

Evaluation of Antibacterial Efficacy Against *Enterococcus Faecalis* of Newly Prepared Endodontic Irrigant Solution (an In vitro study)

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الخلاصة

الاهداف: تهدف الدراسة الى تقييم فعالية محلول ارواء لبي جديد التحضير وهو مزيج من (٢٠) % منظف الخروج و (٤) % انزيم البابين (MCP) ضد بكتريا السحجات البرازية . **المواد وطرائق العمل:** تالفت عينة البحث من (٦٠) سن بشري مقلوع تم تحضيرهم باستخدام نظام الدوار (protaper NiTi) تم ختم الفتحة الذروية لكل عينة بواسطة الراتنج الاكريلي ثم غمر كل جذر بمادة طبعة سلكونية ثم تعقيمها ثم حقن مامقداره (١٠) ميكرو لتر من معلق المزيج بلطف داخل كل قناة من المجموعات (A,B,C) ووضعها في الحاضنة لمدة (٢٤) ساعة عند درجة حرارة (٣٧°) اما المجموعة D فلم تحقن باعتبارها مجموعة شاهدة سالبة. العينات في المجموعات (A,B,C) تم تطهيرها كالاتي: المجموعة A باستخدام محلول (MCP) المجموعة B باستخدام محلول (NaOCl 2.5%) المخضر حديثا. المجموعة (D) فلم تعالج باي محلول باعتبارها مجموعة شاهدة موجبة. ثم تركت وتركزت داخل القناة لمدة خمس دقائق ثم تم تخفيف القناة باستخدام اقماع التحفيف المعقمة. ثم اخذت العينات البكتيرية للمجموعات الاربعة باستخدام مبرد معقم حجم (٤٠) بادخاله على طول القناة وتدويره (٣٦٠°) ثم وضعت المبادر المعقمة في علبه بلاستيكية معقمة تحتوي على (١) مللتر من السيروم الطبيعي واخذت (٢٠٠) مللتر ونشرت على وسط اجار السحجات ووضع في الحاضنة لمدة (١٨) ساعة عند (٣٧° م) ثم تم حساب عدد المستعمرات البكتيرية. **النتائج:** كلا السائلين (MCP & NaOCl) يحدان نمو تام لبكتريا السحجات البرازية من قناة الجذر في خمس دقائق. **الاستنتاجات:** ان محلول منظف الخروج ٢٠% وانزيم البابين ٤% MCP له القدرة على اخو التام لبكتريا السحجات البرازية من قناة الجذر المصابة مختبريا ولمدة خمس دقائق. ان تأثيره المضاد للبكتريا مشابه لتأثير محلول NaOCl ٢.٥% .

ABSTRACT

Aims: To evaluate the efficacy of a newly prepared endodontic irrigant solution, against *E. faecalis*. **Materials and Methods:** Sixty human extracted single rooted teeth samples were prepared by using protaper NiTi rotary system. The apical foramen of each sample was sealed by acrylic resin on the apical 3mm. Each root was embedded in silicon impression material block and autoclaved. A ten µl (4X10⁵) of inoculated broth media (nutrient broth) with *E. faecalis* was injected gently inside the canals of group A,B&C was incubated for 24hours at 37C°. Group D was left without inoculation to serve as a control negative. The samples of group A,B and C were disinfected as follow: Group A was disinfected with MCP solution(mixture of 20% castor detergent and 4% papain). Group B was disinfected with freshly diluted 2.5% NaOCl solution. Group C not treated with any solution control positive. The disinfected solutions were left inside the canal for 5 min then each canal was dried with sterilized paper point, then bacterial samples were taken from the samples of 4 groups using size 40 sterilized file which was inserted to full canal length and rotated 360 degrees in clock wise direction for dentin engagement. The file was put inside the sterilized plastic tube containing 1ml of normal saline then 200 µl was inoculated and spread on *Enterococcus* agar media and incubated at 37C° for 18hours, the numbers of bacterial colonies were counted. **Results:** Both solutions (MCP and NaOCl) produce complete eradication of *E Faecalis* within 5 minutes. **Conclusion:** Castor detergent 20% and papain enzyme 4% (MCP) has ability to completely eradicate *Enterococcus Faecalis* bacteria from the infected root canal in vitro in 5 min. It's antibacterial action is similar to the action of 2.5 % NaOCl . **Keywords:** Antibacterial, E Faecalis, New irrigant

