IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 19, Issue 9 Ser.2 (September. 2020), PP 51-58
www.iosrjournals.org

Water expandable root canal obturation system – A review

[*]Mehreen Kulsum N [1],BorthakurBikash Jyoti[2],Swathika B [3],Ganesan S [4]
[1]*Final year Postgraduate, Department of Conservative Dentistry and Endodontics, Mahatma GandhiPost Graduate Institute of Dental Sciences, Gorimedu, Puducherry,India*
[2]*Professor and Head, Department of Conservative Dentistry and Endodontics, Mahatma Gandhi Post Graduate Institute of Dental Sciences, Gorimedu, Puducherry, India*
[3-4]*Professor, Department of Conservative Dentistry and Endodontics, Mahatma Gandhi Post Graduate Institute of Dental Sciences, Gorimedu, Puducherry, India.*
Corresponding Author: [*]DR.Mehreen Kulsum N

Abstract
Water expandable root canal obturation system has been introduced in endodontics as an alternative to traditional gutta percha based system to obtain an impervious seal. It has properties desirable for root canal obturation such as adhesion to dentin, self- sealing ability based on polymer technology. The most recent advancement in endodontic obturating materials takes advantage of the hydrophilic polymer and the concept of monoblock system in root canal obturation with an aim to improve the marginal seal. Since, its introduction, water expandable root canal obturation system has been widely reported to be successful in endodontic therapy. This article aims to provide a brief overview of this new material based on recent scientificstudies.
Keywords: *Hydrophilic, C-points, Smartpaste bio, obturation, Root canal*

Date ofSubmission:25-08-2020 Date of Acceptance: 09-09-2020

I. Introduction

The most important purpose of root canal obturation is to obtain an impermeable seal.[1] Though gutta-percha is commonly used as an endodontic obturation material, its ability to laterally seal root canal dentin remains questionable. Gutta-percha lacksadhesiveness and rigidity when it is thin. It undergoes shrinkage on cooling thus, it fails to prevent microleakage. It is hydrophobic in nature and does not strengthen endodontically treated tooth. Hydrophobicity isthe major drawback of gutta-percha which inhibit chemical bonding between the gutta- percha and the dentinal wall. [2] To overcome this drawback and to improve quality of obturation a newer root canal obturating material such as water expandable root canal obturation system has beenintroduced.

II. History

Water expandable root canal obturating system was introduced by two manufacturersSmartseal DRFP Ltd, Stanford, Prosmart outside UK and Endo Technologies, LLC, Shrewsbury, MA,USA.Dental Root Filling Products Ltd (DRFP Ltd) was set up by a group of British scientists led by Donald James Highgate, Jonathan Anthony Lloyd who got patented for smartseal on may 2007 and identified that hydrophilic polymers could be used to seal irregular shaped spaces. [3]SmartSeal was launched in October 2007 and after a fantastic start in the UK (and Holland).In late 2010, ProPoint received FDA approval and during 2011 the product was marketed to dentists in the Boston area. In 2011, water expandable root canal obturation system won the Medical Design Excellence Award (MDEA) for the Dental equipment, medical technology community and recognized the technological innovation, ease-of-use.

III. Composition

Water expandable root canal obturation is a two-part system comprising of premade obturation point.which is used along with resin based bioceramic sealer as shown in Figure 1.This new obturation point and resin based bioceramic sealer employs technology derived from water-expandable polymers utilized in contact lens.

Obturation points consists ofconsists of an inner radiopaque nylon core and an outer radiopaque polymer coating.

Central Polyamide Core :
It comprises of a mixture of two proprietary nylon polymers
- Trogamid T

- Trogamid CX.

This provides the point with the flexibility to allow it to easily pass around any curves in the prepared root canal, while being rigid enough to pass easily to length in narrower canals.

Core materials are also used in dental implant abutments, dental bridges and crown cores as well as in surgical sutures.

