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Effects of Anticaries Agents on Microhardness of Different Restorative Materials

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ABSTRACT

Objectives: The objective of this investigation was to compare the consequence of four anticaries agents: Silver diamine fluoride, Curodont Repair, VOCO Profluorid varnish, and Gelato APF gel on microhardness of three restorative materials: Conventional glass-ionomer (Ionofil Molar AC), resin-modified glass-ionomer (Photac Fil) and resin composite (IPS Empress Direct).

Methods: Sixty cylindrical specimens were prepared from each restorative material, polished sequentially with silicon carbide papers, thermocycled, and randomly allocated into five groups of 12 each according to the anticaries agents and control. Specimens were measured at baseline for microhardnessusing microhardness testing machine. Then, application of anticaries agents was preformed according to the instructions of the manufacturers for a total time of 60 minutes. The second-timemeasurement for microhardness was completed similar to baseline.

Results: There was a significant difference between pre- and post- application of anticaries agents when Ionofil Molar AC specimens treated with Curodont Repair (p=0.039) and silver diamine fluoride (p=0.005). There was significant difference between pre- and post- application of anticaries agents when Photac Fil specimens treated with Curodont Repair (p=0.020).There was significant difference between pre- and post- application of anticaries agents when IPS Empress Direct specimens treated with Gelato APF Gel (p=0.035). There was significant difference between all anticaries agents in comparison to the control group (p=0.0001), between Curodont Repair in comparison to all other anticaries agents (p=0.0001), between VOCO Profluorid varnish and Gelato APF Gel compared to silver diamine fluoride (p=0.0001), and between VOCO Profluorid varnish in comparison with Gelato APF Gel (p=0.0001).

Conclusion: The potential reduction of microhardness of tested restorative materials might be anticaries agents dependent. Some of the tested anticaries agents decreased the microhardness of tested restorative materials but none of them increased the microhardness.

Keywords: Anticaries Agent, Silver Diamine Fluoride, FluorideVarnish, Acidulated Phosphate Fluoride, Surface Microhardness, Restorative Materials

I. INTRODUCTION

Dental caries is a major oral health issuefor children in Saudi Arabia, which demands a solution by thecommunity healthofficers.[1]Caries is activecontinuous course, which takesplace when demineralization exceeds remineralization.[2,3] Due to its slow progression, non-invasive techniques can be used in the early stages to convert the lesion from an active into inactive state.[4]The clinical gold standard of fluoridetreatment showed to have a positive impact on thede- and remineralizationequilibrium throughlowering the mineral's solubility product, thus protecting enamel from dissolution by bacterialacids.[5,6]

Fluoride isefficacious in preventing and controlling caries.[7] Other various anticaries agents have been used suchas silver diamine fluoride.[8,9]Numerous clinical investigations reported the use of silver diamine fluoride as an efficient caries-arresting agent.[10-13] Another innovative approach ofanticaries materialsis Curodont™ (Credentis AG, Windisch, Switzerland) a "self-assembling"peptide P11-4 in assembling a remineralization scaffolding on smooth surfaces enamel lesions which is artificially-induced.[14]Curodont has revealed a superior remineralizationeffect than the current gold standard fluoride varnish.[15,16] One moreanticaries agent is fluoride varnish, which is one of the most important materials used for caries prevention in children.[17,18]There are numerousfluoride varnishesexisting in the market including Profluorid varnish.[19]An additional anticaries agent is the topical acidulated phosphatefluoride 1.23%.[20]

Various resin composite, resin-modified glass-ionomer, and glass-ionomer restorative materials are available for restoration of children's teeth using direct restorative techniques.[21-25] The surface properties of restorative materials play important role in theclinicalsuccess.[26] Hardness is an important property, and it is the measure of the resistance of a material to indentation or scratching.[27]To our knowledge, limited studies have comparedmicrohardness of various restorative materials to the new anticariesagents. Thus, the objective of this *in vitro* study was to assess the effect of different anticariesagents: Silver diamine fluoride, Curodont Repair, fluoride varnish (Profluorid varnish), andacidulated phosphate fluoride (APF) (Gelato APF gel) on themicrohardness of three restorative materials: Conventional glass ionomer (Ionofil Molar AC), resin-modified glass ionomer (Photac FilQuick Aplicap)and resin composite (IPS Empress Direct). The tested null hypothesiswas there is no difference of microhardness of IonofilMolar AC, Photac Fil and IPSEmpress Direct after application of the tested anticaries agents.

