORMATION	MEANS OF SAMPLING	MEASURE	RESULTS OF THE STUDY
V. S. Harshitha et al	2022	Journal of Conservative Dentistry	Decoronated single-rooted premolars	In vitro study	120 teeth	Nisin + distilled water Nisin + 2% chitosan Ca (OH) 2 + 2% chitosan TAP + distilled water TAP + 2% chitosan	Ca (OH) 2 + distilled water	1 and 7 days	Specimens were placed brain heart infusion (BHI) broth of a 24 h old E. faecalis (ATCC 29212) suspension	Harvesting of dentin was performed at two depths (200 μm and 400 μm)	colony forming units (CFU)	TAP with chitosan showed least mean CFU than compared to other groups.Antibacterial effect of medicaments tested in the study was enhanced with chitosan.
Mariem Wassel et al	2022	BMC Oral Health	Mesial roots mandibular second primary molars	in vitro study	63 teeth	2% chlorhexidine 500 mg/ml double antibiotic paste (DAP) chitosan-chlorhexidine nanoparticles chitosan nanoparticles (CSNPs)	Control group in which teeth were infected, irrigated with saline, and sampled 3- and 7-days post-infection	3 days and 7 days	E. faecalis (ATCC4083) was anaerobically grown on bile esculin agar for 24 h at 37 °C . C. albicans (ATCC10231) was cultured on Sabouraud Dextrose agar for 24 h followed by suspension in TSB for 24 h at 37 °C.	paper points of each tooth were placed in a single Eppendorf tube containing 1 ml saline and vortexed for 30 s.	colony forming units (CFU)	Comb of combination of CSNPs and CHX showed a synergistic action and displayed the highest effect against C. albicans and E. faecalis at both time points.
Abhishek Parolia et al	2020	BMC Oral Health	Extracted teeth	In vitro study	240 teeth	Chitosan propolis100 μg/ml propolis 250 μg/ml chitosan-propolis nanoparticle 100 μg/ml chitosan-propolis nanoparticle 250 μg/ml	Control group : saline calcium hydroxide 2% chlorhexidine (CHX) gel	1, 3,and 7 days	E. faecalis (ATCC 29212) were suspended in 20.0 ml of tryptic soy broth (TSB) FOR 21 DAYS AT 37 °C	At end of 1,3,7 days Dentinal shavings were collected at two depths (200 μm and 400 μm using peeso reamer) size no. 4 and no.6	colony forming units (CFU) SEM CLSM	Day 1,3 and 7- CPN 250 >CPN100, 2% CHX CPN: Chitosan propolis Nanoparticle.CPN250 can be proposed as a potential intra-canal medicament to be used in future.

Sl No	AUTHOR	YEAR	JOURNAL	SPECIMEN	STUDY DESIGN	N	INTERVENTION	COMPARISON	PERIOD OF PLACEMENT OF ICM	BIOFILM FORMATION	MEANS OF SAMPLING	MEASURE	RESULTS OF THE STUDY
4	Kavalipurapu Venkata Teja et al	2023	BMC Oral Health	extracted human permanent mandibular premolar	in vitro study	400 teeth	calcium hydroxide + 2% chitosan gel calcium hydroxide + 0.02% silver nanoparticle gel calcium hydroxide + Bioactive glass S53P4 calcium hydroxide + 2% chlorhexidine gel	Control group- Calcium hydroxide alone	7 days	E. faecalis (ATCC 29212) strain incubated for 4 h at 37 °C for 21 days	Dentin shavings from the apical third were obtained from the inner third of dentin were obtained using gates glidden no.1 to the apical depth, followed by no.2, 3, 4 and 5	Colony forming units using a stereomicroscope	CH + BAG >CH + AGNP > CH + CHX >CH + 2% chitosan> CH alone.
5	Nadar, et al	2023	Journal of Conservative Dentistry	extracted premolars	In vitro study	60 teeth	NCH + propylene glycol NCH + chitosan NCH + distilled water	calcium hydroxide	24 h, 7 days, 15 days, and 30 days	Apical third of the tooth suspended in the glass vial using silicone putty	One milliliters of DW from the glass vials was withdrawn periodically after 24 h, 7 days, 15 days, and 30 days	solution was then analyzed using a ultraviolet (UV) spectrophotometer (1601 PC, Shimadzu, Japan) at 220 nm	• NCH with PG showed alkaline pH and adequate release of calcium ions till 30 days • CT exhibited a high pH with NCH at the end of 30 days
6	Pallavi Goel et al	2022	International Journal of Clinical Pediatric Dentistry	single-rooted teeth	Invitro study	72 teeth	0.2% Chitosan 3% Sodium hypochlorite 2% Chlorhexidine Subgroups- 10 mL irrigant only 10 mL irrigant, dried and irradiation with diode laser Diode laser	Diode laser alone	72 hours	E. faecalis (MTCC 2729 equivalent to ATCC10100) Incubated at 37°C for 7 days.	Sample paper points were placed in a test tube containing BHI broth, incubated at 37°C for 48 hours	CFU	Saline < 3% sodium hypochlorite < 0.2%chitosan <2% CHX
7	Charu Grover et al	2014	Contemporary Clinical Dentistry	Extracted teeth	in vitro study	40 teeth	Distiiled water Propylene glycol Calcium hydroxide containing gutta-percha points Chitosan	Among the groups	1,7,15,30 days	Not mentioned	Solutions of 3.0 ml were then withdrawn periodically at 24 h, 7, 15, and 30 days	ultraviolet spectrophotometer, pH meter	Chitosan> propylene glycol> distilled water>calcium hydroxide containing GP points

