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M. Folwaczny · C. Loher · A. Mehl
K.-H. Kunzelmann · R. Hickel

Class V lesions restored with four different tooth-colored materials – 3-year results

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Abstract The aim of this study was to compare the treatment results using four different types of tooth colored materials for restoring class V lesions. A total of 197 class V restorations (*n*=197) were placed by one dentist in 37 patients on incisors, canines and premolars. The fillings were placed due to different indications: erosion/non-carious cervical defects (*n*=69), primary carious lesions (*n*=57), and for replacing defective existing fillings (*n*=71). The teeth were assigned on a random basis to four groups for restoration with either a composite (group 1: *n*=36; Tetric, Vivadent), or a polyacid-modified resin composite (group 2: *n*=79; Dyract, Dentsply), or one of two different resin-modified glass ionomer cements (group 3: *n*=51, Fuji II LC,GC; group 4: *n*=31, Photac-Fil, Espe). The restorations were evaluated by a single-blind design, according to a modified USPHS system 36 months following placement. Statistical analysis was completed with the Pearson Chi-square test for comparing the results of the four groups ($P<0.05$). Additionally, the survival rates were analyzed with the Kaplan-Meier estimator and the Log-rank test ($P<0.05$). The Alpha ratings were as follows (Tetric/Dyract/Fuji II LC/Photac Fil): shade match (86%/77%/58%/40%), surface texture (81%/83%/16%/9%), marginal integrity (enamel) (73%/67%/61%/61%), marginal integrity (dentin) (86%/70%/55%/61%), marginal discoloration (enamel) (59%/44%/58%/52%), marginal discoloration (dentin) (82%/84%/71%/48%), anatomic contours (91%/83%/39%/35%). One Tetric restoration, five Dyract restorations, two Fuji II LC restorations and three Photac restorations were dislodged within the study period. The retention of the restorations showed no significant difference among the four materials. However, the clinical performance of the restorations retained over the 3-year period showed distinct differences for the four materials. The best clinical performance was observed for the resin composite, whereas the quality of the Dyract restorations without enamel etching was worse. The poorest results were obtained for the restorations with the resin-modified glass ionomers.

Keywords Cervical lesion · Composite · Glass ionomer · Modified polyacid resin

M. Folwaczny (✉) · C. Loher · A. Mehl · K.-H. Kunzelmann
R. Hickel
Department of Operative Dentistry,
Ludwig-Maximilians-University, Goethestrasse 70,
80336 Munich, Germany
e-mail: mfolwa@dent.med.uni-muenchen.de
Tel.: +49-89-5160-3134, Fax: +49-89-5160-5344

Introduction

The majority of cervical lesions exhibit mixed cavity margins positioned in both the enamel as well as the dentin and/or cementum [1]. Therefore, restoration of this type of cavity appears to be rather difficult with respect to the lack of restorative materials which bond equally well to enamel and dentin. Particularly the integrity of restorations placed with margins in dentin is a major point of concern [2]. For many years, glass ionomer cements have been advocated as the material of choice for restoring cervical lesions since this kind of material is capable of forming a chemical bond with both enamel and dentin and releasing fluoride over long periods, thereby providing a caries protective effect [3, 4, 5]. Previous clinical studies have shown the potential of conventional glass ionomer materials for restoring cervical cavities sufficiently [2, 6]. However, clinical acceptance of conventional glass ionomers has been limited because of their flawed esthetics and inconvenient setting characteristics [7, 8]. The resin composites used with dentin bonding agents are popular alternatives to conventional glass ionomer materials for the restoration of cervical lesions [8]. These materials exhibit high wear resistance as well as good esthetic properties and the bond strength of composite on dentin surfaces appears sufficient to maintain the marginal seal over long periods [9, 10]. Previous clinical trials showed some composites to be effective in restoring class V lesions when used in combination with dentin bonding agents [8, 11]. However, it was also suggested that the clinical outcome of composite restorations is strongly influenced by various factors, e.g., the type of composite or the type of bonding system which might lead to varying treatment results for different resin composites [8, 12].