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INTRODUCTION

The treatment of apical periodontitis and root canal infection consists of

removing the source of the microbial invasion and creating space in the root canal system for irrigation with an

antimicrobial solution.⁽¹⁾ Biomechanical preparation associated with antimicrobial irrigants is important for the elimination of the microorganisms from the root canal.⁽²⁾ Therefore the irrigating solution must have adequate antimicrobial action on microorganisms present in the root canal, dentinal tubules, apical ramifications, cementum, and areas of root resorption.^(3,4) *Enterococcus faecalis* is the most commonly isolated species from the canals of teeth presenting post-treatment diseases. *Enterococcus faecalis* account for up to 77% of therapeutic failures.⁽⁵⁾ Sodium hypochlorite (NaOCl) has been widely used as an irrigant since its introduction in endodontics.⁽⁶⁾ Sodium hypochlorite has been documented as the most effective irrigant in terms of antimicrobial activity⁽⁷⁾ and has several disadvantages, such as: cytotoxicity to vital tissues, foul smell, taste, and inability to remove smear layer when used alone.⁽⁸⁾ In addition, it may alter the dentin structure and may interfere with bonding of adhesive obturating materials to dentin.⁽⁹⁾ Tartari *et al* (2013) founded that NaOCl is able to significantly decrease the dentin microhardness even when used alone.⁽¹⁰⁾ The associated sequelae of NaOCl extrusion have been reported to include life threatening airway obstructions,⁽¹¹⁾ facial disfigurement requiring multiple corrective surgical procedures,⁽¹²⁾ permanent paresthesia with loss of facial muscle control,⁽¹³⁾ and the least significant consequence tooth loss.⁽¹⁴⁾ Sodium hypochlorite is generally not utilized in its most active form in a clinical setting. For proper antimicrobial activity, it must be prepared freshly just before its use.^(15,16)

Recently, there has been a growing trend to seek natural remedies as part of dental treatment.⁽¹⁷⁾ Thus, some alternative irrigating solutions with antimicrobial action and biocompatibility have been proposed.⁽¹⁸⁾ One of these substances is the castor oil. This phytotherapeutic polymer is obtained from the seeds of the *Ricinus communis* plant. It has been reported that 10% castor oil detergent has an acceptable biological and antibacterial properties.^(19,20,21,22) Such studies evaluated the agent in comparison to other irrigating solutions (2% CHX and

NaOCl) and concluded that gram positive microorganism was significantly affected by detergent.

Papain enzyme acts as a debris removing agent. It acts only on affected tissues, which lack the α_1 -antitrypsine plasmatic antiprotease that inhibits proteolysis in healthy tissues.⁽²³⁾ Papain has bacteriocidal, bacteriostatic and anti-inflammatory activity, and debriding agent. It does not damage healthy tissue, but accelerates the cicatricial process.⁽²⁴⁾ Bhardwaj find that papain enzyme has comparable antibacterial effect to calcium hydroxide when used in gel form as an intracanal medicament against *E. faecalis*.⁽²⁵⁾

The purpose of this in vitro study was to evaluate the efficacy of a newly prepared endodontic irrigant solution prepared from a mixture of 20% castor detergent and 4% papain enzyme (MCP) against *E. faecalis*.

MATERIALS AND METHODS

Preparation of irrigant solution:

The (MCP) is an acronym of mixture of castor detergent and papain enzyme. The experimental solution was prepared by converting the castor oil (HEMANI Company, Pakistan) to sodium castorate powder by adding sufficient molar ratio of NaOH to the oil. A twenty grams of sodium castorate powder and 4 gm of papain enzyme powder (HIMEDIA Company India, molecular weight=23000) were dissolved in 100 ml deionized water to produce a solution of 20% castor detergent, and 4% papain enzyme.

