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STUDY THE EFFECT OF USING BOSWELLIC ACID AS INTRACANAL MEDICAMENT ON MICROHARD-NESS OF ROOT DENTINE

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ABSTRACT

Introduction:. Boswellic acid (BA) is a recently introduced antibacterial agent against root canal infections; however, it is yet unclear how this agent would affect the microhardness of root dentine. Therefore, this study's objective was to compare the effects of using boswellic acid as an intracanal medicament (ICM) with the regularly used one, calcium hydroxide ($Ca(OH)_2$) in terms of the microhardness of root dentine.

Material and methods: Sixty single-rooted teeth were sectioned at the cemento-enamel junction (CEJ) level and root canals were prepared till apical size of #30. The prepared teeth were allocated into three groups (n=20): control group, $Ca(OH)_2$ group and Boswellic acid group. After seven days, medicaments were removed using standardized volume of irrigation. All teeth underwent longitudinal sectioning in a bucco-lingual plane and were embedded horizontally in auto-polymerizing acrylic resin with their dentine surface exposed. Microhardness assessment was performed using Vickers microhardness tester with magnification of 100× and a load of 25 g for 10 second.

Results: Both control and Boswellic acid groups ”at the coronal and middle sections« showed significantly greater microhardness compared to $Ca(OH)_2$ group ($P \leq 0.05$), with no significant difference between them. At the apical third, no significant difference ($P \geq 0.05$) was recorded between the three groups regarding microhrdness.

Conclusion: Under the limitations of the current study, Boswellic acid didn't reduce the root dentine microhardness in comparison with $Ca(OH)_2$ when used as ICM.

KEYWORDS: Boswellic acid, Calcium hydroxide, Intracanal medicaments, microhardness.

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INTRODUCTION

Apical periodontitis is a local inflammation of the periapical tissues caused by invasion of bacteria from infected root canals. The result of the root canal treatment (RCT) approach is mainly reliant on the removal of inflamed and necrotic pulp tissue and infected debris from the root canal system (RCS), as well as chemically by using chemicals as antibacterial irrigates and medicamens to cause disinfection of the root canals and induce maximum reduction in the bacterial growth within the RCS.[1]

Of note, CAE$(OH)_2$ is the most broadly used intracanal dressing in dental medicine secondary to its antibacterial and biologic characteristics.[2] $Ca(OH)_2$ powder is added to different vehicles for canal medications, which include distilled water (dH2O), saline (NaCl 0.9%), and local anaesthesia.[3] When a medicament is placed the root canal wall dentine is subject to the effect of the material and such associations of $Ca(OH)_2$ substances could induce different surface changes on root dentine. [4]

In vitro researches demonstrated that using the ICM $Ca(OH)_2$ adversely interferes with dentin characteristics, for example, the dentin microhardness,[5,6] and the root fracture resistance of removed teeth.[7,8] Such weakening is accompanied by the recorded 36% incidence of root fractures in cases being submitted to prolonged management with $Ca(OH)_2$ ICM.[8,9] The effects of $Ca(OH)_2$ against Enterococcus faecalis are controversial. Additionally, the increasing rate of unpredictable cytotoxic reactions and the inefficiency of commercially available medicines to prevent microflora efficiently from the deeper layers of dentinal tubules have led to a necessity for the authors to search for an alternative. [10,11]

Because of the strong anti-bacterial activity, anti-inflammatory, and antioxidant properties of herbal or natural products, they gained much more popularity in recent years. [12] Since the possibility of further bacterial resistance to the antibiotics is greater, the investigators are encouraging the use of other therapeutic modalities in the context of oral disorders.[13~18] As a result, the natural phytochemical agents derived from plants utilized in conventional medicine are regarded as promising substitutions for synthetic chemical agents.

