

Comparative Evaluation Of Canal Transportation And Centring Ability Of Three Rotary File Systems - In-Vitro Study

Research Article

Aravindhan K¹, Delphine Priscilla Antony S., MDS^{2*}, M.S.Nivedhitha, MDS³

¹ Post Graduate student, Department of Conservative dentistry and Endodontics, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai-77.

² Senior Lecturer, Department of Conservative dentistry and Endodontics, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai-77.

³ Professor and Head of the Department, Department of Conservative Dentistry and Endodontics, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai-77.

Abstract

Aim: To compare the canal transportation & centering ability between ProTaper Gold, Trunatomy & Profit S

Materials And Methods: 30 freshly extracted maxillary premolar were included in the study. Pre-operative CBCT and calculation of a1 and b1 at 3,6,9 mm from the apex. Group 1: cleaning and shaping with ProFit S3 up to PF2 file (#25,0.06). Group 2: cleaning and shaping with TruNatomy up to prime shaping file (#25,0.04). Group 3: cleaning and shaping with ProTaper Gold up to F2file (#25,0.08) Post-operative CBCT and calculation of a2 and b2 at 3,6 and 9mm from the apex.

Statistical Analysis: One-way-ANOVA and the independent t-test were done for the pairwise comparison. The significance level was set at P = 0.05; statistical analysis was performed with SPSS statistics version 20.0 (SPSS Inc., Chicago, IL, USA).

Results : There was a significant difference among the three groups. ProTaper Gold showed slightly more canal transportation compared to the other files this could be due to its variable taper (8 % taper). Trunatomy (26 , 4% taper) and ProFit S3 (25 , 6 % VV taper). There was a significant difference among the three groups. ProTaper Gold showed a lesser centering ratio compared to the other files this could be due to its variable taper (8 % taper). Trunatomy (26, 4% taper) and ProFit S3 (25, 4-8 % VV taper) had no significant difference i.e it had a better centering ratio, this could be due to the taper variations and offset design.

Conclusion: From this study, it can be concluded that Trunatomy and ProFit S3 had lesser canal transportation and a better centering ratio compared to ProTaper Gold rotary file system.

Keywords: Niti Files; Profit S3; Protaper Gold; Trunatomy; Rotary Files.

Introduction

Nickel Titanium instruments are used to clean and shape the root canals productively compared to manual instrumentation. The application of NiTi instruments is mainly for its ability to maintain the original canal morphology, maintaining the position of apical foramen[1], and providing adequate taper for the obturating material. Root canal cleaning and shaping are important phases in endodontic therapy. Ledge formation, transportation of apical foramen, and non-tapered hourglass-shaped preparation are problems frequently observed after instrumentation in curved root canals[2]. To overcome these drawbacks manufacturers have brought about different modifications in the file design, taper,

and the material aspect as well. The purpose is to maintain the original canal shape without creating severe irregularities such as zip, ledge, or perforation, particularly in narrow curved canals, because of their super-elastic behavior and shape-memory property. Improved endodontic file versatility would minimize iatrogenic errors caused by canal transportation, while the quality and protection of root canal treatment[3].

Each tooth morphology varies and instruments are to be chosen based on the severity of the canal curvature and the canal width. The important factor in considering an instrument is the taper, cross-section, the rake angle, depth of flutes, and the number of spirals all these have an influence on the instrument behav-

*Corresponding Author:

Delphine Priscilla Antony S., MDS

Senior Lecturer, Department of Conservative dentistry and Endodontics, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai-77.

E-mail : - delphypriscilla@gmail.com

Received: May 04, 2021

Accepted: July 09, 2021

Published: July 17, 2021

Citation: Aravindhan K, Delphine Priscilla Antony S., MDS, M.S.Nivedhitha, MDS. Comparative Evaluation Of Canal Transportation And Centring Ability Of Three Rotary File Systems - In-Vitro Study . *Int J Dentistry Oral Sci.* 2021;8(7):3252-3256. doi: <http://dx.doi.org/10.19070/2377-8075-21000662>

Copyright: Delphine Priscilla Antony S[©]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.

your[4-6] combined with its thermo-mechanical processing.