1. Sample selection and preparation

Sixty extracted human single rooted teeth free of root resorption, root fracture, sever curvature, were selected teeth were decoronated at the cement-enamel junction. The patency of each root canal was confirmed by inserting size 15 K file, the working length of each canal was determined by inserting size 15 K type file inside the canal until the tip of the file was just become visible at the apical foramen under stereomicroscope X20 magnification. The file was reduced 1mm. from the measured working length, each canal length was adjusted to 14mm.

working length by cutting from the cervical part of the root. The apex of samples were closed from the apical area by sticky wax and all root canal samples were prepared by using protaper NiTi rotary system Protaper (Dentsply Maillefer Switzerland) starting from SX, S1, S2, F1, F2 & F3 at 3000 rpm speed and 2.5 Ncm torque using micro motor (NSK Comp. Mekanushi, Japan) hand piece. Preparation of each canal was done with 1% of NaOCl (Clorox, Kingdom of Saudi Arabia) 3ml between each file size, the time was standardized to 10 mins for each canal.⁽²⁶⁾

The irrigation was performed by endodontic syringe with flexible silicon tip

inserted up to 2mm from the apex. The speed of irrigation was 1ml/5 seconds.⁽²⁷⁾ Finally each canal was irrigated with 5 ml of distilled water and immersed in 1 liter of distilled water for 24h to eliminate the residual effect of NaOCl. Samples were removed from distilled water and dried with sterile endodontic paper point.

2. Sterilization of teeth: The apical foramen of each root sample was sealed by applying acrylic resin on the apical 3mm of root to prevent fluid leakage during microbiological work. Each root was embedded in silicon impression material block up to 2 mm of cervical margin Figure (1)

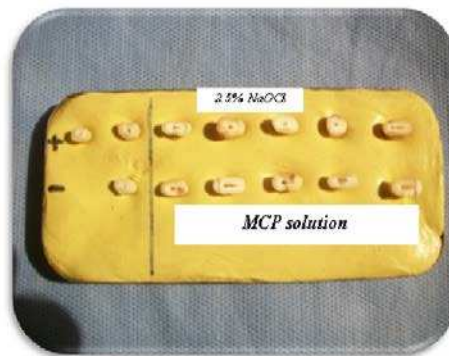


Figure (1): Samples of extracted teeth after decoronation fixed in heavy body impression material.

To facilitate the grasping and holding of root samples. The block of tooth samples was covered with aluminum foil and autoclaved at 121°C for 15 min at 15 pound/inch². The microbiological part was performed in Dental Basic Science Department University of Mosul.

The samples were divided randomly as follow:

Group A n=20 were irrigated with MCP solution.

Group B n=20 were irrigated with 2.5% NaOCl.

Group C n=10 control +ve the samples just inoculated without treatment

Group D n=10 control -ve the samples just autoclaved without bacterial inoculation.

3. Culturing of bacteria:

A single colony of *Enterococcus Faecalis* was inoculated on Enterococcus

agar and incubated aerobically for 18 hours.⁽²⁸⁾ Single colony of fresh bacteria was inoculated in screw capped vial containing 5 ml of nutrient broth (HiMedia India) and incubated for 18 hours, at 37°C then 0.5 ml of bacterial suspension was added to 0.5 ml of nutrient broth in screw capped vial. The vials were shaken well manually in vertical direction, the final dilution of inoculated broth became 4×10^7 cfu/ml.⁽²⁹⁾

4. Inoculation of Root Canal with *Enterococcus Faecalis* A ten μ L (4×10^5) of mixed suspension was taken by micropipette and injected gently inside the each canals of group A, B & C under aseptic condition using micropipette and incubated for 24 hours at 37°C.⁽³⁰⁾ group D was not inoculated and considered as a control positive Figure (2).