Outer bonded hydrophilic Polymer Layer :

It comprises of a cross-linked copolymer of acrylonitrile and vinyl pyrrolidonewhich has been polymerized and cross-linked using allyl-methacrylate and a thermal initiator.This hydrophillic, hydrogel layer allows obturating point to swell so that it adapt to the ramifications of the root canal.Zirconium dioxide particles provide the radiopacity to both the corematerial.[4]

Water expandable Obturating points has central white core (Radiopaque core) and translucent coating (radiolucent coating).This hydrophilic obturation point commercially available as (Propoint/ C- Points) (Endo Technologies, LLC, Shrewsbury, MA,USA).C-points, C stands for the Latin word "Cresco" (cretum), which means to grow, expand or increase.

Figure 1A

It is available in several tip sizes and tapers. One obturating point covers all tip sizes and it's available within the following sizes: [5]

6% taper - 25 to 45 (ISO tip sizes)
4% taper - 25 to 45 (ISO tip sizes)
ProTaper™ - F1to F5
Sendoline™ S5 - S2 to S4.

Root canal Sealer

Sealer recommended with hydrophilic obturation point is a resin- based bioceramic sealer designed to swell through the addition of ground polymer. It contains zirconium oxide, monobasic calcium phosphate, calcium silicates, calcium hydroxide, and filler. The manufacturer claims that bioceramics addition to sealer gives dimensional stability which makes it non resorbable inside the root canal system.It is dispensed in a syringe to ensure an accurate ratio of sealer components is achieved every time and mixing/dispensing trays are provided to aid application. The sealant is delivered through a pre-mixed syringe and mixingis not required as it can be applied directly into the canal using an intra-canal tip thus minimising wastage of material. [6]This resin based bioceramic sealer commercially available as Smart paste Bio (Smartseal TM) or HySeal-bio.

Figure 1B

Accessories

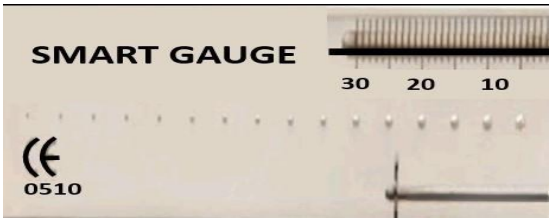
Smart trim

It consists of a kit of two long flame gold burs and couple of pear shaped diamond burs for trimming the excess of propoints.

Smart gauge

It is a measuring block which is designed to trim the 4% and 6% taper propoints to the apical desired size. Thus it reduces the need to carry large stocks of pretrimmed points and also allows a custom size fitting. Selected obturation point should be trimmed to one size less than that has been prepared, i.e. if a size 40 has been prepared, then the propoint should be trimmed to a size 35.Trimming is done gradually by pushing the point through the corresponding hole present within the smartgauge and cutting off excess with help of scalpel blade.The points are rigid enough to be cut at the apex asnug fit is felt with positive tug back at the correct working length.The smartgauge is autoclavable at the usualsettings.[7]

Figure1C



IV. Properties Of Water Expandable Root Canal ObturationSystem

Biocompatibility

Eid AA*et al*. (2013) evaluated biocompatibility of C-Point and commercially available gutta-percha points using a rat odontoblast-like cell line (MDPC-23) by measuring cell viability and mineralization potential of MDPC-23 cells. Author concluded that C-Point biocompatibility is comparable to gutta-percha with minimal adverse effects on osteogenesis after elution of potentially toxic components.[8]

Bueno CR et al (2016) evaluated biocompatibility and mineralization ability of the endodontic sealers in the rat subcutaneous tissue response to implanted polyethylene tubes filled with Smartpaste Bio, Acroseal.They concluded that all tested sealers were found to be biocompatible. All sealers induced biomineralization except Acroseal, which induced a mild tissuereaction.[9]

Push out bond strength:

