Original Article

Received : 13-02-15
Review completed : 17-03-15
Accepted : 11-04-15

COMPARISON OF SEALING ABILITIES OF A NEWER UNIQUE OBTURATING MATERIAL WITH CONVENTIONALLY AVAILABLE MATERIALS USING FLUID FILTRATION SYSTEM- AN IN VITRO STUDY

Nidhi Marya, * Anshum Datta, ** Sahil Handa, ***
Rashmi Singh, † Charu Khurana ††

* Senior Lecturer, Department of Conservative and Endodontics, Rajasthan Dental College, Jaipur, Rajasthan, India
** Post Graduate student, Department of Oral Pathology, SGT Dental College, Gurgaon, Haryana, India
*** Post Graduate Student, Department of Public Health Dentistry, SGT Dental College, Gurgaon, Haryana, India
† Post Graduate Student, Department of Oral Pathology, SGT Dental College, Gurgaon, Haryana, India
†† Post Graduate Student, Department of Public Health Dentistry, SGT Dental College, Gurgaon, Haryana, India

ABSTRACT

Background: Microleakage, whether coronally or apically, adversely affects the success of root canal therapy. Many parameters influence microleakage during the course of root canal treatment and amongst these, the importance of choice of obturating material can never be ignored. This study was done to compare the sealing abilities of a newer unique obturating material (PropointPT) with conventionally available materials (Gutta Percha, Thermafil and Resilon) and to find an ideal obturating system which provides complete sealing of the root canal. **Materials and method:** Ninety extracted human premolars were collected and then randomly divided into four groups of 20 specimens. GROUP I - Gutta Percha with Zinc Oxide Eugenol, GROUP II - Thermafil with Zinc Oxide Eugenol, GROUP III - Resilon with Epiphany SE and GROUP IV - PropointPT with Smartpaste Bio. Ten specimens were divided into 2 groups to serve as negative and positive control. The sealing ability was compared by using fluid filtration system. **Results:** Mean fluid microleakage of group I, II, III and IV was found to be .0000731, .0000826, .0000287 and .0000128 µl/min/cm H_2O. Statistical analysis showed highly significant difference between the group IV and I, between group IV and II, between group III and I and between Group III and II. The difference between the group IV and III was significant but the difference was insignificant between Group II and I. **Conclusion:** PropointPT obturating material is a better obturating material but is still not an absolutely ideal material as this system also showed microleakge when compared with the negative control group specimens.

KEYWORDS: Microleakage; gutta percha; thermafil; resilon; propointPT; fluid filtration system

INTRODUCTION

The goal of non-surgical root canal treatment is to clean the root canal thoroughly, to remove bacteria and debris, to shape the canal and fill the canal space completely. Ingle and Bakland suggested that the most common cause of endodontic failures (60%) was incomplete obturation of the root canal system.[1] Although numerous materials have been used for obturation, the most commonly used material is gutta-percha.[2] Crystalline gutta-percha may occur in α- or β-phase. There are only minor differences in chemical behavior and physical properties between the two. The α phase appears in nature; the β-phase occurs during refining and is dominant in the products used in endodontics. Several techniques using gutta-percha have been used in an attempt to achieve a homogenous well-sealed filling. The cold lateral compaction method is still one of the most frequently used techniques.[3] However, its ability to adapt to the internal surface of root canal has been questioned. Recent advances in technology have also led to development and implementation of many gutta-percha obturating systems.[4] In 1978, Johnson introduced a technique called thermafil in which alpha phase gutta-percha was placed on a carrier, heated and used to obturate the root canal. There are three types of thermafil obturators, the difference based on the carrier material for the gutta percha i.e. stainless steel, titanium and

Table I: Showing mean fluid microleakage (µl/min/cm H_2O) and standard deviation of group I, II, III, IV