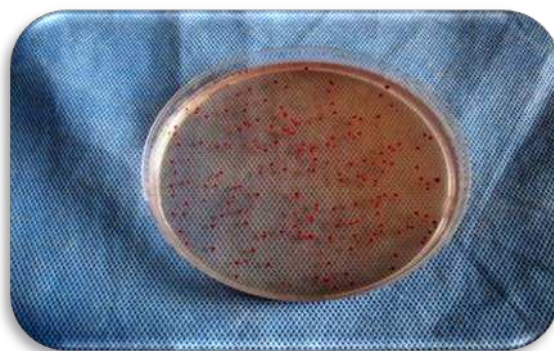


Figure (2): Petri dishe with Enterococcus faecalis growth of control positive.

5. Canal irrigation: After 24hours incubation of the samples, each experimental canal was treated by injection 10 μ L of freshly prepared corresponding solution and left for 5 minutes and then each canal was dried with sterilized paper point, group D was not treated with any solution to consider as control negative then bacterial samples were taken from the samples of 4 groups using size 40 sterilized file which was inserted to full canal length, then the file is rotated 360 degrees in clock wise direction for dentin engagement. The file was inserted inside the

sterilized plastic tube immediately under aseptic condition to tube containing 1ml of normal saline, and shake in vertical direction for 3 seconds, and then 200 μ l was inoculated and spread on Enterococcus agar media and incubated at 37C° for 18hours. After 24hours the numbers of bacterial colonies were counted under good illumination and manual lens for magnification, then multiplied by the dilution factor and the mean values were computed Figure(3).

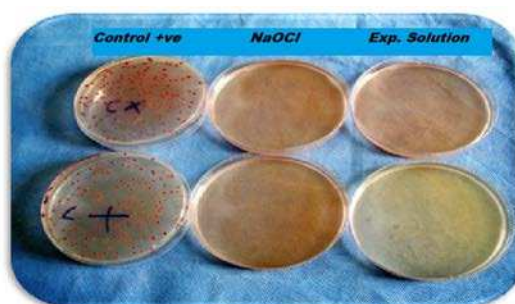


Figure (3): Petri dishes with Enterococcus faecalis growth of control positive, (left side) 2.5%NaOCl (intermediate), and MCP solution (right side).

RESULTS

The results of bacterial count showed clearly that group A (MCP solution) and group B (2.5% NaOCl) were complete eradication of the bacteria from the root canal, all the samples

was negative culture Figure (4).The mean score for both solutions are zero Table (1). The mean score value of control positive was equal to 523.9 (Figure 3), while the control negative the mean score value was zero. (Table 1).

Table (1): the mean of bacterial count for four groups

Group	NaOCl 2.5%	MCP solution	Control +ive	Control -ive
mean	0	0	523.9	0

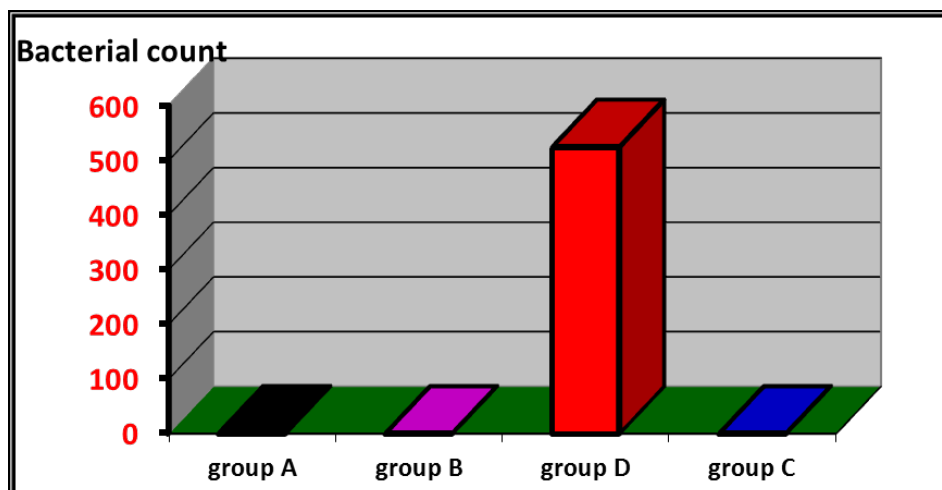


Figure (4): Histogram of bacterial count of four groups

DISCUSSION

Control of bacterial infection of the root canal and prevent its recurrence is the main objective of endodontic therapy, *Enterococcus faecalis* was chosen as the primary test organism because it is the most resistant bacteria found in the root canal system and has been associated with treated root canal failures.⁽³¹⁾ inherent antimicrobial resistance, the ability to invade into the dentinal tubules where they are protected from endodontic medicaments and are therefore difficult to eliminate.^(32,33) The results of control negative conform complete sterilization of the samples by autoclaving, while the results of control positive confirm the root canal inoculation by bacteria after its sterilization.