Canal transportation is defined as the removal of canal wall structure on the outer curve in the apical half of the canal due to the tendency of the file to return back to its original liner shape during canal preparation[7,8] NiTi instruments are rapid and more centered in the root canal compared to stainless steel instruments. The centering ability of a file system is based on its taper and cross-section[9]

Protaper gold files(PTG; Dentsply, Tulsa Dental Specialties, Tulsa, OK, USA) are similar to its predecessor the Protaper universal file system. It has been developed with proprietary advanced metallurgy which has better cutting efficacy with a variable taper and convex triangular cross-section. When compared to its predecessor it appears slightly bent in the package itself, this is not a defect rather due to its metallurgy. This metallurgical advancement is due to its heat treatment.[10,11]

TruNatomy instruments (TRN) (Dentsply Sirona) are new generation file system which are pre-packaged and pre-sterilized files that are designed with improved cutting efficacy, simple to use with a continuous taper which provides for maximum peri-cervical dentin preservation. These are manufactured from a 0.8mm diameter wire blank compared to other conventional ones which are 1.1mm in diameter. A post-manufacturing thermal process is carried out which generates super-elastic NiTi metal properties. [12]

Profit S3(PS3)(Kedo Dental, India) is a new heat-treated file system with blue technology that is coated with titanium oxide coating. It has a rectangular cross-section with a two-point contact which reduces debris extrusion apically. Its taper is variably variable (VV) between 4% to 8% with increased flexibility, adequate shape memory and more resistance to fracture.[13]

With recent advances, a non-destructive technology has been advocated for the pre-and post- instrumentation evaluations of the canal. Cone-beam computed tomography(CBCT) is used to accrue the data in these type of studies and its main advantage is that it provides cross-sectional and 3D images with high accuracy, high resolution, fully quantifiable, and results are repeatable[14]

The aim of the current study is to evaluate the canal transportation and centering ability of three rotary file systems using CBCT in single-rooted extracted teeth. The null hypothesis was that there was no difference in the canal transportation and canal centering ability, between the tested NiTi rotary instruments in single-rooted teeth. Previously our team has a rich experience in working on various research projects across multiple disciplines[15-29] Now the growing trend in this area motivated us to pursue this project.

Materials And Methods

Thirty extracted human mandibular premolar teeth with fully formed apices were included in this study. The teeth exhibited no defects, root canals were not calcified, showed no internal or external root resorption, no signs of prior endodontic treatment, and no aberrant canal morphology; each tooth had a single canal and a single apical foramen, based on buccal and proximal radiographic examination. Crowns were decoronated to increase standardization, and only teeth measuring 16 mm were included

in the analysis[30]. Schneider's methods were used to select mandibular premolars with fully formed apices and curvature angles of 0°–10°. The teeth in this study were extracted for periodontal or orthodontic purposes and preserved in normal saline at 4°C until they were required[31]. By using a diamond disc to decorate all of the samples, they were all uniform to 16 mm in length. [30,31]. The access cavity was prepared using Endo Access bur, 21 mm size 2 (Dentsply Maillefer, Swiss made) was used and K-file (Mani, Utsunomiya, Tochigi, Japan) of size #10 hand files were used to achieve the initial patency of the canal to full working length (WL), visible at the apical foramen, and the WL was established 1 mm short of this length[13].

