

Comparative Evaluation Of Accuracy Of Detection Of Perforation In The Presence Of Various Irrigants Using Different Apex Locators - An In Vitro Study

Research Article

Mulumoodi Rama Sowmya¹, Pradeep^{2*}

¹ Department of Conservative Dentistry and Endodontics, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, India.

² Reader, Department of Conservative Dentistry and Endodontics, Clinical Genetics Lab, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai - 600077, India.

Abstract

Introduction: Cleaning and shaping of the root canal involves cleaning of the canal with irrigating solutions and shaping with instruments. In this process, iatrogenic mishaps such as perforation can occur. Root perforations compromise the success of endodontic therapy and are regarded as one of the most unpleasant accidents to deal with during root canal treatment and are also difficult to diagnose. Radiographic evidence of detection of root perforation is always questionable. Electronic devices such as electronic apex locators can be used for the purpose of determination of perforation.

Irrigation of the canal is an important aspect of endodontic therapy. Saline, EDTA, Sodium hypochlorite and Chlorhexidine digluconate are the commonly used irrigants. But the question arises whether the apex locator can determine the presence of perforation in the presence of various irrigating solutions.

Aim: The aim of the present study is to comparatively evaluate the accuracy of detection of perforation in the presence of various irrigants using different apex locators.

Materials And Methods: Ten extracted, single-rooted human teeth were perforated artificially in the middle section. The actual canal lengths (ALs) up to the perforation site were determined, and then the teeth were embedded in an alginate mold. The teeth irrigated with three different irrigants 17%EDTA, 3% NaOCl and 0.9% Saline, followed by drying with paper points and then determination of perforation with the three apex locators (ROOT ZX, APEX ID, PROPEX PIXI). The electronic measurements of the perforations were obtained using a size 10 K-file by each EAL in various conditions. For each tooth, the AL was subtracted from the electronic length of the perforation.

Results: Among the irrigation solutions in the Root ZX group, Saline gave the most accurate results, and NaOCl gave the least accurate ones. However, the other two apex locators also gave closer values in the presence of saline followed by EDTA and least accurate results were obtained for Sodium hypochlorite. On comparing the total mean values of the irrigants, Root zx(.90+/-0.59)and Apex ID(1.03+/-0.57) showed lower mean values compared to propex pixi(1.4+/-1.01) implying that among the three apex locators, Root ZX detected perforation better followed by Apex ID apex locator.

Conclusion: Within the limitations of the study, it can be inferred that electronic apex locators can be safely used to detect the perforation. But conductive solutions like NaOCl marginally influenced the measurements. Overall, Root ZX detected perforation better followed by Apex ID apex locator.

Keywords: Apex ID; EDTA; Propex pixi; Root ZX; Saline; Sodium Hypochlorite.

Introduction

A root perforation is a non anatomic communication between the root canal and the surrounding periodontal tissues. Such mishaps often comprise the success of endodontic therapy. [1] Hence it is

important to diagnose such mishaps at the earliest. Radiography does not provide sufficient evidence for the detection of perforation.[2, 3]

Ever since an electronic device to determine the working length

*Corresponding Author:

Pradeep,

Reader, Department of Conservative Dentistry and Endodontics, Clinical Genetics Lab, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai - 600077, India.

Tel: 9710404482

E-mail: pandu.pradeep@gmail.com

Received: May 04, 2021**Accepted:** July 29, 2021**Published:** August 02, 2021

Citation: Mulumoodi Rama Sowmya, Pradeep. Comparative Evaluation Of Accuracy Of Detection Of Perforation In The Presence Of Various Irrigants Using Different Apex Locators - An In Vitro Study. *Int J Dentistry Oral Sci.* 2021;8(8):3628-3632. doi: <http://dx.doi.org/10.19070/2377-8075-21000742>

Copyright: Pradeep©2021. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited.

has been introduced by Sunada, various reports have advocated the use of these devices to determine the perforation.[4] EALs are reliable for detecting root perforations.[5] EALs are a useful tool in detecting root perforations. The latest generation apex locators measure alternating impedances at two or multiple frequencies. Moreover they can also work in the presence of canal contents.[6]

