

Comparative Assessment of Antibacterial Effectiveness, Bioactivity, Fluoride Release, and Microleakage of Various Bioactive Smart Composites: An In Vitro Investigation.

Pradnya Chaudhari¹, Shashikiran N.D^{2*}, Sachin gugawad³, Namrata Gaonkar⁴, Swapnil Taur⁵, Savita Hadakar⁶

Abstract

The demand for dental composites with enhanced properties has led to the development of bioactive smart composites aimed at addressing multiple aspects of restorative dentistry. This in vitro investigation aimed to conduct a comparative assessment of the antibacterial effectiveness, bioactivity, fluoride release, and microleakage properties of various bioactive smart composites. Bioactive smart composites are emerging dental materials designed to promote remineralization and inhibit bacterial growth, thereby enhancing the longevity of dental restorations. Five different bioactive smart composites were evaluated for their antibacterial activity against common oral pathogens, bioactivity in simulated body fluid, fluoride release kinetics, and microleakage potential using standardized laboratory tests. Others demonstrated enhanced bioactivity, promoting apatite formation on the composite surface. Fluoride release profiles differed, with certain composites releasing fluoride ions steadily over time, potentially aiding in caries prevention. Results revealed significant variations in antibacterial effectiveness, bioactivity, fluoride release profiles, and microleakage resistance among the tested composites. Understanding the performance characteristics of bioactive smart composites is

crucial for informed decision-making in restorative dentistry and optimizing the clinical outcomes of dental restorations.

***Author for Correspondence**
Shashikiran N.D

¹PG Student, Dept. of Paedodontics, School of Dental Sciences, Krishna Vishwa Vidyapeeth Deemed to be University, Karad

²Dean, Head, Dept. of Paedodontics, School of Dental Sciences, Krishna Vishwa Vidyapeeth Deemed to be University, Karad

³Associate Professor, Dept. of Paedodontics, School of Dental Sciences, Krishna Vishwa Vidyapeeth Deemed to be University, Karad

⁴Associate Professor, Dept. of Paedodontics, School of Dental Sciences, Krishna Vishwa Vidyapeeth Deemed to be University, Karad

⁵Assistant Professor, Dept. of Paedodontics, School of Dental Sciences, Krishna Vishwa Vidyapeeth Deemed to be University, Karad

⁶Assistant Professor, Dept. of Paedodontics, School of Dental Sciences, Krishna Vishwa Vidyapeeth Deemed to be University, Karad

Received Date: April 02, 2024

Accepted Date: May 13, 2024

Published Date: July 08, 2024

Citation: Pradnya Chaudhari, Shashikiran N.D, Sachin gugawad, Namrata Gaonkar, Swapnil Taur, Savita Hadakar. Comparative Assessment of Antibacterial Effectiveness, Bioactivity, Fluoride Release, and Microleakage of Various Bioactive Smart Composites: An In Vitro Investigation.. Journal of Polymer & Composites. 2024; 12(Special Issue 3): S76-S86.

Keywords: Bioactive smart composites, Nanoparticles, bioactivity, fluoride release, microleakage, dental materials,

INTRODUCTION

Dental caries, regarded as one of the oldest and most prevalent infectious diseases in humans, has seen a surge in incidence during the post-industrial era, primarily attributed to rising prosperity and the widespread availability of processed sugar [1]. In India, according to National Oral Health Survey conducted in 2002–2003, children of age Category 5 to 15 years showed DMFT index around 2 and caries prevalence was found to be increased up to 51.9% to 63.1% [2].

During the early 1842 period, there was a significant development in the use of different materials for dental restoration. Dental amalgam,

which became the predominant dental restorative material up to that time, was first employed in 1895. As the focus shifted towards aesthetic considerations, resin-based restorative materials began to emerge in the market from 1947 onwards. Another term for this era of dental material evolution could be described as the era of dental restorative material innovation and progression.[3].

Dr. Rafael Bowen from U.S.A. originally developed the composite resins [4]. In a brief span leading up to the 1940s, they effectively supplanted their forerunners, acrylic resin, and silicate cement (the only aesthetic materials previously accessible), by mitigating their shortcomings. Phillips defined composites as a 3D amalgamation of at least two chemically distinct materials with a distinct interface between the components [5]

Traditional composites typically feature filler particles ranging in size from 1 to 100 micrometers. They can be further classified, with one Category having filler particle sizes of 1 to 6 micrometers, and another Category having a particle size range of 15-20 micrometers, supplemented by larger particles measuring up to 50 to 100 micrometers. Generally, this type comprises 75 wt.% to 80 wt.% of fillers. Hence, due to their very rough surface currently they are not recommended for use, keeping the aesthetics in concern. To eliminate this disadvantage, in recent years, use of smaller, softer, and more rounded microfillers have started, which result in more polished surfaces of composites [6].