Boswellia, a genus in the Burseraceae family, is one of the few studied plants having antibacterial and antibiofilm properties that have been utilized for millennia. There are 43 species of Boswellia known, and their essential oil efficacy varies.[19] Boswelia serrata is broadly utilized in the food and food perfume as well as in the flavor industries.[20] Boswellic acids (BA) have been considered the primarily ingredient in Boswelia and represent about 30 per cent of the resin contents. BA, and acetyl-11-keto-β-BA play important role with regard to malignant cell apoptosis (brain tumours, leukaemia, cells in colorectal cancer).[21] Essentially, these compounds are all characterized by having a high level of biologic activities.[22] Boswellia extract is utilized for treatment of arthritis,[23,24] inflammatory disorders,[25,26] and asthma.[27]

With regard to dental field, Boswellia extract is efficient against Gram-ve bacteria, that ultimately ends in periodontitis.[28] El-Essawy et al. [29] studied the penetrating depth and the efficiency of Boswellia as a new ICM compared to $Ca(OH)_2$ against Enterococcus faecalis biofilm. They found proper antibacterial action and the depth of penetration of Boswellia extends beyond that of $Ca(OH)_2$ thus, it is considered as an effective ICM. Amer et al.(30) evaluated the effect of acetyl-11-keto-β-BA (AKBA) on DPSCs viability and proliferation to be utilized as a possible RCT, they indicated superior cell viability by BA more than TAP and $Ca(OH)_2$ Aldandan et al.(31) studied the osteogenic differentiation of AKBA on BMMSCs as a possible treatment to facilitate the healing after peri radicular surgery, they indicated that AKBA has no toxicity on BMMSCs viability and proliferation with positive impact on BMMSC osteogenic differentiation. Hence, we aimed to assess the effect of using BA as ICM on microhardness of root dentine, compared with the frequently utilized ICM $Ca(OH)_2$.

MATERIALS AND METHODS

Ethical considerations

The current study was directed after the approval of the ethical committee, Faculty of Dentistry, Mansoura University (ID: M04050422). Sixty freshly extracted single-rooted human teeth were assembled from cases after being given informed consent. The teeth were extracted due to orthodontic and periodontal issues. Teeth were radiographed to be selected according to the following inclusion criteria: single rooted single canaled teeth, mature apex with patent foramina, absence of calcification through canal system, and no sign of internal or external resorption.

Teeth Preparation

The teeth were cleansed using sodium hypochlorite (NaOCl) solution in addition to ultrasonic cleaner to remove tissue debris. They were finally kept in dH2O for two days.

The teeth were decoronated at the CEJ level utilizing a diamond saw mounted on a low-speed straight handpiece 40,000 R.P.M to a standardized length of 16 mm under water coolant [32]. After access opening, they were mechanically prepared by ProTaper Gold nickel titanium (Niti) rotary system based on the manufacturer's instructions till apical size of #30 using a rotary endo motor. Each NiTi rotary file was used to prepare five teeth. After each rotary file cleaning, irrigation with two mL of 2.5% NaOCl was performed, followed by 2 mL of NaCl 0.9% to remove all dentine debris.[32]

After the teeth were prepared mechanically, they were haphazardly allocated into three groups (n=20). Control group: in which samples were treated with NaCl 0.9% irrigation only. $Ca(OH)_2$ group in which the $Ca(OH)_2$ placed by the tip of the ready-made injectable paste. For Boswellic acid group: Boswellic acid is applied through using sterile plastic syringe (The boswellic acid GEL was formulated in the department of pharmacognosy, faculty of pharmacy, Mansoura university). The gel was made using a specified amount of carbopola and the concentration of the boswellic acid employed was 25 microgram/ml. To make sure that the medicament filled all the canal and got in contact with all walls, excess medicament was extruded beyond the apex. Finally, intermediate restorative material was utilized in thickness of 3 mm to seal the access cavity.[32] All the samples were successfully prepared for the test with no failure.

Samples preparation for root dentine micro-hardness assessment:

Prepared teeth were sectioned lengthwise in a bucco-lingual plane after the removal of the medicaments.[33] Sectioning was done by low-speed precision cutter 4000. After sectioning into two halves, they were embedded horizontally in self-curing resin with their dentine surface upward. Then dentine surface of the fixed samples was flattened and smoothed using a sequence of carbide finishing sandpapers with ascending grades under flushing dH2O to eliminate any surface scrapes. Finally, to get a smooth polished mirror-like surface, samples were polished utilizing 0.1mm alumina suspension with a rotatory felt polishing disc.