DESCRIPTIVES

µl/min/cmH2O								
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
GUTTA PERCHA	20	0.0000731	0.000042664	0.00000954	0.00005313	0.00009307	0.000018	0.000189
THERMAFIL	20	0.00008255	0.000068703	0.000015363	0.0000504	0.0001147	0	0.000264
RESILON	20	0.00002865	0.000020587	0.000004603	0.00001902	0.00003828	0	0.000075
PROSMART	20	0.0000128	0.000014767	0.000003302	0.00000589	0.00001971	0	0.000037
Total	80	0.00004927	0.00005095	0.000005696	0.00003794	0.00006061	0	0.000264

TABLE II: Showing mean fluid microleakage (µl/min/cm H_2O) and standard deviation of group I, II, III, IV using one way ANOVA

ANOVA

µl/min/cmH2O					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	0	3	0	12.738	0.00
Within Groups	0	76	0		
Total	0	79			

plastic carriers, coated with alpha phase gutta percha which become part of the final obturation.[4] In 2004, a new obturation system was launched under the name RealSeal, containing Resilon and a resin-based sealer. Resilon is a polyester core material with bioactive glass, bismuth and barium salts as fillers. With physical and handling characteristics similar to gutta-percha, the main advantage of thermoplastic resin as core material will be the extent to which it will bond to the sealer used. RealSeal sealer is a dual curable dentin resin composite sealer.[5] This attributes to the "monoblock" which is created by the resilon filling material closely adapting to the sealer and sealer adhering to the dentin walls. Recently, a newer unique obturation system, PropointPT with Smartpaste Bio, has been designed to provide a simple effective method of predictably sealing the root canals in three dimensions. It is a single point and paste system. PropointPT contains a hydrophilic polymer coating around a central core. This coating can absorb moisture from the root canal and swell laterally into any open voids. Smartpaste Bio is a bioceramic sealer which is biocompatible and hydrophilic, and expands slightly on setting. Various methods can be used to evaluate the apical sealing ability of root canal filling material such as dye leakage, electrochemical technique, bacterial penetration measurement, radioisotope techniques but all of these techniques have shown to have a variety of shortcomings.[4] Pashley *et al*., developed a fluid filtration technique to understand the physiology of dentin as well as the effects of various restorative treatment on dentin permeability.[6] This technique was adapted by Wu et al, to measure microleakage of root end filling. They described this technique as being capable of quantitatively measuring volumetric microleakage. Hence, this study was undertaken to compare the sealing abilities of a newer unique obturating material, PropointPT with conventionally available materials i.e. Gutta Percha, Thermafil and Resilon using fluid filtration system and to find an ideal obturating system which provides complete sealing of the root canal.

MATERIALS AND METHODS

Ninety extracted human premolars were collected and stored in 4% w/v sodium hypochlorite to

Table III: showing multiple comparisons between the groups using Post Hoc Test. The value of significance can be interpreted. The mean difference is significant at 0.05 level

Multiple Comparisons

µl/min/cmH2O Dunnett T3						
(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
GUTTA PERCHA	PROSMART	.000060300*	0.000010095	<0.001	0.00003147	0.00008913
	THERMAFIL	-0.00000945	0.000018084	0.995	-0.00005999	0.00004109
	RESILON	.000044450*	0.000010592	0.002	0.00001456	0.00007434
PROSMART	GUTTA PERCHA	-.000060300*	0.000010095	<0.001	-0.00008913	-0.00003147
	THERMAFIL	-.000069750*	0.000015713	0.001	-0.00011512	-0.00002438
	RESILON	-.000015850*	0.000005665	0.048	-0.00003161	-0.00000009
THERMAFIL	GUTTA PERCHA	0.00000945	0.000018084	0.995	-0.00004109	0.00005999
	PROSMART	.000069750*	0.000015713	0.001	0.00002438	0.00011512
	RESILON	.000053900*	0.000016037	0.016	0.00000791	0.00009989
RESILON	GUTTA PERCHA	-.000044450*	0.000010592	0.002	-0.00007434	-0.00001456
	PROSMART	.000015850*	0.000005665	0.048	0.00000009	0.00003161
	THERMAFIL	-.000053900*	0.000016037	0.016	-0.00009989	-0.00000791

*. The mean difference is significant at the 0.05 level.