Evolutionary leap in hybrid composite technology, marking the transition to micro-hybrid composites with enhanced efficiency due to the incorporation of multiple particle sizes. Micro-hybrids give polished smooth surfaces but the largest particles in the mix are small hence these materials suffer from low particle density. Hence, they are not recommended for posterior fillings [7]

S-PRG fillers release other ions along with fluoride. Their beneficial effects are: (i) Fluoride release and recharge, (ii) acid buffering capacity and reduce acid production by acidogenic bacteria (iii) formation of acid resistant layer (iv) antiplaque effect (v) remineralization of dentin (vi) reinforcement of tooth structure.[8]

With these advancements, the combination of excellent aesthetics, strength, and fluoride release collectively diminishes the likelihood of composite restoration failure. Subsequent following research, it became evident that composite material surfaces continued to accumulate plaque and biofilm over time, leading to the formation of acids and subsequent secondary decay. In response, two strategies were identified to address this issue, particularly focusing on the margins: inhibiting biofilm formation and promoting remineralization. In pursuit of these strategies, various "bioactive" restorative materials have been engineered.[8]

The concept of 'bioactive' has sparked diverse interpretations regarding the defining characteristics of such materials. In June 2018, the American Dental Association released a statement outlining that a bioactive material should have the ability to stimulate the formation of reparative dentin for pulp capping. Additionally, it should support tooth remineralization by releasing ions and exhibit the capacity to form hydroxyapatite on its surface, effectively sealing cement gaps.[9]

Studies revealed that dental resins infused with calcium phosphate fillers could liberate substantial quantities of calcium and phosphate ions, fostering in vitro remineralization of tooth structure. Nonetheless, these resins demonstrated mechanical fragility, with a flexural strength approximately half that of unfilled resin. Alternative experimental strategies included the integration of sol-gel-derived silver-doped bioactive glass, incorporation of silver sodium hydrogen zirconium phosphate into composite resin and blending quaternary ammonium methacrylate into the resin matrix. These approaches endowed the composite with both antibacterial and remineralizing properties. Presently, bioactive restorative materials are touted for their ability to generate layers of hydroxyapatite on their surfaces.[10]

To enlist the advantages of modern restorative composite materials, one can successfully consider the good handling properties, good aesthetic results, increased wear resistance, better strength, conservative cavity preparations, radio opaque quality, low coefficient of thermal conductivity, less polymerization shrinkage, less technique sensitive. However, the advent of a new era brings forth fresh challenges, with secondary caries being a major concern. Consequently, these advanced composites have undergone testing against emerging challenges to yield enhanced outcomes, including antibacterial surface properties, material bioactivity, fluoride release, and reduced marginal microleakage, all aimed at mitigating the risk of secondary decay in recent years.

Considering the frequent occurrence of recurrent caries following restorative treatment, considerable focus has been directed towards the therapeutic properties exhibited by direct filling materials. There is a clear difference between fluoride releases of different fluoride containing materials. It is a complex process. Several intrinsic factors such as composition of matrix or filler particles, can affect the fluoride release. Fluoride exerts an anticaries effect primarily by reducing demineralization and enhancing the remineralization of tooth structure. However, the effectively reduced acid production and improved acid tolerance is related to the concentrations of the fluoride released from material. Hence the quantitative analysis of fluoride release and pattern assessment of release is important to determine the effectiveness of material.

While remineralization through fluoride release is a crucial attribute, the antibacterial efficacy is another significant characteristic aimed at minimizing the risk of secondary caries. By neutralizing bacteria, this property directly targets the eradication of the root cause of dental caries. The antibacterial properties of filling composites primarily involve inhibiting plaque accumulation on the surface.[11] When a dental material is introduced into the oral cavity, it rapidly acquires a pellicle coating composed of salivary proteins, facilitated by normal salivary flow. Hence, there is a strong desire to develop composites that deter the attachment of these proteins and impede bacterial adhesion.[12] Many studies have used different ways to evaluate antibacterial potential of composite materials such as agar-disc diffusion method. However, this method doesn't give the quantitative and differential data for the live and dead cells. Hence to overcome this flaw, more advanced methods have been introduced such as differential staining for viability of cells followed by imaging under confocal laser scanning microscopy. This method provides both numerical data as well as images for thorough analysis of samples.