Economides N,Gogos C, Kodonas K, Beltes C, Kolokouris I. (2011) evaluated push-out bond strength of water expandable root canal obturation system and compared it with gutta-percha/AH- 26. They concluded that there was no significant differences between mean bond strengths of various groups, thus indicating that there was no difference in adhesion to dentine between the Smartseal systemand gutta-percha/AH- 26 applied using either single cone or lateral condensation technique.[10]

Hedge V, Arora S (2015) evaluated bond strength of Smart-Seal system to root canal dentin and concluded that water expandable root canal obturation may improve bond strength with UA (ultrasonic activation) in the coronal and middle thirds and Manual dynamic activation /EndoActivator in the apical third.[11]

Hedge V, Arora S (2015) evaluate the effects of intracanal medicaments such as calcium hydroxide, triple and double antibiotic pastes on the push out bond strength of Smart-Seal obturation with Bio-ceramic sealer to the root canal dentin and concluded that The double antibiotic pastes and calcium hydroxide did not affect the bond strength of the novel hydrophilic obturating system. Triple antibiotic pastes improved the bond strength of Smart-Seal system in the middle and apical thirds.[12]

Abdelaziz SE, FawzyMI,Bastawy HA (2019) assess the effect of 17% ethylenediaminetetraacetic acid (17%EDTA) and 0.2% Chitosan as chelating agents on bond strength of CPoint obturation system to root canal dentin and concluded that 17% EDTA when used as final rinse produced higher bond strength with CPoint obturation system compared to 0.2% chitosan, especially at the middle third.[13]

Expansion

DidatoA,Eid AA, Levin MD, Khan S, Tay FR, Rueggeberg FA.(2013) compared time-based lateral expansion of two sizes i.e 25 and 40 size of water expandable root canal obturation points with a similar-sized gutta-percha pointatvarious distances from the root apex. Water expandable obturating Points/ Propoints shows dimensional changes which were significantly higher for both sizes at each tip distance after 20min of water immersion but gutta-percha did not significantly show dimensional change from the dry value during water immersion.The expansion of this new hydrophilic obturation points is complete within 20 minutes, a time period in which most root canal sealers still exhibit flow during setting.It can expand up to around 17% with the same X- ray appearance as with conventional root canal obturation materials.[14]

The delayed hygroscopic expansion of the obturation points when coated with a hydrophilic sealer that impedes water sorption may partially compensate for the gaps arising from sealer dissolution.[15]

RajkumarB,Tekriwal S, Kumar A,Gupta V (2016)compared the immediate and delayed volumetric changes of Propoint, Thermafil and Gutta Flow using CBCT. There was an expansion seen in ProPoint system 44% after four hours of obturation and Gutta Flow shows expansion 8.9% that is much less than that of propoints whereas 9.8% contraction seen in Thermafil.[16]

Tekriwal S and Kumar A (2017) evaluated the immediate and delayed volumetric changes after obturation with ProPoint using CBCT immediately and after four hours of obturation. It was found that there was a considerable amount of expansion after four hours of obturation due to the swellable nature of the sealer and the obturating ProPoint. Volumetric expansion of 13-27% approximately was observed.[17]

Microleakage

Hegde V and Arora S (2015) compared sealing ability of a novel hydrophilic versus conventional hydrophobic obturation systems using a bacterial leakage study and found that hydrophilic obturations of the root canal shows a better resistance to bacterial leakage as compared to hydrophobic obturations.[18]

The single- cone technique utilize taper that matches with Propoint PT which is used with Smartpastebio showed the lowest amount of glucose leakage.[19]

Marya N, Datta A, Handa S, Singh R, Khurana C. (2015) compared the sealing abilities of a newer unique obturating material (PropointPT) with conventionally available materials (Gutta Percha, Thermafil and Resilon). PropointPT obturating material showedmicroleakage value of 0.0128 µl/min/cm H_2O which was less when compared with other obturation systems but still did not show complete sealing.[20]

