Artificial formed caries-like lesions around esthetic restorative materials

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Dental restorations fail for a variety of reasons. Secondary caries is one of the primary causes of failure of dental restorations. One method for reducing frequency and severity of this problem is the use of fluoride containing restorative materials. The ability of a material to inhibit secondary caries formation is an important clinical therapeutic property. This investigation assessed the capacity of esthetic restorative materials to resist caries in vitro. *Class V cavities were prepared in buccal and lingual surfaces of 50 extracted sound third molars. The occlusal and gingival cavosurface margin of each preparation was on enamel surface. The five materials were used: Conventional glass ionomer cement Ceramfil ß (PSP), two polyacid modified resin composites Compoglass (Vivadent) and Dyract (Dentsply/DeTrey), non fluoride releasing composite resin Valux Plus (3M) and fluoride releasing composite resin Tetric (Vivadent). After 10 weeks in an acid gel for caries-like lesion formation, the teeth were sectioned occluso-gingivally through the middle of the restorations and examined by polarized light microscopy, while immersed in water. The statistical analysis of the results showed that secondary caries initiation and progression might be reduced significantly when fluoride-containing materials were placed. The conventional glass ionomer cement (Ceramfil ß) provided the highest protection against caries attack and the non-fluoride releasing composite resin (Valux Plus) restoration provided the least (p<0.05).*
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INTRODUCTION

Recurrent caries has been shown to be the most important factor in the failure of amalgam and composite resin restorations.[1-5] The observation of the low incidence of secondary caries around silicate restorations, which contain fluoride, has prompted the idea of using fluoride-containing dental materials to prevent secondary caries. However, the amount of fluoride released from fluoride containing materials has also been shown to decrease significantly with time.[6] The ability of a restorative material to resist a secondary caries attack and microleakage at its margins will, to great extent, determine whether a restoration will succeed or fail.

Glass ionomer cements were first introduced to the dental profession by Wilson and Kent in 1972. Their main characteristics are an ability to chemically bond to enamel and dentine with insignificant heat formation or shrinkage, exhibit biocompatibility with the pulp and periodontal tissues and release fluoride producing a cariostatic and antimicrobial action.[7-13] Many investigators have demonstrated the ability of glass ionomer to increase the fluoride content in enamel and dentine adjacent to restorations.[14-16] The uptake of fluoride would increase enamel resistance to acid demineralization and prevent caries formation around restorations.[11,12,14-19] Additonally fluoride release from glass ionomers has an antimicrobial action against *Streptococcus mutans* in plaque.[20-22] However, they are not widely used as a restorative material. The lack of acceptance may be a result of the technique sensitivity to moisture, low mechanical strength and wear resistance.[23,24]

Recently, there have been rapid developments in the field of hybrid resin-ionomer restorative materials. These developments include the resin-modified glass ionomer cements and the polyacid modified resin composites (Compomers). Resin modified glass ionomer materials were basically formed by adding methacrylate derivatives to the glass ionomer formula. Both laboratory and clinical research has clearly demonstrated the ability of the resin modified glass ionomers to release from and uptake by

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the resin modified products was higher than or the same as that of conventional glass ionomers.[23,25-27] Also resin-modified glass ionomer cement appears to significantly inhibit demineralization of interproximal enamel of teeth adjacent to those restored with the material.[12,28,29] The name Compomer (polyacid modified resin composite) means that the material possesses a combination of the characteristics of both composites and glass ionomers, but actually it shows minimal glass ionomer reactions.[24,30] Polyacid modified resin composites were formed by adding acidic polymers to the original methacrylate resin matrix. Compomer is being marketed for use as a restorative alternative to glass- ionomer cements.

The use of resin composites as restorative dental materials has increased. Resin composite exhibits several beneficial properties, including a coefficient of thermal expansion similar to natural tooth structure, excellent marginal seal after acid-etching, good esthetics, greater strength than traditional resin composites, good stability and good rate of wear. In recent years, resin composite has been formulated to release fluoride.[31-33] Fluoride uptake has been shown to occur in enamel and dentin adjacent to fluoride releasing resin composite material.[34-36]

Fluoride release from conventional glass ionomers and resin modified glass ionomers have been demonstrated *in vitro*.[25-28] However, fluoride-release studies may not necessarily predict the resistance of restorative material toward the formation of secondary caries.[28,37,38] The cavity sealing ability and the reactivity of released fluoride are additional considerations.