Additional to antibacterial effect of composites, the property of self- healing adds major advantage against secondary caries. These bioactive materials have the ability to interact biologically with tissue, and to stimulate the deposition of minerals. Two prevalent approaches have been employed to assess in vitro bioactivity. One method involves evaluating the material's capacity for apatite formation by immersing it in phosphate buffered saline (PBS), while the other method assesses the impact of ceramics on osteogenic differentiation through cell experiments. The PBS method is considered an efficient average to investigate in vitro bioactivity associated with hydroxyapatite crystal formation.[13]

The objective of this investigation is to Evaluation and comparison of antimicrobial effectiveness, Hydroxyapatite crystal growth on the surface, Fluoride Ion Release and Microleakage in Bioactive restorative materials.

LITERATURE REVIEW

Present study showed SEM images of the morphology of the deposited crystals which are in apatite-like phase for Category 1 (Beautiful Flow Plus) and Category 2 (Activa BioACTIVE), while the analysis by EDS method shows that Calcium and phosphate are the major components of newly formed crystal phase with ratio of 1.22 and 2.95 respectively. Inter Category comparison showed statistically significant higher ratio with Category 2 (Activa BioACTIVE) in all three Categories followed by in Category 1 (Beautiful Flow Plus). Fluoride administered to the oral cavity is gradually cleared over time,

underscoring the importance of a sustained fluoride supply for its anticaries effect. Therefore, restorative material with steady release of fluorides is an important discovery in restorative dentistry. The steady release of fluorides over the time period can help us to achieve the anticariogenic effects of fluoride in oral cavity over long period of time.[14]

The ability of re-mineralization in Category 2 is confirmed by presence of calcium and phosphate apatite-like phase, formed on the sample surfaces after 28 days. Category 1 also showed the presence of these crystals, however in less dense and thinner layer patterns. The nucleation of Ca and P formed during the apatite crystal formation further favour the remineralization by initiating the formation of high molecular weight complex.[15]

Dental restorations show signs of failure when they start degrading and reach the level where it is not able to give proper performance in the terms of aesthetics or functions. Because of which it is unable to prevent the secondary caries. Restorations showing poor marginal adaptation and microleakage through tooth-material interfaces results in dentinal sensitivity, seepage of fluid through gaps, secondary caries progression, degradation and dis-colouration of either dental materials or tooth structures. This movement of oral fluids between interfaces is responsible for carrying bacteria and acids into an inaccessible area and affects the tooth/pulp biologic unit. Hence, to avoid microleakage through these gaps, composites are playing a major role in operative dentistry.

In thermocycling, restoration and tooth are subjected to temperature limits equivalent to those seen in oral cavity, to have in-situ simulation of oral temperature changes. Because of the difference in coefficients of thermal expansion of teeth and restorations, this rapid temperature change can cause potential negative effects. Thermocycling causes the stress build-up between resin and the tooth structure. Depending on the adhesive system, these stresses will affect the bond strength to different degrees. Hence, to check the marginal seal even after the thermal changes experienced by material similar to oral cavity; in this study the samples were subjected to thermocycling.

In current study the lowest average value for microleakage was seen with Category 2, which was statistically significant when we compared with other Categories. Category 1 showed statistically significant lower average values when compared to Category 3 i.e. control.

Mamta Kaushik and Mitesh Kumar Yadav evaluated the marginal leakage of Activa BioACTIVE and nanohybrid composite with and without adhesives in class V cavities. In all these Categories, maximum microleakage was seen at gingival margins. In comparative evaluation, Activa Bioactive material showed least microleakage when used with bonding agent.[16] These findings are in agreement with this current study.

Dina Magdy Ghazal et al. evaluated the microleakage of a smart bioactive material, Activa Bioactive Restorative, and compared it to the commercially established composite resin known for its good sealing properties, Tetric® N-Ceram. The study revealed no significant difference in the frequency of bacterial penetration and serial dilution between ACTIVA Bioactive and Tetric N-Ceram. Therefore, they concluded that ACTIVA Bioactive can serve as a suitable restorative material in situations where strong sealing ability is required.[17]

The study done by Sufyan Garoushi et al, in which they compared fluoride release from different restorative materials and stated that the difference between Beautifil II and Activa BioACTIVE was significant for 1st day, which gradually decreased and was not significant at 7 days.[18] The fluoride release in present was found to be decreased gradually in 28 days period. At the end of the 28 days, the cumulative values for fluoride release for all three materials were calculated and again statistically compared. It was found out that the average values for fluoride release combined for 28 days in Category 1 and Category 2 were not significantly different. However, the values in Category 3 are

significantly lower than both the other Categories as it is a non-fluoride containing composite material used as control in present study.