remove the debris. With the help of a diamond disk with air-water spray coolant, the teeth were decoronated to create a standardized root canal length of 17mm. The pulp tissue was removed and canal was located with the help of DG-16. The working length was determined by inserting a #15 K-file (Mani, Inc.) into the root canal until it was just visible at the apical foramen and then subtracting one millimeter. This length was confirmed by taking a radiograph. The canals were instrumented using a crown down technique with Rotary ProTaper Nickel Titanium files (Dentsply, Maillefer) to an apical file size of finishing file no. 30 and in between the instrumentation, the canal was recapitulated with a #15 K-file. Irrigation was done with 2ml flush of irrigant using 4% of sodium hypochlorite and 17% of EDTA (Prevest DenPro), which was delivered through a side vented 30-gauge needle (Biodent Co. Ltd), which was placed as far as possible into the canal without allowing the needle to bind with the canal walls. The final rinse of sterile saline (Claris Otsuka Ltd.) was used. The teeth were then randomly divided into four groups of 20 specimens each for final obturation as followed:

Group I: Gutta Percha (Dentsply Maillefer) with Zinc Oxide Eugenol.

Group II: Thermafil (Dentsply Maillefer) with Zinc Oxide Eugenol.

Group III: Resilon with Epiphany SE (Pentron Clinical Technologies LLC).

Group IV: PropointPT with Smartpaste Bio (DRFP Ltd.) (Fig. 1).

CONTROL GROUPS

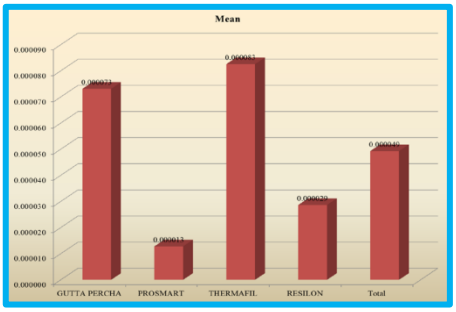
10 specimens were randomly divided into 2 groups of five each to serve as the negative and positive control.

Positive Control: Specimens were instrumented and were left unobturated.

Negative Control: Specimens were instrumented and obturated with cyanoacrylateadhesive.

GROUP I (GUTTA PERCHA WITH ZINC OXIDE EUGENOL SEALER)

The root canal of the specimens in this group were dried with three F3 paper points, each



Graph 1: The mean fluid microleakage (µl/min/cm H2O) of Group I, II, III, IV

Fig. 2: Fluid filtration system

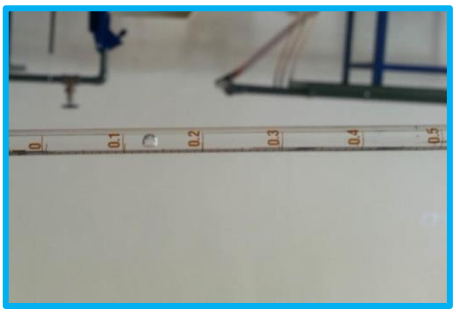


Fig. 3B: At 8 min time interval in one of the specimen

placed in the canal for 5 seconds and then filled with F3 gutta-percha and Zinc Oxide Eugenol sealerusing cold lateral compaction technique. Zinc Oxide Eugenol sealer was coated on the canal wall using a lentulo spiral after which master cone coated with the sealer was placed into the root canal till working length. Lateral compaction with accessory gutta-percha cones was done till complete obturation was accomplished.

GROUP II (THERMAFIL WITH ZINC OXIDE EUGENOL)

The root canal of the specimens in this group were dried with three F3 paper points, each placed in the canal for 5 seconds and then were obturated by using the Thermafil Plus technique. Thermafil Obturators ISO size 30 and Zinc oxide

Fig. 1: Materials used for obturation

Fig. A3: At O min time interval

eugenol sealer were used. The expected adaptation of the Thermafil component to the root canal walls of each canal was verified by using the appropriate Thermafil Verifier before each obturation. While the Thermafil Obturator was being heated in the ThermaPrep Plus oven, the sealer was applied with the help of letulo spiral. After completion of the heating procedure, the obturator was inserted immediately into each canal with a slow, firm, and continuous apical movement. The removal of the shank was done using a bur with an air turbine handpiece (300,000 rpm) without spray.