Artificial caries media have been employed, *in vitro*, to examine any cariostatic effect imparted by fluoride containing restorative materials. In artificial caries systems, acidified solutions or gels are used to demineralize tooth structure around restorations to determine if the restorative material will decrease demineralization in tooth structure. Outer surface lesions (OSL) and wall lesions (WL) developed during these investigations. The outer surface lesion occurs because of a cariogenic attack on the tooth surface and typically has the characteristic features of primary caries. The wall lesion forming as a consequence of microleakage of acidic products and hydrogen ions from dental plaque or acidified gelatin gel along the enamel restoration interface.

The main aim of this study was to compare fluoride containing composite resin, non-fluoride containing composite resin, polyacid modified resin composite and conventional glass ionomer cement for their abilities to inhibit the development of secondary caries. An acidified-gel technique was used to create caries-like lesions around restorations.

MATERIALS AND METHODS

The restorative materials that were used in this study were shown in Table 1. In this study sound extracted human third molars, which had been stored in distilled water with 0.1 percent thymol, were used. The teeth were cleaned with aqueous slurry of pumice using a hand piece and rubber cup. The buccal and lingual surfaces were examined with a dissecting binocular microscope (X 16) to ensure that these surfaces were intact. Teeth with visible defects were discarded. The remaining 50 teeth were randomly divided into 5 groups, corresponding to the five different restorative dental materials.

Table 1. Manufacturer details of the test materials

Material	Details	Batch no	Manufacturer
Ceramfil β	Conventional glass ionomer cement	#0694236	PSP Belvedere, Kent. U.K.
Compoglass	Polyacid modified resin composite	#800647	Vivadent Ets Schaan, Liechtenstein
Dyract	Polyacid modified composite	#9511060	Dentsply/DeTrey Konstanz
Tetric	Fluoride releasing composite resin	#618661	Vivadent Ets Schaan, Liechtenstein
Valux Plus	Non fluoride releasing composite resin	#70201013029	3M Malakoff France

These materials were Ceramfil ß (PSP Belvedere), Compoglass with Compoglass SCA adhesive, (Vivident Ets), Dyract with Dyract Prime/Adhesive (Dentsply / DeTrey), Tetric with Syntac adhesive (Vivadent Ets), Valux Plus with Scotchbond Multi Purpose (3 M Dental).

For each tooth, two Class V preparations were cut in the middle third of buccal and lingual surfaces. The preparations extended 3mm mesiodistally, 2mm occlusogingivally and 1.5mm in depth**.** A diamond fissure bur was used in a high-speed hand piece with copious water-cooling. The cavosurface margins were all butt-joints. A single operator cut two cavities in each tooth on opposite surfaces. After cavity preparation, each tooth was rinsed with water and dried with compressed air. Ten teeth each group were placed with the restorative materials according to the instructions of the manufacturer.

Ceramfil ß was mixed according to the instructions of the manufacturer. After the glass ionomer material was placed into the cavity preparations, a cervical foil matrix was pressed to ensure good adaptation. Ceramfil ß sets chemically. The matrix was removed and the restoration trimmed with a scalpel and covered with a moisture- resistant varnish.

The materials Compoglass, Dyract, Tetric, Valux Plus were light cured according to the instructions of the manufacturers using a visible light unit (Translux® EC Kulzer). All restored teeth were stored in a humid environment for 24 hours before finishing and polishing the restorations. The restorations were finally polished

Table 2. The mean (±standard deviation) depth-length of the body of the outer surface lesion and extent of the wall lesions on coronal part and cervical of the restoration (micron).