Recently, new generations of light curing, tooth colored hybrid restorative materials, resin-modified glass ionomer cements and polyacid-modified resin composites have experienced increasing attention in the treatment of cervical lesions. In the resin-modified glass ionomer materials, the fundamental acid-base curing reaction is supplemented by a photopolymerization process [13]. The on-demand set of the resin-modified glass ionomer materials allows the material to be hardened almost instantly and, thus, appears to solve the problem of moisture sensitivity [14, 15]. The advantageous properties of glass ionomer materials, e.g., fluoride release, were maintained or even improved in hybrid ionomers and it was also suggested that they form a stronger bond with mineralized tissue and show less microleakage than the conventional glass-ionomer materials [16, 17].

The polyacid-modified resin composites are composed of an ion-leachable glass, e.g. a strontium-fluoro-alumino silicate glass and a light curing monomer system. The latter contains a polymerizable resin, e.g, tetracarboxyl butane (TCB) with alkenoic acid groups. After the restoration had taken up water, the polyalkenoic acid was claimed to participate in a secondary acid–base reaction [7]. Applying the polyacid-modified resin composites with the acid etch technique and a dentin bonding agent creates strong adhesion on the surfaces of the cavity [3]. Besides the easy clinical handling, these materials exhibit physical properties, e.g., microhardness or compressive strength, much more comparable to those of resin composites than those of glass ionomers [18, 19]. The results of previous clinical studies have shown that both resin-modified glass ionomer materials as well as polyacid-modified resin composites can be used for esthetic restoration of cervical cavities [14, 21, 22].

Although several previous clinical trials have investigated the performance of modern tooth-colored filling materials for restoring cervical lesions, some controversy still exists as to which of the materials promises the best results in clinical use. The present clinical study attempts to evaluate the performance of three different types of tooth-colored restoratives, the resin-modified glass ionomers, the polyacid-modified resin composites, and the conventional resin composites for restoring cervical cavities.

Materials and methods

Study subjects

The study involved 197 cervical lesions in incisors, canines and premolars in 37 patients aged between 26 and 67 years (n=197). The restorations were placed because of erosion/non-carious cervical defects in 69 cases, because of primary caries lesions in 57 cases, and to replace defective existing restorations in 71 cases (Table 1). All cavities had mixed margins in enamel and dentin. The teeth were assigned on a random basis to four groups for restoration either with a composite in combination with a dentin bonding agent (group 1: n=36; Tetric; DBA: Syntac, Vivadent, Schaan, Liechtenstein), or a polyacid-modified resin composite with a dentin bonding agent (group 2: n=79; Dyract; DBA: PSA, Dentsply De Trey, Konstanz, Germany), or one of two different resin-modified glass ionomer cements (group 3: n=51, Fuji II LC, GC Dental Industrial Corp., Tokyo, Japan; group 4: n=31, Photac-Fil, Espe, Seefeld, Germany). Each patient presented at least two and a maximum of five cervical lesions which were restored with at least two and a maximum of four different materials. All restorations were placed by one dentist. Written informed consent was provided by all participants prior to starting the treatment.

Preparation and pretreatment of cavities

In the present study none of the restorations were placed with rubber dam isolation. Moisture control was accomplished with cotton rolls and a saliva ejector. In general, the cavities were prepared without creating any macroretention. In case of erosion, the cavities were thoroughly cleaned mechanically using a brush and non-fluoride polishing paste (Zircate, Caulk Dentsply, Milford, USA). Primary carious lesions were only excavated. Defective existing fillings were removed and carious tooth structure excavated. Thereafter, the margins of the cavities were finished using ultra fine grit diamond burs (blend-

Table 1 Number of teeth restored with the four different restoratives (Tetric/Syntac, Dyract, Fuji II LC and Photac Fil): data show the distribution of the cases reevaluated after 8, 24 and 36 months, and the reasons for placing the filling