GROUP III (RESILON WITH EPIPHANY SE SEALER)

The root canal of the specimens in this group were dried with three F3 paper points, each placed in the canal for 5 seconds and then were filled with resilon (.06 taper; tip size 30) and epiphany sealer. After instrumentation, Epiphany SE sealer was placed using a lentulo spiral. The master cone was coated with sealer and placed into the root canal. Lateral compaction with fine accessory resilon (0.02 taper; size 20-25) cones was performed till complete obturation was accomplished.

GROUP IV (PROPOINTPT WITH SMARTPASTE BIO)

The root canal of the specimens in this group

were dried with a single F3 paper point for 5 seconds and then were obturated by using PropointPT corresponding F3 ProTaper file and Smart paste Bio. The sealer was delivered using a pre-mixed syringe and was simply injected into the root canal. The PropointPT (corresponding to F3 protaper file) was introduced into the canal to the working length. A slow firm pressure was applied to allow the point to evenly distribute the sealer down into the canal. The PropointPT was trimmed using the SmartTrim Trimming Kit (DRFP Ltd.). All specimens were tested after 24 hrs of obturation. The sealing ability was compared by using fluid filtration system (Fig. 2). For the standardization of the system, negative control samples were considered which ensured that there was no leakage or fluid movement within the system and the positive control samples which ensured fluid movement without any obstruction. Four subsequent pictures were taken at 2-min intervals (2, 4, 6 and 8 min after the first picture) (Fig. 3). The longitudinal displacement of the bubble was then converted into the volume of fluid passing from the samples, showing it as µl/min/cm H_2O. Thus a single number was obtained for each sample representing the amount of leakage in its canal as µl/min/cm H_2O.

RESULTS

The positive controls had extensive immeasurable bubble movement whereas the negative controls had zero bubble movement. Measurements of fluid movement were made at 2-minute intervals for 8 minutes and calculation of microleakage in µl/min/cm H_2O for each sample was done for group I (Gutta Percha with Zinc Oxide Eugenol), group II (Thermafil with Zinc Oxide Eugenol), group III (Resilon with EpiphanySE) and group IV (PropointPT with Smart paste Bio). One way ANOVA was used to calculate mean and standard deviation of group I, II, III and IV (Table I and II). Mean fluid microleakage of group I, II, III and IV was found to be .0000731, .0000826, .0000287 and .0000128 µl/min/cm H_2O, respectively (Graph 1). Post Hoc test was done to do multiple comparisons between the groups (Table III). Statistical analysis showed highly significant difference between the group IV and I, and between group IV and II, between group III and I and between Group III and II. The difference between the group III and IV was significant but the difference was insignificant between Group II and I.

DISCUSSION

One of the keys to successful root canal therapy is to adequately obturate the prepared root canal space.[7] This is validated by the fact that nearly 60% of failures in endodontics can be attributed to incomplete obturation of the root canal.[8] Microleakage, whether coronally or apically, adversely affects the success of root canal therapy.[9] Many parameters influence microleakage during the course of root canal treatment like isolation, patient cooperation, canal anatomy, operator skill, root canal sealing, and the choice of filling material.[9] Amongst these, the importance of choice of filling material can never be ignored. While a plethora of materials has been advocated over the last 150 years for root canal obturation, Gutta-percha is the standard material of choice as a solid core filling material for canal obturation. It demonstrates minimal toxicity, minimal tissue irritability, and is the least allergenic material available when retained within the canal system.[10] In cases of inadvertent gutta-percha cone overextension into the periradicular tissues, it is well tolerated provided the canal is clean and sealed. But the advantages of gutta percha cannot overshadow its disadvantages. The main disadvantage of gutta-percha is its non adhesiveness to the dentin wall. Other problems with gutta percha are its lack of rigidity, ease of displacement under pressure and the requirement of sealer/cement with gutta-percha to fill the spaces between the filling material and the dentin wall. Although, it has satisfied the majority of criteria for an ideal root filling material, it is still not the ideal filling material. Contemporary techniques include the use of gutta-percha carrier-based obturators as root canal filling material but this too does not guarantee an impervious seal of the root canal system. Also, with softened gutta-percha obturation techniques there has been a greater incidence of material extrusion beyond the confines of the canal.[11] Research continues to find alternatives which may seal better, mechanically reinforce compromised roots, and avoid any potential for adverse responses in latex-allergic patients. One such landmark was the introduction of a Resin-based obturation system. Resilon is a synthetic material developed to replace gutta percha and traditional obturation