In this study we don't use any other method with the irrigation which increase the effectiveness of root canal irrigant (sonic, ultrasonic and mechanical instrumentation) this was done by slowly injection of the solution in to the canal by micropipette to ensure that any reduction in the bacterial count is due to antibacterial action of the tested solution.

(MCP) solution is a promising solution because in clinical endodontic we use larger amount of irrigant solution (3-5 ml for each irrigation) this will give more irrigant fluid volume and velocity inside the canal which will give more potent disinfecting action than in vitro study due to increases both volume and velocity of

the fluid. The concentration of NaOCl 2.5% was selected according to modern reduction of NaOCl because the range of concentration is between 0.1 to 6%, so 2.5% concentration is less toxic, more biocompatible and had a good solvating and antibacterial actions similar to 5.25%.⁽³⁴⁾ The concentration 2.5 % NaOCl was used because NaOCl is highly toxic to vital tissues at undiluted high concentrations. At higher concentration, for example, 1:10 (vol/vol) dilution, the tissue irritation may be substantial⁽³⁵⁾ and displacing highly concentrated NaOCl into periapical tissues can cause severe tissue damage.⁽³⁶⁾ Also there is some dispute regarding the most effective concentration of NaOCl, although theoretically the concentration should be kept to the lowest level that is effective. When used in contaminated canals of extracted teeth, Siqueira *et al.* (2000). found no difference in the antibacterial effect of 1%, 2.5% and 5.2% NaOCl.⁽⁷⁾

Both concentrations of 4% papain and 20% castor detergent were selected according to study of different concentrations for both materials and measurement the inhibition zone to determined the optimum concentration for the antibacterial action of the solution. The results showed that the optimum concentration was 4% papain and 20% castor detergent which give similar inhibition zone to the 2.5% NaOCl. Also the concentrations of MCP solution

constituent were chosen according to the ability to remove smear layer by using scanning electron microscope (SEM), other part of Study.

Also the root canal sampling was done using endodontic file with engagement in the apical part to ensure good sampling from dentin particles from the apical area. The concentration of papain enzyme 4% and castor detergent 20% in MCP solution was selected according to pilot studies to get maximal anti-bacterial action, the ability to remove smear layer, and surface tension of solution (other part of the study). Table (1) showed that MCP solution has antimicrobial activity identical to that of 2.5 % NaOCl in which both of them completely eradicate the microbial inoculation of all samples of both MCP and NaOCl solutions, so MCP solution is a promising endodontic irrigant solution which could overcome many disadvantages of NaOCl. The two component of MCP solution was selected to remove both organic and inorganic (papain enzyme for organic part and castor detergent for inorganic part) component of smear layer which is produced during root canal instrumentation.

The castor oil detergent acts by breaking sugar leakage of the cellular wall of pathogenic microorganisms, consequently the loss of cytoplasmic material leads to cell destruction.^(37,38) Also the papain enzyme has a well-known bacteriocidal, bacteriostatic and antiinflammatory activity and it is possibly make a synergistic effect to kill bacteria by affecting the protein of its cell membrane.⁽²⁴⁾ These results coincide with the results of Ferreira *et al* (1999).⁽²¹⁾ Leonardo *et al* (2001)⁽²²⁾ who found that 3.3% castor oil solution and 0.5% sodium hypochlorite showed similar antimicrobial action and Papaine gel (0.4%) presented less antimicrobial action on all the microorganisms evaluated.⁽²⁶⁾

CONCLUSIONS

Within the limitation of this invitro study, it is concluded that mixture of 20% castor detergent and 4% papain enzyme (MCP) as endodontic irrigant solution has a strong antibacterial action that completely eradicate *Enterococcus faecalis* from the

infected root canals when applied for 5 mints, it's antibacterial action is similar to that 2.5% NaOCl.