The decoronated teeth were randomly divided into three groups and embedded in modeling wax in mandibular arch form, Group I – Profit S3(PS3), Group II – TruNatomy, and Group III – Protaper Gold(PTG). Pre-operative CBCT was taken for all the were taken for all the decoronated teeth to determine the morphology of the canals before instrumentation and tabulated as a1 and b1 at the following length from the apex. At 3, 6, and 9 mm from the root apex, the centering capacity, canal transportation, and amount of dentin extracted were assessed[14]. After the cleaning and shaping process, post instrumentation scans were taken and tabulated as a2 and b2 at 3,6 and 9mm from the apex. Pre- and post-instrumentation scans were analyzed using CBCT, and the values were obtained on axial view. According to Gambill et al, canal transportation was measured

$$([a1-a2]-[b1-b2])$$

$$\text{Canal centering ability } (a1-a2)/b1-b2 \text{ or } (b1-b2)/(a1-a2)$$

The changes in the canal centering ratio and canal transportation data were analyzed using one-way ANOVA and the independent t-test was done for the pairwise comparison. The significance level was set at P = 0.05; statistical analysis was performed with SPSS statistics version 20.0 (SPSS Inc., Chicago, IL, USA).

Results And Discussion

The mean value for canal transportation and centering ability had a significant difference between the three groups(P<0.05).PS3 and TruNatomy had no significant difference(P>0.05) in canal transportation(Figure 1) and centering ability(Figure 2) and PTG has a significant difference when compared to the other two file systems.

The biomechanical preparation of the root canal space is thought to be critical for the success of endodontic therapy. The goal is to remove all essential tissue, necrotic waste, and microorganisms from a root canal system completely[32]. The aim of root canal mechanical preparation is to preserve the tooth's natural or original canal morphology, which allows for sufficient irrigation, intracanal medication placement, and three-dimensional obturation.(33).Endodontic planning is complicated by some deviation or curvature in the canal. Canal curvature especially in the apical third provides an endodontic challenge[33]

Adequate canal cleaning can be obtained only when the shaping of the canal is appropriate for the irrigant to penetrate to the apical region which is of prime importance. Disinfection of the apical 3rd of the root canal can be obtained by a synergistic effect

Figure 1: The graph shows the mean of canal transportation of Group I – Profit S3 , Group II – Trunatomy, Group III – ProTaper Gold at 3, 6 and 9 mm from the root apex of the teeth. There was statistically significant difference between the 3 groups (P > 0.05)

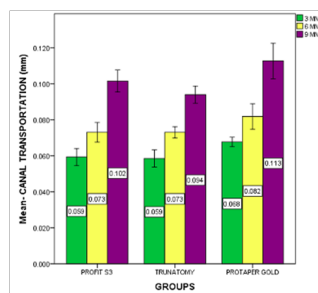
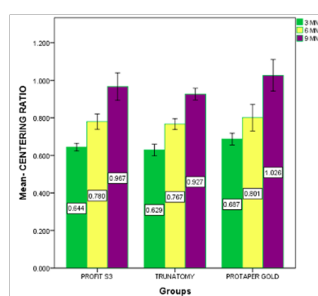


Figure 2: The graph shows the mean of canal centering ratio of Group I – Profit S3 , Group II – Trunatomy, Group III – ProTaper Gold at 3, 6 and 9 mm from the root apex of the teeth. There was a statistically significant difference between the three groups (P > 0.05)



of both instrumentation and irrigation protocol. Shaping of the canal provides for the foundation for the disinfection protocol which can be achieved by endodontic irrigation and placement of intracanal medicament.

In the current study, all the teeth were cleaned and shaped in the following sizes Protaper gold till size #25, Trunatomy #26, and ProFit S3 #25. After which the post instrumentation CBCT was taken. A major advantage of using CBCT is that the results obtained are reproducible and repeatable. The 3- dimensional geometric values are accurate compared with conventional radiographic methods. CBCT provides images that eliminate superimposition thereby providing good quality images.[34]