systems of endodontically treated teeth. Resilon is a thermoplastic synthetic polymer-based root canal filling material composed of a parent polymer, polycaprolactone 25-40%, which is a biodegradable aliphatic polyester, with filler particles consisting of bioactive glass, bismuth oxychloride and barium sulfate.[12] More recently, new Epiphany self-etch (SE) soft resin endodontic obturation system has been marketed consisting of 2 components: Epiphany self-etch sealer and the core material (Resilon). With the addition of Epiphany SE sealer, no change in technique is needed when transferring from gutta-percha to the Epiphany system. It was claimed that the components of resin based obturation system could bond with each other and with canal walls to produce an impervious seal, can reinforce rootand allow monoblock formation.[13,14] But this bonding with dentin wall or monoblock formation is still a controversial issue.[15] Other areas of debate with resin based obturation system include the C-factor and polymerization shrinkage.[16] Search continued for alternative obturation system which led to introduction of yet another and newer unique obturation system called "prosmart obturation system" which claims to provide an impervious seal to bacterial microleakge. Prosmart is a single point (PropointPT) and sealer (smartpaste Bio) obturation system. The PropointPT is constructed in two parts: 1) Central Core which provides the point with flexibility and allows it to easily pass around any curves in the prepared canal, while being rigid enough to pass easily to length in narrower canals; 2) the other part being, the outer polymer layer which is hydrophilic. This hydrogel layer allows the point to swell in order to adapt to the ramifications of the root canal. The key advantages of using this hydrogel over existing obturation materials are controlled expansion and biocompatibility. Smartpaste Bio is a hydroxyapatite based sealer that is used with the prosmart obturation points.The sealer component of the prosmart system is also biocompatible. It consists of a combination of hydroxyapatite and calcium hydroxide. The antibacterial, osteoinductive and biocompatible nature of both of these materials are well known.[17] The sealer is injected into the root canal. The sealer will expand slightly on setting and provides a highly biocompatible alternative to traditional endodontic sealers. The prosmart polymer which is hydrophilic allows the minute amount of fluid present in the root canal to be absorbed by the points. The point thus swells and adapt to the ramifications of the root canal. This fluid can bond to the polar sites present, enabling expansion within the polymeric chains. Polymers like prosmart (Hydrogels) expand with a miniscule force that is well below the reported tensile stress of dentine and only a fraction of force is generated inside the tooth when compared with traditional techniques such as warm vertical compaction. This expansion occurs within the first 4 hours after placing the point into the canal and allowing the point to gently adapt to any irregularities in the root canal.[17] Therefore, in the present study, four different obturation systems were used and it was decided to compare their sealing abilities in an attempt to find an ideal obturating system which could provide a complete seal of the root canal and therefore prevent subsequent leakage into the periradicular tissues. The study was conducted on single rooted human premolar teeth with single canal which were decoronated to achieve a root length of 17 mm for the purpose of standardization using a diamond disk under saline irrigation. The root canals of all the specimens were instrumented using a crown down technique with Rotary ProTaper Nickel Titanium files to a size of finishing file 3 (F3- equivalent to apical size 30) to standardize the apical tip size and taper of all the specimens. The root canal of specimens in group I, II and III were dried with three F3 paper points, each placed in the canal for 5 seconds but the root canal of group IV were dried with a single F3 paper point for 5 seconds only. This was done to conform with the clinical technique of the Prosmart obturation system because it has been hypothesized that PropointPT absorb fluid from the dentinal tubules and adapts to the root canal. Between the commonly used obturation techniques namely lateral compaction and warm vertical compaction, Cold lateral compaction is probably the most commonly taught and practiced filling technique worldwide.[18] This technique has been the "gold standard" to which other techniques have been compared. Therefore in this study, Group I and Group III were obturated using lateral compaction technique. In case of group II, thermafil obturators were used. The