		Coronal part			Cervical part		
Materials	number of sections	OSLL	OSLD	WLL	OSLL	OSLD	WLL
Ceramfil β	20	142.00±37.22	61.50±20.84	-	151.50±45.91	85.50±20.84	-
Compoglass	20	477.00±78.14	91.00±35.23	124.00±71.33	456.50±113.52	118.50±38.43	142.50±62.14
Dyract	20	579.50±104.55	116.00±28.17	153.00±74.49	602.50±89.55	112.00±41.24	169.50±66.05
Tetric	20	593.50±187.23	152.20±57.85	272.50±95.25	602.50±150.85	171.50±47.71	344.00±132.12
Valux Plus	20	691.50±144.20	212.50±86.50	452.50±86.56	776.00±113.06	212.00±69.18	512.50±113.41
F and p values	20	F = 60.7148 p < 0.01	F = 25.6940 p < 0.01	F = 107.5233 p < 0.01	F = 93.4804 p < 0.01	F = 24.3365 p < 0.01	F = 101.8010 p < 0.01

Number of sections = 100

using Sof-lex disks (3M Dental Products) in sequence. Each tooth was then painted with an acid-resistant varnish with the exception of a rim of enamel approximately 1mm in width, which was left exposed adjacent to each restoration.

The specimens were subjected to thermocycling for 500 cycles between 5°C and in 55°C with dwell time of 30 seconds and stored in a humid environment for 1 week. Secondary caries was formed with an acidified gelatin gel (The gel contained 1.08mM KH_2PO_4, 1.8mM $CaCI_2$. The gel was adjusted to pH 4.28 by adding 0.1M lactic acid).[39]

The teeth were then immersed in jars containing 20 ml of an acidified gelatin gel for storage at 37°C for a period of 10 weeks. The acidified gelatin gel was changed at 1-week intervals.

After 10 weeks, the teeth were sectioned occlusogingivally through the middle of the restorations. Two longitudinal sections were obtained through the middle part of each restoration. The sections were then ground and polished to a thickness of about 100µm. Each section was imbibed in water and examined for caries-like lesions by polarized light microscope.

The lesion consisted of two parts, outer surface lesion and cavity wall lesion (Figure 1). Measurements were made on the two parts of the lesion using a calibrated eyepiece reticule. In lesions with irregular advancing fronts, only the deepest measurement was recorded. The measurements included (Figure 1): A (1-4) The length of the outer lesion, the length of the lesion on the outer surface enamel, B (2-5) The depth of the outer lesion as the largest distance between the enamel surface and the inner border of the lesion, C (3-6) The wall lesion extent from the enamel surface to the axial wall of the cavity preparation. Representative specimens were also photographed under polarized light on color film. One examiner examined the specimens in a blinded fashion.

Statistical analysis

Scores were statistically analyzed by ANOVA and the Duncan's Multiple Range test that were used to examine the effects of the different material test groups on the development of recurrent enamel decays, on coronal part and cervical part of the restorations. The differences between the length and depth of outer surface lesions and the differences between the length of the wall lesions on coronal and cervical part according to restorative materials were analyzed with the significance test of the difference between the two means.

A probability values (p value) less than 0.05 was considered statistically significant. All values are expressed as the mean ± standard deviation.

RESULTS

Figures 3 and 4 show typical lesions produced after a 10-week immersion in acid gel consisting of outer surface lesion and cavity wall lesion. Table 2 shows the mean and standard deviation of lesion distances in microns.

Evaluation of outer surface and wall lesions on coronal part of the restorations OSLL (Outer Surface Lesion Length) The mean OSLL from the coronal part of the restorations ranged from 142.00µm for Ceramfil ß restorations to 691.50µm for Valux Plus composite resin restorations (Table 2). The average length of the body of the outer surface lesions in teeth restored with Valux Plus was significantly higher than for the teeth restored with the other materials ($p<0.05$).

There was no significant difference in the length of the body of the outer lesion between teeth restored with Dyract and Tetric ($p>0.05$), but there was significant difference between the other groups ($p<0.05$).

Table 3. The effect of the different material test goups on the development of recurrent enamel decay on coronal part and cervical part of the restoration.