Transportation of the canal occurs due to the rigidity of the file during canal preparation. This leads to the non-uniform distribution of stresses which in turn causes straightening of the file within the canal at the canal curvature.[33] On the outside curve of the apical region of the root canal during canal preparation, the files have a tendency to straighten and restore to their original form[35].The fact that all of the instruments have non cutting tips that operate with minimal apical pressure and only serve as a guide to allow easy penetration into the canal[36]. In the present study, it was evident that the canal transportation among the three groups was not statistically significant (P > 0.05) implying some deviation was present but not to the extent that it could result in a deleterious effect on the tooth. This result is consistent with the results provided in the previous study by Antony et al[13]. A study by Shivashankar et al stated in his study that instruments that have a 3 point contact in the canal can lead to more canal transportation compared to the 2 point contact (offset design) which is validated in the current study where Protaper Gold produces more canal transportation compared to ProFit S3.

Canal transportation is an iatrogenic mistake or alteration that affects the canal's external surface. It results in inadequate debris-

removal of the canal's apical region and excessive removal of the canal's concave surface[33]. When comparing the groups individually ProTaper Gold showed slightly more canal transportation compared to the other files this could be due to its variable taper (8 % taper). Trunatomy (26, 4% taper) and ProFit S3 (25 ,VV taper) had no significant difference this could be due to the taper variations and offset design.

Centering ability was defined as the ability of an endodontic instrument or file to remain in the central axis of the root canal.[37] Canal centering ability of the file is influenced by the alloy used in the manufacturing process of the instrument, along with the file design which consists of cross-section, tip, and taper of the instrument.[38] The lower the value in the centering ratio analysis, the more centered the preparation within the canal.[13] There was a significant difference among the three groups. ProTaper Gold showed a lesser centering ratio compared to the other files this could be due to its variable taper (8 % taper). Trunatomy (26, 4% taper) and ProFit S3 (25, VV taper) had no significant difference i.e it had a better centering ratio, this could be due to the taper variations and offset design. Though both these files have different tapers their centering ratio was similar this could be due to its cross-section and flexibility of the file.

In the current study Protaper gold and Trunatomy files were compared, both were manufactured by the same manufacturer. No study has been done in the past to compare these two instruments. Though these two systems had different taper, the idea to compare was to identify which file performed better though they were developed by the same manufacturer. Our institution is passionate about high quality evidence based research and has excelled in various fields [39][49].

The aim of this study was to test heat-treated rotary file systems, such as PTG, PS3, and TruNatomy. The three systems were found to have no major differences in canal centering capacity and canal

transportation in this analysis, but PTG shows a mild difference in centering ability and canal transportation.

Conclusion

From this study, it can be concluded that Trunatomy and ProFit S3 had lesser canal transportation and a better centering ratio compared to ProTaper Gold rotary file system. Further studies are to be carried out to substantiate the in-vitro study for clinical purposes.

Acknowledgement And Declarations

The authors would like to acknowledge the institution and all the staff members of the Department of Conservative Dentistry and Endodontics for their support towards completion of this research. The authors deny any conflicts of interest associated with this paper.