The accuracies of EALs in fractured, root resorption and perforation cases have been evaluated in a few studies, but the results reported have been inconsistent.[7] Previously used apex locators were not very precise in the presence of irrigating solutions as they were based on the measurement of resistance between the root canal and the periodontal ligament, whereas the modern generation EALs use two or more different frequencies to calculate the impedance and can work even in the presence of irrigating solutions such as saline and sodium hypochlorite (NaOCl) which are the most commonly used irrigants.[8, 9]

There are six generations of electronic apex locators with specific functions. The latest generation of EALs measure impedances at multiple frequencies and they can also work in the presence of various intracanal contents and irrigants.[10] Different EALs have been recommended for the detection of perforation. Root ZX is the most sought after EAL which is based on the ratio type with dual Frequency (8 and 0.4 kHz). Propex pixi is a fifth generation EAL and Apex ID is a fourth generation EAL.[11]

Dual frequency EALs ROOT ZX, simultaneously uses 2 frequencies, a high (8kHz) and a low(400hz) frequency. (comparative impedance type based on ratio method).[12] PROPEX II has the latest, multi frequency technology incorporated and activates when the file reaches the apical area.[13]

Irrigation is an important aspect of cleaning and shaping. Saline, EDTA, Sodium hypochlorite and Chlorhexidine digluconate are the commonly used irrigants.[14] Previous studies have reported that the presence of root canal contents may influence the measurements recorded by electronic devices.[15] Saline and Sodium hypochlorite are touted to be the electro conductive solutions. Hence there are chances in the deviation of measurements made by apex locators.[16] The aim of this study is to comparatively evaluate the accuracy of detection of perforation in the presence of various irrigants using different apex locators.

Previously our team has a rich experience in working on various research projects across multiple disciplines [17-31] Now the growing trend in this area motivated us to pursue this project.

Materials And Methods

Sample preparation

Ten single rooted teeth were collected. Standard access cavity preparations were made and the incisal edges were flattened to achieve a reproducible reference point. The crown of each tooth was sectioned at the cemento--enamel junction using a diamond disc to establish a surface level to serve as a stable reference point for all the measurements.

Preparation of artificial perforation

A perforation of 0.5-1 mm was made in the middle third at 12 mm from the reference point using a carbide bur. A 10k file was inserted and allowed to be seen through the perforation site under stereomicroscope at 25X magnification.

Preparation of the alginate model

Alginate was poured in a rectangular plastic box. The teeth were embedded in the alginate after the application of ECG gel onto the implantation site. To complete the electrical circuit, an indentation for the placement of lip clip was also made at the edge of the alginate model.

Irrigation of the canal

Three different irrigants (0.9% Saline, 3% NaOCl and 17% EDTA) were used to irrigate the canals. This was followed by thorough drying with paper points before the placement of the file to detect perforation.

Detection of perforation

A 10k file was inserted into the canal and the apex locators were arranged accordingly to detect the perforation. The length at which the perforation was detected was noted.

Results And Discussion

The results of the study are expressed in terms of comparison of accuracy of readings between three different apex locators in the presence of various irrigants. The comparison between three irrigants when using Propex pixi showed p values as follows:(p -0.630 between Sodium hypochlorite and EDTA; p- 0.74 between Sodium hypochlorite and Saline; p- 0.630 between Saline and EDTA). (Figure 1)

Figure 1. Stereomicroscopic view of the perforation.



Figure 2. Bar graph depicting the comparison of three apex locators using three different irrigants.

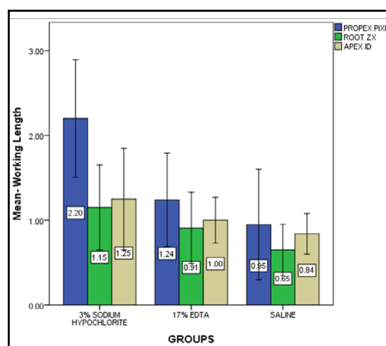


Table 1. Table showing the Mean and Standard deviation of the measurements recorded by the apex locators.

