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Does radiopacity of restorative materials change with aging?

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Duygu Tuncer: She prepared the specimens, made the experiment, prepared the manuscript.
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Neslihan Arhun: She prepared the specimens, prepared the manuscript.

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ABSTRACT

Background: Dental materials should be radiopaque enough to be identified from enamel and dentin and enable the detection of secondary caries, marginal defects. The aim was to evaluate the radiopacity of restorative materials after 6 months of aging in distilled water.

Material and Methods: Twenty-two restorative materials were used and the radiopacity them were first evaluated after setting and after 6-months of storage in distilled water. Human primary and permanent tooth slices were also used in the study. Restorative material specimens were prepared by using Teflon molds. Twelve specimens were prepared for each material group. All specimens were exposed together with an aluminum stepwedge using a phosphor plate. The analysis was made with Digora system.

Results: Filtek-Silorane, Aelite-LSPosterior, Theracal-LC, Biodentine, Ionofil-U, Vitrebond and GCP-Glass-Seal exhibited lower radiopacity values at the initial setting and after 6-months of aging with respect to permanent enamel. When compared with deciduous enamel, Filtek-Z550, Charisma, Riva-Light Cure and Equia-Fil exhibited lower radiopacity values at both readings. Spectrum-TPH, Filtek-Ultimate, Clearfil-Majesty Flow, Sultan-Versa, IRM and Adhesor exhibited statistically significant higher values of radiopacity at the 6-month evaluation.

Conclusion: The radiopacity of restorative materials is dependent on the material type exerting different radiopacity values after 6-months.

Keywords: Restorative materials, radiopacity, aging

1. INTRODUCTION

A thorough clinical examination supported by radiographic evaluation is priceless in every field of dentistry. It is always a dilemma for a clinician to decide whether to replace or repair an existing resin composite restoration which involves a doubtful area that the presence of caries cannot be definitively decided.[1] Restorative materials have different radiopacity values. Manufacturers are responsible for improving the degree of radioopacity of their products, by incorporating fillers or by using radio-opaque compounds.[2]Elements such as barium, strontium, zinc, yttrium and ytterbium which have high atomic numbers, can improve radioopacity for optimal diagnostics.[3] Therefore, restorative materials must appear in different radiopacity levels to distinguish the enamel and dentin tissues as well as caries[4] since the radiopacity of restorative materials plays an important role for the treatment planning.[1] Preferably, restorative materials should have higher radiopacity values than that of enamel.[5] Contrasting with adjacent recurrent caries and applied restorative materials, voids and gingival overhangs would be more apparent when the restorative materials with adequate radiopacity is used.[6] The detectability of recurrent caries underneath a restorative material with a radiopacity similar or greater than enamel can improve the radiographic visualization of the caries.[7] ISO 40490:2009 states that, a 1-mm thick sample of dental material should have a radiopacity equal to or greater than a 1-mm thick sample of aluminum.[8] Digital systems are used as an alternative to conventional radiologic systems which provides clinical and diagnostic advantages such as less exposure to radiation, quick image processing, reduced toxic wastes from liquid processors, and the ability to utilize systems' programs to handle images and make measurements, including the density of restorative materials.[9] To the authors knowledge, there is no research about the radiopacity of restorative materials after aging. Thus, the aim of this in vitro study was to determine and compare the radiopacity of different restorative materials after 6 months of aging in distilled water.

