Evaluation of Fluoride release from orthodontic acrylic resin by using two different polymerizations techniques: An In-Vitro Study

Diyar B. Sabir[1]**; Zana Q. Omer**[2]

Background and objectives: Oral hygiene is mandatory for patients with orthodontic appliances and prevention of microbial biofilms in the oral environment. One method for inhibiting the growth of micro-organisms is commonly by use fluoridated dental material. The aim of this study was to evaluate releasing fluoride after addition into the orthodontic acrylic resin with 40% hydroxyethyl methacrylate, and amount of fluoride release from the orthodontic acrylic resin that was polymerized by Auto polymerization and IVOMAT polymerization.

Materials and methods: Sixty disc-shaped samples measured 10 mm diameter and 1mm thickness of orthocryle were divided into two groups according to polymerization technics, thirty samples for Auto polymerization and thirty samples for polymerization by IVOMAT. Each of these groups was subdivided into three groups according to the concentration of NaF. Group A 0% NaF, Group B 10%NaF, and Group C 20%NaF. For testing fluoride release, samples stored for 28 days in deionized distilled water for testing measurements for days 1,4,7,14,21, and day 28. Precision ion meter was used to measure fluoride release. Repeated measure ANOVA was undertaken to compare fluoride release in each group. Paired sample t-test was utilized to differentiate between groups.

Results: Significant difference was observed in the fluoride-releasing of both groups and within the subgroups ($P \leq 0.05$). The highest amount of fluoride release is present in 20% NaF followed by 10% NaF for Auto polymerized acrylic resin in the first day. The lowest fluoride release is presented in 10% on day 28 for IVOMAT polymerization. In general, the Auto polymerized acrylic resin had higher fluoride release than IVOMAT from all groups for 0%,10% and 20% NaF.

Conclusion: Orthodontic acrylic resin has the ability to release fluoride more than 28 days for both types of polymerization technics in different concentrations.

Keywords: Orthocryle, auto polymerization, IVOMAT, sodium fluoride, fluoride release.

(1)Department of Pedodontics, Orthodontics and Preventive Dentistry, College of Dentistry, Hawler Medical University, Erbil, Iraq.
(2)Department of Pedodontics, Orthodontics and Preventive Dentistry, College of Dentistry, Hawler Medical University, Erbil, Iraq.

Introduction

The demand for orthodontic services is increasing and about 25.4% of Children in Kurdistan require some form of orthodontic treatment. Thus, there is an increasing need for the use of orthodontic acrylic resins in removable appliances and retainers.[1] Patients have to wear appliance made by acrylic resin all day (orthodontic retainer or removable appliance). Oral hygiene control is essential especially for dental issues such as caries in which the bacteria's are the major

cause for it.[2] Removable orthodontic appliances and dentures have usually been fabricated from polymethyl methacrylates (PMMAs) since the 1930s. Moreover, polymethyl methacrylates are used for maxillary orthopedic appliances for newborn cleft lip and palate patients and splints for orthognathic surgery patients.[3] This material continues to be used to fabricate denture bases due to its various advantages, including low cost, biocompatibility, ease of processing, stability in the oral environment, and acceptable aesthetics.[4] Removable orthodontic appliances often promote the accumulation and colonization of dental plaque bacteria including Streptococcus mutans and growth of biofilms on the surface of these appliances may compromise the oral health of patients, and threaten the efficiency of orthodontic treatment.[5] Porosities on the outer and inner surfaces of orthodontic acrylic appliances also provide favorable conditions for microbial colonization.[6] Therefore, good oral hygiene is essential for the prevention of micro-organism colonization and prevention of oral diseases. Different anti-plaque agents have been assessed for their ability to decrease the adhesion of microorganisms to dentures, by interfering with bacterial co-aggregation or by reducing bacterial vitality thereby minimizing bacterial growth and biofilm formation.[7] Fluoride is the most popular caries preventive agent, and there is evidence that it can inhibit the growth of micro-organisms.[8] Various methods shows the ability of fluoride in controlling dental caries by delivering fluoride into the oral cavity, such as fluoride-containing dentifrices, fluoride mouth-rinses, varnishes, and fluoride-releasing restorative materials.[9,10] Orthodontic removable appliance wearers have a higher risk of caries and biofilm formation and make a site for bacterial adhesion to the tooth surface and the demineralization processes, for this resin this study has been done to evaluate the beneficial amount of fluoride release containing removable orthodontic base acrylic resin.