obturator by virtue of being a solid core of plastic, covered with a layer of alpha phase gutta-percha did not necessitate any cold lateral compaction. No lateral compaction was required in group IV also as prosmart obturation system being a single point and paste system in which point swells by absorbing fluid from the dentinal tubules and expands. The positive control specimens showed extensive immeasurable bubble movement in a fraction of second, which indicated severe leakage. This can be clinically correlated with the importance of root canal obturation and the free movement of fluid across the apex in the absence of an obturation. The negative control specimens demonstrated zero bubble movement which indicated that there is no means of leakage when cyanoacrylate adhesive was used. The statistical analysis showed mean fluid microleakage of 0.0128 µl/min/cm H_2O in Group IV (PropointPT with Smartpaste Bio), 0.0287 µl/min/cm H_2O IN group III (Resilon with Epiphany SE), 0.0731 µl/min/cm H_2O in group I (Gutta Percha with Zinc Oxide Eugenol), 0.0869 µl/min/cm H_2O in group II (Thermafil with Zinc Oxide Eugenol). The results showed no significant difference between Group I and group II. This may be due to the fact that both the obturation system contain Gutta percha with only slight difference in the chemical and physical nature of gutta percha. Group II showed maximum mean fluid microleakage among all the four groups. The possible explanation for this leakage with the thermafil technique could be the shrinkage of Gutta Percha when used in warm root canal obturation techniques. In addition to this, it is possible that the carrier did not stay centered in some specimens and gutta percha was stripped from the carrier in the apical portion of the canal and fluid thus may penetrate through the remaining space.[19] The results showed highly significant difference in mean fluid microleakage between group III and I and; between Group III and II. The adhesive properties, penetration of the sealer into the dentinal tubules and formation of monoblock by the resin based adhesive material can be the possible explanation for the significantly less microleakage in group III.[14] There is highly significant difference in the mean fluid microleakage between group IV and I and between group IV and II. The possible reason for minimal microleakage in this group could be the expansion of the prosmart polymer – prosmart being hydrophilic and which allows the minute amount of fluid present in the root canal to be absorbed by the point and expand. The slight positive pressure against the canal wall that is created forms a seal that is virtually impermeable to bacterial microleakage. The results of group IV can further be explained by the fact that the sealer is expressed into the dentinal tubules which expands slightly while setting. The results showed significant difference in the mean fluid microleakage of Group IV and Group III. Group III showed more microleakage when compared to Group IV. The possible reason for more microleakage in the resilon group may be that despite the hybridization of resin filling materials, a tight seal is difficult to achieve because of complex root canal anatomy and mechanical challenges, such as polymerization shrinkage and unfavourable C- factor, formation of areas of interfacial separation and incomplete infiltration of resin into demineralized dentin. All these factors may reduce the bonding efficacy of resin based obturation system inside the root canals.[16] However, the present study on microleakage may not be enough to completely refute the concept of monoblock which finds considerable support in literature.[20,21] The group showed microleakage value of .0128 µl/min/cm H_2O which was less when compared with other obturation systems but still did not show complete sealing. This provides evidence against manufacturer's claim of prosmart being a leakproof obturation system. The possible reason for this minimal microleakage may be due to its inability to completely comform to the irregularities of the root canal. The swelling of the point may not translate into its complete adaptation to the minute irregulaties and ramifications of the root canal leading to microleakage.

CONCLUSION

Within the limitations of the study, it can be shown that PropointPT obturating material is better obturating material when compared to commonly used obturating materials but is still not an absolutely ideal obturating material as this system also showed microleakge when compared with the negative control group specimens. In accordance with this study, further research is required to understand with greater degree of reliability and precision, the dynamic that

determine the microleakage in obturation system. It can certainly be concluded, that such studies including this one will go a long way in increasing the predictability of contemporary endodontics.