II. MATERIALS AND METHODS

The Ethical Committee, College of Dentistry Research Center, King Saud University, approved this investigation.In this *in vitro* study, 60 cylindrical specimens (8 mm diameter, 2 mm thickness) were prepared from three restorative materials (shade A3) according to the instructions of the manufacturers using cylindrical metal molds. The three selected restorative materials areconventional glass ionomer (Ionofil Molar AC), resin-modified glass-ionomer(Photac Fil Quick Aplicap) and resin composite (IPS Empress Direct).Each material was placed into the cylindrical metal molds and covered with a Mylar matrix strip and pressed using glass slide (ShandonPolysine Slides, Thermo Scientific, Kalamazoo, MI, USA). Where applicable, the specimens werepolymerized according to the instructions of the manufacturers using a LED curing light (EliparS10, 3M ESPE, Seefeld, Germany). Specimens were stored in distilled water for 72 hours at room temperature (25°C). Specimenswere polished sequentially with 240, 320, 400, and 600 siliconcarbide paper (JEANWIRTZ GmbH & Co. Charlottestrabe Dusseldorf W. Germany) underrunning water. After that, specimens were stored in distilled water for 18 days at 37°C and then thermocycled 1500 times cycles (SD Mechatronik GmbH DentalResearch Equipment, W. Germany) in baths at 5°C and 55°C, with 5 seconds transfer timeand 30 seconds dwell times.

The 60 specimens prepared from each material were randomly allocated into five groupsof 12 each according to the anticaries agent and control (Control, Curodont Repair, acidulated phosphatefluoride"Gelato APF Gel", Profluorid varnish, and silver diamine fluoride). The pH of anticaries agents and distilled water was measured using 3540 conductivity/pH meter (JENWAY-Barloworld Scientific, CM6 3LB, Essex, England). The five groupsand the pH of the anticaries agents are presented in Table 1.Following the allocation, specimens were measured for Vickers hardness numbers at baseline for microhardness using microhardness testing machine(INNOVATEST NOVA 130, Maastricht, Netherlands). All specimens were stored indistilled water at room temperature (25°C) in sealed containers for four days before initiating surfacetreatment with the anticaries agents.Each specimen was dried with a cotton roll and application of different anticaries agents were performedaccording to the manufacturer's instructions, surface was keptwet with re-application every 15 minutes with a total time of 60 minutes (equal to 3minutes application for 20 days) and the control group was only kept in distilled water.After application of the anticaries agents, the second-time measurement for microhardness was completed similar to baseline.

The results were analyzed using one-way and two-way repeatedmeasures analysis of variance (ANOVA) and Fisher's least significant difference (LSD) test. All statisticalanalyses were set at a significance level of $p<0.05$. The statistical analysis wasperformed with SPSS Version 16.0 (SPSS Inc. Released 2007. SPSS for Windows, Chicago,SPSS Inc., Ill).

III. RESULTS

The microhardness at baseline before application of the anticaries agents(mean ± std. deviation) of conventional glass ionomer Ionofil Molar AC, resin-modified glass ionomer Photac FilQuick Aplicap, and resin composite IPS Empress Direct were 96.348 ± 0.816, 97.024 ± 0.888, and 74.798 ± 0.804 respectively.

Two-way repeated measures ANOVA analysis of the variables showed significant difference between pre- and post- application of anticaries agents when conventional glass-ionomer (Ionofil Molar AC)specimens treated with Curodont Repair (p=0.039) and silver diamine fluoride (p=0.005) (Table 2). There was significant difference between pre- and post- application of anticaries agents when resin-modified glass ionomer (Photac FilQuick Aplicap) specimens treated with Curodont Repair (p=0.020) (Table 3).There was significant difference between pre- and post- application of anticaries agents when resin composite (IPS Empress Direct) specimens treated with Gelato APF Gel (p=0.035) (Table 4).One-way repeated measures ANOVA and multiple comparison of measurements analysis of microhardness between specimens of the three restorative materials post-application of anticaries agents are presented in (Tables 5-7).ForIonofil Molar AC, there was significant difference between all anticaries agents in comparison to the control group (p=0.0001),and between Curodont Repair in comparison to all other anticaries agents (p=0.0001). There was significant difference in VOCO Profluorid varnish and Gelato APF Gel compared to silver diamine fluoride (p=0.0001)(Table 5).ForPhotac Fil, there was significant difference between all anticaries agents in comparison to the control group (p=0.0001), and Curodont Repair in comparison to all other anticaries agents (p=0.0001). There was significant difference in