MATERIALS AND METHODS

The current experimental investigation was taken in the Department of Paediatric and preventive dentistry, School of dental Sciences, KIMSDU, Karad, after due approval of the Institutional Ethical Committee (Protocol number 0323/2018-2019, dated; 11/12/2018).

Sample sizes were calculated using formula.

$$n = \frac{(Z\alpha + Z\beta)^2 (S1^2 + S2^2) (M2 - M1)^2}{}$$

Were,

$Z\alpha = 1.96$; Type I Error at 5% level of significance $Z\beta = 1.64$; Type II Error at 95% power $M1 = 2.20$

$S1 = 0.5$

$M2 = 2.74$

$S2 = 0.75$

Therefore, $n = 36$ per Category

So, sample size of 40 per Category was finalized. Accordingly, the total sample size was 120.

Inclusion criteria for teeth sample:

60 morphologically intact, non-carious, non- hypoplastic, non-restored premolars which were extracted due to therapeutic orthodontic treatment were selected for this study.

Exclusion criteria for teeth sample:

Teeth with morphological variations, caries, fractured crowns, fluorosed teeth and teeth with hypoplastic lesions were excluded from this study.

Materials used in study

- Extracted teeth.
- Twizzers
- Double faced diamond disc
- Airotor and burs
- Diagnostic and Resorative instruments
- Beautifil Flow Plus (Shofu)
- Activa BioACTIVE Restorative (Pulpdent)
- Filtek z250 XT (3M ESPE)
- Single Bond universal adhesive (3M ESPE)
- Light curing machine
- Silicone Mould (3mm×2mm×2mm)
- Streptococcus Mutans culture
- Blood Heart Infusion Broth
- Multiwell Plates
- Phosphate buffered saline
- Brain Heart Infusion Broth supplemented with 5% Sucrose
- Micropipette
- Incubator
- GasPak

- Physiological saline
- Artificial saliva
- Beakers
- Test tubes
- Baclight LIVE/DEAD viability stating kit
- Bottom dish coverglass
- Nail varnish
- Simulated Body Fluid
- De-ionized water
- 2% Methylene Blue Dye

OBSERVATIONS AND RESULTS

Antibacterial Efficacy

Category 1 showed maximum live count of 45.08% and minimum live count of 34.11% with the average value of 39.91% and std. deviation 3.66%. Category 1 showed maximum dead count of 65.89% and minimum dead count of 54.92% with the average value of 60.08% and std. deviation 3.66%. Category 2 showed maximum live count of 33.63% and minimum live count of 21.51% with the average value of 26.44% and std. deviation 4.18%. Category 2 showed maximum dead count of 78.49% and minimum dead count of 66.37% with the average value of 73.56% and std. deviation 4.18%. Category 3 as negative control showed maximum live count of 92.40% and minimum live count of 86.82% with the average value of 89.97% and std. deviation 2.07%. Category 3 showed maximum dead count of 13.18% and minimum dead count of 7.60% with the average value of 10.02% and std. deviation 2.07% shown in Table 1.

Table 1. Statistics of the Live and Dead Bacterial Count in Experimental Categories

Categories	Parameter	N	Maximum (in%)	Minimum (in%)	Average (in%)	Std. Deviation
Category 1 (Beautifil Flow Plus)	Live bacterial count	10	45.08	34.11	39.91	3.66
	Dead bacterial count	10	65.89	54.92	60.08	3.66
Category 2 (Activa BioACTIVE)	Live bacterial count	10	33.63	21.51	26.44	4.18
	Dead bacterial count	10	78.49	66.37	73.56	4.18
Category 3 (Filtek Z250 XT)	Live bacterial count	10	92.40	86.82	89.97	2.07
	Dead bacterial count	10	13.18	7.60	10.02	2.07