CONFLICT OF INTEREST & SOURCE OF FUNDING

The author declares that there is no source of funding and there is no conflict of interest among all authors.

BIBLIOGRAPHY

1. Ingle JI, Bakland LK. Endodontics. 5th ed. London: BC Decker Inc; 2002.
2. Carrotte P. Endodontics: Part 8. Filling the root canal system. Br Dent J 2004;197:667-72.
3. Lin ZM, Jhungroo A, Ling JQ. An evaluation of the sealing ability of a polycaprolactone-based root canal filling material (Resilon) after retreatment. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;104:846-51.
4. Rajeswari P, Gopikrishna V, Parameswaran A, Gupta T, Kandaswamy D. In vitro evaluation of apical microleakage of thermafil and obtura II heated gutta percha in comparison with cold lateral condensation using fluid filtration system. Endodontology 2005;17:24-8.
5. Shipper G, Orstavik D, Teixeira FB, Trope M. An evaluation of microbial leakage in roots filled with a thermoplastic synthetic polymer-based root canal filling material (Resilon). J Endod 2004;30:342-7.
6. Pommel L, Camps J. Effects of pressure and measurement time on the fluid filtration method in endodontics. J Endod 2001;27:256-8.
7. Epley SR, Feischman J, Cicalese C. Completeness of root canal obturation: epiphany techniques versus gutta percha techniques. J Endod 2006;32:541-4.
8. Ingle JI, West JD. Endodontics 4th ed Lea and Febiger 1994.
9. Beatty RG, Baker PS, Haddix J, Harr F. The efficacy of four root canal obturation techniques in preventing apical dye penetration. J Am Dent Assoc 1989;119:633-7.
10. Ørstavik D. Materials used for root canal obturation: technical, biological and clinical testing. Endod Topics 2005;12:25-38.
11. Budd CS, Weller RN, Kulild JC. A comparison of thermoplasticized injectable gutta-percha obturation techniques. J Endod 1991;17:260.
12. Hiraishi N, Yau JY, Loushine RJ, Armstrong SR, Weller RN, King NM, *et al*. Susceptibility of a polycaprolactone-based root canal-filling material to degradation. III. Turbidimetric evaluation of enzymatic hydrolysis. J Endod 2007;33:952-6.
13. Teixeira FB, Teixeira EC, Thompson JY, Trope M. Fracture resistance of roots endodontically treated with a new resin filling material. J Am Dent Assoc 2004;135:646-52.
14. Shipper G, Trope M. In vitro microbial leakage of endodontically treated teeth using new and standard obturation techniques. J Endod 2004;30:154-8.
15. Pasqualini D, Scotti N, Mollo L, Berutti E, Angelini E, Migliaretti G. Microbial leakage of gutta-percha and Resilon root canal filling material: a comparative study using a new homogeneous assay for sequence detection. J Biomater Appl 2008;22:337-52.
16. Perdigao J, Lopes MM, Gomes G. Interfacial strength adaptation of adhesive materials to root canal dentin. J Endod 2007;33:259-63.
17. Propoint 21st century obturation. From internet source: http://www.smart-seal.co.uk/products/propoint-pt as accessed on 3rd September 2011.
18. Hommez GMG, De Moor RJG, Braem M. Endodontic treatment preformed by Flemish dentists. Part 2. Canal Filing and decision making for referrals and treatment of apical periodontitis. Int Endod J 2003;36:344-51.
19. Yucel AC, Ciftci A. Effect of different root canal obturation techinques on bacterial penetration. Oral Surg oral Med Oral Pathol Oral Radiol Endod 2006;102:88-92.
20. Brodrumlu E, Tunga U. Apical leakage of Resilon obturation material. J Contemp Dent Prac 2006;7:45-52.
21. Tunga U, Broadrumlu E. Assessment of the sealing ability of a new root canal obturation material. J Endod 2006;32:876-8.