Dentine microhardness assessment (Vickers test)

Using Wilson hardness tester, a load of 25 g was put on gently, without heavily imposing the indenter to the samples. The indenter was held in position for 10 s. The microhardness measurements were taken at three mm, six mm, and nine mm from the root apex, which corresponded to each root area, at 0.5 mm from the canal lumen. For accurate measurements, the physical quality of the indenter must be checked up and the applied load must be under control. After removal of the load, the produced indentation was focused using the magnifying eye piece [Figure 1]. Then, two impression diagonals were calibrated to the nearest 0.1-µm using a micrometre and averaged.[34]

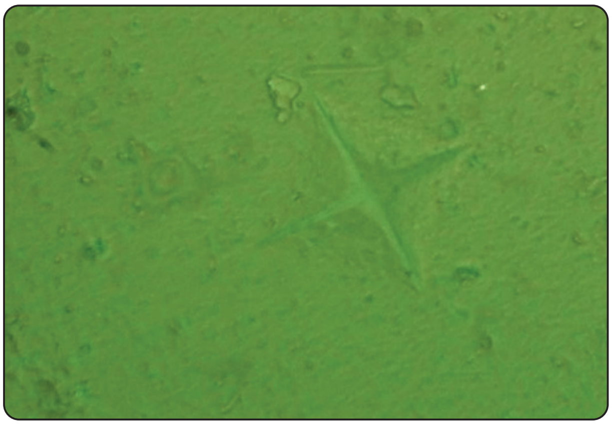

Fig. (1): An example of the magnified indentations.

The microhardness (HV) calculation could be done by utilizing: HV = 1854.4L/d2

The load (L) was in gram force (gf) and the average diagonal (d) was in µm. This provided the hardness number units of gf/µm2, while in practice the numbers were described without indication of the units. Microhardness measures were recorded on the buccal side, and they were detected at three various levels for each sectioned sample. At each level three measures were recorded. Then, their mean was calculated for the analysis.

Statistical analysis

The data were analysed using IBM-SPSS software (IBM Corp. Version 27.0, Armonk,NY). The normality of the data was verified with the Shapiro-Wilk's test. Data were expressed as mean and SD. ANOVA test then post-hoc test was utilized for both intergroup comparison and intragroup comparison at different sections. In terms of the previously utilized tests, p is considered significant when its value was less than 0.05.

RESULTS

Vickers test Results

This study involved sixty teeth allocated into three equal groups (n=20): Control, $Ca(OH)_2$ and Boswellic acid. The microhardness of the root dentine was tested for each sample at three different sections: coronal, middle, and apical. The data were expressed in the form of mean±SD.

At the coronal and middle sections, the microhardness in control and Boswellic acid groups was significantly higher than that in the $Ca(OH)_2$ group ($P \leq 0.05$). There was no significant difference between both groups at coronal and middle sections ($P \geq 0.05$). At the apical section, ANOVA test demonstrated that no significant difference was noticed between the tested groups regarding dentine microhardness ($P \geq 0.05$) [as demonstrated in table[1].

TABLE (1) Comparison of intergroup microhardness at three distinct levels (coronal, middle, and apical).

Site	Groups			P-Value
	Control	$Ca(OH)_2$	Boswellic acid	
Coronal	$49.56^{A} \pm 4.3$	$42.17^{B} \pm 5.26$	$47.94^{A} \pm 1.64$	< 0.0001*
Middle	$47.55^{A} \pm 3.92$	$42.2^{B} \pm 6.25$	$47.7^{A} \pm 3.84$	0.0006*
Apical	$45.09^{A} \pm 4.07$	$43.98^{A} \pm 3.33$	$44.62^{A} \pm 3.89$	0.6493

Data expressed as mean ± SD. P: Probability *: significance ≤0.05. Different superscript letters indicate significance difference between groups.

DISCUSSION

Intracanal medications (ICM) play an important contribution in disinfecting the RCS, as conventional cleaning and shaping is inadequate to irradicate remaining bacteria that can proliferate in-between endodontic visits.[35] Ideally, physico-mechanical criteria of root dentine like hardness, elasticity, and flexural strength should not be affected by ICM. Also, it should be non-harmful to periapical surrounding tissues. However, some root canal dressing was found to adversely act on vital criteria of root dentine, like microhardness.[36] ICM such as $Ca(OH)_2$ utilized in RCT were found to reduce the dentine flexure strength, resistance to fracture and microhardness. Therefore, they may negatively interfere with the physico-mechanical properties of root dentine. [37-41] In addition, they were found to affect the chemical structure of root dentine. [42-45] Microhardness could provide an indirect clue about mineral change of dental mineralized tissue because it relies on the calcified matrix volume in a square of millimeter.[46]