Reason for restoration	Photac Fil				Fuji LCII				Dyract				Tetric/Syntac				Total			
Period (months)	0	8	24	36	0	8	24	36	0	8	24	36	0	8	24	36	0	8	24	36
Caries	5	5	5	6	13	9	10	9	27	20	19	16	12	12	9	7	57	46	43	38
Erosion/angular lesion	11	8	9	7	18	16	8	10	28	25	24	12	12	12	9	8	69	61	50	37
Restoration	15	15	13	10	20	20	17	12	24	24	20	15	12	12	8	7	71	71	58	44
Total	31	28	27	23	51	45	35	31	79	69	63	43	36	36	26	22	197	178	151	119

a-mant D234–012f, Blendax, Mainz, Germany). Prior to placing the composite resins, the margins in enamel were beveled in a 1-mm area. Deep cavities suspected to be near the pulp were lined with a self-hardening calcium hydroxide material (Dycal, Dentsply DeTrey, Konstanz, Germany). In particular, 8 cavities in the Tetric group, 25 cavities in the Dyract group, 18 cavities in the Fuji II LC group, and 11 cavities Photac-Fil group were lined with calcium hydroxide. All cavities were thoroughly rinsed with water spray following preparation. The materials were kept and handled strictly according to the manufacturers' instructions. Following placement, the restorations were cured with a high-energy light source (550 W/cm^2; Vivalux, Vivadent, Schaan, Liechtenstein).

Placement and finishing of the restorations

Group 1 (Tetric/Syntac)

The enamel margins of the cavities in the composite group were acid etched for 60 s with 37% phosphoric acid (Esticid-Gel, Kulzer, Germany) and then rinsed thoroughly with water spray. Afterwards, the dentin bonding system primer (Syntac, Vivadent, Schaan, Liechtenstein) was applied, left undisturbed for 20 s and then excess was removed using an air syringe. Then, adhesive was applied to the entire cavity, left undisturbed for 20 s and gently air dried. The bonding agent was applied, blown dry and light cured for 60 s. The restorative was placed in incremental layers, adapted, and each layer cured for 60 s. After polymerization, the restorations were finished under profuse water spray using diamonds, Sof-Lex finishing discs (3 M, Leicestershire, UK), and the Enhance polishing system (Dentsply DeTrey, Konstanz, Germany).

Group 2 (Dyract/PSA)

According to the recommendations of the manufacturer, no acid etching was required for the polyacid-modified resin composite. The cavities in this group were only primed with a single component dentin bonding agent (PSA, Dentsply, Germany) in two consecutive cycles. The material was applied, left undisturbed for 30 s, dried with a gentle stream of air and light cured for 60 s. A second coat of dentin bonding agent was applied, immediately blown dry and light cured. The polyacid-modified resin composite was then placed, cured and finished in a similar fashion as described for the composite resin (group 1).

Table 2 Rating scale used for clinical determination of the quality of the restorations in the single criteria: shade match, surface texture, marginal integrity, marginal discoloration, anatomical contours

Category	Alpha	Bravo	Charlie	Delta
Surface texture	Surface of restoration smooth	Surface of restoration rough or deeply pitted	–	–
Shade match	No mismatch in shade and/or translucency between restoration and adjacent tooth structure	Mismatch in shade and/or translucency between restoration and adjacent tooth structure	–	–
Marginal integrity (enamel)	Closely adapted, no detectable or visible marginal crevice	Explorer detects marginal crevice and/or visible evidence of ditching along the margins, superficial	Explorer detects and penetrates marginal crevice, extended to dentin, localized	Explorer detects and penetrates marginal crevice, extended to dentin, major parts of margins, restoration is mobile, fractured or missing
Marginal integrity (cementum/dentin)	Closely adapted, no detectable or visible marginal crevice	Explorer detects marginal crevice and/or visible evidence of ditching along the margins, superficial	Explorer detects and penetrates marginal crevice, extended to dentin, localized	Explorer detects and penetrates marginal crevice, extended to dentin, major parts of margins, restoration is mobile, fractured or missing
Marginal discoloration (enamel)	No evidence of marginal discoloration	Slight marginal discoloration, no axial penetration	Marginal discoloration with axial penetration, localized	Marginal discoloration with strong axial penetration at major parts of margins
Marginal discoloration (cementum/dentin)	No evidence of marginal discoloration	Slight marginal discoloration, no axial penetration	Marginal discoloration with axial penetration, localized	Marginal discoloration with strong axial penetration at major parts of margins
Anatomical contours	Restoration is continuous with existing anatomical contours	Slight discontinuity, missing material is not sufficient to expose dentin	Severe discontinuity, missing material sufficient to expose dentin	Restoration is partially or totally missing

