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Influence of Polymeric Carriers on the pH-Modifying Properties of Intracanal Medicaments in Root Canal Treatment

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Abstract

Calcium hydroxide (CH) preparations and medicated gutta-percha are widely used intracanal medicaments in root canal treatment. These materials often incorporate polymeric carriers to deliver the CH payload and influence its therapeutic effect. This in-vitro study investigates the impact of different polymeric carriers on the pH-modifying properties of intracanal medicaments within the root canal system. The research focuses on two key aspects: (1) the ability of the polymers to control the release of CH, and (2) the influence of polymer properties on the sustained elevation of dentin pH over time. By analyzing the release kinetics and pH modification profiles of different CH-polymer combinations, the study aims to contribute to the development of optimized intracanal medicaments with improved control over CH delivery and sustained disinfection efficacy in endodontic therapy. This in vitro study aimed to compare the pH changes in root dentin following the placement of different calcium hydroxide preparations and medicated gutta-percha as intracanal medicaments. Intracanal medicaments play a crucial role in root canal treatment by disinfecting the root canal system and promoting periapical healing. Four commonly used calcium hydroxide preparations and medicated gutta-percha were evaluated for their ability to alter the pH of root dentin. pH measurements were taken at various time intervals to assess the sustained effect of each intracanal medicament on dentin pH. Results revealed significant differences in pH changes among the tested materials. Understanding the pH-modifying properties of intracanal medicaments is essential for optimizing root canal disinfection and promoting successful endodontic outcomes.

Keywords: Polymeric carriers, calcium hydroxide, intracanal medicaments, root canal disinfection, pH modification, controlled drug release, endodontics, dentin

INTRODUCTION

Endodontic therapy involves removal of all bacteria and pulpal tissue from diseased root canals, in order to completely seal the cleansed root canals.A successful endodontic procedure depends on the pillars of root canal system obturation, disinfection, and debridement. Despite these cornerstones,root canal treatment now depends on more principles. The old concepts of debridement and disinfection through improvements in irrigation protocols and intracanal medications, obturation and coronal restoration are all included in this. It also includes diagnosis and treatment planning [1].

Pulpal and peri-radicular infections are mostly treated using endodontic procedures in order to avoid and manage these infections. It is obvious that the success of the study will depend on how microorganisms contribute to the pathogenesis of peri-radicular lesions. Successful endodontic

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therapyrelies on the elimination of bacteria. Since mechanical instrumentation alone was not enough to completely clean the root canal, use of chemical agents hasbeen advocated. Various irrigating solutions such as normal saline, EDTA, NaOCI, Chlorhexidine, etc. are practiced by dentists at present. Sodium hypochlorite (0.5–5.25%) is the irrigant of choice in endodontics owing to its properties like excellent antimicrobial effect, ability to dissolve vital pulp tissue,necrotic tissue, organic components of dentin and biofilm. Because of its low viscosity, it may be easily incorporated into canal construction. It also has a acceptable shelf life and is widely accessible. 17% EDTA is used in conjunctionwith sodium hypochlorite due to its action on the inorganic content of smear layer. It acts as a lubricant, chelator, and decalcifying agent.

With the advent of newer irrigating solutions and activation techniques, efficiency of disinfection of canals has improved over the years. This in turn, has led to a rise in success of single visit endodontics. Although thorough chemomechanical preparation is regarded as a crucial stage in root canal disinfection, it is still challenging to completely eradicate bacteria [2].

It is still not indicated to go for a single visit therapy in cases with pulp necrosis, swelling, large periapical lesions and retreatment cases. In absence of supplements, the microorganism present in root canal may die. But if they remain, they may multiply. The microorganism which remains deep in dentinal tubules cannot be completely eliminated by chemo mechanical preparation alone. In the absence of an effective intracanal medicament between the appointments, the microorganism may multiply. Thus, a good intracanal medicament for cleaning of root canal is necessary. The main rationale behindthe concept of placing an intracanal medicament is to eliminate the microorganism inside the root canal and to avoid reinfection. Medicament withlong-lasting effect and least irritation to peri-radicular tissue should be employed for eliminating bacteria when single visit therapy is not indicated [3].

According to Ba-Hattab (2016), the use of this substance in the USA led to a greater public awareness of calcium hydroxide in the 1930s. Between 1934and 1941, the first reports on effective periapical healing with calcium hydroxidewere published. This substance has several biological properties that have been linked to it, including antimicrobial activity, tissue-dissolving ability, inhibition oftooth resorption, and induction of repair by hard tissue formation [4, 5].