VOCO Profluorid varnish and Gelato APF Gel compared to silver diamine fluoride (*p*=0.0001) as well as significant difference of VOCO Profluorid varnish in comparison with Gelato APF Gel (*p*=0.0001) (Table 6).For IPS Empress Direct, there was significant difference between Curodont Repair, VOCO Profluorid varnish and Gelato APF Gel in comparison to all other anticaries agents and to the control group (Table 7).

IV. DISCUSSION

The tested null hypothesis in this investigation was rejected, as there were some differences of microhardness of Ionofil Molar AC, Photac Fil Quick Aplicap,and IPS Empress Direct after application of the tested anticaries agents.In the present *in vitro* study, the microhardness was analyzed because it has been demonstrated that physical properties of different restorative materials such as microhardness is influenced by exposure to the oral environment.[26]One of the clinical significance of the microhardness property is its resistance to wear or abrasion,and measurements of hardness permit assessment of this behavior.[28]In this investigation, Vickers microhardness test was used, as it is appropriate for measurement of the hardness of restorative materials.[28,29] The application ofsome anticaries agents decreased microhardness of tested restorative materials. The decrease of microhardness of restorative materials may enhance their deterioration in a clinical setting, which may increase surface roughness and plaque retention, discoloration, loss of anatomical form, and reduction of the lifespan of restorations.[30]Since this was an *in vitro* study, these factors could not be evaluated. Difference in microhardness of tested restorative materials in this study after application of anticaries agents may be due to their surface microhardness which is influenced by the resistance to abrasion and cutting, material's strength, proportional limit, malleability, type of storage media, duration of storage, and ductility.[28,31]In addition, because of the differences in methodologies, assessment time points, type of storage media and the understudy materials, it is difficult to compare the present observations to those of previous studies.