It has been demonstrated that investigators used herbal materials to evade the cytotoxic action of several irrigates and medicaments and to prevent bacterial overgrowth that was particularly detected within dentinal tubules of RCS. Novel therapeutic modalities have emphasized using the extracts of natural plants. BAs have been considered active components of the plant Boswella serrata, known for its efficiency in the context of numerous inflammatory disorders. Such acids demonstrated their strong anti-inflammatory, antibacterial activities. Mush research was conducted to evaluate its role as the ICM, [47,29,30] Laboratory studies have to be conducted prior to utilizing novel medicaments to assess the advantages and adverse events. As a result, our study aimed to compare the effects of utilizing BA as an ICM with the commonly used $Ca(OH)_2$ medicament.

In the current study, single-rooted teeth have been selected for standardization, because this presents a vital role in improving the reliability of the hardness testing.[48] Each NiTi rotary file was used to prepare five teeth because of the high cyclic fatigue resistance of ProTaper Gold files.[49] In addition, mechanical preparation was done minimally to apical size of (#30) to reduce changes in dentine collagen composition and thus, reducing microhardness changes resulting from mechanical preparation.[50] Teeth sectioning was done longitudinally in a bucco-lingual direction because of the higher thickness of root dentine at the later direction which is suitable for accurate measurements and simulation of the clinical situations.[51] Vickers microhardness test was employed in our study because it is an acceptable and easy method to estimate the surface alterations in deeper hard dental tissues.[52] Also, it is extremely sensitive to measuring errors, less affected by surface conditions and could be applied on small samples.[53] The indentations were done usually to the nearest 0.5mm from root dentine surface for standardization and to provide accurate assessment of the root dentine which is in contact with the medicament.[54,55]

In the present study, the inter-group comparison between both control and $Ca(OH)_2$ groups great changes of microhardness at the level of coronal and middle third was detected, which means that $Ca(OH)_2$ was associated with a significant decrease in microhardness of root dentine following one week in comparison with control group at the coronal and middle thirds. This outcome was in the same line with Yoldas et al. [56] who demonstrated that the $Ca(OH)_2$ ICM diminished the microhardness of the root dentine, they attributed that to the proteolytic actions of the $Ca(OH)_2$. As the increased pH which is noticed following $Ca(OH)_2$ application can minimize the organic support of the dentine resulting in protein breakdown and interruption in the connections between both the collagen fibres and the hydroxyapatite dental material, that may adversely interfere with the mechanical characteristics of root dentine.

In addition, Andreasen et al. [57] were in agreement with the theory of the proteolytic effects of $Ca(OH)_2$ on root dentine, as they found that the $Ca(OH)_2$ weakened a tooth up to fifty per cent in their study, and this weakness might result in increase in fracture.[55] Moreover, White et al. [46] found that dentine strength decreased by about 32% after $Ca(OH)_2$ medicament application and illustrated by the breakdown of protein structures of root dentine due to the higher alkalinity of $Ca(OH)_2$. Although, $Ca(OH)_2$ is the most broadly utilized RCT, it was reported by Yaseen et al. that it caused reduction in the root dentine microhardness from moderate to intermediate level which was in accordance with our findings.[50] A possible reason for this reduction could be attributed to the denaturation to the organic matrix and the interruption of the dentine inorganic structure because of the higher alkaline inorganic molecule. Another reason, may be due to the penetration of $Ca(OH)_2$ with their minute molecular size through the intrafibrillar structure of the mineralised collagen fibrils, causing variations in the three-dimensional configurations of tropocollagen, resulting in minimized microhardness of the dentine which agrees with Leiendecker and colleges.[58] Hassan and Khalaf [59] stated that $Ca(OH)_2$ showed the significantly lowest dentine microhardness values after 1 week. This result agrees with the findings found by Seyed et al. [60] as he concluded that the $Ca(OH)_2$ medicament created structural changes in the root dentine that was accompanied by a reduction in the dentine microhardness.

In the current study although the reduction in the microhardness when using $Ca(OH)_2$ was detected at the coronal and middle levels in comparison to the control group, no obvious difference was recorded between them at the apical third, this finding may be explained by previous studies.[61-64] that reported that there was a change in the microhardness levels of the three sections. Reductions in microhardness levels were higher in the coronal 1/3 compared to the apical 1/3. The potential cause for this may be that the microhardness of dentin is based on the tubular density that differs among areas. The tubular density interferes with microhardness, as when it raises (coronal section), dentin microhardness diminishes.