Table 3 Ratings for the four different restoratives (Tetric/Syntac, Dyract, Fuji II LC, Photac Fil) concerning shade match (SM), surface texture (ST), marginal discoloration (enamel) (MD/E), marginal discoloration (dentin) (MD/C), marginal integrity (enamel) (MI/E), marginal integrity (dentin) (MI/E), anatomical contours (AC) after 36 months. The significant differences, as obtained with the Pearson-Chi-square-test (* $P<0.05$)

(%)		Tetric (Group 1)		Dyract (Group 2)		Fuji II LC (Group 3)		Photac (Group 4)	
Period	Score	8	36	8	36	8	36	8	36
SM	A	100	86	94	77	100	58	88	40
	B	0	14	6	23	0	42	12	60
	C	0	0	0	0	0	0	0	0
	D	0	0	0	0	0	0	0	0
$P<0.05$ vs. group		(3); (4)		(3); (4)		(1); (2)		(1); (2)	
ST	A	100	81	94	83	17	16	8	9
	B	0	19	6	17	83	84	92	91
	C	0	0	0	0	0	0	0	0
	D	0	0	0	0	0	0	0	0
$P<0.05$ vs. group		(3); (4)		(3); (4)		(1)		(1); (2)	
MI (E)	A	89	73	74	67	79	61	76	61
	B	11	18	23	16.5	11	16	16	13
	C	0	9	3	16.5	10	23	8	26
	D	0	0	0	0	0	0	0	0
$P<0.05$ vs. group		(2); (3); (4)		(1); (4)		(1); (4)		(1); (2); (3)	
MI (C)	A	83	86	86	70	83	55	48	61
	B	17	14	11	21	7	22.5	12	9
	C	0	0	3	9	10	22.5	40	30
	D	0	0	0	0	0	0	0	0
$P<0.05$ vs. group		(2); (3); (4)		(1); (4)		(1); (4)		(1); (2); (3)	
MD (E)	A	94	59	89	44	93	58	92	52
	B	6	32	11	49	7	32	4	30
	C	0	9	0	7	0	10	4	18
	D	0	0	0	0	0	0	0	0
$P<0.05$ vs. group		(2); (3); (4)		(1); (4)		(1); (4)		(1); (2); (3)	
MD (C)	A	86	82	94	84	86	71	84	48
	B	14	18	6	9	12	19	12	22
	C	0	0	0	7	2	10	4	30
	D	0	0	0	0	0	0	0	0
$P<0.05$ vs. group		(3); (4)		(4)		(1); (4)		(1); (2); (3)	
AC	A	100	91	100	83	55	39	56	35
	B	0	9	0	10	43	55	32	26
	C	0	0	0	7	2	6	12	39
	D	0	0	0	0	0	0	0	0
$P<0.05$ vs. group		(2); (3); (4)		(1); (3); (4)		(1); (2); (4)		(1); (2); (3)	

Group 3 and 4 (Fuji II LC/Photac Fil)