The influence of professional topical fluoride therapy on esthetic restorative materials is due to their high reactivity which depends on the type of material and decreased hardness may be due to the different pH or fluoride concentration used.[30,31]In addition, APF 1.23% gel and foam, have reactivity 0.9% more than the neutral foam and 0.4% more than stannous fluoride.[31,32]Three main routes exist for the interaction of materials and fluoride. An interaction exists between the organic matrix, filler matrix coupling agents or reinforcing fillers.[31,32]Organic matrix of some resin composites is organic esters derived from methyl methacrylate(,) and the organic esters due to hydrolytic differences are similar to low pH esters. This reaction is accelerated by acid and is pH dependent.[31,32]The 1.23% APF gel, which has twice the fluoride concentration and a ten-fold greater hydrogen-ion concentration, should be more reactive than the 0.5% APF gel.[33,34] In the present study, we used VOCO Profluorid varnish and Gelato APF Gel similar to previous studies, which used NaF gel 2% with pH 7 and APF gel 1.23% with pH 3.5.[30]These fluorides are recommended by the American Academy of Pediatric Dentistry for professionally applied topical fluorides.[35] Gelato APF Gel with low PH contains 1.23% fluoride ion and is recommended for a 60-second application time.In general, fluoride particles have adverse effect on the resin matrix of the materials due to the monomers content in the resin matrix and the type of fluoride particles content used.[32,36] These fluoride particles leadto chemical softening and affect the strength and rigidity of the material, thereby decreasing the surface hardness of the resin composite restorations.[36]In the present study, after application of Gelato APF Gel (pH 6.4) for 60 minutes the microhardness of the resin composite increased but not conventional glass-ionomer or resin-modified glass-ionomer.In contrast, a study applied 1.23% APF gel for 4 minutes produced significant decrease in the microhardness of all the tested materials particularly for conventional glass-ionomer and least evident in resin-modified glass-ionomer while no significant difference was found after NaF treatment.[30]These findings were similar to other studies.[37,38]On the other hand, a study reported no statistically significant difference in microhardness after APF gel application between high viscosity conventional glass-ionomer and conventional glass-ionomer, and attributed this to the fact that both materials set by the acid-base reaction.[39]APF gel including Gelato APF Gel contains hydrofluoric acid and phosphoric acid.[33]APF gel contain phosphoric acid to etch the enamel and increase uptake of fluoride.[30]Phosphoric acid significantly modifies the morphology of the surface of different restorative materials causingalterationsoferosion resistance, microhardness, and roughness.[40,41]Hydrofluoric acid is added to topical APF agents to increase the fluoride concentration.[42,43]Additionally, hydrofluoric and/or phosphoric acid are also added to lower the pH of topical APF agents.[42]A study reported that hydrofluoric acid in the APF gel affects the filler particles. In addition, composite resins containing boroaluminosilicate glass show the greatest surface changes after the application of APF gel.[29] Hydrofluoric acid is more destructive than phosphoric acid because it can etch glass at lower temperatures and dissolves the composite filler particles resulting in a pitted surface.[44] Another study showed that the glass-ionomer surface integrity was essentially destroyed after 1 min of phosphoric acid etching and that individual particles dissociated from each other as the gel matrix dissolved.[45]In contrast, neutral sodium fluoride had no significant effect on glass-ionomer, whereas APF and nonproprietary sodium fluoride, containing phosphoric acid and citric acid were shown to cause significant dissolution of the matrix of glass-ionomer.[46]Erosion and decrease in microhardness of resin-modified glass-ionomers have been reported far less than conventional glass-ionomers, which is due to the resin component, which exists in this type of glass-ionomer.[41]A study reported that 60 second APF gel treatments caused decrease of microhardness and increase of surface roughness for some resin compositesas evident by SEM showing dissolving fillers.[47] The pH values of some APF gel was 3.5, however, this was not a factor for the changes of microhardness and roughness.[47]In the present study, the pH values of Gelato APF gel was 4.9 and of Profluorid Varnish was 6.4 and we did not examinedthe rheological properties of the anticaries agents by Rheometer to measure the way in which a material respond to applied forces.A study reported no significant difference in the microhardness before and after the application of APF gel for the filled sealants.[29] The insignificant effect of APF gel on filled sealants was attributed to the absence of gap between filler particles, as it appears that if the distance between filler particles is less than 0.1mm, the protective effect of filler particles confers resistance against APF gel.[48]It seems that the effect of APF on the resin composites largely depends on the size and type of fillers and APF's exposure time.[49] This effect is higher on resin composites containing barium aluminosilicate glass particles (that are sensitive to hydrofluoric acid) and lower in the microfilled composites in comparison with composites with larger macrofilled inorganic particles.[38]A study concluded that potential adverse effects of APF and titanium tetrafluorideapplications might be material dependent.[50]Several other secondary factors may influence the effect of fluorides on resin composites, such as surface roughness of the restorative material, viscosity of fluoride agents, thixotropy and shear rate of gels.[51] These factors may increase the interracial surface area or prolong the contact period of fluorides with restoratives accelerating the degradation process. A study assessed the effect of APF gel on the surface of resin-modified glass-ionomers with/without a protective glaze indicated that APF gel significantly etches the surface and the glaze protects surface from the abrasive effects of APF gel and the difference was attributed to the different under study materials and different storage time in distilled water.[52]

The effect of fluoride varnishes on the surface characteristics of restorative materials has received little, if any, attention. VOCOProfluorid varnish (pH 6.4) used in the present study is a colophony-based varnish consisting of 5% sodium fluoride (22,600 ppm fluoride).[19]It effectively seals the dentinal tubules by the accumulation of both fluoride ions and calcium ions, which precipitate into calcium fluoride.[19]In the present study,the three tested restorative materials showed some significant difference after application of anticaries agents.A study assessed the effect of repeated (twice) applications of two fluoride varnishes on the surface micromorphology of a compomer, a high-viscosity glass ionomer, and a flowable composite concluded that the last two significantly have higher roughness after two applications of one fluoride varnish compared to control.[53]We assume that fluoride varnish effectis partially due to its apparent ability to adhere to the restorative material specimens much more tenaciously with prolonging contact with the surface.[54]As more fluoride varnishes are available in the market and with prolonging contact to tooth enamel and restorative materials, more studies should be performed in order to fully determine whether or not surface etching is occurring and whether or not there are any clinical effects and implications.