Bioactivity

Table 2 shows statistical analysis of average values of Energy dispersive spectrophotometric values (in wt%) for Ca and P and the Ca/P ratio on the surfaces of all experimental Categories. Category 1 showed a maximum Ca deposition value of 79.28 wt% and minimum Ca deposition value of 60.34 wt% with the average value of 71.57 wt% and std. deviation 7.31 wt%. Category 1 showed a maximum P deposition value of 65.39 wt% and minimum P deposition value of 52.38 wt% with the average value of 58.73 wt% and std. deviation 3.85 wt%. The maximum value of Ca/P ratio value in Category 1 (Beautifil Flow Plus) is 1.50 and minimum value is 1.05 with average value 1.22 and std. deviation 0.12. Category 2 showed a maximum Ca deposition value of 77.39 wt% and minimum Ca deposition value of 72.72 wt% with the average value of 74.89 wt% and std. deviation 1.43 wt%. Category 2 showed a maximum P deposition value of 27.28 wt% and minimum P deposition value of 23.74 wt% with the average value of 25.36 wt% and std. deviation 1.02 wt%. The maximum value of Ca/P ratio value in Category 2 is 3.08 and minimum value is 2.67 with average value 2.95 and std. deviation 0.12. Category 3 as negative control showed maximum Ca deposition value of 37.60 wt% and minimum Ca deposition value of 24.23 wt% with the average value of 33.13 wt% and std. deviation 4.24 wt%. Category 3 showed a maximum P deposition value of 77.90 wt% and minimum P deposition value of

62.40 wt% with the average value of 69.76 wt% and std. deviation 4.84 wt%. The maximum value of Ca/P ratio value in Category 3 is 0.60 and minimum value is 0.32 with average value 0.47 and std. deviation 0.07.

Table 2. Statistics of the EDS Values of Ca, P and Ca/P in Experimental Categories

Categories	EDS values	N	Maximum (wt%)	Minimum (wt%)	Average (wt%)	Std. Deviation
Category 1 (Beautiful Flow Plus)	Ca	10	79.28	60.34	71.57	7.31
	P	10	65.39	52.38	58.73	3.85
	Ca/P	10	1.50	1.05	1.22	0.12
Category 2 (Activa BioACTIVE)	Ca	10	77.39	72.72	74.89	1.43
	P	10	27.28	23.74	25.36	1.02
	Ca/P	10	3.08	2.67	2.95	0.12
Category 3 (Filtek Z250 XT)	Ca	10	37.60	24.23	33.13	4.24
	P	10	77.90	62.40	69.76	4.84
	Ca/P	10	0.60	0.32	0.47	0.07

Fluoride Release

Category 1 showed maximum fluoride release (in 24 hrs) value of 3.21 ppm and minimum fluoride release value of 2.12 ppm with the average value of 2.47 ppm and std. deviation 0.32 ppm. Category 2 showed maximum fluoride release (in 24 hrs) value of 3.56 ppm and minimum fluoride release value of 2.45 ppm with the average value of 3.08 ppm and std. deviation 0.36 ppm. Category 3 showed maximum fluoride release (in 24 hrs) value of 0.10 ppm and minimum fluoride release value of 0.01 ppm with the average value of 0.03 ppm and std. deviation 0.02 ppm shown in Figure 1.

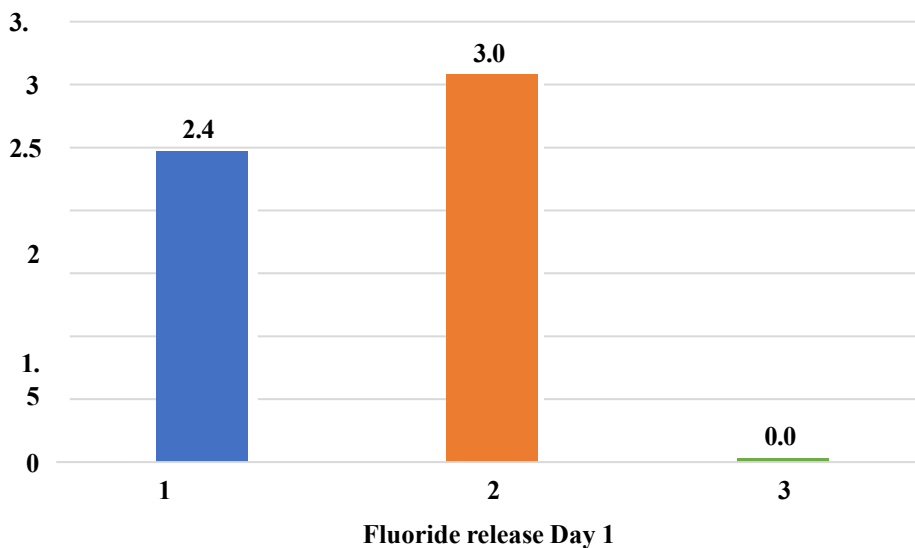


Figure 1. Average Fluoride Release on Day 1 in Experimental Categories.