Materials and methods

In the current study, the sodium fluoride (NaF) (Central Drug House-India) was added in to orthodontic acrylic resin (Orthocryl EQ, Dentaurum, Germany) for 60 samples, 30 samples for Auto polymerization and other 30 samples for IVOMAT polymerization, the samples were prepared as shown in study design scheme (Fig. 1) and each group had three subgroups of control 0% NaF,10%NaF, and 20% NaF. For testing fluoride releasing measurements. Metal discs with 10 mm diameter and 1 mm thickness, for making acrylic samples.[12,25]

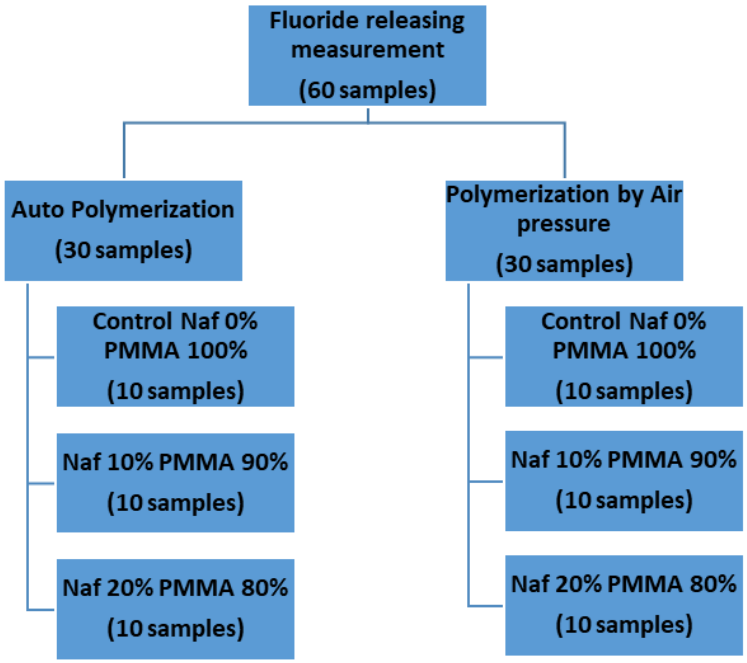

Figure 1: Distribution of the samples in the study groups.

Proportioning of materials. Table 1 shows the percentages and amounts of polymer, monomer, and NaF powder used in the study.

Table 1: Percentages and amounts of a polymethyl methacrylate, sodium fluoride, methyl methacrylate, and 2-hydroxyethyl methacrylate.

POLYMERIZATION	GROUP	POWDER PMMA %	NAF %	LIQUID MMA %	HEMA %
- AUTO - IVOMAT	A	100	0	100	0
	B	90	10	60	40
	C	80	20	60	40

Preparing the powder and liquid. Prior to mixing powder and liquid together 3 different ratios from the powder (NaF, PMMA) were prepared according to the grouping of the samples and weighted by Electronic balance (KERN, Germany) (Table 1). The overall ratio of MMA (Orthocryl- Dentaurum, Germany) to HEMA (Beijing Solarbio) in the liquid component of the experimental materials was 60wt% to 40wt%. According to the table 1 Where required, the MMA will be added and mixed using magnetic stirring. (Snijders-Holland) for 30 minutes.[2] Immediately after all the proportions are ready and dissolving NaF in the prepared liquid, acrylic (powder) was mixed with prepared liquid to decrease the possibility of particle aggregation and phase separation [25]. Sodium fluoride powder NaF will be weighed by Electronic balance and added to the monomer [2]. According to the concentration in this study:0%, 10%, 20%, For 10% concentration 10gram of NaF powder was dissolved in 100 ml prepared liquid, for 20% concentration 20 gram of NaF powder was dissolved in 100 ml prepared liquid, then mixed with prepared liquid, the mixing was done by a stirrer. The suspension of the monomer with NaF was immediately mixed with Orthocryl EQ powder according to the manufacturer's instructions.[2]

Polymerization. For this experimental study, the polymerization of the (Orthocryl EQ) was done in two ways:

Auto: Auto polymerized resin represent chemically cured PMMA, in which the reaction starts as soon as the powder and liquid are mixed together at room temperature.