2. MATERIAL AND METHODS

2.1. Sample Preparation

Twenty-two different restorative materials (nine composite resins, two compomer based, five glass ionomer based restorative materials, six other cavity base materials), were used for the study. These materials are presented in Table 1. In addition to restorative material samples, 2 mm thick human primary and permanent tooth slices which include both enamel and dentin were prepared. Anonymized teeth were used in the study. This study was approved by Baskent University Institutional Rewiev Board (with the project number D-DA 16/05) and supported by Baskent University Research Fund. Each restorative material was prepared according to the manufacturer's instructions. All restorative material specimens were prepared by using Teflon mold (4-mm diameter, 2-mm height). 12-specimens were prepared for each material group. The radiopacity of the specimens were evaluated first at 24 hours after setting and after storage in distilled water for 6 months. Distilled water was changed every week during the 6 months of aging.All specimens of each group were exposed together with an 8-step aluminum stepwedge (each stepwedge was 2 mm) using a phosphor plate (Digora, Soredex, Helsinki, Finland) with a standard condition (70 kVp, focus-object distance:30 cm and exposure time:0.2 second). Digital images of the tested materials were obtained with the Digora Phosphor Storage System using a size 2 plate. The same plates were used for all specimens to avoid the probable differences related to the plates. After exposure, the images were transferred to a computer using a Digora scanner, stored in DICOM format. The radio opacities of the specimens were analyzed using Digora for Windows software (ver.2.8, Digora, Soredex; Helsinki, Finland) in five different areas with 40x40 pixel area to reduce the measurement bias. The mean radiopacity was calculated for each specimen. Thereafter, the mean radioopacity was transformed to the equivalent aluminum thickness (eq Al mm) with the equation obtained from plotting the aluminum thickness against the correspondent radiopacity of the stepwedge. (Figure 1A, B, C) All measurements were performed by the experienced dentomaxillofacial radiologist (AG). The eq Al mm values of each group was obtained using Regression analysis. The mean radiopacity values for each group were compared using Kruskal Wallis test ($p < 0.05$).

Table 1 Restorative Materials used in the study

Product	Type	Composition	Manufacturer
SpectrumTPH3 Batch:1207001016	Microhybrid Resin Composite	TEGDMA, Dimethacrylate, Multifunctionalpolymethacrylate, Camphorquinone, Ethyl-4(dimethylamino)benzoate, BHT, UV stabilizer, Barium-aluminium-borosilicateglass (meanparticle size < 1 µm), Silanatedbarium-boron-fluoro-alumino-silicateglass (meanparticle size < 1 µm), Highlydispersedsilicondioxide (particle size 10-20 nm), Fluorescentagent, Ironoxidepigments, Titaniumdioxide	Dentsply, De Trey, Konstanz, Germany
Filtek Z250 Batch:N388381	Microhybrid resin Composite	Silane treated ceramic, BisEMA6, UDMA, BISGMA, TEGDMA, Aluminum Oxide, Benxotriazol, EDMAB, Bis-GMA, Bis-EMA, UDMA, photo initiators, and stabilizers, Filler Zirconium/silica filler [0.01–3.5 mm]: 84.5wt% , 60 vol%	3M ESPE, St. Paul, MN, USA
Filtek Z550 Batch:N437063	Nanohybrid resin Composite	Silane processed ceramic, silane processed silica, BISGMA, UDMA, bısphenol a polyethylene glycol dıetherdımethacrylate, TEGDMA	3M ESPE, St. Paul, MN, USA
FiltekSilorane Batch:N377859	Silorane Based Resin Composite	Siloraneresin,Silanized quartz; yttrium flüoride, 76 wt %; 3,4-epoxycylohexyl-ethylcylophenyl-methysilane Filler size: Silicon dioxide, ytterbium trifluoride 0.1-2.0 µm(filler 76%, silorane resin 23%, stabilizer 0.13%, initiator 0.9%, pigments 0.005%)	3M ESPE, St. Paul, MN, USA
Filtek Ultimate Batch:N175893	Nanohybrid Resin Composite	Bis-GMA, UDMA, TEGDMA, PEGDMA and Bis-EMA. Non-agglomerated/non-aggregated 4 to 11 nm zirconia filler and aggregated zirconia/silica cluster filler(comprised of 20 nm silica and 4 to 11 nm	3M ESPE, St. Paul, MN, USA