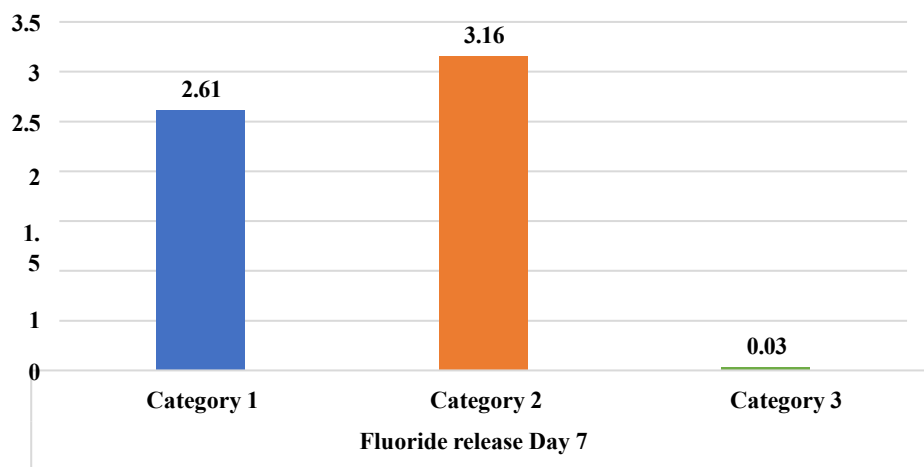


Figure 2. Average Fluoride Release on Day 7 in Experimental Categories.

In Figure 2 category 1 showed maximum fluoride release (after 7 days) value of 3.12 ppm and minimum fluoride release value of 2.12 ppm with the average value of 2.61 ppm and std. deviation 0.35 ppm. Category 2 showed maximum fluoride release (after 7 days) value of 3.89 ppm and minimum fluoride release value of 2.45 ppm with the average value of 3.16 ppm and std. deviation 0.57 ppm. Category 3 showed maximum fluoride release (after 7 days) value of 0.10 ppm and minimum fluoride release value of 0.01 ppm with the average value of 0.03 ppm and std. deviation 0.02 ppm.

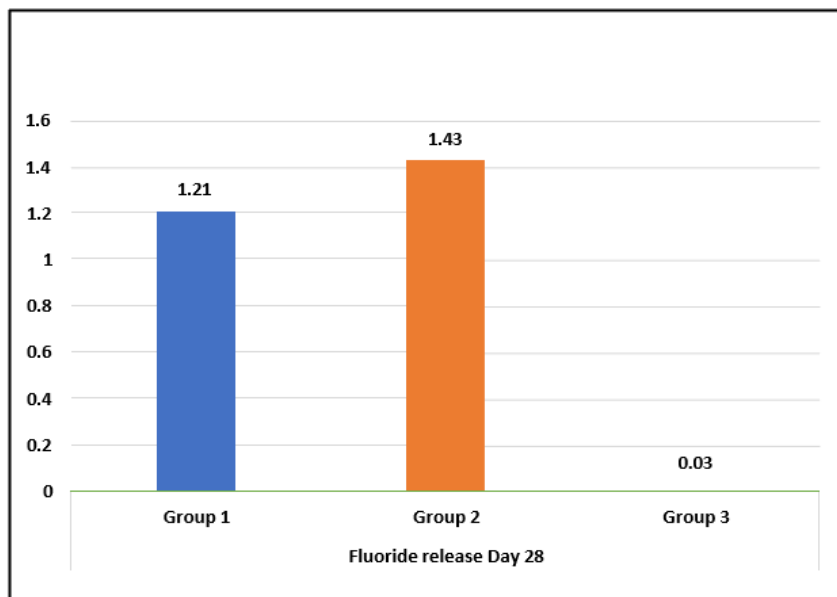


Figure 3. Average Fluoride Release on Day 28 in Experimental

In Figure 3 category 1 showed maximum fluoride release (in 28 days) value of 1.98 ppm and minimum fluoride release value of 0.83 ppm with the average value of 1.21 ppm and std. deviation 0.33 ppm. Category 2 showed maximum fluoride release (in 28 days) value of 1.84 ppm and minimum fluoride release value of 1.06 ppm with the average value of 1.43 ppm and std. deviation 0.25 ppm. Category 3 showed maximum fluoride release (in 28 days) value of 0.10 ppm and minimum fluoride release value of 0.01 ppm with the average value of 0.03 ppm and std. deviation 0.02 ppm.