	Coronal part			Cervical part		
Materials	**OSLL**	**OSLD**	**WLL**	**OSLL**	**OSLD**	**WLL**
Ceramfil β (1)						
Compoglass (2)	*	*	*	*		*
Dyract (3)	**	*	*	**		*
Tetric (4)	**	***	***	**	***	***
Valux Plus (5)	****	****	****	****	****	****

* There is statistical difference between group 1 (p < 0.05)
** There is statistical difference betwwen groups 1 and 2 (p < 0.05)
*** There is statistical difference betwwen groups 1, 2 and 3 (p < 0.05)
**** There is statistical difference betwwen groups 1, 2, 3 and 4 (p < 0.05)

Table 4. The differences between the OSLL and OSLD and WLL on coronal and cervical part according to restorative materials.

	Coronal and Cervical part of the restoration		
Materials	**OSLL**	**OSLD**	**WLL**
Ceramfil β	t= -0.72 p >0.05	t=-3,64* p< 0.05	
Compoglass	t= 0.67 p> 0.05	t=-2.36* p< 0.05	t=- 0.87 p> 0.05
Dyract	t= -0.75 p> 0.05	t= 0.36 p> 0.05	t=-0.74 p> 0.05
Tetric	t= -0.17 p> 0.05	t= -1.13 p> 0.05	t= -1.96 p>0.05
ValuxPlus	t= -2.06* p< 0.05	t= 0.02 p> 0.05	t=-1.88 p>0.05

OSLD (Outer surface lesion depth)

The mean OSLD from the coronal part of the restorations ranged from 61.50µm for Ceramfil ß restorations to 212.50µm for Valux Plus composite resin restorations (Table 2).

There was no significant difference in the OSLD between teeth restored with Compoglass and Dyract ($p>0.05$). The lesion depth for the teeth restored with Valux Plus was significantly higher than for the other groups ($p<0.05$). There was significant difference between Tetric and Ceramfil ß or Compoglass or Dyract ($p<0.05$).

There was significant difference in the OSLD between teeth restored with Ceramfil ß and Compoglass and also Ceramfil ß and Dyract ($p<0.05$).

WLL (Wall Lesion Length)

Regarding the wall lesions, no microscopic evidence of demineralization was found along the cavity wall adjacent to Ceramfil ß restorations.

The mean WLL from the coronal part of the restorations ranged from 124.00µm for Compoglass restorations to 452.50µm for Valux Plus (Table 2). The WLL for the teeth restored with Valux Plus was significantly higher than for the other groups ($p<0.05$). There was no significant difference in the WLL between Compoglass and Dyract ($p>0.05$). There was significant difference between Tetric and Ceramfil ß or Compoglass or Dyract ($p<0.05$).

Evaluation of outer surface lesions and wall lesions on cervical part of the restorations OSLL (Outer Surface Lesion Length)

The OSLL from the cervical part of the restorations from 151.50µm for Ceramfil ß restorations to 776.00 micron for Valux Plus (Table 2). There was no significant difference between Dyract and Tetric ($p>0.05$). There was significant difference in the OSLL between the other groups ($p<0.05$).

OSLD (Outer Surface Lesion Depth)

The mean OSLD from the cervical part of the restorations ranged from 85.50(µm for Ceramfil ß restorations to 212.0 0µm for Valux Plus restorations (Table 2).

There was no significant difference in the OSLD between teeth restored with Ceramfil ß, Compoglass, Dyract ($p>0.05$). The average depths of the outer lesions in teeth restored with Valux Plus were significantly higher than for the teeth restored with Ceramfil ß, Compoglass, Dyract and Tetric ($p<0.05$).