Root dentine microhardness (RDM) testing offers information about the increase or loss in minerals as it mainly reliant on the degree of calcified matrix/mm. As a result, a diminished RDM value displays the softening action of the ICM on the root dentine. Due to the reduction in RDM, such comparative softening action negatively interferes with the sealing ability of endodontic sealers to the root dentine and ultimately affects the quality of endodontic therapies. [46] Of note, till now no previous studies have assessed the actions of boswellia when utilized as an ICM on the dentine microhardness compared to $Ca(OH)_2$, and as a result, such a parameter was chosen to be assessed in the current study.

In the context of Boswellic acid effects on dentine microhardness, our study displayed that no obvious difference was recorded in dentine microhardness between the control group without medication and boswellic acid treated teeth at the 3 levels, the rationale behind this similarity can be attributed to the inherent nature of BA pure plant extract that prevent any adverse effect on dentin. Moreover, the positive effect of BA and dentin microhardness is clear, as it was previously confirmed that it has the capability for inhibiting matrix metalloprotinase MMps action, which stimulates dentin organic matrix decomposition.[65-67] The findings of the current research suggested that, while boswellic acid didn't harm the root dentine when used as ICM, further studies is indicated to support its use in endodontics.

CONCLUSION

Within the limitations of this steady , Boswellic acid application to the root dentine did not reduce root dentine microhardness compared to Ca(OH)2. Consequentially, boswellic acid may be considered a talented ICM owing to its previously reported antibacterial action against microbes in the root canal and absence of dentin microhardness reduction.

REFERENCES

1. Rôças IN, Siqueira Jr JF. Comparison of the in vivo antimicrobial effectiveness of sodium hypochlorite and chlorhexidine used as root canal irrigants: a molecular microbiology study. J Endod 2011; 37:143 -50.

2. Ghabraei S, Bolhari B, Yaghoobnejad F, Meraji N. Effect of intra-canal calcium hydroxide remnants on the push-out bond strength of two endodontic sealers. Iran. Endod. J 2017; 12:168.

3. Öztan MD, Akman A, Dalat D. Intracanal placement of calcium hydroxide: a comparison of two different mixtures and carriers. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2002; 1; 94(1):93-7.

4. Yoldaş O, Doğan C, Seydaoğlu G. The effect of two different calcium hydroxide combinations on root dentine microhardness. Int. Endod. J 2004; 37(12):828-31.

5. Leiendecker AP, Qi YP, Sawyer AN, Niu LN, Agee KA, Loushine RJ, Weller RN, Pashley DH, Tay FR. Effects of calcium silicate–based materials on collagen matrix integrity of mineralized dentin. J. Endod 2012; 1; 38(6):829-33.

6. Yilmaz S, Dumani A, Yoldas O. The effect of antibiotic pastes on microhardness of dentin. Dent Traumatol 2016; 32(1):27-31.

7. Andreasen JO, Farik B, Munksgaard EC. Long-term calcium hydroxide as a root canal dressing may increase risk of root fracture. Dent Traumatol 2002; 18(3):134-7.

8. Yassen GH, Vail MM, Chu TG, Platt JA. The effect of medicaments used in endodontic regeneration on root fracture and microhardness of radicular dentine. Int. Endod. J 2013; 46(7):688-95.

9. Cvek M. Prognosis of luxated non-vital maxillary incisors treated with calcium hydroxide and filled with gutta-percha. A retrospective clinical study. Dent Traumatol 1992; 8(2):45-55.

10. Evans MD, Baumgartner JC, Khemaleelakul SU, Xia T. Efficacy of calcium hydroxide: chlorhexidine paste as an intracanal medication in bovine dentin. J. Endod 2003; 1; 29(5):338-9.

11. Williams JM, Trope M, Caplan DJ, Shugars DC. Detection and quantitation of E. faecalis by real-time PCR (qPCR), reverse transcription-PCR (RT-PCR), and cultivation during endodontic treatment. J. Endod 2006; 1; 32(8):715-21.

12. Lee JK, Kwak SW, Ha JH, Lee WC, Kim HC. Physicochemical Properties of Epoxy Resin-Based and Bioceramic-Based Root Canal Sealers. BioinorgChem Appl 2017; 2017:2582849.