Table 3. Comparison of Fluoride Release on Day 1 and Day 28 in different Categories

Dependent Variable	(I) Time intervals	(J) Time intervals	Average Difference (I-J)	p value
Category 1 (Beautiful Flow Plus)	Day 1	Day 7	-.14000	.628
		Day 28	1.26700*	.000*
	Day 7	Day 1	.14000	.628
		Day 28	1.40700*	.000*
	Day 28	Day 1	-1.26700*	.000*
		Day 7	-1.40700*	.000*
Category 2 (Activa BioACTIVE)	Day 1	Day 7	-.08300	.898
		Day 28	1.65400*	.000*
	Day 7	Day 1	.08300	.898
		Day 28	1.73700*	.000*
	Day 28	Day 1	-1.65400*	.000*
		Day 7	-1.73700*	.000*
Category 3 (Filtek Z250 XT)	Day 1	Day 7	-.00200	.984
		Day 28	-.00400	.936
	Day 7	Day 1	.00200	.984
		Day 28	-.00200	.984
	Day 28	Day 1	.00400	.936
		Day 7	.00200	.984

Table 3 shows, pairwise within Category comparison of fluoride release on Day 1 and Day 28 in Category 1, Category 2 and Category 3 using Tukey's post hoc test. This comparison showed statistically significant differences in Category 1 between Day 1 and Day 28 and Day 7 and Day 28; in Category 2 between Day 1 and Day 28 and Day 7 and Day 28 (p value <0.05) and in Category 3 between no statistically notable differences were noted. (p value >0.05).

Table 4. Comparison of Fluoride Release on Day 1 and Day 28 Between Experimental Categories.

Dependent Variable	(I) Categories	(J) Categories	Average Difference (I-J)	p value
Fluoride release day 1	Category 1	Category 2	-.60700*	.000*
		Category 3	2.44400*	.000*
	Category 2	Category 1	.60700*	.000*
		Category 3	3.05100*	.000*
	Category 3	Category 1	-2.44400*	.000*
		Category 2	-3.05100*	.000*
Fluoride release day 28	Category 1	Category 2	-.22000	0.127
		Category 3	1.17300*	.000*
	Category 2	Category 1	.22000	0.127
		Category 3	1.39300*	.000*
	Category 3	Category 1	-1.17300*	.000*
		Category 2	-1.39300*	.000*

Table 4 shows, within Category comparison of fluoride release between Day 1, Day 7 and Day 28 in Category 1, Category 2 and Category 3 using One-way Analysis of variance (ANOVA). This comparison showed statistically significant differences in Category 1, Category 2 and Category 3 on day 1. Statistically notable differences are shown in Category 1 and Category 3 also in Category 2 and Category 3 on 28 days. (p value <0.05)

Microleakage

In Table 5 category 1 showed maximum microleakage score of 3 with 5 samples and minimum microleakage score of 0 with 1 sample, having the average value of 2.20 and std. deviation 1.03. Category 2 showed maximum microleakage score of 3 with 1 sample and minimum microleakage score of 0 with 1 sample, having the average value of 1.60 and std. deviation 0.84. Category 3 showed maximum microleakage score of 3 with 6 samples and minimum microleakage score of 2 with 4 samples, having the average value of 2.60 and std. deviation 0.51.

Table 5. Descriptive Statistics of the Microleakage Scores in Experimental Categories

Parameter	Categories	N	Sample distribution as per scores.		Average	Std. Deviation
Microleakage	Category 1 (Beautiful Flow Plus)	10	Score 0	1	2.20	1.03
			Score 1	1		
			Score 2	3		
			Score 3	5		
	Category 2 (Activa BioACTIVE)	10	Score 0	1	1.60	0.84
			Score 1	3		
			Score 2	5		
			Score 3	1		
	Category 3 (Filtek Z250 XT)	10	Score 0	0	2.60	0.51
			Score 1	0		
			Score 2	4		
			Score 3	6		

CONCLUSION

Within the limitations of this study, several conclusions were drawn. Firstly, Activa BioACTIVE restorative material exhibited the highest antibacterial efficacy against *S. mutans* compared to Beautiful Flow Plus and Filtek Z250 XT. Secondly, Activa BioACTIVE demonstrated the highest amount of hydroxyapatite crystal formation, with a average Ca/P ratio of 2.95, confirming the presence of stoichiometric hydroxyapatite crystals. In contrast, Beautiful Flow Plus showed a moderate level of crystal formation on the surface, with a average Ca/P ratio of 1.22, indicative of non-stoichiometric hydroxyapatite crystals. These findings suggest that both materials possess bioactive properties and can form hydroxyapatite crystals at the surface. Thirdly, Activa BioACTIVE exhibited the highest fluoride release after 24 hours and significantly higher cumulative fluoride release after 28 days compared to Beautiful Flow Plus and Filtek Z250 XT, with Beautiful Flow Plus showing higher fluoride release than Filtek Z250 XT. Lastly, Activa BioACTIVE demonstrated superior marginal sealing ability, displaying higher resistance to microleakage through the tooth-material interface compared to Beautiful Flow Plus and Filtek Z250 XT.