		zirconia particles. Avarage cluster particle:0.6 to 10µ	
Sultan Versa Comp Batch:121107	Universal Hybrid Resin Composite	Barium Boron FluoroAlumino Silicate Glass, Amorphous Silica, (1-methylethylidene)bis[4,1-phenyleneoxy(2-hydroxy-3,1-propanediyl)] bismethacrylate, Polymerizable Dimethacrylate, Urethane Modified Bis-GMA dimethacrylate	Sultan Healthcare, Hackensack, NJ, USA
Aelite LS Posterior Batch:1200002085	Low shrinkage Hybrid Resin Composite	Bis-EMA, TEGDMA glass frit, amorphous silica, filler vol 74%, filler weight 88%	Bisco, Inc, Schamburg, IL, USA
Charisma Classic Batch:010022	Microhybrid Resin Composite	Bis-GMA, 61% filler by volume, with 60% inorganic filler by volume, 0.005-10µm particle size, barium aluminum fluoride glass, pre-polymerized filler	Heraeus Kulzer GmBH, Hanau, Germany
Clearfil Majesty Flow Batch:00310B	Flowable Resin Composite	TEGDMA, silanated barium glass filler, silanated colloidal silica, hydrophobic aromatic dimethacrylate, dl-camphorquinone, filler weight 48%	Kuraray Medical Inc., Tokyo, Japan
Dyract Extra Batch:0704	Polyacid-Modified Resin Composite (Compomer)	Strontium-alumino-sodium-fluorophosphor- silicate glass UDMA, TEGDMA, TCB, SrF_2, SiO_2 fillers	Dentsply DeTrey GmbH, Konstanz, Germany
GCP Glass seal Batch: 7212011	Carbomer and Fluorapatite Enhanced Glass Ionomer Sealant	Glass carbomer	GCP Dental GmBH, Elmshorn Germany
Riva Self Cure Batch:B1209172EG	Glass Ionomer Restorative Material	Compartment 1:Polyacrylic Acid , Tartaric acid Compartment 2: Fluoro Aluminosilicate glass, Polyacrylic Acid, Strontium	SDI, Victoria, Australia
Riva Light Cure	High Viscosity Light Cured Resin Reinforced Glass Ionomer Restorative	Compartment 1:Polyacrylic Acid, Tartaric Acid 2-Hydroxyethyl Methacrylate Dimethacrylate Cross-linker, Acidic Monomer Compartment 2: Fluoroaluminosilicate glass powder	SDI Victoria, Australia
İonofil U Batch:1303636	Glass Polyalkenoate Cement	aluminium fluorosilicate glass, polyacrilic acid	Voco, Cuxhaven, Germany
Equia Fil Batch:1301171	Glass Ionomer For Restorative Treatment	Polyacrilic acid, aluminosilicate glass, distilled water	GC, Tokyo, Japan
Vitrebond Batch:N421755	Light Cure Glass Ionomer Liner	Powder: Radiopaque floroaluminosilicate glass, dıphenylıodonıumchlorıde Liquid:Modifiedpolyalkenoic acid, copolymer of acrylıcandıtaconıcacıds, water, 2-hydroxyethyl methacrylate (HEMA)	3M ESPE, St. Paul, MN, USA
Dycal Batch:120821	Calcium Hydroxide Liner	Base:Disalicylate ester of 1,3, butylene glycol; calcium phosphate; calcium tungstate; zinc oxide, iron oxide Catalyst:Calcium hydroxide; ethyl toluenesulfonamide; zinc esterate; titanium dioxide; zinc oxide; iron oxide	Dentsply Caulk, Milford, USA
Theracal LC Batch: 1200007211	Resin Modified Calcium Silicate Liner	Portlant Cement type III, polyethylene glycol dimethacrylate, bisphenol A, digilycidyl methacrylate, barium zirconate	Bisco, Schaumburg, IL, USA
IRM	Polymer Reinforced	Powder: Zinc oxide, PMMA powder, pigment	Dentsply Caulk, Milford,