References

- Yilmaz F, Eren İ, Eren H, Badi MA, Ocak M, Çelik HH. Evaluation of the Amount of Root Canal Dentin Removed and Apical Transportation Occurrence after Instrumentation with ProTaper Next, OneShape, and Edge-File Rotary Systems. *J Endod.* 2020 May;46(5):662-667. Pubmed PMID: 32151482.
- Park H. A comparison of Greater Taper files, ProFiles, and stainless steel files to shape curved root canals. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2001 Jun;91(6):715-8. Pubmed PMID: 11402288.
- Gambarini G. Cyclic fatigue of ProFile rotary instruments after prolonged clinical use. *Int Endod J.* 2001 Jul;34(5):386-9. Pubmed PMID: 11482722.
- Lopes HB, Gambarra-Soares T, Elias CN, Siqueira JF Jr, Inojosa IF, Lopes WS, et al. Comparison of the mechanical properties of rotary instruments made of conventional nickel-titanium wire, M-wire, or nickel-titanium alloy in R-phase. *J Endod.* 2013 Apr;39(4):516-20. Pubmed PMID: 23522548.
- García M, Duran-Sindreu F, Mercadé M, Bueno R, Roig M. A comparison of apical transportation between ProFile and RaCe rotary instruments. *J Endod.* 2012 Jul;38(7):990-2. Pubmed PMID: 22703667.
- Al-Manei KK, Al-Hadlaq SM. Evaluation of the root canal shaping ability of two rotary nickel-titanium systems. *Int Endod J.* 2014 Oct;47(10):974-9. Pubmed PMID: 24387043.
- Dhingra A, Ruhail N, Miglani A. Evaluation of Single File Systems Reciprocal, Oneshape, and WaveOne using Cone Beam Computed Tomography -An In Vitro Study. *J Clin Diagn Res.* 2015 Apr;9(4):ZC30-4. Pubmed PMID: 26023639.
- Mantri SP, Kapur R, Gupta NA, Kapur CA. Type III apical transportation of root canal. *Contemp Clin Dent.* 2012 Jan;3(1):134-6. Pubmed PMID: 22557916.
- Gundappa M, Bansal R, Khoriya S, Mohan R. Root canal centering ability of rotary cutting nickel titanium instruments: A meta-analysis. *J Conserv Dent.* 2014 Nov;17(6):504-9. Pubmed PMID: 25506134.
- Ruddle CJ. Shaping complex canals: clinical strategy and technique. *Dent Today.* 2014 Nov;33(11):88-95.
- Elnaghy AM, Elsaka SE. Shaping ability of ProTaper Gold and ProTaper Universal files by using cone-beam computed tomography. *Indian J Dent Res.* 2016 Jan-Feb;27(1):37-41. Pubmed PMID: 27054859.
- Van der Vyver PJ, Vorster M, Peters OA. Minimally invasive endodontics using a new single-file rotary system. *Int Dent-African ed.* 2019;9(4):6-20.
- Antony SD, Subramanian AK, Nivedhitha MS, Solete P. Comparative evaluation of canal transportation, centering ability, and dentin removal between ProTaper Gold, One Curve, and Profit S3: An in vitro study. *Journal of Conservative Dentistry.* 2020 Nov 1;23(6):632.
- Jain A, Asrani H, Singhal AC, Bhatia TK, Sharma V, Jaiswal P. Comparative evaluation of canal transportation, centering ability, and remaining dentin thickness between WaveOne and ProTaper rotary by using cone beam computed tomography: An in vitro study. *J Conserv Dent.* 2016 Sep-Oct;19(5):440-4. Pubmed PMID: 27656063.
- 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.
- Christabel A, Anantanarayanan P, Subash P, Soh CL, Ramanathan M, Muthsekhar 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.
- 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.
- 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.
- 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.
- 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.
- Kumar S, Sneha S. Knowledge and awareness regarding antibiotic prophylaxis for infective endocarditis among undergraduate dental students. *Asian Journal of Pharmaceutical and Clinical Research.* 2016;154.
- Christabel SL, Gurunathan D. Prevalence of type of frenal attachment and morphology of frenum in children, Chennai, Tamil Nadu. *World J Dent.* 2015 Oct;6(4):203-7.
- Kumar S, Rahman RE. Knowledge, awareness, and practices regarding biomedical waste management among undergraduate dental students. *Asian Journal of Pharmaceutical and Clinical Research.* 2017;10(8):341.
- Sridharan G, Ramani P, Patankar S. Serum metabolomics in oral leukoplakia and oral squamous cell carcinoma. *J Cancer Res Ther.* 2017 Jul-Sep;13(3):556-561. Pubmed PMID: 28862226.
- Ramesh A, Varghese SS, Doraiswamy JN, Malaippan S. Herbs as an antioxidant arsenal for periodontal diseases. *J Intercult Ethnopharmacol.* 2016 Jan 27;5(1):92-6. Pubmed PMID: 27069730.
- Thamaraiselvan M, Elavarasu S, Thangakumar 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-Feb;19(1):66-71. Pubmed PMID: 25810596.
- Thangaraj S, 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.
- 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.
- Ramakrishnan M, Bhurki M. Fluoride, Fluoridated Toothpaste Efficacy And Its Safety In Children-Review. *International Journal of Pharmaceutical Research.* 2018 Oct 1;10(04):109-14.
- Mamede-Neto I, Borges AH, Guedes OA, de Oliveira D, Pedro FL, Estrela C. Root Canal Transportation and Centering Ability of Nickel-Titanium Rotary Instruments in Mandibular Premolars Assessed Using Cone-Beam Computed Tomography. *Open Dent J.* 2017 Feb 14;11:71-78. Pubmed PMID: 28357000.
- Tambe VH, Nagmode PS, Abraham S, Patait M, Lahoti PV, Jaju N. Comparison of canal transportation and centering ability of rotary protaper, one shape system and wave one system using cone beam computed tomography: An in vitro study. *J Conserv Dent.* 2014 Nov;17(6):561-5. Pubmed PMID: 25506145.
- Goldman M, White RR, Moser CR, Tenca JI. A comparison of three methods of cleaning and shaping the root canal in vitro. *J Endod.* 1988 Jan;14(1):7-12. Pubmed PMID: 3162937.
- Hasheminia SM, Farhad A, Sheikhi M, Soltani P, Hendi SS, Ahmadi M. Cone-beam Computed Tomographic Analysis of Canal Transportation and Centering Ability of Single-file Systems. *J Endod.* 2018 Dec;44(12):1788-1791. Pubmed PMID: 30390970.
- Patel S, Dawood A, Ford TP, Haines E. The potential applications of cone beam computed tomography in the management of endodontic problems. *Int Endod J.* 2007 Oct;40(10):818-30. Pubmed PMID: 17697108.
- Schäfer E, Dammaschke T. Development and sequelae of canal transportation. *Endodontic Topics.* 2006 Nov;15(1):75-90.
- Kum KY, Spångberg L, Cha BY, Il-Young J, Msd, Seung-Jong L, et al. Shaping ability of three ProFile rotary instrumentation techniques in simulated resin root canals. *J Endod.* 2000 Dec;26(12):719-23. Pubmed PMID: 11471641.