IVOMAT: Acrylic resin was cured by water under air pressure and constant heating. (IVOMAT). Deionized distillated water was used. The curing time and air pressure as manufacture recommended for (Orthocryl EQ) were 15 minutes at 45C° under a pressure of 2.2 bar. After the samples had been set, removed from the mold, excesses removed, during finishing and polishing the diameter and thickness of the samples were measured intermittently using digital Vernier caliper. After that samples were placed into a plastic cylindrical vial with 5 ml distilled deionized water and stored in an incubator at 37°C 24 hours before fluoride release measurement. The water in the containers was changed a day before the measurement, days 1,4,7,14, 21, and day 28[12].

Fluoride release measurements tests. An acetic buffer solution total ionic strength adjusting buffer (TISAB III-Germany) of 0.5 ml will be added to provide a background of constant ionic strength for fluoride measurement. to each storage solution [21]. Fluoride concentration measured using a calibrated ion selective electrode at-

tached to an ion meter (Precision ion meter 931, China). Standard fluoride solution, with different concentrations (0.01,0.1,1,10,100 ppm F-) was prepared from a 1000 ppm standard solution and used for calibration. All readings in a (ppm), the readings record from the (ppm) converted to (µg/cm2) by dividing it by the surface area of the sample. Therefore, the results were presented as the rate of fluoride released per unit surface area of the sample per day (µg/cm^2).

Statistical analysis. All data were analyzed using statistical software (SPSS 22 for Windows, IBM SPSS Inc., USA). The Shapiro-Wilk test was used to test the normality of the data. The fluoride releasing data were normally distributed. Parametric tests were used to investigate the statistical difference between groups. Repeated measure ANOVA was used to find significant differences in the fluoride release for each fluoride group for each day. Paired sample t-tests were used to demonstrate the differences between auto and IVOMAT polymerization at (P<0.05).

Results

The descriptive statistics including mean, standard deviation, amount of fluoride release from all tested orthodontic acrylic samples measured by calibrated ion selective electrode for both (Auto polymerized & IVOMAT) for (0%,10% and 20% NaF) containing orthodontic acrylic resin at days 1,4,7,14,21 and 28 are listed in tables 2 and 3.

Table 2: Mean and standard deviation of fluoride release for Auto and IVOMAT polymerized acrylic resin of Group B 10% NaF, at day 1,4,7,14,21and 28.

AUTO POLYMERIZATION GROUP B				POLYMERIZATION BY IVOMAT GROUP B			
DAY	Mean	SD	ANOVA	Day	Mean	SD	ANOVA
1	132.72	20.44	<0.001	1	99.40	15.92	<0.001
4	54	12.0		4	22.07	4.93	
7	29.92	8.26		7	9.68	2.44	
14	10.07	1.10		14	2.96	1.23	
21	6.40	0.87		21	1.58	0.71	
28	3.8	0.89		28	0.87	0.23	

- **Mean fluoride release in (µg/cm2).**

Table 3: Mean and standard deviation of fluoride release for Auto and IVOMAT polymerized acrylic resin of Group C 20% NaF, at day 1,4,7,14,21 and 28.

Auto Polymerization Group C				Polymerization by IVOMAT Group C			
Day	Mean	SD	ANOVA	Day	Mean	SD	ANOVA
1	457.97	50.83	<0.001	1	179.56	44.95	<0.001
4	167.35	18.05		4	39.02	10.38	
7	39.12	10.32		7	17.00	5.38	
14	14.63	4.13		14	5.85	2.46	
21	12.83	2.31		21	2.53	1.43	
28	5.44	1..71		28	1.21	0.23	