WLL (Wall lesions length)

Regarding the wall lesions, no microscopic evidence of demineralization was found along the cavity wall adjacent to Ceramfil ß restorations. The mean WLL from the cervical part of the restorations ranged from 142.50µm for Compoglass restorations to 512.50µm for Valux Plus. The wall lesion length for restored with Valux Plus was significantly higher than the other

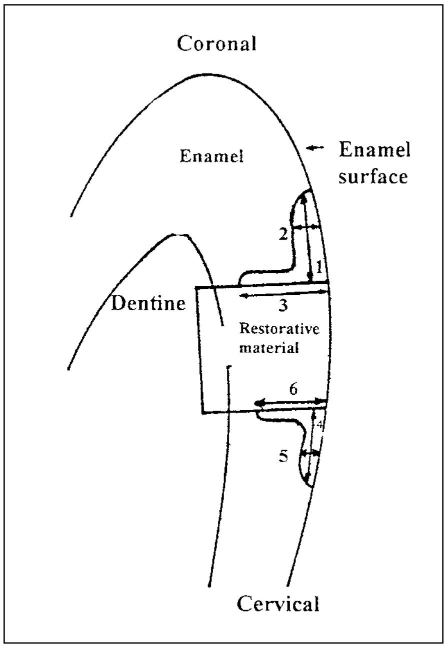

Figure 1. Schematic representation of various parts of caries like lesion that formed around a restoration. The carious lesion consists of a primary outer surface lesion (OSL), and a secondary cavity wall lesion (WL). The measurements which were made on each lesion were from coronal part of the restorations: 1: OSLL 2: OSLD 3: WLL and cervical part of the restorations 4: OSLL 5: OSLD 6: WLL

OSLL (Outer Surface Lesion Length) (1,4): The length of the lesion on the outer surface enamel.

OSLD (Outer Surface Lesion Depth) (2, 5): The body depth of the outer surface as the largest distance between the enamel surface and the inner order of the lesion.

WLL (Wall Lesion Length) (3,6): The wall lesion length was measured from enamel surface to the innermost extended portion of the wall lesion towards the dentin enamel junction.

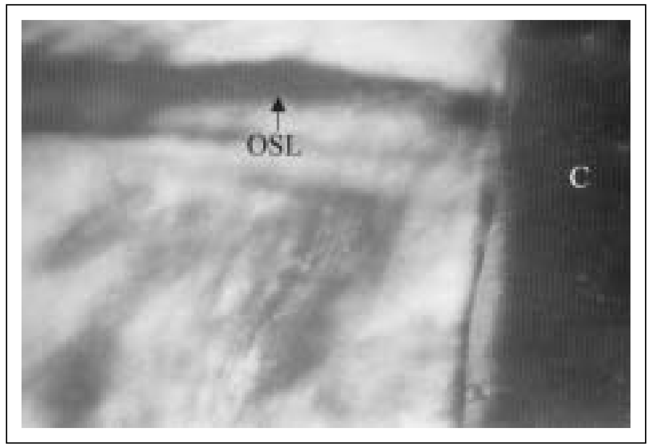

Figure 2. A typical caries-like lesion formed coronally around conventional glass ionomer cement Ceramfil ß (C) restored cavity. An outer surface lesion (OSL) is present but no cavity wall lesion exists adjacent to the glass ionomer enamel interface. Polarized light microscopy with water imbibitions of longitudinal sections; original magnification X 100.

groups of the teeth ($p<0.05$). There was no significant difference in wall lesion length between Compoglass and Dyract.

The differences between the OSLL and OSLD and the differences between the WLL on coronal part and cervical part according to restorative materials were analyzed with the significance test of the difference between two means. The values of t and p are shown in Table 4. The coronal and cervical OSLL of the teeth restored with Valux Plus showed significant difference ($p<0.05$). The coronal and cervical OSLD of the teeth restored with Ceramfil ß and Compoglass showed significant difference ($p<0.05$). According to these results, there were deeper lesions on the cervical part than coronal part.

DISCUSSION

In vitro studies have shown that fluoride released from fluoride containing dental restorative materials is effective in inhibiting tooth demineralization in artificial caries solutions or gels.[12,35,40-42]

The method with acidified gels to simulate caries lesions has been widely used for decades. The similarity to clinical caries has been investigated and found satisfactory.[17,43,44] Different concentrations and exposure times do not change the principal appearance of the lesion.