Table 2 characteristics of included studies.

3.2 Assessment of risk of bias

The risk of bias was assessed using the ROB 2 tool, considering factors like randomization, deviations from interventions, missing data, outcome measurement, and selective reporting. Most studies had a low risk of bias, ensuring reliable findings, though some lacked blinding and had variations in protocols. Despite these concerns, the studies provide valid evidence on the antibacterial efficacy of chitosan nanoparticle-based intracanal medicaments(Table 3).

S No	AUTHOR	RANDOMISATION	OPERATOR BLINDING	SAMPLE SIZE CALCULATION	STANDARDIZED SAMPLING	DEPTH OF DENTIN	>21 DAY OLD BIOFILM	CONTROL GROUP	SMEAR LAYER REMOVAL	BIOFILM DEVELOPMENT CONFIRMATION	PROPORTIONS	OVERALL RISK
1	V.S. Harshitha et al	✖	✖	✖	✚	✚	✖	✚	✚	✚	5 LR= 62.5%	MODERATE RISK
2	Mariem Wassel et al	✖	✖	✚	✖	✖	✖	✚	✚	✚	7 LR= 70%	LOW RISK
3	Abhishek Parolia et al	✖	✖	✖	✖	✚	✚	✚	✚	✚	7 LR= 70%	LOW RISK
4	Kavalipurapu Venkata Teja et al	✖	✖	✖	✖	✚	✚	✚	✚	✚	7 LR= 70 %	MODERATE RISK
5	Nadar, et al	✖	✖	✖	✖	NA	NA	✚	✚	NA	5 LR= 62.5 %	MODERATE RISK
6	Pallavi Goel et al	✖	✖	✚	✖	✖	✖	✚	✚	✚	8 LR= 80%	LOW RISK
7	Charu Grover et al	✖	✖	✖	✖	NA	NA	✚	✚	NA	4 LR= 50%	MODERATE RISK