Batch:111210	Zinc Oxide-Eugenol Restorative Material	Liquid: Eugenol, acetic acid	USA
Adhesor Batch:2236694	Zinc Phosphate Cement	Powder: Zinc oxide, magnesium oxide, aluminum trihydroxide, boron trioxide Liquid: "normal" aqueous solution of phosphoric acid and aluminum orthophosphate and "rapid" aqueous solution of phosphoric acid, aluminum orthophosphate and zinc orthophosphate	Spofadental, Kerr Company, USA
SDR Batch:1208224	Posterior Bulk fill Flowable Base	Barium-alumino-floro-borosilicate glass, strontium alumino-fluoro-silicate glass, modified urethane dimethacrylate resin, EBPADMA, TEGDMA, Camphorquinone, BHT, UV stabilizer, titanium dioxide, iron oxide pigments, fluorescing agent	Dentsply Caulk, Milford, USA
Biodentine Batch:B01091	Restorative Dentin Substitude	tricalcium silicate, zirconium oxide calcium carbonate, calcium chloride, hydrosoluble polymer.	Septodont, Saint Maur des Foss´es, France

Bis-GMA: Bisphenol A diglycidylmethacrylate, UDMA: urethane dimethacrylate, TEGDMA: triethyleneglycoldimethacrylate, PEGDMA: photopolymerised poly(ethylene glycol) dimethacrylate, Bis-EMA: ethoxylated bisphenol a dimethacrylate, HEMA: 2-Hydroxyethyl methacrylate, MDP:10-Methacryloyloxydecyl dihydrogen phosphate, SrF2:Stronsium floride SiO2: Silisumokside,PMMA:poly-methyl methacrylate, EBPADMA: ethoxylated bisphenol A dimethacrylate, BHT:Photoaccelerator, butylated hydroxyl toluene, UV: Ultraviolet, EDMAB: Ethyl 4 dimethylaminobenzoate