REFERENCES

- Lamont RJ, & Eglund PG. Dental Caries. *Molecular Medical Microbiology*, 2015; 945–55. doi:10.1016/b978-0-12-397169-2.00052-4.
- Bali RK, Mathur VB, Talwar PP, Channa HB. *National Oral Health Survey & Fluoride Mapping*. New Delhi: Dental Council of India; 2002.
- Zero DT, Fontana M, Martínez-Mier EA, Ferreira-Zandoná A, Ando M, González-Cabezas C, Bayne S. The Biology, Prevention, Diagnosis and Treatment of Dental Caries. *The Journal of the American Dental Association*. 2009;140:25S–34S.
- BOWEN RL. Properties of a silica reinforced polymer for dental restorations. *J. Am. Dent. Assoc.* 1963;66:57-64.
- Mc CABE JF. Developments in composite resins. *Br. Dent. J.* 1984;157:440-4.
- CRAIG RG. Chemistry, composition and properties of composite resins, *Dent. Clin. North Am.*

- 1981;25:219-39.
7. Martin SS. Dental Composites: A Comprehensive Review. The Academy of Dental Learning and OSHA Training, LLC. Publication Date: October 2012 Updated Date: July 2017.
 8. Najma Hajira NSW, Meena N. GIOMER- The Intelligent Particle (New Generation Glass Ionomer Cement). *Int J Dent Oral Health* 2015;2(4).
 9. American Dental Association. ACE Panel Report: Bioactive Materials. ADA website. 2018. <https://www.ada.org/en/publications/ada-news/2018-archive/june/ace-panel-report-focuses-on-bioactivematerials>. Accessed October 10, 2019.
 10. Gregg AH. Bioactive Bulk Composite Satisfies Esthetic Demands While Protecting Against Restoration Failure. *Compendium*. 2019 Nov;40(10).
 11. Satoshi I. Antibacterial properties of resin composites and dentin bonding systems. *Dental Materials*. 2003;19:449–57.
 12. Ke Z, Ning Z, Michael DW, Mark AR, Yuxing B, Hockin HK. Bioactive dental composites and bonding agents having remineralizing and antibacterial characteristics. *Dent Clin North Am*. 2017 Oct;61(4):669– 87.
 13. Li P, Ohtsuki C, Kokubo T, Nakanishi K, Soga N, et al. Effects of ions in aqueous media on hydroxyapatite induction by silica gel and its relevance to bioactivity of bioactive glasses and glassceramics. *J Appl Biomater*. 1993;4: 221-9.
 14. Gururaj M, Shetty R, Nayak M, Shetty S, Kumar CNV. Fluoride releasing and Uptake Capacities of Esthetic Restorations. *J Contemp Dent Pract* 2013;14(5): 887-891.
 15. Kremer E. A., Chen Y., Suzuki K., Nagase H., Gorski J. P. Hydroxyapatite induces autolytic degradation and inactivation of matrix metalloproteinase 1 and 3. *J. Bone. Miner. Res*. 1998;13:1890–902. 10.1359/jbmr.1998.13.12.1890
 16. Kaushik M, Yadav M. MARGINAL MICROLEAKAGE PROPERTIES OF ACTIVA BIOACTIVE RESTORATIVE AND NANOHYBRID COMPOSITE RESIN USING TWO DIFFERENT ADHESIVES IN NON-CARIOUS CERVICAL LESIONS - AN IN VITRO STUDY. *Journal of the West African College of Surgeons*. 2017; 7:1-14.
 17. Ghazal D, Koheil S, Mehesen M. MICROLEAKAGE OF A RECENT TYPE OF BIOACTIVE RESTORATIVE MATERIALS (ACTIVA) (IN VITRO STUDY). *Alexandria Dental Journal*, 2020. doi: 10.21608/adjalexu.2020.21395.1031
 18. Garoushi S, Vallittu PK, Lassila L. Characterization of fluoride releasing restorative dental materials. *Dent Mater J*. 2018 Mar 30;37(2):293-300. doi: 10.4012/dmj.2017-161. Epub 2017 Dec 27. PMID: 29279547.