GROUPS	MEAN +/- SD	N
PROPEX PIXI	1.67+/-0.7	10
ROOT ZX	0.95+/-0.8	10
APEX ID	0.96+/-0.5	10
TOTAL	1.19+/-0.7	30

The comparison between the three irrigants when using Root ZX showed p values as follows:(p-0.589 between Sodium hypochlorite and EDTA; p-0.253 between Sodium hypochlorite and Saline; p- 0.583 between Saline and EDTA).

The comparison between the three irrigants using Apex ID showed p values as follows: (p-0.589 between EDTA and Sodium hypochlorite; p-0.803 between EDTA and Saline; p-0.253 between Saline and Sodium hypochlorite).

The results of this study showed that EDTA and Saline gave closer values to the actual length of perforation site compared to Sodium hypochlorite. Among the apex locators, Root ZX and Apex ID managed to give better results compared to PROPEX pixi.

On comparing the total mean values of the irrigants (Table 1), Root zx (.90+/-0.59) and Apex ID(1.03+/-0.57) showed lower mean values compared to propex pixi(1.4+/-1.01) implying that among the three apex locators, Root ZX detected perforation better followed by Apex ID apex locator.

Among the irrigation solutions in the Root ZX group, Saline gave the most accurate results, and NaOCl gave the least accurate ones. However, the other two apex locators also gave closer values in the presence of saline followed by EDTA and least accurate results were obtained for Sodium hypochlorite. Significant differences were noted among the EALs when the measurements were taken with NaOCl, Saline, and EDTA (P< .05).

Root perforations are the unwanted complications that occur during the treatment and often compromise the success of endodontic therapy. Successful repair of perforations depend on the factors such as identification, location of the site of perforation and proper diagnosis of the type of perforation.[32, 33] Root perforations are often difficult to diagnose with radiographic examination.[34] It has been suggested that electronic apex locators (EALs) can precisely determine the location of apical constriction, root resorption and also perforation.[35]

There are six generations of EALs. Root ZX is a third generation apex locator. It shows 97.5% accuracy rate and has the ability to work in wet canals.[36] It uses two different frequencies (8kHz and 0.4kHz) to simultaneously measure the impedance in the canal. The device determines the quotient value.[37] It can be used in all types of fluids as the quotient value is touted to remain the same.[38, 39] Propex pixi is also a multi frequency fifth generation pocket sized EAL but determines the impedance at multiple frequencies. Apex ID is a fourth generation apex locator which is akin to Root ZX but previous in vitro studies have shown its accuracy levels to be marginally lower than Root ZX (93%). [40, 41]

This in vitro study was designed to detect the perforation in the presence of different irrigants. The irrigants used in this study are 3% NaOCl, 17% EDTA and 0.9% Saline.

The media used for embedding the teeth in this study was alginate as it has similar electrical resistance as that of periodontal tissue. The main disadvantage of alginate medium is that it has short working time as it tends to desiccate due to lack of moisture.

The results of this study showed that EDTA and Saline gave closer values to the actual length of perforation site compared to Sodium hypochlorite. Among the apex locators, Root ZX and Apex ID managed to give better results compared to PROPEX pixi. The results are in correspondence with the previous studies conducted.[42] The reason can be attributed to the fact that Sodium hypochlorite is a highly electro conductive solution which can marginally influence the measurements recorded by electronic apex locators.[33]

In a study conducted by Shin et al, the accuracies of the Root ZX in perforated teeth were significantly different between liquid types (saline, NaOCl) and gel types (chlorhexidine gel, RC-Prep). According to the results of the above study,the accuracy in locating root perforation was higher in liquid type irrigant rather than gel based irrigant.[9]

In another study conducted by Sindreu et al, comparison between iPex and Root ZX apex locator was made.[43]The accuracy of the

iPex nor Root ZX EAL was not affected by 2.5% NaOCl or 2% CHX ($P > 0.05$). The iPex was less accurate than the Root ZX in determining the RWL.[44]

In another study by Ikhar et al, statistically insignificant difference existed between DENTAPORT ZX AND PROPEX II apex locators with various canal contents. Among the irrigants 3% NaOCl showed the least accurate results. In the presence of NaOCl, Shabahang et al. evaluated the accuracy of EALs in detecting root perforations and concluded that the largest deviation from ALP was reported with NaOCl.[45]