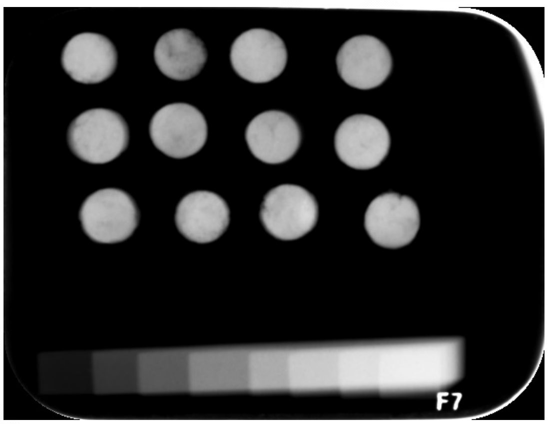

Figure 1A: Specimen with high radiopacity value

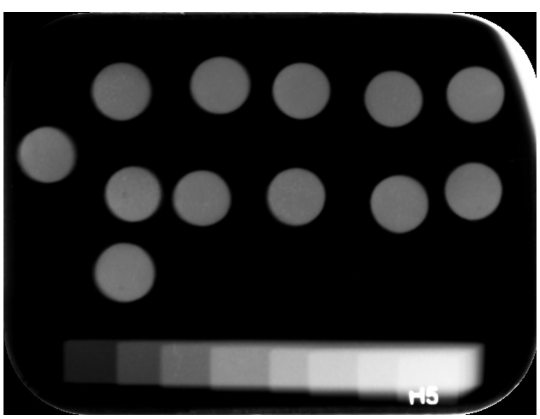

Figure 1B: Specimen with lower radiopacity value

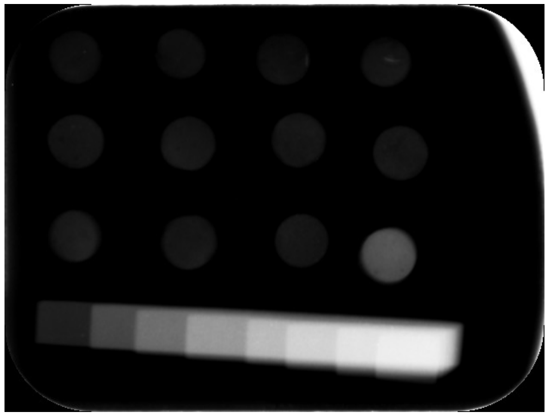

Figure 1C: Specimen with lowest radiopacity value

Figure 1 Specimens with different radiopacity values

3. RESULTS

The descriptive statistics of the radiopacity values (Eq Al mm), and the corresponding aluminum step wedge values of the tested materials at 24 hours after setting and after 6 months of water storage are shown in Table 2. When the difference between the radiopacity values of the tested materials at initial and after 6 months of water storage taken into consideration it was seen that Spectrum-TPH, Filtek Ultimate, Clearfil Majesty Flow, Sultan Versa, IRM and Adhesor exhibited statistically significant higher values of radiopacity at the 6-month evaluation. When the tested materials were compared to each other at the initial setting, it was seen that GCP Glass Seal, Vitrebond and Aelite LS Posterior showed statistically significant lower radiopacity values than Riva Self Cure, SDR, Z250, Dyract Extra, Majesty Flow, IRM, Sultan Versa and Adhesor. Likewise Ionofil U also showed statistically significant lower radiopacity values than Filtek Ultimate along with the aforementioned materials (Table 2).

After 6 months of aging, GCP Glass Seal and Ionofil U exhibited statistically significant lower values of radiopacity than SDR, Z250, Filtek Ultimate, Dyract Extra, TPH Spectrum, Majesty Flow, IRM, Sultan Versa and Adhesor. Besides, GCP Glass Seal's values of radiopacity was also significantly lower than Riva Light Cure (Table 2). FiltekSilorane, Aelite LS Posterior, Theracal LC, Biodentine, Ionofil U, Vitrebond and GCP Glass Seal exhibited lower radiopacity values at the initial setting and after 6-months of aging with respect to permanent enamel. When compared with deciduous enamel, along with the aforementioned materials Filtek Z550, Charisma, Riva Light Cure and Equia Fil exhibited lower radiopacity values at both readings (Table 2).

Table 2 Thedescriptivestatistics of thealuminumstepwedgevalues of theexperimentalgroups (Eq Al mm)

	Initial		**6 Months**		***p***
	Mean±SD	**Median [Min-Max]**	**Mean±SD**	**Median [Min-Max]**	
SpectrumTPH3	6,36±0,25 ^{b}	6,37 [6,02 - 6,73]	7,49±0,3 ^{b}	7,45 [7,04 - 8,05]	0,002*
Filtek Z250	4,79±0,21 ^{b}	4,79 [4,47 - 5,13]	4,45±0,53^{b}	4,32 [3,91 - 5,53]	0,099
Filtek Z550	4,12±0,22	4,21 [3,75 - 4,4]	3,91±0,14	3,88 [3,75 - 4,15]	0,060
FiltekSilorane	2,46±0,23	2,4 [2,13 - 2,76]	2,49±0,14	2,51 [2,28 - 2,7]	0,638
Filtek Ultimate	4,32±0,15^{b,c}	4,35 [4,03 - 4,54]	4,79±0,21^{b}	4,81 [4,42 - 5,13]	0,002*
Clearfil Majesty Flow	6,45±0,41 ^{b}	6,51 [5,86 - 7,13]	7,5±0,59 ^{b}	7,3 [6,56 - 8,7]	0,003*
Sultan Versa	6,78±0,61 ^{b}	6,83 [5,27 - 7,79]	7,84±0,78^{b}	7,84 [5,75 - 8,72]	0,012*
AELİTE LS Posterior	1,96±0,4 ^{a}	1,96 [1,2 - 2,51]	2,2±0,08	2,2 [2,1 - 2,41]	0,071
Charisma	4,08±0,37	4,1 [3,59 - 4,63]	3,91±0,16	3,9 [3,69 - 4,17]	0,158
DyractExtra	4,92±0,48 ^{b}	5,06 [3,91 - 5,45]	5,3±0,72 ^{b}	5,33 [4,3 - 6,68]	0,136
Dycal	3,21±0,61	3,38 [1,89 - 3,92]	2,57±0,76	2,45 [1,87 - 4,35]	0,263