Vats A,Farva U, Paliwal A, Bharadawaj K, Chhabbra HS, Singh A. (2019) evaluate the apical leakage of hydrophilic and hydrophobic obturation systems using a dye penetration method under stereomicroscope and concluded that sealing to apical leakage shown by hydrophilic obturation systems was significantly better as compared to hydrophobic obturation systems, though none of the obturation systems were found out to be completely devoid of leakage.[21]

Fracture resistance

Hedge V and Arora S (2015) compared fracture resistance of roots which is obturated with three different hydrophilic systems such as water expandable root canal obturation system , Resilon/Epiphany system, and EndoSequence BC sealer and one hydrophobic gold standard gutta-percha/AHPlus system and concluded that In contrast to hydrophobic systems, hydrophilic systems showed higher fracture resistance.[2]

Elayed MA, Elgendy AA.(2017) compared fracture resistance of roots obturated either with water expandablerootcanalobturationsystem(PropointPTconeandSmart- pasteBiosealer)orwithgutta- perchain combination with either MTA Fillapex or AH Plus sealers and concluded that water expandable root canal obturation system improved the fracture resistance of the endodontically treated roots more than MTA Fillapex/gutta- percha or AH Plus/gutta- perchacombinations.[22]

Retreatment

Hegde V, Murkey L (2017) evaluated the remaining novel hydrophilic (smartseal system) and conventional hydrophobic obturating Material (guttapercha) on the walls of root canals after retreatment under scanning electron microscopy (SEM) and concluded that none of the tested obturating systems could be completely removed from root canal walls however hydrophilic obturating system was difficult to retrieve as compared to hydrophobic system.[23]

Prasad A,Nair RS, Angelo JM, Mathai V, Vineet RV, Christopher SR. (2018) compare the retrievability of gutta- percha (GP), Resilon, and CPoints, using Protaper and Mtwo rotary retreatment systems and concluded that Canals obturated with CPoints and bioceramic sealer are the least retreatable among the studygroups.[24]

***pH*>7**

AbuZeid STH, Mokeemsaleh AAY (2019) conducted an *in vitro* study revealed that the solubility of resin based bioceramic sealer i.e smartpaste bio promotes alkalinity and calcium release superior to that with a MTA-based sealer after settingtime.[25]

Setting time – 4-10hr

ADA/ANSI Specification # 78

Handling and setting characteristics of water expandable root canal sealer[5]

Parameter	Acceptable Limit Results (ISO 6876:2001 & ANSI/ADA Specification # 57	Values for bioceramic sealer (smartpaste bio)
Flow	Not less than 20mm	44mm
Working time	Not less than 90% stated by manufacturer	35 mins at 37ºC
Setting time	Within range stated by manufacturer	45 mins at 37°C
Film thickness	Not more than 50 µm	3.3 µm
Solubility	Shall not exceed 3%	0.0324%
Radiopacity	Not less than 3mm Al equivalent	I5.4mmAl equivalent

V. Mechanism Of Action

Water expandable root canal obturation system is a point-and-paste root canal obturation technique that consists of premade, hydrophilic obturation points and an accompanying sealer. The principle of water expandable root canal obturation system is based mainly on its hydrophilic nature which can absorb surrounding moisture and expand resulting in filling of voids and spaces thus providing an impermeable seal.[26]The obturation points consist of a core coated with a radiopaque hydrophilic polymer layer allows the point to swell and adapt the canal wall by expanding laterally because the polyamide coating is present only laterally not axially. Lateral expansion of obturation points occurs by absorbingmoisture and dihydrogen monoxide present in the instrumented canal space form a hydrogen bond to the polar sites present, enabling expansion within the polymericchains.