In a study conducted by Ikhar et al, the accuracy of third generation apex locator (DENTAPORT ZX) and fifth generation apex locator (PROPEX PIXI) was detected in both dry and wet conditions. The results showed that there was a Statistically insignificant difference. Accurate measurements were obtained in dry conditions with accuracy of 75% for DENTAPORT ZX and 60% for PROPEX II apex locators ($P > 0.05$). Whereas among the irrigants 3% NaOCl showed the least accurate results.[45]

Our institution is passionate about high quality evidence based research and has excelled in various fields [21, 46-55]

Conclusion

Within the limitations of the study, it can be inferred that electronic apex locators can be safely used to detect the perforation. But conductive solutions like NaOCl marginally influence the measurements. Overall, Root ZX detected perforation better followed by Apex ID apex locator.

References

- [1]. Khandelwal A, Palanivelu A. Correlation between dental caries and salivary albumin in adult population in Chennai: An in vivo study. *Braz. Dent. Sci.* 2019 Apr 30;22(2):228-33.
- [2]. Janani K, Sandhya R. A survey on skills for cone beam computed tomography interpretation among endodontists for endodontic treatment procedure. *Indian J Dent Res.* 2019 Nov-Dec;30(6):834-838. Pubmed PMID: 31939356.
- [3]. Altunbaş D, Kuştarıcı A, Toyoğlu M. The Influence of Various Irrigants on the Accuracy of 2 Electronic Apex Locators in Locating Simulated Root Perforations. *J Endod.* 2017 Mar;43(3):439-442. Pubmed PMID: 28104321.
- [4]. Siddique R, Nivedhitha MS. Effectiveness of rotary and reciprocating systems on microbial reduction: A systematic review. *J Conserv Dent.* 2019 Mar;22(2):114-22.
- [5]. Mull JP, Manjunath V, Manjunath MK. Comparison of accuracy of two electronic apex locators in the presence of various irrigants: An in vitro study. *J Conserv Dent.* 2012 Apr;15(2):178-82.
- [6]. Ramarao S, Sathyanarayanan U. CRA Grid - A preliminary development and calibration of a paper-based objectivization of caries risk assessment in undergraduate dental education. *J Conserv Dent.* 2019 Mar-Apr;22(2):185-190. Pubmed PMID: 31142991.
- [7]. Shacham M, Levin A, Shemesh A, Lvovsky A, Ben Itzhak J, Solomonov M. Accuracy and stability of electronic apex locator length measurements in root canals with wide apical foramen: an ex vivo study. *BDJ Open.* 2020 Nov 17;6(1):22. Pubmed PMID: 33298851.
- [8]. Govindaraju L, Neelakantan P, Gutmann JL. Effect of root canal irrigating solutions on the compressive strength of tricalcium silicate cements. *Clin Oral Investig.* 2017 Mar;21(2):567-571. Pubmed PMID: 27469101.
- [9]. Shin HS, Yang WK, Kim MR, Ko HJ, Cho KM, Park SH, et al. Accuracy of Root ZX in teeth with simulated root perforation in the presence of gel or liquid type endodontic irrigant. *Restor Dent Endod.* 2012 Aug 1;37(3):149-54.
- [10]. Muthu MS, Sivakumar N. Accuracy of electronic apex locator in length determination in the presence of different irrigants: An in vitro study. *J Indian Soc Pedod Prev Dent.* 2006 Oct 1;24(4):182.