TheracalLight-Cure	2,77±0,35	2,74 [2,37 - 3,61]	2,61±0,23	2,64 [2,31 - 2,94]	0,779
IRM	6,64±0,67 [b]	6,6 [5,75 - 7,53]	9,27±0,69[b]	9,54 [7,83 - 10,03]	0,012*
Adhesor	10,47±0,93[b]	10,7 [8,1 - 11,39]	11,99±0,44[b]	12,11 [11,13 - 12,41]	0,002*
SDR	4,7±0,4 [b]	4,65 [4,24 - 5,69]	4,98±0,58 [b]	5,04 [4,15 - 5,77]	0,099
Biodentine	2,24±0,67	2 [1,33 - 3,5]	2,23±0,33	2,23 [1,83 - 3,08]	0,875
Riva Self-Cure	4,62±0,53 [b]	4,56 [3,77 - 5,51]	4,38±0,66 [c]	4,28 [3,56 - 5,68]	0,388
Riva Light-Cure	3,33±0,89	3,63 [1,84 - 4,29]	3,94±0,62	4,03 [2,56 - 4,63]	0,208
Ionofil U	1,46±1,09 [a]	1,29 [0,66 - 4,8]	2,05±1,15[a,c]	1,69 [1,57 - 5,69]	0,028
Equia Fil	3,13±0,56	3,05 [2,17 - 4,16]	3,11±0,3	3,05 [2,64 - 3,65]	0,859
Vitrebond	1,92±0,66 [a]	1,74 [1,19 - 3,23]	1,96±0,23	1,99 [1,52 - 2,27]	0,594
GCP GlassSeal	1,74±0,52[a,c]	1,96 [0,76 - 2,57]	1,55±0,17 [a]	1,61 [1,31 - 1,83]	0,272
Human PermanentEnamel	2,9	2,9 [2,9 - 2,9]	2,9	2,9 [2,9 - 2,9]	-
Human PermanentDentin	2,3	2,3 [2,3 - 2,3]	2,3	2,3 [2,3 - 2,3]	-
Human DeciduousEnamel	4,41	4,41 [4,41 - 4,41]	4,41	4,41 [4,41 - 4,41]	-
Human DeciduousDentin	2,17	2,17 [2,17 - 2,17]	2,17	2,17 [2,17 - 2,17]	-

Different letters on the same column represents statistical significance (p<0.05)

4. DISCUSSION

The quality and long term prognosis of restorations are followed by radiographs to check the presence of secondary caries, faulty proximal contours and inadequate marginal adaptation. The exact distinction between the restorative materials, the cavity walls and the liners/bases is accomplished by "adequate" radiopacity of these materials. The word "adequate" is very important in this issue since materials with a radiopacity less than enamel can cause false-positive results causing over treatment which ends up with unnecessary replacement of the restorations. Likewise, high radiopacity such as amalgam near a less radiopaque area can cause a visual illusion that deteriorates both the perception of the details and the visual acuity, the Mach Band effect, making the dark borderline area darker and mimic dental caries.[6, 10]This restoration placement and replacement cycle not only sacrifices money and time of the patient but also some of the remaining healthy tissue. Most studies suggest that a material with a radiopacity equal to or slightly greater than that of enamel would be ideal to detect secondary caries in radiographs to avoid imaging misdiagnosis leading false positive results.[11]