There are no previous studies about surface microhardness of restorative materials after application of silver diamine fluoride and Curodont Repair in dental literature. Future investigations are needed to elucidate the short- and long-term effects of these anticaries agents on different properties of restorative materials under *in vitro and in vivo* conditions. In the present study, significant reduction of microhardness was evident for some restorative materials after application of some anticaries agents. A decrease in the hardness of a material may contribute to a deteriorating effect of the restorative materials in a clinical setting, including loss of anatomical form, discolorations, and premature failure requiring its replacement.[55,56]

In the present study, Ionofil Molar AC showed significant reduction of microhardness after application of silver diamine fluoride despite the fact that pH was 10.7. However,it causes erosion of glass and metals as reported in the safety data sheet of the product.[57]It has been suggested that when carious dentin is treated with silver diamine fluoride, silver phosphate is formed and precipitated.[58]The 38% silver diamine fluoride solution contains high concentrations of silver (253,870 ppm) and fluoride (44,800 ppm) ions.[59] Although studies have demonstrated that silver diamine fluoride is effective in arresting dental caries, the mechanism of action is unclear. A literature review concluded that silver diamine fluoride reduces the growth of cariogenic bacteria as the silver ion is bactericidal.[60] In addition, silver diamine fluoride can remineralize both enamel and dentin caries, and the possible mode of action for arresting caries may be attributed to its inhibition of demineralization, promotion of the demineralization of enamel and dentin, and protection of the collagen matrix from degradation.[60]

In the present study, Ionofil Molar AC and Photac FilQuick Aplicap showed significant reduction of microhardness after application of Curodont Repair (pH 4.7).Curodont Repair forms a biomatrix based on the Curolox® Technology just like the extracellular matrix (ECM) during odontogenesis,it triggers the growth of hydroxyapatite crystals (tooth mineral) and lost enamel is regenerated.[61]A study evaluated the remineralization potentials of different agents on demineralized enamel surfaces concluded that the remineralization was most successful in the APF and Curodont Repair groups, with higher values than for those of the other treatments.[62]Another study which investigated the effectiveness of different remineralization agents by quantitative light-induced fluorescence digital Biluminator™ (QLF-D) on artificial caries lesions concluded that APF and Curodont Repair yielded greater remineralization ability than other remineralization agents and control groups.[63]Curodont patented peptide diffuses into an initial caries lesion and induces the buildup of new hydroxylapatite crystals.[14] As a response to the environmental pH and salt concentration, self-assembling peptides assemble into a three-dimensional fibrillary scaffold in the lesion. It can then stimulate tissue regeneration from within, acting as a nucleator for hydroxyapatite.[62]

Comparing the effect of the anticaries agents on restorative materials *in vitro* to *in vivo* clinical studies may differ.[64]The treatment regimen employed in this study was based on clinical procedures for the application of anticaries agents' instructions of the manufacturers, and surface was kept wet with re-application every 15 minutes with total time of 60 minutes (equal to 3 minutes application for 20 days) while the control group was only kept in distilled water.Although the application time of anticaries agents on restorative materials in this study might looktoo much,it in facthappens in clinical conditionsas children are informednot to eat, drink, or rinse for some time after treatments. In addition, some anticaries agents are viscous and contact the surface of the restorative materials for anextended time. In the present study, we stored specimens in distilled water as control. It has been reported that water in some mouthwashes affect surface microhardness, which leads to adverse effect of water sorption and softening of material and decreasing hardness.[65,66] Due to the hygroscopic expansion, there is accumulation of water molecules in the microspaces. Such accumulation of water results in the reduction in the mechanical properties, such as hardness[67,68] as well as leaching out component as fillers.[65] The homogeneous distributions of the fillers in the resin matrix improve the material's function in the humid environment but voids at filler-matrix interface are likely to enhance water absorption by material.[67] The strength and rigidity of materials are related to the surface hardness property.[69]Water could also,produce some swelling, especially for hydrophilic polymers.[40]