- [11]. Malli Sureshbabu N, Selvarasu K, V JK, Nandakumar M, Selvam D. Concentrated Growth Factors as an Ingenious Biomaterial in Regeneration of Bony Defects after Periapical Surgery: A Report of Two Cases. *Case Rep Dent.* 2019 Jan 22;2019:7046203. Pubmed PMID: 30805222.
- [12]. Jenarthanan S, Subbarao C. Comparative evaluation of the efficacy of diclofenac sodium administered using different delivery routes in the management of endodontic pain: A randomized controlled clinical trial. *J Conserv Dent.* 2018 May-Jun;21(3):297-301. Pubmed PMID: 29899633.
- [13]. Saraf PA, Ratmakar P, Patil TN, Penukonda R, Kamatagi L, Vanaki SS. A comparative clinical evaluation of accuracy of six apex locators with intraoral periapical radiograph in multirrooted teeth: An in vivo study. *J Conserv Dent.* 2017 Jul-Aug;20(4):264-268. Pubmed PMID: 29259365.
- [14]. Marek E, Łagocka R, Kot K, Woźniak K, Lipski M. The influence of two forms of chlorhexidine on the accuracy of contemporary electronic apex locators. *BMC Oral Health.* 2019 Dec 31;20(1):3. Pubmed PMID: 31892327.
- [15]. Poorni S, Srinivasan MR, Nivedhitha MS. Probiotic Streptococcus strains in caries prevention: A systematic review. *J Conserv Dent.* 2019 Mar;22(2):123-8.
- [16]. Bilaiya S, Patni PM, Jain P, Pandey SH, Raghuvanshi S, Bagulkar B. Comparative Evaluation of Accuracy of Ipex, Root Zx Mini, and Epex Pro Apex Locators in Teeth with Artificially Created Root Perforations in Presence of Various Intracanal Irrigants. *Eur Endod J.* 2020 Mar 19;5(1):6-9. Pubmed PMID: 32342031.
- [17]. Govindaraju L, Gurunathan D. Effectiveness of Chewable Tooth Brush in Children-A Prospective Clinical Study. *J Clin Diagn Res.* 2017 Mar;11(3):ZC31-ZC34. Pubmed PMID: 28511505.
- [18]. Christabel A, Anantanarayanan P, Subash P, Soh CL, Ramanathan M, Muthusekhar MR, et al. Comparison of pterygomaxillary dysjunction with tuberosity separation in isolated Le Fort I osteotomies: a prospective, multi-centre, triple-blind, randomized controlled trial. *Int J Oral Maxillofac Surg.* 2016 Feb;45(2):180-5. Pubmed PMID: 26338075.
- [19]. Soh CL, Narayanan V. Quality of life assessment in patients with dentofacial deformity undergoing orthognathic surgery--a systematic review. *Int J Oral Maxillofac Surg.* 2013 Aug;42(8):974-80. Pubmed PMID: 23702370.
- [20]. Mehta M, Deeksha, Tewari D, Gupta G, Awasthi R, Singh H, et al. Oligonucleotide therapy: An emerging focus area for drug delivery in chronic inflammatory respiratory diseases. *Chem Biol Interact.* 2019 Aug 1;308:206-215. Pubmed PMID: 31136735.
- [21]. Ezhilarasan D, Apoorva VS, Ashok Vardhan N. Syzygium cumini extract induced reactive oxygen species-mediated apoptosis in human oral squamous carcinoma cells. *J Oral Pathol Med.* 2019 Feb;48(2):115-121. Pubmed PMID: 30451321.
- [22]. Campeau PM, Kasperaviciute D, Lu JT, Burrage LC, Kim C, Hori M, et al. The genetic basis of DOORS syndrome: an exome-sequencing study. *Lancet Neurol.* 2014 Jan;13(1):44-58. Pubmed PMID: 24291220.
- [23]. Sneha S. Knowledge and awareness regarding antibiotic prophylaxis for infective endocarditis among undergraduate dental students. *Asian J Pharm Clin Res.* 2016 Oct 1:154-9.
- [24]. Christabel SL, Linda Christabel S. Prevalence of type of frenal attachment and morphology of frenum in children, Chennai, Tamil Nadu. *World J Dent.* 2015 Oct;6(4):203-7.
- [25]. Kumar S, Rahman R. Knowledge, awareness, and practices regarding biomedical waste management among undergraduate dental students. *Asian J Pharm Clin Res.* 2017;10(8):341.
- [26]. Sridharan G, Ramani P, Patankar S. Serum metabolomics in oral leukoplakia and oral squamous cell carcinoma. *J Cancer Res Ther.* 2017 Jul 1;13(3):556-61.
- [27]. Ramesh A, Varghese SS, Doraiswamy JN, Malaippan S. Herbs as an antioxidant arsenal for periodontal diseases. *J Interact Ethnopharmacol.* 2016 Jan 27;5(1):92-6. Pubmed PMID: 27069730.
- [28]. Thamaraiselvan M, Elavarasu S, Thangakumaran S, Gadagi JS, Arthie T. Comparative clinical evaluation of coronally advanced flap with or without platelet rich fibrin membrane in the treatment of isolated gingival recession. *J Indian Soc Periodontol.* 2015 Jan;19(1):66-71.
- [29]. Thangaraj SV, Shyamsundar V, Krishnamurthy A, Ramani P, Ganesan K, Muthuswami M, et al. Molecular Portrait of Oral Tongue Squamous Cell Carcinoma Shown by Integrative Meta-Analysis of Expression Profiles with Validations. *PLoS One.* 2016 Jun 9;11(6):e0156582. Pubmed PMID: 27280700.
- [30]. Ponnulakshmi R, Shyamaladevi B, Vijayalakshmi P, Selvaraj J. In silico and in vivo analysis to identify the antidiabetic activity of beta sitosterol in adipose tissue of high fat diet and sucrose induced type-2 diabetic experimental rats. *Toxicol Mech Methods.* 2019 May;29(4):276-290. Pubmed PMID: 30461321.
- [31]. Ramakrishnan M, Shukri M. Fluoride, Fluoridated Toothpaste Efficacy And Its Safety In Children-Review. *Int J Pharm Res.* 2018 Oct 1;10(04):109-14.
- [32]. Azeem RA, Sureshbabu NM. Clinical performance of direct versus indirect