Ca (OH)2 produces a pH of over 11.1 which contributes to its antibacterial effects. Necrotic pulp and dentin have a pH of 6.0–7.4, however, after placing calcium hydroxide in the canal, the peripheral dentin has a pH. range of 7.4–9.5. The formation of hydroxyl ions, which raises pH, is the basisfor the therapeutic efficacy of calcium hydroxide dressing materials. Till it maintains a high pH, calcium hydroxide has antimicrobial actions in the root canal. Since commercial pastes' ingredients vary, they may form hydroxyl ionsat different rates, which can vary the pH of calcium hydroxide. When this powder is combined with an appropriate carrier, a paste is created. Because of their high pH, Hasselgren (1976) referred to them as alkaline pastes [6]. One of the causes for the persistent infection is the formation of biofilm. The extra radicular microbial biofilms located close to the root apex of teeth with endodontic infections are known as biofilms produced on the root(cementum) surface, these layers of biofilm can cause failure of root canal treatment due to delayed periapical healing.

When combined with various vehicles in these clinical settings, calciumhydroxide has demonstrated the ability to permeate these ions through the dentin,reducing bacterial count.

In this total process, the vehicle is crucial. It determines the formation ofions, which results in the medicament to be reabsorbed and solubilized from the root canal space at different rates, it is directly related to the antibacterial efficacy. Therefore, the optimal vehicle should be enabled to moderate the release of these ions [7].

Dissociation of Ca(OH2) in nonaqueous media is not exactly understood, and the effect of application of the powder mixed with a nonaqueous vehicle is not known, so viscous vehicles are used in this study. Calcium hydroxide is available in various commercial preparations or in powderform for self-preparation to be mixed with an aqueous-based vehicle, such as saline or local anesthetic solution. This allows disassociation to occur for it tobe an effective antimicrobial. Introduction of calcium hydroxide pastes into the root canals can be performed with files, reamers, lentulo spirals, or syringes without much difficulty [8].

Studies using calcium hydroxide-releasing, gutta-percha points (CH points) indicate that the alkalizing potential is not only significantly lowercompared with the use of an aqueous suspension of calcium hydroxide, but it also could not be maintained for longer than 3 days. Recently, new version of CH points, the Calcium Hydroxide Plus Points (Roeko, Germany), was introduced [9].

The latter is a prerequisite for effective action of medicament as an intracanal dressing because bacteria reside within dentinal tubules, forming reservoir for root canal infection. It has been said that diffusion of hydroxyl ionsin root dentin occurs and are measurable as a pH gradient across it. However, to our knowledge, the diffusion dynamics of these ions through root dentin fromthis new product, calcium Hydroxide Plus Points (CH points), has not been studied [10].

This study aimed to assess and compare the pH alterations in root dentin after the application of calcium hydroxide using different vehicles and medicated gutta-percha as intracanal medicaments.

LITERATURE REVIEW

An effective broad-spectrum antibacterial is CHX, a cationic bisguanide. It has the capacity to infiltrate into dentine and the cell wall of microorganisms,leading to intracellular component leakage. Chlorhexidine-releasing medicatedgutta percha points have recently been introduced for use as intra canal medicament. These points are simple to insert into the root canal all the way tothe apex and simple to remove [11].

Normally the size of the intracanal medicament particularly will not penetrate the inaccessible areas like dentinal tubules and microbial biofilm. So, to overcome these drawbacks the size is reduced in the nanoparticles which allows better cleaning of root canals. The development of nanotechnology caused revolutionary changes in dentistry. This technology is built on nanoparticles (1-100 nm). Numerous nanomaterials are produced chemically or naturally. Researchers and clinicians in the field of endodontics have paid close attention to nanoparticles because of their high antimicrobial activity [12].

Bacterial cell membrane-disrupting metallic nanoparticles have been around for a while. Nanoparticles made of silver, gold, copper, or zinc have allbeen used to treat persistent infections; each has distinct physical characteristics and underlying biological processes that support its antibacterial effects [13].

Silver nanoparticles are most studied due to their broad range of antimicrobial properties against various microorganisms. In endodontics,AgNPs have been tested for use as endodontic obturating material, andirrigation solution. Even while these nanoparticles have potential in endodontics, their lengthy contact and toxicity may cause a problem. AgNPs are distinctive among metallic nanoparticles because of their surface characteristics, particle reactivity and ion formation [14].

Calcium hydroxide powder with various vehicles shows better results than commercial products. According to various articles there is no inter group comparison between calcium hydroxide with vehicles and commercial productslike Metapex.

Medicated gutta percha like calcium hydroxide points are not used most due to slow dissociation of Ca^{+} and OH^{-} ions, so other medicated gutta percha like chlorhexidine releasing and silver nano particles releasing gutta percha have sustained release and adequate disinfection. These medicines also possess good antibacterial properties but there is no intergroupcomparison. So, in this study these two main groups are compared for pH changein root dentin as it decreases the antibacterial activity [15].