The lateral expansion of obturating point is non-uniform, with its expansion mainly depends on the extent to which the hydrophilic polymer is prestressed (i.e.,contact with a canal wall will reduce the rate or extent of polymer expansion).[27] The expansion occurs with a miniscule force that is claimed to be well below the reported tensile stress of dentine.This expansionmostly occurs within first four hours after placing the obturating point into the root canal wall which allows polymer and sealer being enter into the dentinal tubules. The slight positive pressure against the root canal wall that is created forms a seal that is believed to be virtually impermeable to bacterial microleakage. A polymeric obturation point takes advantage of dentinal fluid and induces nonisotropic lateral expansion to adapt to canal irregularities thereby enhancing the sealing ability of the root canal obturation, finally reducing the possibility of reinfection and potentiating the long-term success of root canal treatment.As claimed by the manufacturer, although obturation point is capable of achieving a relative good fit of an irregular canal space, gaps may still remain between the root canal walls and the expanded point. Consequently, an accompanying sealer must be used to seal those areas.[28]A bioceramic resin based sealerwhich produces calcium hydroxide along with hydroxyapatite as byproducts of setting reaction rendering the material both anti-bacterial and biocompatible. It is hydrophilic in nature, allowing the propoint to hydrate and swell to fill any voids. This cement absorbs water present within the canal and once set bioceramic resin based sealer produces a radiopaque biocompatible cement. It gives less voids and greater efficiency in filling simulated lateral canals and a comparable homogeneity of obturation using water expandable obturation system over Gutta-percha.[29]The water expandable root canal obturation system bonds with dentine inside the root canal forms a superior seal by secondary monoblock effect. Such improved sealing ability can be attributed to its self- expansionproperty.

VI. ObturationTechnique

Water expandable root canal obturation system is consists of polyamide polymer cones and a resin sealer with additional polymer powder to be mixed during manipulation of the sealer.

- Select the correct hydrophilic obturationpoint that matches size of final master apical file which is used to complete canalpreparation.
- Try in the selected obturation Point to ensure it reaches full working length and have adequate tug-back. If the point passes beyond the working length then trim apical portion to correct length. If the obturation point doesn't go to desired length then either use final master apical file again to ensure adequate shape or use a smaller size obturation point.
- With apex locator or take a radiograph to confirm the desired position of the hydrophilic obturation point.

- Irrigate canals with saline three times prior to insertion of the system. If this regime is followed, the remaining value of 0.01% sodium hypochlorite will have no effecton the safety and effectiveness and undiluted 17% EDTA has shown to have no effect on thesystem.
- Bioceramic resin based sealant is a pre-mixed sealer paste that can be introduced into coronal 2/3 of canal using provided syringetips.
- Obturation point is introduced into the canal to desired working length using tweezers following that a slow firm pressure is applied to allow the point to evenly distribute the sealer down into thecanal.
- Tooth can then be restored immediately using any conventional restorative material.[6] Figure1,2,3
-

Figure 1D Preoperative radiograph of mandibularfirst molar and post operative radiograph of the tooth obturated with water expandable root canalobturation

Figure 2 Smartseal points with hydrophilic polymer swelling laterally (Note polymer is colourless and expansion of polymer is clearly visible for illustrative purposes)

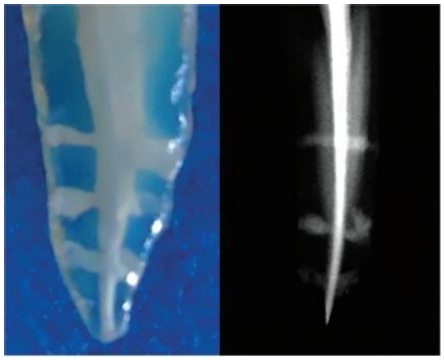


Figure 3 Photographic and radiographic analysis of Polyamide polymer obturation.