Currently, there is limited research on the properties for restorative materials after application of the new anticaries agents *in vitro*. Further *in vitro* and *in vivo* studies are required to improve the knowledge of the mechanical and physical behavior of the restorative materials. The results of this investigation should consider the limitations of the study, including its *in vitro* setting. *In vitro* studies lack reproduction of oral environment, such as saliva, oral mastication and antagonist occlusion, and other factors, whichaffect the surface of the restorative materials. In addition, the clinical conditionin the mouth is not easy to mimic in the laboratory setting.[70]Nevertheless, *in vitro* studies can provide isolated data of some variables with no interference from other factors. Thermocycling was performed in this study to simulate some aspects of the oral environment. Another limitation of this study was the use of one resin composite, one conventional glass ionomer and one resin- modified glass ionomer only. It would be beneficial if more and different restorative materials/systems are tested. Furthermore, application ofanticaries agents on microhardness of tested restorative materials after longer and shorterapplication time after prolonged aging specimens wasnot tested in this study.In addition, restorative material surface was flat which do not mimic clinical situation. However, despitethese limitations, the research does describe a number ofpositive links between *in vitro* effect and clinical effect.

V. CONCLUSIONS

Under the experimental conditions and based on the results of this *in vitro* study, the following conclusionscan be made:

1) The potential reduction of microhardness of tested restorative materials might be anticaries agents dependent.
2) The highest microhardness of tested restorative materials at baseline were ranked in the following order: Photac FilQuick Aplicap, Ionofil Molar AC, and IPS Empress Direct.
3) Ionofil Molar AC and Photac Fil showed significant reduction of microhardness after application of Curodont Repair with pH 4.7 for 60 minutes.
4) Conventional glass-ionomer Ionofil Molar AC showed significant reduction of microhardness after application of silver diamine fluoride for 60 minutes despite the fact that pH was 10.7.
5) Resin composite IPS Empress Direct showed significant reduction of microhardness after application of Gelato APF Gel with pH 4.9 for 60 minutes.
6) None of the tested anticaries agents increased the microhardness of tested restorative materials.

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Table 1. Distribution of restorative materials, groups,and anticaries agentsand their pH

Restorative Material	Group #	Anticaries Agents - Patch Number	pH
Conventional glass- ionomer (Ionofil Molar AC)	1A	Curodont Repair (Credentis, Windisch, Switzerland) - 0095/2015-340	4.7
	2A	VOCO Profluorid Varnish (VOCO GmbH, Cuxhaven, Germany) - 1706212	6.4
	3A	Gelato APF gel (Deepak Products, Miami, FL, USA) - 24-0337	4.9
	4A	Advantage Arrest Silver Diamine Fluoride(Elevate Oral Care, West Palm Beach, FL, USA) - 16092	10.7
	5A	Control Group	5.66
Resin-modified glass-ionomer (Photac Fil)	1B	Curodont Repair	
	2B	VOCO Profluorid Varnish	
	3B	Gelato APF gel	
	4B	Advantage Arrest Silver Diamine Fluoride	
	5B	Control Group	
Resin composite (IPS Empress Direct)	1C	Curodont Repair	
	2C	VOCO Profluorid Varnish	
	3C	Gelato APF gel	
	4C	Advantage Arrest Silver Diamine Fluoride	
	5C	Control Group	

Table 2: Mean and Std. Deviation of microhardness of conventional glass-ionomer (Ionofil Molar AC) pre- and post- application of anticaries agents and statistical significance

Anticaries Agents	Microhardness	N	Mean	Std. Deviation	*p* values
Curodont Repair	Pre-	36	96.38	0.86	0.039*
	Post-	36	62.94	0.85	
VOCO Profluorid Varnish	Pre-	36	95.87	0.60	0.778**
	Post-	36	77.34	1.27	
Gelato APF Gel	Pre-	36	96.17	0.98	0.585**
	Post-	36	77.53	0.90	
Silver Diamine Fluoride	Pre-	36	96.71	0.91	0.005*
	Post-	36	81.57	0.72	
Control	Pre-	36	96.61	0.73	0.269**
	Post-	36	88.36	0.78	