Heintze and Mornstad investigated the development of caries-like lesions around three different amalgams (fluoride-containing, dispersed and conventional). In all teeth investigated, less demineralized enamel was found around the fluoride containing amalgam than around the other two.[45] Also they found the number, depth and extent of wall lesions were significantly smaller in the cervical part of the cavities than in the coronal part. They explained the acid penetration and shape of the lesion are also influenced by the angle between the enamel prisms and the cavity wall. In the coronal part, the direction of the prisms may allow hydrogen ions to move from the surface along the prism sheaths into the micro space. On the other hand, the direction of the prisms excludes this possibility in the cervical part.[46] Another reason for the lower rate of demineralization can be the higher natural fluoride content in this part of the tooth.[47]

The result of this study showed coronal and cervical OSLL of the teeth restored with Valux Plus showed significant difference ($p<0.05$). The coronal and cervical OSLD of the teeth restored with Ceramfil ß and Compoglass showed significant difference ($p<0.05$). According to these results, there were deeper lesions on the cervical part than coronal part.

The ability of glass-ionomer materials to provide fluoride to adjacent tooth structure and the local environment has a considerable effect on caries development around restorations and adjacent non-restored tooth

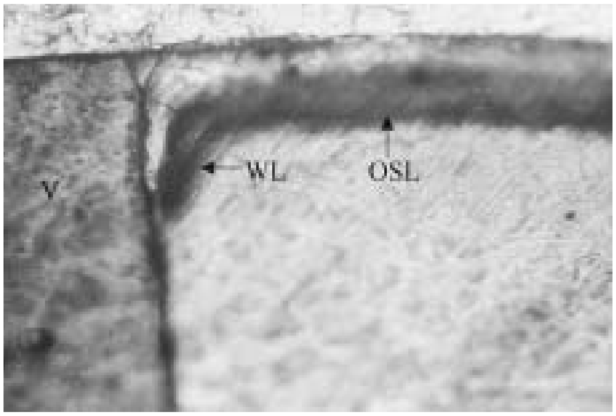

Figure 3. A typical caries-like lesion formed cervically around a composite resin Valux Plus (V) restored cavity. It consists of on outer surface lesion (OSL) and a cavity wall lesion (WL); Polarized light microscopy with water imbibitions of longitudinal sections; original magnification X63.

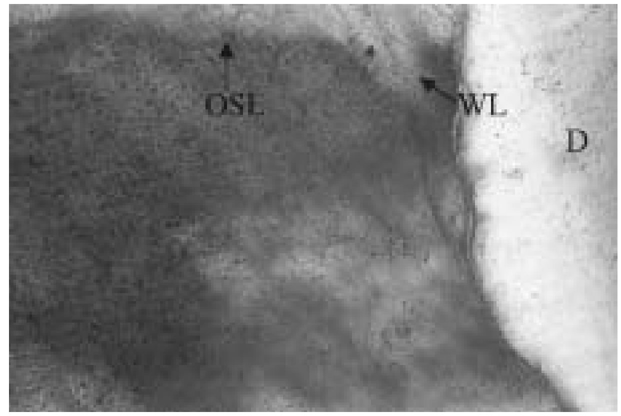

Figure 4. A typical caries-like lesion formed coronally around a polyacid modified composite resin Dyract (D) restored cavity. It consists of on outer surface lesion (OSL) and a cavity wall lesion (WL); Polarized light microscopy with water imbibition of longitudinal sections; original magnification X100.

surfaces, as well as more remote surfaces.[11,12,14-19] In one of the first experiments examining caries-inhibiting ability of glass ionomers *in vitro*, Kidd compared the recurrent caries produced around Class V glass ionomer and composite-resin restorations when the restored teeth were placed into an acidified gel for 10 weeks.[48] Fewer outer lesions and wall lesions formed around the glass ionomer restorations than formed around the composite resin restorations. Previous studies indicated that conventional glass-ionomer materials provided a significant protection against a caries-like attack at the enamel restoration interface.[12,17,37,38,41]