Researches about this phenomenon broadly employed aluminum as a radiographic standard to compare enamel or dentin with a dental material since 99.5% pure aluminum is the reference material with radiopacity similar to dentin according to ISO standards.[9, 10, 12] For the same thickness, the radiopacities of aluminum and dentin are approximately equivalent and enamel has approximately twice the radiopacity of aluminum.[13] In fact, it is also prudent to employ enamel and dentin as secondary standards.[14] The permanent dentin and enamel reference radiopacity values in our study were 2.3 and 2.9 mm eq Al, respectively. Whereas, these values were 2.17 and 4.41 for deciduous dentin and enamel. There are numerous studies comparing radiopacity of different 2 mm restorative materials with 2 mm of dentin and enamel like the present research; however the resultant radiopacity values were wide in range: 0.93 to 2.96 for dentin and 1.63 to 4.3 for enamel.[10, 15] This wide range was attributed to the differences generated by evaluation techniques consisting of conventional or digital images with different resolutions.[15] To the authors' knowledge, there is no study evaluating the radiopacity of deciduous teeth.

Dental materials' radiopacity values can be influenced by several factors such as evaluation technique, specimen's thickness, filler percentage and particle size related to the water absorption of the material, film development, atomic number of materials' constituent . The atomic number of materials' constituents is the most important one since it influences the radiopacity raised even to the exponent of four.[16] Elements such as barium, zinc, aluminum, strontium, zirconium, silicon, yytrium, yyterbium and lanthanum that have high atomic numbers enhance the capacity to absorb X-rays, thus, increase the radiopacity of the materials.[6] However, it should be kept in mind that the radiopaque particles increase the thermal expansion, hydrolyze the silane bonding agent, cause opacity14 and loss of dimensional stability of the composites materials.[12]

The exact chemical composition of resin composites is not clearly reported and kept as confidential data by the manufacturers because of commercial issues. So, it is inevitably not possible to correlate the filler content and the radiopacity results due to the limited available data about the exact composition of the commercial resin composite products.[17]

Radiopacity of dental materials are mainly evaluated by conventional and digital radiographs. Radiopacity measurements were expressed in optical density for conventional films and in pixels and grey shades for digital systems. The evaluation of radiopacity of a material by a conventional radiograph is mainly based on the measurement of optical density on the radiographic film, however, special software is used for evaluation in a digital radiograph.[18] This software in the digital system allows the clinicians to enhance the digital images to focus on or measure regions of interest by adjusting and sharpening images.[9] If traditional film development is not accomplished properly, there may be substantial variations in the final radiograph.

In the present study, a digital radiographic system was used like previous studies.[17] However, literature predicts contradictory data between conventional and digital radiography techniques about measurement of radiopacity of the restorative materials. It is claimed that a restorative material appear 10-13% more radiopaque in a storage phosphor plate digital sensor than a conventional film.[9] On the contrary, some researches showed that the conventional radiograph allowed the most efficient radiographic differentiation between enamel and resin composites regardless of copious advantages of digital imaging systems.[10, 15]

Glass ionomer materials have been extensively used as a restorative material since early 70s.[19]However, these pioneer glass ionomers were deficient in radiopacity causing false positive misdiagnosis, which made it difficult to radiographically differentiate any recurrent/secondary caries from the restoration.[20]Thus, these materials were further improved by incorporating glass particles like calciumfluoroalumino silicates.[21] Since strontium is the most similar element to calcium, and glasses containing it were already being used in the dental resin composite restoratives[22] in the mid-1980s patents describing strontium as radiopacifier glass component were filed.[23] Patents were also filed for the use of strontium fluoride as a radiopacifiying cement additive which did not adversely affect the opacity or color of the cement.[24] In the current research, Riva Self Cure also has strontium as an radiopacifying agent.

In the present study, there was a large variation among the radiopacities of resin-based and glass ionomer-based restorative materials which is similar with a study performed by Yasa et al[25.] SDR had exceedingly high radiopacity value than enamel like in the study of Yasa et al[25]. It is suggested that a material with moderate radiopacity is more appropriate not to obscure the presence of caries lesions.[26] GCP Glass Seal had lower radiopacity value than dentin and this characteristic of the material may cause misinterpretation related to the secondary caries adjacent to the restorative material. Equia Fil also showedsimilar resultswhich were obtained in the study of Yasa et al[25].