Table 3 Assesment of risk of bias

4. DISCUSSION

It is widely recognized that one of the primary mechanisms of bacterial resistance in endodontic infections is the ability of bacterial biofilms to infiltrate and colonize the dentinal tubules. It is true that chemo mechanical instrumentation has limitations in addressing all root canal spaces, leaving a significant amount of untouched canal walls and remaining bacteria. Therefore, the use of intracanal medicaments can be an effective approach in reducing the bacterial load inside the root canal system. A study conducted by V. S. Harshitha et al revealed that 2% chitosan as a vehicle for medicaments achieved higher antimicrobial efficacy, possibly due to its slow and sustained drug release properties.The study suggested that the additive effect between tested medicaments (TAP, nisin, and Ca (OH) 2) with 2% chitosan as a vehicle contributes to enhanced antibacterial activity against E. faecalis. A study conducted by Mariem Wassel et al concluded that Ca (OH) 2 with chitosan as a vehicle exhibited controlled release of calcium ions for a prolonged duration, potentially contributing to the reduction of CFUs over time. The combination of Chitosan nanoparticles (CSNPs) and Chlorhexidine (CHX) showed a synergistic antimicrobial effect against Candida albicans and Enterococcus faecalis. Chitosan as a Carrier: Chitosan, while ineffective alone, demonstrates promise as a carrier for CPN, suggesting its potential role in enhancing the efficacy of intracanal medicaments The study conducted by Abhishek Parolia et al suggests that chitosan-propolis nanoparticles (CPN250) exhibit significant effectiveness in reducing colony forming units (CFUs) of Enterococcus faecalis, potentially making them a promising intracanal medicament. A study conducted by Nadar, et al , Charu Grover et al states that Different carriers, such as propylene glycol (PG), chitosan (CT), and distilled water (DW), significantly impact drug release and pH changes. PG is identified as a carrier with sustained release properties, and CT exhibits a biphasic release pattern. The included studies did not provide conclusive evidence regarding the optimum duration for intracanal placement, as the studies used different time periods ranging from 72 hours(Pallavi Goel et al), 7 days (Kavalipurapu Venkata Teja et al) , 24 h, 7 days, 15 days, and 30 days(Nadar, et al) In this systematic review, it was observed that Five studies demonstrated enhanced antibacterial efficacy with the use of Chitosan nanoparticle based intracanal medicament , while the remaining two studies reported comparatively limited antibacterial properties when compared to other intracanal medicaments. These studies were carried out with proper experimental protocol and showed a low risk of bias. Therefore, the results of these studies can be taken into consideration in clinical decision-making for the selection of intracanal medicaments.

LIMITATIONS

The complex root canal anatomy houses the infected tis-sue along with the biofilm masses. Ideally, the root canal biofilm is extremely complex and organized. Its almost a difficult task or impossible to duplicate its characterisics in the invitro experimentations.CFU assessing the E. faecalis might not indeed translate a clinical condition. Studies on mono or dual species over simplify the real root canal ecology and might not give a true implication of the clinically achievable results. Hence, future studies are advised to be carried out by considering all these factors.

CONCLUSION

From the above review it was concluded that chitosan is used as a vehicle for the tested intracanal medicaments, the antibacterial effect was enhanced, it provides an additive action to the antibacterial properties of the medicaments. .The combination of chitosan with the tested medicaments resulted in a greater antimicrobial efficacy than when the medicaments were used alone.

REFERENCES

[1] Del Carpio-Perochena A, Kishen A, Felitti R, Bhagirath AY, Medapati MR, Lai C, Cunha RS. Antibacterial properties of chitosan nanoparticles and propolis associated with calcium hydroxide against singleand multispecies bioflms: An In Vitro and In Situ Study. J Endod.2017;43(8):1332–6.

[2] Parolia A, Kumar H, Ramamurthy S, Davamani F, Pau A. Effectiveness of chitosan-propolis nanoparticle against Enterococcus faecalis biofilms in root canal. BMC Oral Health. 2020 Nov 25;20(1):339.

[3] Ge J, Li M, Fan J, Celia C, Xie Y, Chang Q, Deng X. Synthesis, characterization, and antibacterial activity of chitosan-chelated silver nanoparticles. J Biomater Sci Polym Ed. 2024 Jan;35(1):45-62.

[4] Ratih DN, Mulyawati E, Fajrianti H. Antibacterial efficacy, calcium ion release, and pH using calcium hydroxide with three vehicles. J Conserv Dent. 2022 Sep-Oct;25(5):515-520.

[5] Wong J, Zou T, Lee AHC, Zhang C. The Potential Translational Applications of Nanoparticles in Endodontics. Int J Nanomedicine. 2021 Mar 9;16:2087-2106.

[6] Prabhakar A, Taur S, Hadakar S, Sugandhan S. Comparison of Antibacterial Efficacy of Calcium Hydroxide Paste, 2% Chlorhexidine Gel and Turmeric Extract as an Intracanal Medicament and their Effect on Microhardness of Root Dentin: An in vitro Study. Int J Clin Pediatr Dent. 2013 Sep;6(3):171-7.