- composite restorations in posterior teeth: A systematic review. *J Conserv Dent.* 2018 Jan;21(1):2-9.
- [33]. Khatri MP, Ghivari SB, Pujar M, Faras R, Gopeshetti P, Vanti A. Accuracy of two electronic apex locators in locating root perforations in curved canals in dry and wet conditions: A comparative in vitro study. *Dent Res J (Isfahan).* 2019 Nov 12;16(6):407-412. Pubmed PMID: 31803387.
- [34]. Nandakumar M, Nasim I. Comparative evaluation of grape seed and cranberry extracts in preventing enamel erosion: An optical emission spectrometric analysis. *J Conserv Dent.* 2018 Sep-Oct;21(5):516-520. Pubmed PMID: 30294113.
- [35]. Marroquín BB, Fernández CC, Schmidtmann I, Willershausen B, Goldberg F. Accuracy of electronic apex locators to detect root canal perforations with inserted metallic posts: an ex vivo study. *Head Face Med.* 2014 Dec 23;10:57. Pubmed PMID: 25533476.
- [36]. Manohar MP, Sharma S. A survey of the knowledge, attitude, and awareness about the principal choice of intracanal medicaments among the general dental practitioners and nonendodontic specialists. *Indian J Dent Res.* 2018 Nov-Dec;29(6):716-720. Pubmed PMID: 30588997.
- [37]. Teja KV, Ramesh S, Priya V. Regulation of matrix metalloproteinase-3 gene expression in inflammation: A molecular study. *J Conserv Dent.* 2018 Nov;21(6):592-6.
- [38]. Rajakeerthi R, Nivedhitha MS. Natural Product as the Storage medium for an avulsed tooth—A Systematic Review. *Cumhur. Dent. J.* 2019 Jun 11;22(2):249-56.
- [39]. Aguiar BA, Reinaldo RS, Frota LM, do Vale MS, de Vasconcelos BC. Root ZX Electronic Foramen Locator: An Ex Vivo Study of Its Three Models' Precision and Reproducibility. *Int J Dent.* 2017;2017:1-4. Pubmed PMID: 28367215.
- [40]. Siddique R, Sureshbabu NM, Somasundaram J, Jacob B, Selvam D. Qualitative and quantitative analysis of precipitate formation following interaction of chlorhexidine with sodium hypochlorite, neem, and tulsi. *J Conserv Dent.* 2019 Jan-Feb;22(1):40-47. Pubmed PMID: 30820081.
- [41]. Taneja S, Kumar M, Sharma SS, Gogia H. Comparative evaluation of accuracy of three electronic apex locators in different simulated clinical conditions—an invitro study. *Ann Med Health Sci Res.* 2017;7(3).
- [42]. Aydın ZU, Altunbaş D, Meşeci B. The Effect of Different Irrigation Solutions on the Accuracy of Two Electronic Apex Locators in Locating Artificial Root Perforations. *Meandros med. dental j.* 2020 Aug 1;21(2):134-9.
- [43]. Rajendran R, Kunjusankaran RN, Sandhya R, Anilkumar A, Santhosh R, Patil SR. Comparative evaluation of remineralizing potential of a paste containing bioactive glass and a topical cream containing casein phosphopeptide-amorphous calcium phosphate: An in vitro study. *Pesqui Bras Odontopediatria Clin Integr.* 2019 Oct 10;19:1-10.