Since the radiopacity of enamel is the threshold of the radiopacity of any restorative material, use of materials with a radiopacity lower than that of enamel as a first increment is not appropriate. The initial increment has to be radiopaque enough to enable the clinician identify the cavity walls and restoration margins.[27] Thus, as there is a wide range of restorative materials with different values of radiopacity, special attention should be given when choosing an appropriate restorative material in every unique clinical situation. In this research FiltekSilorane, Aelite LS Posterior, Theracal Light Cure, Biodentine, Ionofil U, Vitrebond and GCP Glass Seal were found to be less radiopaque then enamel.

The flowable resin composites have readily gained acceptance from many clinicians to ease restoring margins that are below the gingival margin or in deep carious lesions.[28]Besides, flowable composites mostly have less fillers than conventional resin composites and therefore cause diagnostic challenges on radiographs with lower radiopacity values since they have a tendency to accumulate in deeper cavity angles leading to radiographic misdiagnosis.[29] However, herein, Clearfil Majesty Flow exerted more radiopacity then enamel. The high radiopacity values obtained might be attributed to the silanated barium glass fillers of Clearfil Majesty Flow. Similarly, the conventional and resin-modified glass ionomer cements are often employed on the gingival margin in the open and closed sandwich techniques because of their inherited advantages.[30] On other hand, their radiopacity may compromise their proof of presence in the follow up radiographs.[31]In the light of these facts, it will not be wrong to claim that manufacturers should also publish radiopacity values to allow the dental professional to determine where and when a certain product should be used for better results.[19]

Hitij and Fidler[10]investigated the radiopacity values of 56 restorative materials and found out that for 1 mm of the investigated materials. The radiopacity values of all tested materials were above the dentin reference radiopacity value. However, the measured radiopacity values of 5 out of 33 conventional resin composite materials, 7 out of 16 flowable resin composite materials, and none of 7 restorative glass ionomer materials were significantly lower or similar to the enamel reference radiopacity value.

A study[17]related that currently the composite materials have presented an appropriate radiopacity to the guidelines, despite a wide range of radiopacity, as observed in the current study as well. These wide ranges of radiopacity occur principally as a result of different kinds and proportions by volume of radiopacifying agents, considering the diversity of the manufacturers. Variations in radiopacity values of the same restorative materials among different studies can already occur because there are many methodological factors, such as those relating to film, X-ray machines, radiographic processing, and image analysis, that could induce such ranges.

In the present study, Filtek Z250, Filtek Z550 and Filtek Ultimate showed higher radiopacity values than enamel both in baseline and after six months of aging. But Aelite LS Posterior showed lower radiopacity value than dentine. These results were similar with the results of a study made by Ermis et al in 2014[32]. In their study,Aelite LS Posterior also showed lower radiopacity value than other resin composites like in the present study. But in another study this composite resin showed higher radiopacity value than dentine in contrast to the result of the present study.[33]TPH Spectrum and Charisma had also higher radiopacity value than enamel in the present study that was similar with another study which was published in 2016, but Charisma was showed lower value than enamel contrary to our findings.[34]

TPH Spectrum, Filtek Ultimate, Clearfil Majesty Flow, IRM and Adhesor Zinc Phosphate Cement were found to be more radiopaque after 6 months of aging. The reason behind this finding may be chemical changes that were encountered during aging in distilled water. The constituents of the materials may be soluble or the material may absorb water. Although the manufacturers claim that most of the materials are insoluble, numerous researches found out that they are mostly soluble.[35] But this finding requires further research about the constituents of the materials before and after aging in water.

5. CONCLUSION

Within the limitations of this study, the radiopacity of different restorative materials is dependent on the material type and brand exerting different radiopacity values after 6 months of distilled water storage. Some of the tested restorative materials did not fulfill the ISO requirements about the radiopacity threshold level.

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