*Significant
**Not Significant

Table 3: Mean and Std. Deviation of microhardness of resin-modified glass ionomer (Photac Fil) pre- and post- application of anticaries agents and statistical significance

Anticaries Agents	Microhardness	N	Mean	Std. Deviation	*p* values
Curodont Repair	Pre-	36	96.63	1.20	0.020*
	Post-	36	62.94	0.85	
VOCO Profluorid Varnish	Pre-	36	96.82	0.88	0.288**
	Post-	36	38.71	0.94	
Gelato APF Gel	Pre-	36	97.28	0.88	0.548**
	Post-	36	58.81	0.70	
Silver Diamine Fluoride	Pre-	36	97.27	0.69	0.689**
	Post-	36	53.87	0.70	
Control	Pre-	36	97.12	0.79	0.412**
	Post-	36	67.83	1.04	

*Significant
**Not Significant

Table 4: Mean and Std. Deviation of microhardness of resin composite (IPS Empress Direct) pre- and post-application of anticaries agents and statistical significance

Anticaries Agents	Microhardness	N	Mean	Std. Deviation	*p* values
Curodont Repair	Pre-	36	75.46	0.76	0.067**
	Post-	36	79.91	12.11	
VOCO Profluorid Varnish	Pre-	36	74.48	0.87	0.071**
	Post-	36	56.47	8.08	
Gelato APF Gel	Pre-	36	74.18	0.81	0.035*
	Post-	36	65.61	3.17	
Silver Diamine Fluoride	Pre-	36	74.79	0.68	0.173**
	Post-	36	72.09	6.13	
Control	Pre-	36	75.08	0.90	0.934**
	Post-	36	73.82	0.72	

*Significant
**Not Significant

Table 5: Comparison of measurements of microhardness between specimens of the conventional glass ionomer (Ionofil Molar AC) post-application of anticaries agents

Anticaries Agents	ANOVA P-Value	Multiple Comparison Test				
		Curodont Repair	VOCO Profluorid Varnish	Gelato APF Gel	Silver Diamine Fluoride	Control
Curodont Repair	0.0001*	1	0.0001*	0.0001*	0.0001*	0.0001*
VOCO Profluorid Varnish		0.0001*	1	0.909**	0.0001*	0.0001*
Gelato APF Gel		0.0001*	0.909**	1	0.0001*	0.0001*
Silver Diamine Fluoride		0.0001*	0.0001*	0.0001*	1	0.0001*
Control		0.0001*	0.0001*	0.0001*	0.0001*	1

*Significant
**Not Significant

Table 6: Comparison of measurements of microhardness between specimens of the resin-modified glass ionomer (Photac Fil) post-application of anticaries agents

Anticaries Agents	ANOVA P-Value	Multiple Comparison Test				
		Curodont Repair	VOCO Profluorid Varnish	Gelato APF Gel	Silver Diamine Fluoride	Control
Curodont Repair	0.0001*	1	0.0001*	0.0001*	0.0001*	0.0001*
VOCO Profluorid Varnish		0.0001*	1	0.0001*	0.0001*	0.0001*
Gelato APF Gel		0.0001*	0.0001*	1	0.0001*	0.0001*
Silver Diamine Fluoride		0.0001*	0.0001*	0.0001*	1	0.0001*
Control		0.0001*	0.0001*	0.0001*	0.0001*	1

*Significant
**Not Significant

Table 7: Comparison of measurements of microhardness between specimens of the resin composite (IPS Empress Direct) post-application of anticaries agents

Anticaries Agents	ANOVA P-Value	Multiple Comparison Test				
		Curodont Repair	VOCO Profluorid Varnish	Gelato APF Gel	Silver Diamine Fluoride	Control
Curodont Repair	0.0001*	1	0.0001*	0.0001*	0.0001*	0.004*
VOCO Profluorid Varnish		0.0001*	1	0.0001*	0.0001*	0.0001*
Gelato APF Gel		0.0001*	0.0001*	1	0.002*	0.0001*
Silver Diamine Fluoride		0.0001*	0.0001*	0.002*	1	0.848**
Control		0.004*	0.0001*	0.0001*	0.848**	1

*Significant
**Not Significant

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