- [44]. Duran-Sindreu F, Gomes S, Stöber E, Mercadé M, Jané L, Roig M. In vivo evaluation of the iPex and Root ZX electronic apex locators using various irrigants. *Int Endod J.* 2013 Aug;46(8):769-74. Pubmed PMID: 23551276.
- [45]. Ikhar Y, Gade V, Patil S, Gade J. The Influence of Various Irrigants on The Accuracy of Third Generation Apex Locator And Fifth Generation Apex Locators In Locating Simulated Root Perforation: An In Vitro Study. *IOSR J Dent Med Sci e-ISSN [Internet].* 2019;18(7):86-91.
- [46]. Vijayashree Priyadharsini J. In silico validation of the non-antibiotic drugs acetaminophen and ibuprofen as antibacterial agents against red complex pathogens. *J Periodontol.* 2019 Dec;90(12):1441-1448. Pubmed PMID: 31257588.
- [47]. Pc J, Marimuthu T, Devadoss P, Kumar SM. Prevalence and measurement of anterior loop of the mandibular canal using CBCT: A cross sectional study. *Clin Implant Dent Relat Res.* 2018 Apr 6;20(4):531-4.
- [48]. Ramesh A, Varghese S, Jayakumar ND, Malaiappan S. Comparative estimation of sulfiredoxin levels between chronic periodontitis and healthy patients - A case-control study. *J Periodontol.* 2018 Oct;89(10):1241-1248. Pubmed PMID: 30044495.
- [49]. Ramadurai N, Gurunathan D, Samuel AV, Subramanian E, Rodrigues SJ. Effectiveness of 2% Articaine as an anesthetic agent in children: randomized controlled trial. *Clin Oral Investig.* 2019 Sep;23(9):3543-50.
- [50]. Sridharan G, Ramani P, Patankar S, Vijayaraghavan R. Evaluation of salivary metabolomics in oral leukoplakia and oral squamous cell carcinoma. *J Oral Pathol Med.* 2019 Apr;48(4):299-306.
- [51]. Mathew MG, Samuel SR, Soni AJ, Roopa KB. Evaluation of adhesion of *Streptococcus mutans*, plaque accumulation on zirconia and stainless steel crowns, and surrounding gingival inflammation in primary molars: randomized controlled trial. *Clin Oral Investig.* 2020 Sep;24(9):1-6. Pubmed PMID: 31955271.
- [52]. Samuel SR. Can 5-year-olds sensibly self-report the impact of developmental enamel defects on their quality of life? *Int J Paediatr Dent.* 2021 Mar;31(2):285-286. Pubmed PMID: 32416620. <https://pubmed.ncbi.nlm.nih.gov/32416620/>
- [53]. R H, Ramani P, Ramanathan A, R JM, S G, Ramasubramanian A, et al. CYP2 C9 polymorphism among patients with oral squamous cell carcinoma and its role in altering the metabolism of benzo[a]pyrene. *Oral Surg Oral Med Oral Pathol Oral Radiol.* 2020 Sep;130(3):306-312. Pubmed PMID: 32773350.
- [54]. Chandrasekar R, Chandrasekhar S, Sundari KKS, Ravi P. Development and validation of a formula for objective assessment of cervical vertebral bone age. *Prog Orthod.* 2020 Oct 12;21(1):38. Pubmed PMID: 33043408.
- [55]. Priyadharsini JV, Girija AS, Paramasivam A. In silico analysis of virulence genes in an emerging dental pathogen *A. baumannii* and related species. *Arch Oral Biol.* 2018 Oct 1;94:93-8.