13. Badr AE, Omar N, Badria FA. A laboratory evaluation of the antibacterial and cytotoxic effect of Liquorice when used as root canal medicament. International endodontic journal. 2011 Jan;44(1):51-8.

14. Alrashidi MA, Badawi MF, Elbeltagy MG, Badr AE. The Effect of Glycyrrhizin on the Viability and Proliferation of Dental Pulp Stem Cells Compared to Intracanal Medicaments. The Journal of Contemporary Dental Practice. 2024 Apr 19;25(3):267-75.

15. Alazemi MJ, Badawi MF, Elbeltagy MG, Badr AE. Examining the Effects of Asiaticoside on Dental Pulp Stem Cell Viability and Proliferation: A Promising Approach to Root Canal Treatment. The Journal of Contemporary Dental Practice. 2024 Feb 1;25(2):118-27.

16. Alhaila KA, Badawi MF, Elbeltagy MG, Badr AE. In Vitro Evaluation of the Effect of Oleanolic Acid as a Potential Root Canal Medicament on Viability and Proliferation of Dental Pulp Stem Cells. European Journal of General Dentistry. 2024 Jan;13(01):051-9.

17. Gomaa MA, Elhawary YM, Badr AE. Glycyrrhizin enhances the proliferation of diabetic bone marrow-derived mesenchymal stem cells: A potential therapeutic agent in endodontic surgery. J Contemp Dent Pract. 2023 Aug 19;24(7):494-9

18. Othman NM, Elhawary YM, Elbeltagy MG, Badr AE. The effect of Rosmarinus officinalis as a potential root canal medication on the viability of dental pulp stem cells. The Journal of Contemporary Dental Practice. 2023 Oct 13;24:623-31.

19. Camarda L, Dayton T, Di Stefano V, Pitonzo R, Schillaci D. Chemical Composition and Antimicrobial Activity of Some Oleogum Resin Essential Oils from Boswellia SPP. (Burseraceae). Ann. Chim 2007; 97, 837–844.

20. Ayub MA, Hanif MA, Sarfraz RA, Shahid M. Biological activity of Boswellia serrata Roxb. oleo gum resin essential oil: Effects of extraction by supercritical carbon dioxide and traditional methods. Int. J. Food Prop 2018; 21, 808–820.

21. Raja AF, Ali F, Khan IA, Shawl AS, Arora DS, Shah BA, et al. Antistaphylococcal and biofilm inhibitory activities of acetyl-11-keto-boswellic acid from Boswellia serrata. BMC Microbiol 2011; 11, 54.

22. Al-Harrasi A, Avula SK, Csuk R, Das B. Cembranoids from Boswellia species. Phytochem 2021; 191, 112897.

23. Singh S, Khajuria A, Taneja SC, Khajuria RK, Singh J, Qazi GN. Boswellic acids and glucosamine show synergistic effect in preclinical anti-inflammatory study in rats. Bioorgan. Med. Chem. Lett 2007; 17, 3706–3711.

24. Prasad S, Kulshreshtha A, Lall R, Gupta SC. Inflammation and ROS in arthritis: Management by Ayurvedic medicinal plants. Food Funct 2021; 12, 8227–8247.

25. Safayhi H, Rall B, Sailer ER, Ammon HP. Inhibition by boswellic acids of human leukocyte elastase. J. Pharmacol. Exp. Ther 1997; 281, 460–463.

26. Safayhi H, Sailer ER, Ammon HP. Mechanism of 5-lipoxygenase inhibition by acetyl-11-keto-beta-boswellic acid. Mol. Pharmacol 1995; 47, 1212–1216.

27. Kimmatkar N, Thawani V, Hingorani L, Khiyani R. Efficacy and tolerability of Boswellia serrata extract in treatment of osteoarthritis of knee–a randomized double blind placebo-controlled trial. Phytomedicine 2003; 10, 3–7.

28. Vahabi S, Hakemi-Vala M, Gholami S. In vitro antibacterial effect of hydroalcoholic extract of Lawsoniainermis, Malva sylvestris, and Boswellia serrata on aggregatibacter actinomycetemcomitans. Adv. Biomed. Res 2019; 8, 22.

29. El-Essawy RH, Al-Ashry S, Sabet NE, Ghobashy AM. Assessment of depth of penetration and antibiofilm properties of Boswellia sacra compared with calcium hydroxide intracanal medicament. A.E.J 2023 ;94, (2) 295-301.