- [37]. de Albuquerque MS, Nascimento AS, Gialain IO, de Lima EA, Nery JA, de Souza Araujo PR, et al. Canal Transportation, Centering Ability, and Dentin Removal after Instrumentation: A Micro-CT Evaluation. *J Contemp Dent Pract.* 2019 Jul 1;20(7):806-811. Pubmed PMID: 31597800.
- [38]. Kandaswamy D, Venkateshbabu N, Porkodi I, Pradeep G. Canal-centering ability: An endodontic challenge. *J Conserv Dent.* 2009 Jan;12(1):3-9. Pubmed PMID: 20379433.
- [39]. 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.
- [40]. J PC, Marimuthu T, C K, 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 Aug;20(4):531-534. Pubmed PMID: 29624863.
- [41]. 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.
- [42]. Ramadurai N, Gurunathan D, Samuel AV, Subramanian E, Rodrigues SJL. Effectiveness of 2% Articaine as an anesthetic agent in children: randomized controlled trial. *Clin Oral Investig.* 2019 Sep;23(9):3543-3550. Pubmed PMID: 30552590.
- [43]. 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. Pubmed PMID: 30714209.
- [44]. 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.
- [45]. 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):3275-3280. Pubmed PMID: 31955271.
- [46]. 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.
- [47]. 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.
- [48]. 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.
- [49]. Vijayashree Priyadharsini J, Smiline 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;94:93-98. Pubmed PMID: 30015217.