Comparison of Natural and Synthetic Polymeric Carriers for pH Modulation in Root Canal Therapy

Natural and synthetic polymeric carriers differ in their effectiveness for pH modification during root canal therapy. Natural carriers, such as chitosan and gelatin, are biocompatible and biodegradable, making them safe for clinical use [16]. However, their pH-modifying capacity can be inconsistent due to variations in chemical structure and degradation rates. Synthetic carriers, like polylactic acid (PLA) and polyethylene glycol (PEG), offer greater control over pH modulation, enabling sustained and predictable release of therapeutic agents. This is due to their customizable properties, such as molecular weight and degradation rate. However, synthetic polymers may pose challenges in biocompatibility and potential toxicity, requiring careful consideration [17].

Role of Polymeric Carriers in Enhancing Long-Term Success of Root Canal Therapy

Polymeric carriers can significantly enhance the long-term success of root canal therapy by improving sealing, reducing leakage, and promoting tissue healing. Their ability to deliver antimicrobial agents and sealers effectively ensures better adaptation to canal walls, minimizing microbial infiltration [18]. Natural polymers like chitosan offer excellent biocompatibility and promote tissue regeneration, while synthetic polymers provide controlled drug release and enhanced mechanical stability. These carriers can also facilitate the delivery of bioactive molecules, encouraging periapical healing. By combining sealing efficiency with therapeutic benefits, polymeric carriers address key challenges in root canal therapy, contributing to improved outcomes and long-term treatment success [19].

Factors Influencing pH Modulation by Polymeric Carriers

The rate and duration of pH modulation by polymeric carriers are influenced by several factors, including polymer type, concentration, and environmental conditions. Natural polymers, like chitosan, degrade faster, leading to shorter pH modulation, while synthetic polymers, such as polylactic acid (PLA), enable sustained release due to slower degradation rates. Polymer concentration determines the availability of pH-modulating agents, with higher concentrations often providing prolonged effects. Environmental conditions, including temperature, pH, and the presence of enzymes, can accelerate or slow polymer degradation and ion release. Additionally, carrier morphology, such as particle size and porosity, affects the release profile, influencing pH modulation effectiveness [20].

MATERIALS AND METHODS

Materials

For preparation of samples:

- Modelling Wax
- Sterile gloves
- Mouth mask.
- 17% Ethylene diamine tetra acetic acid
- 3% NaOCl
- Normal saline
- Distilled water
- Nail Varnish

For preparation and placement of intracanal medicaments:

(a) Calcium hydroxide powder
(b) Metapex
(c) Vehicles – Normal Saline
(d) 10 % Propylene Glycol

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For placement of Medicated gutta percha
(a) Calcium hydroxide releasing gutta percha.
(b) 20.6 % Gutta percha
(c) Silver Nano particles
(d) 2 % Chlorhexidine gel
(e) Paper points

Equipments

For preparation of samples:
- Contra angled Handpiece
- Diamond discs
- Airotor.
- Straight bur
- Gates Glidden drills
- Needle and syringe.
- Autoclave

For preparation and placement of intracanal medicaments:
- Mixing pad and spatula
- Syringe and needle tips.
- Lentulo spiral

For Decoronation of Teeth at CEJ
- Carborundum discs
- Straight Handpiece
- Motor

For checking pH:
- Digital pH Meter

For root canal preparation
- 10 and 15 no K files
- Neo Endo flex Files 21 and 25 mm
- Endo motor

Selection of Teeth

For this in-vitro study 120 intact permanent single rooted extracted teeth werecollected, irrespective of patients age and sex

The inclusion criteria were intact teeth extracted for:
- Orthodontic purpose
- Mobile tooth

Exclusion criteria were:
- Grossly decayed.
- Teeth with fracture
- Teeth with two roots
- Teeth with resorbed roots

OBSERVATIONS AND RESULTS

Group 1 – Calcium Hydroxide with Vehicles

There was no statically significant difference seen at 1hr between Group 1 the mean pH For Subgroup B (CH + saline) was highest i.e. 9.762 andlowest for Subgroup D (Metapex) i.e. 9.159. On day 1 there was a statistically significant difference seen the mean pH For Subgroup C (CH + PG) was highesti.e. 10.162 and lowest for Subgroup D (Metapex) i.e. 9.364. On day 2 there was a statistically significant difference seen the mean pH For Subgroup C (CH + PG)was highest i.e. 10.72 and lowest for Subgroup D (Metapex) i.e. 9.44. But on Day 7 there was no statically significant difference seen betweenthe mean pH For Subgroup C (CH + PG) was highest i.e. 10.918 and lowest forSubgroup D (Metapex) i.e. 9.711.