Cavity conditioner (group 3: GC Cavity Conditioner; GC Dental Industrial Corp.; group 4: Ketac Conditioner; Espe) was applied to the cavities and left undisturbed for 20 s (Fuji II LC) and 10 s (Photac Fil), respectively. Afterwards, the cavities in these groups were rinsed thoroughly with water for an additional 30 s and gently air dried, avoiding desiccation. The capsulated resin-modified glass ionomer was activated and subsequently mixed for 10 s (Silamat, Vivadent, Liechtenstein). Following mixing, the material was placed in the cavities using a previously adapted matrix as a contouring aid. The restorations were light cured for 60 s. After removing the matrix, contouring was completed with hand instruments and fine grit diamonds. The restoration surface was finished using polishing discs (Sof-Lex finishing discs, 3 M, Leicestershire, UK; Enhance polishing system, Dentsply DeTrey, Konstanz, Germany) and finally sealed with a varnish (Fuji Varnish, GC Corp., Japan; Ketac Glaze, ESPE, Germany).

Assessment of the restorations

The restorations were evaluated single-blind according to a modified USPHS system [23] at 8, 24 and 36 months after placement using a mirror and probe. Shade match, surface texture, anatomical contours, marginal discoloration and marginal integrity were assessed (Table 2). For each of the separate criteria the scoring scale had four classes except for “surface texture” and “shade match” (Table 3). The latter criteria were determined by comparing the shade and smoothness of the restoration with the adjacent enamel. The restorations were not altered (e.g., finished or polished) during the recalls. The clinical evaluation was carried out single-blind and independently by two operators. In case of disagreement, consensus was reached by immediate reexamination and discussion.

Statistical analysis

Statistical analysis of the ratings in the four experimental groups was completed using the Pearson Chi-square test. Additionally, the probability of risk of losing a filling was calculated with the Kaplan-Meier survival analysis. The Log-Rank-operation was used to compare the survival rates pair-wise among the groups, depending on the variable “material”. The statistical calculations were carried out at a level of significance of 5% ($P<0.05$)

Results

Due to patient drop-out, a total of 130 restorations in 24 patients were available for clinical examination after the 3-year period. In particular, 23 Tetric, 48 Dyract, 33 Fuji II LC, and 26 Photac Fil restorations were evaluated at this recall. Reasons for restorations not being available for evaluation included replacement of the restoration with a crown and patients discontinuing with the study. None of the restorations showed secondary caries.

Clinical evaluation of restorations

Ratings for the shade match, surface texture, anatomical contours, marginal discoloration, marginal integrity at three years criteria are presented in Table 3. At baseline, the ratings were 100% Alpha. The surface texture of 18 (81%) Tetric restorations, 36 (83%) Dyract restorations, 5 (16%) Fuji II LC restorations and 2 (9%) Photac restorations was evaluated Alpha. The anatomical contours of 20 Tetric restorations were classified to be excellent (Alpha; 91%). Only 36 Dyract fillings (83%), 12 Fuji II LC restorations (39%) and 8 Photac Fil restorations (35%) were rated Alpha regarding their anatomical contours. The shade match of 19 Tetric restorations (86%) and 33 Dyract restorations (77%) was evaluated Alpha after 3 years. A considerable number of the Fuji II LC restorations (n=13, 42%) and Photac Fil restorations (n=14; 60%) were rated Bravo regarding the “shade match”. The integrity of the margins placed in enamel was classified Alpha for 16 Tetric restorations (73%), 29 Dyract restorations (67%), 19

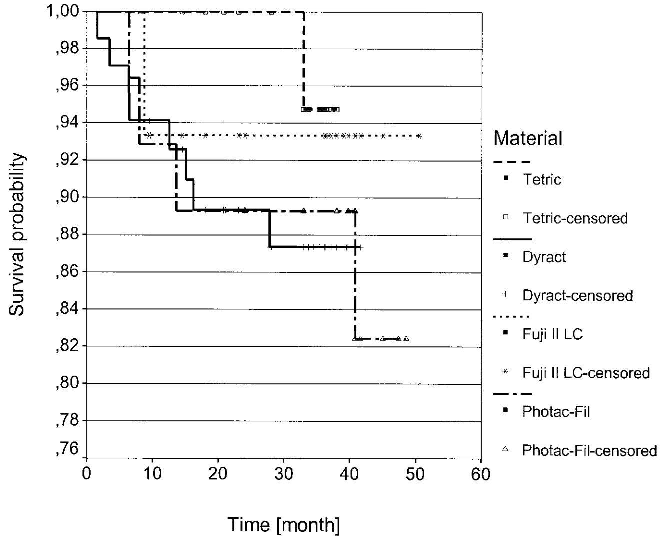

Fig. 1 Survival analysis for the restorations placed using four different restoratives, using the Kaplan-Meier estimator. (95% confidence interval: Tetric ±15.36, Dyract ±74.82, Fuji II LC ±91.32, Photac Fil ±136.61)