The apparent caries resistance of surface enamel and the enamel that forms the cavity walls adjacent to the glass ionomer restorations is thought to be caused by the availability of fluoride for release from the glass ionomer materials.[14,49,50] Fluoride release from glass ionomer cements occurs with an initial burst following the setting reaction and during the first 24 hours.[51-53] However, continuous low levels of fluoride may be released for up to 8 years.[53] Examination of cumulative fluoride release over several weeks from various conventional glass ionomer cements, resin modified glass ionomer cements, and non fluoride containing resin composite has provided interesting results.[28]

Conventional glass ionomer cement (Chemfil II Express) released the greatest amount of fluoride at all time periods (1 day: 16ppm, 1 week: 37 ppm, 10 week: 156ppm). Although resin modified glass ionomer cements provided a lesser amount of fluoride at 10 weeks (89ppm Vitremer; 94ppm Fuji II LC), levels similar to those for conventional glass ionomer material were released at 1 day, 1 week, 2 weeks and 4 weeks. Resin composite (Bis- Fil) that lacked fluoride provided a cumulative total fluoride release of 0.08 ppm, representing background levels. The remarkable fluoride release from glass ionomer materials occurred without the benefit of 'recharging' the glass ionomer fluoride stores. It is possible to replenish the fluoride releasing capabilities of glass ionomer cements by exposure to various fluoride sources (Fluoride rinses, fluoridated dentifrices, topical fluoride).[23,25-27]

The ability of glass ionomer restorative materials to resist a caries-like attack at the enamel / restoration interface would appear to be of great importance in prevention of secondary caries. In the present study, the conventional glass ionomer Ceramfil ß provided complete protection against secondary lesion formation in cavity wall enamel and the extent of lesion formation adjacent to the glass ionomer materials was also reduced significantly when compared to other materials. Compoglass, Dyract and Tetric were less effective than Ceramfil ß in preventing the formation of secondary caries.

A cariostatic effect of fluoride containing resin restorations along cavity walls has been elucidated in other studies.[54,55]

Arends, Ruben and Dijkman investigated by quantitative micro radiography the effect of fluoride released from a fluoride containing composite resin (Heliomolar-Ro) on secondary caries.[35] In all teeth investigated, less demineralization was found near the fluoride containing composite resin restorations than was found near the non-fluoride releasing polymethyl methacrylate (PMMA). In this study compared with the Valux Plus group, the Tetric group has been demonstrated a significantly smaller outer lesion depth- length and wall lesion length.

The results showed that, comparing with the non-fluoride releasing composite resin, the fluoride releasing composite resin, the compomers, and the conventional glass ionomer had an *in vitro* inhibiting effect on the development of experimental lesions *in vitro*. The inhibiting effect on the development of experimental cavity wall lesion length, outer lesions around fluoride containing composite, compomers and conventional glass ionomer fillings reported in this study may be due to fluoride presenting in the materials or less marginal leakage around the fillings. Previous studies indicated that conventional glass ionomer and resin modified glass ionomer materials provided a significant protection against a caries-like attack at restoration interfaces.[12,17,28,37,41,42,55]

People are living and retaining their teeth longer than ever before. The result is that there are many older people who have natural teeth instead of artificial dentures. The need for caries-preventive restorative materials in these patients, and in others with such impairments is evident.

Dental caries continues to be a major public health problem. Dentists need to increase the use of caries-preventive dental restorative materials when accomplishing restorative procedures for patients at high risk of developing dental caries. Prevention of secondary caries by employment of fluoride releasing restorative materials and frequent exposure to topical fluoride agents may allow retention of caries affected teeth throughout a lifetime.

CONCLUSIONS

Secondary caries progression may be reduced significantly when conventional glass ionomer (Ceramfil ß) is placed. In the present *in vitro* study the conventional glass ionomer material provided the highest protection against caries attack, and the non-fluoride releasing composite resin restoration provided the least.

The ranked efficacy of the restorative materials examined in the study was Ceramfil ß> Compoglass > Dyract > Tetric > Valux Plus.

The use of fluoride containing restorative containing restorative materials may prevent secondary caries formation in a certain proportion of restorations.

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