- **Mean fluoride release in (µg/cm2).**

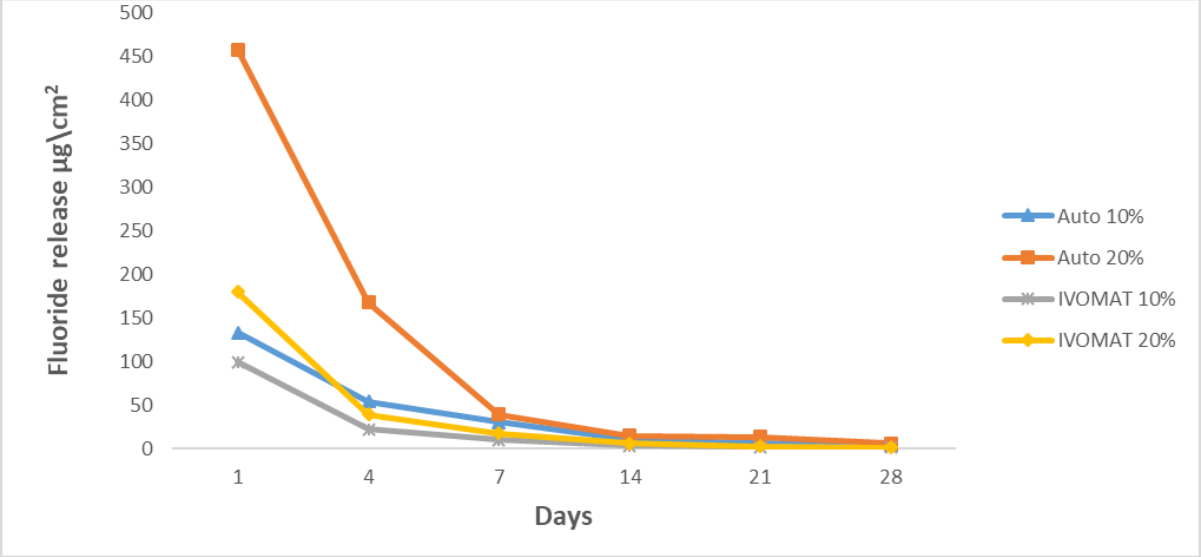

Figure 2: Mean of fluoride release for Auto and IVOMAT polymerized acrylic resin of Groups B10% and C 20% NaF, at day 1,4,7,14,21and 28.

Group A (0% NaF) auto polymerized had the highest fluoride release on day 1 which was 0.12 ± 0.88 µg/cm^2 and lowest fluoride release at day 1 for IVOMAT which was 0.8 ± 0.3. the fluoride release for this group had only at day 1, followed by a negligible amount of fluoride release.

Group B (10% NaF) auto polymerized acrylic samples showed highest amount fluoride release was 132.72±20.44 µg/cm^2 at 1 day and the lowest amount fluoride release was 3.8 ±0.89 µg/cm^2 at day 28. Fluoride release for Group B (10% NaF) that was polymerized by IVOMAT similar as auto polymerized, the highest amount of fluoride release at 1 day was 99.40 ± 15.92 µg/cm^2 and lowest amount was 0.87± 0.23 µg/cm^2. There were highly significant differences found between means Group B (10% NaF) auto polymerization at all days tested samples and further major differences between means IVOMAT polymerization (Repeated measure ANOVA P<0.05, Table 2).

Group C (20% NaF) was in line with Group B outcome, (10% NaF) the highest mean amount fluoride release was 457.97 ± 50.83 µg/cm^2 at 1 day and the lowest amount fluoride release was 1.21 ± 0.23 µg/cm^2 at day 28 (Table 3).

The Auto Polymerization Group B (10%, 20% NaF) and IVOMAT Group B (10%, 20% NaF), are shows significant differences. (paired samples t-test P<0.05, Tables 2 and 3).

The pattern of fluoride release for all samples was decrease daily. The greatest amount of fluoride release was observed during the first days, then followed by a sharp decrease on the second day, and gradually diminished over the next days (Figure 3).

Discussion

Children in treatment with removable orthodontic appliances (ROA) have a higher risk for proximal caries, gingivitis, and halitosis than children without ROA.[24] The most effective way to prevent dental caries is by using fluoridated dental materials.[11] The released fluoride will be helpful for controlling dental cerise for patients who receive orthodontic treatment with removable or fixed appliance followed by wearing retainers produced from acrylic resin, This study shows that adding sodium fluoride to orthodontic acrylic samples can act as a fluoride delivery in the oral cavity more than 28 days by different concentration and tow polymerization technics. The source of fluoride used in this study was Sodium fluoride (NaF) as its very soluble salt and it is easily dissolved to free Na+ and F- ions.[20]

The obtained results in this study showed that Group A that contained 0% sodium fluoride release small amount fluoride for three days for auto polymerized orthocryle

and only for two days for polymerization by IVOMAT. The probable reason is due to contamination of the metal moulds and instruments that were used for the preparation of the samples. The other cause would be due to the accumulation of fluoride ions around the electrode membrane. This was similar to the results of Ismail in which he had detected the small amount of fluoride ion release on day one from group 10:0.[12] Also same as Zahroon in which fluoride was detected from the samples that containing free-fluoride during the first four days of fluoride ion measurement.[13] The pattern of fluoride release was similar for all orthodontic acrylic samples containing sodium fluoride in which the maximum amount of fluoride release was observed on the first day, because the fluoride firstly released from the initial surface (wash-off) of the exposed surface of the material[12,14-16] than followed by a sharp decrease on the second day, and gradually diminished over next days the results of present study are in accordance with study by Srithongsuk et al 2011. They mixed NaF with orthodontic acrylic resin in three different amount of fluoride 5%,10% and 20% They detected that high level of fluoride release on the day 1, and fluoride level decreased greatly at day 2 in every concentration. The similar results "burst effect" was also reported by Upadhyay et al 2013[19] and Prapansilp et al 2017.[17]