REFERENCES

1. Ricucci D, Siqueira Jr., J.F. Biofilms and apical periodontitis: study of prevalence and association with clinical and histopathologic findings. *J Endod.* 2010; 36:1277-88.
2. Bystrom A, Sundqvist G. Bacteriologic evaluation of the effect of 0.5 percent sodium hypochlorite in endodontic therapy. *Oral Surg Oral Med Oral Pathol.* 1983;55:307-12.
3. Sen BH, Safavi KE, Sphgberg LSW. Antifungal effects of sodium hypochlorite and chlorhexidine in root canals. *J Endodon.* 1999; 25:235-8.
4. Leonardo MR, Leal JM. Endodontia. Tratamento de canais radiculares. 3rd ed. SLo Paulo: Ed M6dica Panamericana. 1998; 1:908.
5. Siqueira Jr., J.F., Rocas IN. Exploiting molecular methods to explore endodontic infections: Part 2-Redefining the endodontic microbiota. *J Endod .* 2005; 31:488-98.
6. Walker A. Definite and dependable therapy for pulpless teeth. *J A D A.* 1936 ; 23:1418-24.
7. Siqueira Jr., J.F., Rôças IN, Favieri A, Lima KC. Chemomechanical reduction of the bacterial population in the root canal after instrumentation and irrigation with 1%, 2.5% and 5.25% sodium hypochlorite. *J Endod.* 2002; 26:331-4.
8. Siqueira Jr., J.F., Treatment of endodontic infections. London: Quintessence Publishing, 2011. January 31, 416 pages; Publisher: Quintessence Pub Co; 1st edition.
9. Fouad AF. The microbial challenge to pulp regeneration. *Adv Dent Res.* 2011; 23:285-289.
10. Tartari T, Souza P, Almeida B., Júnior J, Pessoa O, Junior M. A new weak chelator in endodontics: Effects of different irrigation regimens with etidronate on root dentin microhardness. Hindawi publishing corporation. *Int J. Dentistry.* 2013; 743018, 6pages.