[7] S R S, Singh S, Hindlekar A, Desai N, Vyavahare N. Comparative Evaluation of Antimicrobial Efficacy of Various Antibiotic Pastes and Calcium Hydroxide Using Chitosan as a Carrier Against Enterococcus faecalis: An In Vitro Study. Cureus. 2023 Aug 15;15(8):e43541.

[8] Parakh K, Shetty RM, Shetty S, Desai V, Shetty S, Al Jadaa A, Jain S, Vannala V. Antimicrobial Properties and Substantivity of Gentamicin, Amoxicillin and Metronidazole (GAM) Antibiotic Solution with Chitosan as a Root Canal Irrigant - A Preliminary Study. J Pharm Bioallied Sci. 2023 Jul;15(Suppl 1):S341-S345.

[9] Moradi S, Moushekhian S, Najafi E, Sedigh HS, Navabi S. Efficacy of propolis and triple antibiotic paste as intra-canal medicaments for revascularisation of immature teeth in dogs: a comparative study. Eur Arch Paediatr Dent. 2023 Jun;24(3):321-326.

[10] Teja KV, Janani K, Srivastava KC, Shrivastava D, Natoli V, Di Blasio M, Cicciu M, Minervini G. Comparative evaluation of antimicrobial efficacy of different combinations of calcium hydroxide against Enterococcus faecalis. BMC Oral Health. 2023 Nov 11;23(1):849.

[11] Prabhakar A, Taur S, Hadakar S, Sugandhan S. Comparison of Antibacterial Efficacy of Calcium Hydroxide Paste, 2% Chlorhexidine Gel and Turmeric Extract as an Intracanal Medicament and their Effect on Microhardness of Root Dentin: An in vitro Study. Int J Clin Pediatr Dent. 2013 Sep;6(3):171-7.

[12] Harshitha VS, Ranjini MA, Nadig RR. Antibacterial efficacy of nisin, calcium hydroxide, and triple antibiotic paste in combination with chitosan as an intracanal medicament against Enterococcus faecalis - An in vitro study. J Conserv Dent. 2022 Sep-Oct;25(5):504-509.

[13] Lakshmi, and Nanobiomedicine Lab, Department of Pharmacology, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Chennai. 2021. "Anticariogenic Activity of Silver Nanoparticles Synthesized Using Fresh Leaves Extract of Kalanchoe Pinnata." *International Journal of Dentistry and Oral Science*, July, 2985–87.

[14] Nasim, Iffat, Zohra Jabin, S. Rajesh Kumar, and V. Vishnupriya. 2022. "Green Synthesis of Calcium Hydroxide-Coated Silver Nanoparticles Using Andrographis Paniculata and Ocimum Sanctum Linn. Leaf Extracts: An Antimicrobial and Cytotoxic Activity." *Journal of Conservative Dentistry: JCD* 25 (4): 369–74

[15] Kamath, Ajith K., Iffat Nasim, N. P. Muralidharan, and Ravalika N. Kothuri. 2022. "Anti-Microbial Efficacy of Vanilla Planifolia Leaf Extract against Common Oral Micro-Biomes: A Comparative Study of Two Different Antibiotic Sensitivity Tests." *Journal of Oral and Maxillofacial Pathology: JOMFP* 26 (3): 330–34.

[16] Choudhari, Sahil, Jogikalmat Krithikadatta, Ipsitha Vejendla, Swathi, and Mukesh Doble. 2023. "Microbial Interactions in Oral Biofilm: Evaluating Therapeutic Interventions and the Emergence of Resistance: A Narrative Review." *Cureus*, October.

[17] Deepika, Burra Anand, Jaiganesh Ramamurthy, Smiline Girija, and Nadathur Duraisamy Jayakumar. 2022. "Evaluation of the Antimicrobial Effect of Ocimum Sanctum L. Oral Gel against Anaerobic Oral Microbes: An in Vitro Study." *World Journal of Dentistry* 13 (S1): S23–27.

[18] Janani, Krishnamachari, Kavalipurapu Venkata Teja, P. Ajitha, and Raghu Sandhya. 2020. "Evaluation of Tissue Inflammatory Response of Four Intracanal Medicament - An Animal Study." *Journal of Conservative Dentistry: JCD* 23 (3): 216–20.