The mechanism by which fluoride release into an aqueous environment from all experimental materials supported the two-phase diffusion theory. Phase one relates to initially accelerated surface elution of short-term fluoride release. phase two is more gradual elution and long-term release from the subsurface layers of the fluoride-releasing materials.[12,21] The burst effect is probably associated with the initial surface 'wash-off' of the exposed surface of the material.[12,14] The burst effect of fluoride release is crucial for inhibiting enamel and dentin demineralization as well as for the reduction of viability of bacteria that may have been left in the inner carious dentine.[19] The fluoride release is higher in 20% NaF than 10% for both polymerization type this is due to a higher amount of NaF that dissolved to fluoride ions. NaF is a very soluble salt and it is easily dissolved to free Na and F ions this is in agreement with previous study.[18,20]

Fluoride release in auto is higher in IVOMAT polymerization. When orthodontic acrylic resin cured in IVOMAT in water temperature of (45°C) and under pressure of (2.2 bar) for (15 minutes) fluoride release is lower than in auto polymerized orthodontic samples for both groups 10%and 20% NaF this is explained that initial surface 'wash-off' of the exposed surface of the material happens inside IVOMAT which contains deionized distilled water and remain for 15 minutes.[12,14-16] Which means some amount of fluoride is lost during polymerization in IVOMAT, during sample preparation we take 5ml deionized distillated water that we used for polymerization in IVOMAT for each concentration 10% and 20% we detected that 61 ppm and 121 ppm of fluoride was presented in 10% and 20 % respectively. Another cause may be related to a temperature that was used in IVOMAT curing device during polymerization processes for 15 minutes with (45 °C).In the study that is done by Yan et al 2007 they study the effects of environmental temperature on the fluoride release and recharging ability of glass ionomers, the fluoride release of each material was measured at 4°C, 37°C and 55°C they concluded that fluoride release significantly increased as the temperature increased.[22] Also in the study by Madhyastha et al 2013, they evaluated the effect of temperature, time interval and storage condition on glass ionomer cement they showed that the amount of fluoride release depends on temperature, time interval, and storage condition, as the temperature increases the fluoride release increase.[23]in another way we can say more fluoride release in IVOMAT than auto because some amount of fluoride were lost during polymerization.

The concentration of fluoride powder mixed in acrylic resin powder and hydroxy-ethyl methacrylate with methyl methacrylate for orthodontic base must consider the level of fluoride release. In the current article, the amount of fluoride released from orthodontic acrylic resin in auto polymerized samples is greater than fluoride

released by IVOMAT. Which means the more fluoride concentration the more fluoride release. The results of this study may be used as a guide to conduct further research in the future.

Conclusion

Fluoride release was observed from orthodontic acrylic base mixed with NaF, and HEMA. The level of fluoride release was different among mode of polymerization and concentrations (0%, 10%, and 20%). Orthocryle has the ability to release fluoride for both types of polymerization technic but the amount of fluoride release by the auto-polymerization is higher than polymerization by IVOMAT.

Conflicts of interest

The authors reported no conflict of interest.