11. Bowden JR, Ethunandan M, Brennan PA. Life-threatening airway obstruction secondary to hypochlorite extrusion during root canal treatment. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2006; 101(3):402-4.
12. Markose G, Cotter CJ, Hislop WS. Facial atrophy following accidental subcutaneous extrusion of sodium hypochlorite. *Br Dent J.* 2009; 206(5):263-4.
13. Pelka M, Petschelt A. Permanent mimic musculature and nerve damage caused by sodium hypochlorite: a case report. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2008; 106(3):80-3.
14. Linden J. When Irrigation Leads to Litigation. *Dental Products Report.* Sept. 2010; 75-81.
15. Clarkson RM, Moule AJ, Podlich HM. The shelf-life of sodium hypochlorite irrigating solutions. *Aust Dent J.* 2001; 46:269-76.
16. Piskin B, Turkun M. Stability of various sodium hypochlorite solutions. *J Endod.* 1995; 21:253-5.
17. Little JW. Complementary and alternative medicine: impact on dentistry. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2004; 98:137-45.
18. Sundqvist G, Johansson E, Sjogren V. Prevalence of black-pigmented bacterioides species in root canal infections. *J Endod.* 1999; 15(1):13-9.
19. Camargo CH, Camargo SE, Valera MC, Hiller KA, Schmalz G, Schweikl H. The induction of cytotoxicity, oxidative stress, and genotoxicity by root canal sealers in mammalian cells. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2009; 108(6):952-60.
20. Camargo SE, Camargo CH, Hiller KA, Rode SM, Schweikl H, Schmalz G. Cytotoxicity and genotoxicity of pulp capping materials in two cell lines. *Int Endod J.* 2009; 42(3):227-37.
21. Ferreira CN, Bonifácio KC, Froner IC, Ito IY. Evaluation of the antimicrobial activity of three irrigating solutions in test with pulpal necrosis. *Braz Dent J.* 1999; 10:15-21.
22. Leonardo MR, Silva LA, Tanomaru Filho M, Bonifácio KC, Ito, IY. In vitro evaluation of the antimicrobial activity of a castor oil. based irrigant. *J Endod.* 2001; 27(12):717-9. Iraqi Virtual library.
23. Maragakis GM, Hahn P, Hellwig E. Chemomechanical caries removal; a comprehensive review of literature. *Int Dent J.* 2001; 51,(4):291-9.
24. Bussadori SK, Guedes CC, Ram D. Chemo – mechanical Removal of caries in an Adolescent patient using a papain gel. *J. Clin. Pediatric Dent.* 2008; 32: 177-180.
25. Bhardwaj A, Ballal S, Velmurugan N. Comparative evaluation of the antimicrobial activity of natural extracts of *Morinda citrifolia*, papain and aloe vera (all in gel formulation), 2% chlorhexidine gel and calcium hydroxide, against *Enterococcus faecalis*: An in vitro study. *J Conserv Dent.* 2012; 15(3):293-7.
26. Schneider SW. A comparison of canal preparations in straight and curved root canals. *Oral Surg Oral Med Oral Pathol* 1971;32:271–5.
27. Torabinejad M, Khademi AA, Babagoli J. A new solution for the removal of the smear layer. *J Endod.* 2003; 29 (3):170–5.
28. Neelakantan P, Subbarao C., Sharma S, Subbarao CV. Garcia-godoy James L Guntmann Effectiveness of curcumin against *Enterococcus faecalis* biofilm *Acta Odontologica Scandinavica*, 2013 Early Online, 1–5.
29. Garcez AS, Núñez SC, Marques JL, Jorge AOC, Ribeiro MS, Paulo S, and Taubaté. Efficiency of NaOCl and laser-assisted photosensitization on the reduction of *Enterococcus faecalis* in vitro. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2006; 102(4): 93-98.
- 30-Yim N, Jung YP, Cho WK, Kim T, Kim A, Minju Im, Yeul Ma J. Screening of aqueous extracts of medicinal herbs for antimicrobial activity against oral bacteria. *Integrative Medicine Research* (2013) 2: 18–24
31. Bansal R , Jain A, Mittal S, Kumar T, Jindal N, Kaur D. A Comparison Of The Antibacterial Efficiency Of MTAD (Mixture Of Tetracycline, Citric Acid And Detergent), 2.5% Sodium Hypochlorite And 2% Chlorhexidine Root Canal Irrigants Against *Enterococcus Faecalis* In Root Canals Of Single Rooted Mandibular Premolars. An In Vitro Study. *J. Den. Med.Sci.* 2013; (5): 3, 47-53.
32. Ricucci D, Siqueira JF Jr. Biofilms and apical periodontitis: study of prevalence and association with clinical and

- histopathologic findings. *J Endod.* 2010; 36:1277–88.
33. Haapasalo M, Orstavik D. In vitro infection and disinfection of dentinal tubules. *J Dent Res.*1987; 66:1375–9.
34. Gomes-Filho JE, Aurélio KG, Costa MM, Bernabé PF. Comparison of the biocompatibility of different root canal irrigants. *J Appl Oral Sci.* 2008; 16 (2):137-44.
35. Pashley EL, Birdsong NL, Bowman K, Pashley DH. Cytotoxic effects of NaOCl on vital tissue. *J. Endodo.* 1985; 11(12):525-8.
36. Hulsmann M, Hahn W. Complications during root canal irrigation—literature review and case reports. *Int. Endod. J.* 2000; 33(3):186-93.
37. Ferreira CM, Bonifacio KC, Frijner IC, Ito IY. Evaluation of the antimicrobial activity of three irrigating solutions in teeth with pulpal necrosis. *Braz Dent J.* 1999; 10:15-21.
38. Ito I, Froner IC, Mian H, Chierece GO. Castor oil: antimicrobial activity of detergent derived from ricinolic acid. *J Dent Res.* 1999; 78:344-345.