Subgroup B had an aqueous vehicle (saline) at 1hr the mean pH was highest for this group, while lowest for subgroup D as Metapex is oily intracanal medicament. On day 1,2 and 7 subgroup C which had viscous vehicle(Propylene glycol) had the highest mean Ph. And lowest for subgroup D (Metapex) (Table 1)

Group 2 – Medicated Gutta Percha

At 1hr, 1day, 2 day and 7 day the highest mean pH was seen in subgroupB ie calcium hydroxide points and lowest for subgroup D ie Silver nanoparticlesreleasing gutta percha, there was statically significant difference between subgroup B and subgroup D at 24 hr. and 48 hr. At 1hr subgroup B had a mean pH of 9.73 and subgroup C and D had 8.25 and 8.22 respectively.

At day 1 mean pH of subgroup B increased up to 10.35 while it decreased for subgroup C and D which was 7.69 and 7.76, At day 2 mean pH of subgroup B decreased up to 9.84 while it was increased for subgroup C and D which was 7.74 and 7.52. But at day 7 the mean pH of subgroupB increased up to 10.41 and it increased for subgroup C and D which was 8.22and 7.95 as well. (Figure 1)

Table 1. Overall comparison of pH changes in root dentin after placing different calcium hydroxide preparation as intracanal medicament using One-way Anova F test.

Calcium Hydroxide(Group 1)	1h Mean (SD)	24h Mean (SD)	48h Mean (SD)	1 week Mean (SD)
Subgroup A(CONTROL)	7.148(0.107)	6.958(0.137)	7.022(0.185)	6.9(0.102)
Subgroup B(CH +SALINE)	9.762(0.183)	10.018(0.227)	10.42(0.406)	10.52(0.304)
Subgroup C (CH+PG)	9.262(0.296)	10.162(0.23)	10.72(0.29)	10.918(0.384)
Subgroup D (METAPEX)	9.159(0.255)	9.364(0.27)	9.44(0.166)	9.711(0.201)
One-way AnovaF test value	F=402.781	F=671.539	F=540.449	F=674.829
P value(overall)	P<0.001**	P<0.001**	P<0.001**	P<0.001**

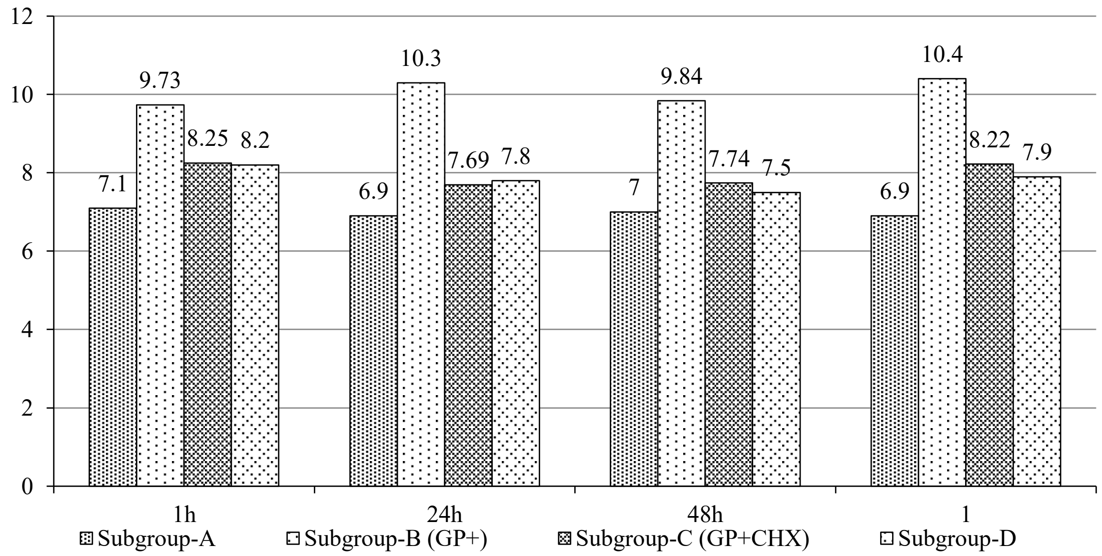

Figure 1. Bar Graph of inter subgroup comparison of Medicated GuttaPercha

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CONCLUSION

In this in vitro study, the findings suggest distinct pH trends over a 7-day observation period. During this timeframe, calcium hydroxide preparations and medicated gutta-percha consistently maintained an alkaline pH. Within the first hour, both saline and calcium hydroxide points from both groups exhibited elevated pH levels, with the lowest levels seen in Metapex and silver nanoparticles releasing gutta-percha. At 24 and 48 hours, the Propylene glycol group and calcium hydroxide points continued to show high pH levels, while Saline, Metapex, and chlorhexidine releasing and silver nanoparticles releasing gutta-percha displayed comparatively lower pH levels. By the 7th day, Propylene glycol displayed the highest pH, followed by saline and Metapex, while Calcium hydroxide points, chlorhexidine releasing, and silver nanoparticles releasing gutta-percha showed declining pH levels, respectively.

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