30. Amer NA, Badawi MF, Elbeltagi MG, Badr AE. Effect of Boswellic Acid on Viability of Dental Pulp Stem Cells Compared to the Commonly Used Intracanal Medications: An In Vitro Study. J Contemp Dent Pract. 2023 Dec 1;24(12):957-966. DOI: 10.5005/jp-journals-10024-3609. PMID: 38317393.

31. Aldandan AA, El-Kenawy MH, Al-Sharif AA, Hamam ET, Badr AE. Boswellic acid as a potential adjunct for bone healing after endodontic surgery: In vitro study. Saudi Endod J 2024; 14:224-35. DOI: 10.4103/sej.sej_34_24

32. AgrawalVineet S, Rajesh M, Sonali K, Mukesh P. A contemporary overview of endodontic irrigants–A review. J Dent App 2014; 1:105-5

33. Kachur K, Suntres Z. The antibacterial properties of phenolic isomers, carvacrol and thymol. Crit Rev Food Sci Nutr 2020; 60:3042-53.

34. Dakah A, Maarrouf M. Antileishmanial and antibacterial activity of essential oils of medicinal plant achilleasantolina L. J Bio Sci 2019; 19: 69-76.

35. Shabbir J, Khurshid Z, Qazi F, Sarwar H, Afaq H, Salman S, Adanir N. Effect of different host- related factors on postoperative endodontic pain in necrotic teeth dressed with interappointment intracanal medicaments: A multicomparison study. Eur. J. Dent 2021; 15:152- 157.

36. 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; 6:171-176.

37. Da Silva Beraldo ÂJ, Silva RV, Da Gama Antunes AN, Silveira FF, Nunes E. Scanning electron microscopic evaluation of smear layer removal using isolated or interweaving EDTA with sodium hypochlorite. Iran Endod J 2017; 12:55-59.

38. Gonçalves LS, Rodrigues RC, Andrade Junior CV, Soares RG, Vettore MV. The effect of sodium hypochlorite and chlorhexidine as irrigant solutions for root canal disinfection: A systematic review of clinical trials. J Endod 2016; 42:527-32.

39. Estrela C, Estrela CR, Barbin EL, Spanó JC, Marchesan MA, Pécora JD. Mechanism of action of sodium hypochlorite. Braz Dent J 2002; 13:113-7.

40. Ayad MF. Effects of rotary instrumentation and different etchantson removal of smear layer on human dentin. J Prosth Dent 2001;85: 67–72.

41. Singh S, Singh M, Salgar AR, Chandrahari N, Prathibha N, Koppolu P. Time dependent effect of various irrigants for root canal on smear layer removal. J Pharm Bioallied Sci 2019; 11:51-58.

42. Estrela C, Lopes HP, Elias CN, Leles CR, Pécora JD. Cleanliness of the surface of the root canal by apple vinegar, sodium hypochlorite, chlorhexidine and EDTA. Rev Assoc Paul Cir Dent 2007; 61: 177-82.

43. Sharaf NF, Alshareef WA. The Comparative evaluation of the post-antimicrobial effect of MTAD and 2% Chlorhexidine against Enterococcus faecalis of permanent teeth with necrotic pulp. Open Access Maced J Med Sci 2019; 7:3270-75.

44. Shabahang S, Torabinejad M. Effect of MTAD on Enterococcus faecalis contaminated root canals of extracted human teeth. J Endod 2003; 29:576– 9.

45. Asad M, Alhomoud M. Proulcerogenic effect of water extract of Boswellia sacra oleo gum resin in rats. Pharm. Biol 2016 1; 54:225-30

46. White JD, Lacefield WR, Chavers LS, Eleazer PD. The effect of three commonly used endodontic materials on the strength and hardness of root dentin. J. Endod. 2002; 28: 828-830.

47. Raja et al.: Acetyl-11-keto-b-boswellic acid (AKBA); targeting oral cavity pathogens. BMC Research Notes 2011 4:406.

48. Ossareh A, Kishen A. Role of dentin compositional changes and structural loss on fracture predilection in endodontically treated teeth. Univ. of Toronto 2015; 8:1-79.