References

1. Alhuwaizi A, Rasheed A. Assessment of orthodontic treatment needs of Iraqi Kurdish teenagers using the Dental Aesthetic Index. East Mediterr Health J 2009; 15(6):1535–41.
2. Rashid A. Influence of different concentrations of Fluoride on the porosity of acrylic resin denture base materials. Iraq Dent J 2015; 37(2):56–61.
3. Içа R, Öztürk F, Ates B, Malkoc M, Kelestemur Ü. Level of residual monomer released from orthodontic acrylic materials. Angl Orthod 2014; 84(5):862–7.
4. Gad M, Fouda S, Al-Harbi F, Näpänkangas R, Raustia A. PMMA denture base material enhancement: a review of fiber, filler, and nanofiller addition. Int J Nanomedicine 2017; 12:3801 –12.
5. Batoni G, Pardini M, Giannotti A, Ota F, Rita Giuca M, Gabriele M et al. Effect of removable orthodontic appliances on oral colonization by mutans streptococci in children. Eur J Oral Sci 2001; 109(6):388–92.
6. Kuroiwa A, Nomura Y, Ochiai T, Sudo T, Nomoto R, Hayakawa T, et al. Antibacterial, hydrophilic effect and mechanical properties of orthodontic resin coated with UV-responsive photocatalyst. Materials 2018; 11(6):889.
7. Baehni P, Takeuchi Y. Anti-plaque agents in the prevention of biofilm-associated oral diseases. Oral Diseases 2003; 9(s1):23–9.
8. Liao Y, Brandt B, Li J, Crielaard W, Van Loveren C and Deng D. Fluoride resistance in Streptococcus mutans: a mini review. J Oral Microb 2017; 9(1):1 –9.
9. Pessan J, Al-Ibrahim N, Buzalaf M, Toumba K. Slow -release fluoride devices: a literature review. J Appl Oral Sci 2008; 16(4):238–44.
10. Kamijo K, Mukai Y, Tominaga T, Iwaya I, Fujino F, Hirata Y, et al. Fluoride release and recharge characteristics of denture base resins containing surface pre-reacted glass-ionomer filler. Dent Mater J 2009; 28(2):227–33.
11. Wong M, Clarkson J, Glenny A, Lo E, Marinho V, Tsang B et al. Cochrane reviews on the benefits/ risks of Fluoride toothpastes. J Dent Res 2011; 90 (5):573–9.
12. Ismail H. Further development of a novel Fluoride releasing acrylic orthodontic adhesive, [Ph.D. thesis]. Newcastle University. 2016.
13. Zahroon, S. Development of a novel acrylic resin as a fissure sealant, [Ph.D. thesis] Newcastle University. 2014.
14. Anusavice KJ, Zhang NZ, Shen C. Effect of CaF2 content on rate of Fluoride release from filled resins. J Dent Res 2005; 84(5): 440–4.
15. Mousavinasab SM, Meyers I. Fluoride release by glass ionomer cements, compomer, and Giomer. Dent Res J 2009; 6(2):75–81.
16. Khouw-Liu VHW, Anstice HM, Pearson GJ. An in vitro investigation of a poly (vinyl phosphonic acid) based cement with four conventional glass-ionomer types of cement. Part 1: flexural strength and fluoride release. J Dent 1999; 27 (5):351–7.
17. Selimović-Dragaš M, Hasić-Branković L, Korać F, Đapo N, Huseinbegović A, Kobašlija S, et al. In vitro fluoride release from a different kind of conventional and resin-modified glass-ionomer cement. Bosn J Basic Medic Sci 2013; 13(3):197–02.
18. Prapansilp W, Rirattanapong P, Surarit R, Vongsavan K. Fluoride release from different powder liquid ratios of Fuji VII. M Dent J 2017; 37 (21):217–22.
19. Srithongsuk S, Anuwongnukroh N, Dechkunakorn S, Srikhirin T, Tua-Ngam P. Investigation of Fluoride release from orthodontic acrylic plate. Advanced Materials Research 2011; 378–9:681–7.
20. Upadhyay S, Rao A, Shenoy R. Comparison of the amount of Fluoride release from nanofilled resin modified glass ionomer, conventional and resin modified glass ionomer cements. J Dent, Tehran University of Medical Sciences 2013; 10 (2):134–40.
21. Nakajo K, Imazato S, Takahashi Y, Kiba W, Ebisu S, Takahashi N. 'Fluoride released from glass-ionomer cement is responsible to inhibit the acid production of caries-related oral streptococci. Dent Mater 2009; 25(6):703–8.

22. Dionysopoulos D, Koliniotou-Koumpia E, Helvatzoglou-Antoniades M, Kotsanos N. Fluoride release and recharge abilities of contemporary fluoride-containing restorative materials and dental adhesives. Dent Mater J 2013; 32(2): 296–304.
23. Yan Z, Sidhu S, Mahmoud G, Carrick T, McCabe J. Effects of temperature on the Fluoride release and recharging ability of glass ionomers. Operative Dent 2007;32(2): 138–43.
24. Madhyastha P, Kotian R, Pai V, Khader A. Fluoride release from glass-ionomer cements: effect of temperature, time interval, and storage condition. J Contem Dent 2013; 3:68–73.
25. Pathak A, Sharma D. Biofilm associated microorganisms on removable oral orthodontic appliances in children in the mixed dentition. J Clin Pediat Dent 2013; 37(3):335–40.
26. Yassin s. A Fluoride releasing dental prosthesis copolymer for oral biofilm control, [Ph.D. thesis]. Newcastle University. 2014.