Source:
[Figure - 1]www.Semantic scholar.org
[Figure -2] Tomson RM, Polycarpou N, Tomson PL. Contemporary obturation of the root canal system. British dental journal. 2014 Mar;216(6):315-22.
[Figure - 3]www.researchgate.net

VII. Advantages

- Hydrophilic,Radioopaque
- Does not shrink onsetting
- Biocompatible, non-mutagenic and non-cytotoxic with antimicrobialproperties
- Hydrophilic obturation points are self-sealingas it expands or swells to fill voids and lateralcanals
- Improves the fracture resistance ofroots
- Used with bio-active sealer and has osteoinductiveproperty
- Increased pushout bondstrength

- Strengthen endodontically treatedteeth
- Geometry of point can be accuratelymade
- Controlled expansion
- Compatible to use with protaper and sendolinefile
- Single-cone, one-step obturation device
- Simplicity ofuse

VIII. Disadvantages

- Minimal supporting clinicaldata
- Difficult inretreatment
- Limited evidence oneffectiveness
- Expensive

IX. Conclusion

The selection of suitable obturating material is important in successful endodontic therapy. Proper root canal filling technique along with obturating material and sealer will ensure a complete seal of the root canal. Hydrophilic obturating system is significantly superior to the hydrophobic obturating system, as far as the sealing ability is concerned. Hence, hydrophilicity should be of paramount importance when selecting an obturating system. Considering the composition and the properties of water-expandable root canal obturation system, it provides a solution to many of the drawbacks whichencountered with the use of conventional gutta percha obturation system such as coronal and apical microleakage, inadequate adaption of core material to root canal dentin, hydrophobic nature, inadequate bioactive property and inability to reinforce the root canal treated tooth. Thus, it can be used as an alternative to gutta-percha. Most of the recent studies done on water-expandable root canal obturation system are *in vitro*, need and necessity calls for more clinical studies to establish its long-term use.

References

[1]. BansodePV,PathakSD,WavdhaneMB,KaleD.Obturatingmaterialspresentandpast:Areview.IOSRJDentMedSci. 2018;17:27-33.
[2]. Hegde V, Arora S. Fracture resistance of roots obturated with novel hydrophilic obturation systems. JCD. 2015May;18(3):261
[3]. Highgate DJ, Lloyd JA, inventors; Dental Root Filling Products Ltd, assignee. Expandable/contractable composition for surgical or dental use. United States patent US 7,210,935. 2007 May1.
[4]. Heggade V, Bhandary S, Naik R, Damda A. IntelligentMaterial: the essence of smart materials. Int J Appl Dent Sci. 2016;2:7-10.
[5]. Smartseal DRFP Limited 2012.http://www.smartseal.Co.uk/how-it-works.
[6]. Pathivada L, Munagala KK, Dang BA. Smartseal: New age obturation. Ann Dent Spec2013;1:13-15.
[7]. Baig AR, Ali SN, Saoji H. Smart seal: Unique obturation system in dentistry. Int J Appl Dent Sci.2016;2:1-2.
[8]. Eid AA et al., "In vitro biocompatibility evaluation of a root canal filling material that expands on water sorption," *JOE*, 2013 Jul 1;39(7):883-8.
[9]. BuenoCRetalBiocompatibilityandbiomineralizationassessmentofbioceramic,epoxy,andcalciumhydroxide-basedsealers. Brazilian oral research. 2016;30(1).
[10]. Economides N, Gogos C, Kodonas K, Beltes C, Kolokouris I. An ex vivo comparison of the push-out bond strength of a new endodontic filling system (Smartseal) and various gutta-percha filling techniques. Odontology. 2012 Jul1;100(2):187-91.
[11]. Hegde V, Arora S. Effect of advanced irrigation protocols on self-expanding Smart-Seal obturation system: A scanning electron microscopic push-out bond strength study. Contemporary clinical dentistry. 2015Jan;6(1):26-30.
[12]. Hegde V, Arora S. Effect of intracanal medicaments on push-out bond strength of Smart-Seal system.JCD. 2015 Sep;18(5):414.
[13]. AbdelazizSE,FawzyMI,BastawyHA.EffectofDifferentChelatingAgentsonBondStrengthofC-PointObturatingSystemto Radicular Dentin. Al-Azhar Dental Journal for Girls. 2019 Apr 1;6(2):1-0.
[14]. Didato A, Eid AA, Levin MD, Khan S, Tay FR, Rueggeberg FA. Time-based lateral hygroscopic expansion of a water-expandable endodontic obturation point. Journal of Dentistry. 2013 Sep 1;41(9):796-801.
[15]. Sinhal TM et al An In vitro comparison and evaluation of sealing ability of newly introduced c-point system, cold lateral condensation, and thermoplasticized gutta-percha obturating technique: A dye extraction study. Contemporary Clinical Dentistry. 2018 Apr;9(2):164.
[16]. Rajkumar B, Tekriwal S, Kumar A, Gupta V. Research PaperComparative Evaluation Of Volumetric Changes Of Propoint, Thermafill And Gutta Flow After Obturation Using CBCT- A Case Series. IJACR2016may:5.
[17]. Tekriwal S, Kumar A Comparative Evaluation Of Volumetric Changes Of Propoint Obturating System: An In Vitro Study. 2017may:3.
[18]. Hegde V, Arora S. Sealing ability of a novel hydrophilic vs. Conventional hydrophobic obturation systems: A bacterial leakage study. JCD 2015 Jan;18(1):62- 5.
[19]. Mohamed Abdel Aziz El-Sayed,Ahmed Abdel Aziz.Taleb, Mohamed Sulaiman Mubarak Balbahaith. An in vitro comparative analysis of glucose leakage for three contemporary single-cone obturation systems. 2014;2(1):1-5.
[20]. Marya N, Datta A, Handa S, Singh R, Khurana C. Comparison Of Sealing Abilities Of A Newer Unique Obturating Material With Conventionally Available Materials Using Fluid Filtration System-An In Vitro Study.Int J Oral care res2015apr:4
[21]. Vats A, Farva U, Paliwal A, Bharadawaj K, Chhabbra HS, Singh A. Comparative evaluation of apical dye penetration of hydrophilic and hydrophobic obturation system: A stereomicroscopic study. Endodontology. 2019 Jan1;31(1):40.
[22]. Elayed MA, Elgendy AA. Fracture resistance of roots obturated with a single expandable polymer cone. Tanta Dental Journal. 2017 Jan1;14(1):25.