49. Khaleefah O, El-Souda A, Badr A. Cyclic fatigue and fracture surfaces evaluation of different nickel titanium endodontic files. Egyptian Dental J 2021; 67:883-891.

50. Yassen GH, Eckert JE, Platt JA. Effect of intracanal medicaments used in endodontic regeneration procedures on microhardness and chemical structure of dentin. Restor Dent Endod 2015; 40:104-112.

51. Cruz-Filho AM, Sousa-Neto MD, Savioli RN, Silva RG, Vansan LP, Pécora JD. Effect of chelating solutions on the microhardness of root canal lumen dentin. Endod J 2011; 37:358-362.

52. Fuentes V, Toledano M, Osorio R, Carvalho RM. Microhardness of superficial and deep sound human dentin. J Biomed Mater Res A 2003; 15;66(4):850-3.

53. Saleh AA, Ettman WM. Effect of endodontic irrigation solutions on microhardness of root canal dentine. J Dent 1999; 27(1):43-6.

54. Ulusoy Öİ, Görgül G. Effects of different irrigation solutions on root dentin microhardness, smear layer removal and erosion. AustEndod J 2013; 39:66-72.

55. Kandil HE, Labib AH, Alhadainy A. Effect of different irrigant solutions on microhardness and smear layer removal of root canal dentin. Tanta Dent J 2014; 1:1-11.

56. Yoldas O, Dogan C, Seydaoglu G. The effect of two differentcalcium hydroxide combination on root dentin microhardness. Int Endod J 2004; 37(12):828-831.

57. Andreasen JO, Farik B, Munksgaard EC. Long term calcium hydroxide as a root canal dressing may increase risk of root fracture. Dent Traumatol 2002; 18:134-137.

58. Leiendecker AP, Qi YP, Sawyer AN, et al. Effects of calcium silicatebased materials on collagen matrix integrity of mineralized dentin. J Endod 2012; 38(6):829-833.

59. Hassan R, Khalaf M. Effect of a silver nanoparticle intracanal-based medicament on the microhardness of human radicular dentine. Endo (Lond Engl) 2018; 12(2):125-131.

60. Seyed MH, Sadegh N, Mahmoobe F. The effect of three different calcium hydroxide combinations on the root dentin microhardness. Res J Biol Sci 2009; 4:121-125.

61. Massoud, S.F.; Moussa, S.M.; Hanafy, S.A.; El Backly, R.M. Evaluation of the Microhardness of Root Canal Dentin after Different Irrigation Protocols (in Vitro Study). Alex. Dent. J. 2017, 42,73– 79.

62. Abdelrhman, M.; Mahraan, A.; Bayoumy, A. Impact of Two Nano Irrigating Solutions on Microhardness of Root Canal Dentin. Egypt. Dent. J. 2023, 69, 847–854.

63. Abdelgawad, R.; Fayyad, D. Comparative Evaluation of Smear Layer Removal, Calcium Ions Loss and Dentin Microhardness after Different Final Irrigation Solutions. Egypt. Dent. J. 2017, 63, 3551–3562.

64. Nikhil, V.; Jaiswal, S.; Bansal, P.; Arora, R.; Raj, S.; Malhotra, P. Effect of Phytic Acid, Ethylenediaminetetraacetic Acid, and Chitosan Solutions on Microhardness of the Human Radicular Dentin. J. Conserv. Dent. JCD 2016, 19, 179–183.

65. Blain, E.J., Ali, A.Y. and Duance, V.C. (2010), Boswellia frereana (frankincense) suppresses cytokine-induced matrix metalloproteinase expression and production of pro-inflammatory molecules in articular cartilage. Phytother. Res., 24: 905-912. https://doi.org/10.1002/ptr.3055

66. Roy S, Khanna S, Krishnaraju AV, Subbaraju GV, Yasmin T, Bagchi D, Sen CK. Regulation of vascular responses to inflammation: inducible matrix metalloproteinase-3 expression in human microvascular endothelial cells is sensitive to antiinflammatory Boswellia. Antioxidants & redox signaling. 2006 Mar 1;8(3-4):653-60.

67. Ranzato E, Martinotti S, Volante A, Tava A, Masini MA, Burlando B. The major Boswellia serrata active 3-acetyl-11-keto-β-boswellic acid strengthens interleukin-1α upregulation of matrix metalloproteinase-9 via JNK MAP kinase activation. Phytomedicine. 2017 Dec 1;36:176-82.