[23]. Hegde V, Murkey L. Evaluation of residual root canal filling material after retreatment of canals filled with hydrophilic and hydrophobic obturating system: An in vitro scanning electron microscopy study. Endodontology. 2017 Jan 1;29(1):47.
[24]. Prasad A, Nair RS, Angelo JM, Mathai V, Vineet RV, Christopher SR. A comparative evaluation of retrievability of Guttapercha, Resilon and CPoints for retreatment, using two different rotary retrieval systems-An ex vivo study. Saudi endod J. 2018 May 1;8(2):87.
[25]. Abu Zeid STH, Mokeem Saleh AAY. Solubility, pH Changes and releasing elements of different bioceramic and mineral trioxide aggregate root canal sealers comparative study. J Trauma Treat. 2015;4:249.
[26]. Gupta V. Smart materials in dentistry: A review. International Journal for Advance Research and Development. 2018;3(6):89-96.
[27]. Highgate DJ, Frankland JD, inventors; Highgate Donald J, Frankland John D, assignee. Deformable polymericcompositions. United States patent US 4,565,722. 1986 Jan 21.
[28]. Badami V, Ahuja B. Biosmart materials: Breaking new ground in dentistry. The Scientific World Journal. 2014 Feb 2;1-7.
[29]. Arora S, Hegde V. Comparative evaluation of a novel smart-seal obturating system and its homogeneity of using cone beam computed tomography: In vitro simulated lateral canal study.JCD. 2014Jul;17(4):364-368.

DR.Mehreen Kulsum N, et. al. "Water expandable root canal obturation system – A review." *IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)*, 19(9), 2020, pp. 51-58.