Table 4 Loss of restorations at 3 years for Tetric/Syntac, Dyract, Fuji II LC, and Photac Fil

Material	Loss	Retention
Tetric	1	22
Dyract	5	43
Fuji II LC	2	31
Photac Fil	3	23

Fuji II LC restorations (61%) and 14 Photac Fil restorations (61%). Regardless of the material used, some restorations were evaluated Bravo or even Charlie regarding this criterion. Considering the integrity of the margins in dentin, excellent adaptation (Alpha) was noted for 19 Tetric fillings (86%), 30 Dyract fillings (70%), 17 Fuji II LC restorations (55%), and 14 of the Photac Fil (61%) restorations. 13 Tetric (59%), 19 Dyract (44%), 18 Fuji II LC (58%), and 12 Photac Fil restorations (52%) were evaluated Alpha regarding discoloration of margins placed in enamel. In each group, some of the margins placed in enamel exhibited discoloration rated Bravo or Charlie. Eighteen of the Tetric restorations (82%) showed no signs of discoloration at the margins in dentin (Alpha). No discoloration at margins placed in dentin was present in 36 (84%) Dyract, 22 (71%) Fuji II LC, and 11 (48%) Photac Fil restorations. None of the restorations showed secondary caries.

Retention of restorations

One of the Tetric restorations failed within the 3-year period. Five Dyract, two Fuji II LC and three Photac-Fil restorations had to be replaced during this time (Table 4).

Table 5 Comparison of the survival rates among the four different kinds of material (Tetric/Syntac, Dyract, Fuji II LC and Photac Fil) as obtained by the Log-Rank-test

Comparison	Log-rank	*P*-value
Tetric vs. Dyract	2.06	0.151
Tetric vs. Fuji II LC	0.51	0.44
Tetric vs. Photac Fil	1.28	0.258
Dyract vs. Fuji II LC	0.77	0.379
Dyract vs. Photac Fil	0.00	0.976
Fuji II LC vs. Photac Fil	0.91	0.339

Survival analysis

The probability of survival of the Tetric restorations over a period of 3 years was 97.1% and that for Dyract restorations was 88.2%. The survival rate of Fuji II LC fillings was 93.3% and that of Photac Fil restorations was 85.7% within this period (Fig. 1). The Log-rank operation indicated that the type of material used did not appear to influence the survival rate of the cervical restoration significantly (Table 5).

Discussion

Clinical assessment of quality

In this study, a modified USPHS system was used for the clinical evaluation of the class V restorations. In general, for clinical assessment of dental restorations different protocols have been developed and described in literature, e.g., the USPHS, the Ryge, and the CDA system [23, 24]. To judge quality, the various evaluation systems are based upon the classification of the quality of four to six different clinical criteria, e.g., anatomical contours, marginal integrity, shade match, or marginal discoloration, and categorized as either acceptable or non-acceptable. Previous studies demonstrated that an objective and reproducible clinical assessment of dental restorations can be completed using one of these systems [24]. In order to get more detailed information regarding the quality of the different restorative materials, some of the criteria have been further subdivided in this study, e.g., marginal discoloration in the cementum or enamel, according to the special needs for evaluating of class V restorations.

Surface texture

Considering the surface texture, clinically detectable roughness was most frequently exhibited by resin-modified glass ionomers. This result may be mostly due to the greater mean particle size of the glass powder in these materials compared to the inorganic fillers in the polyacid-modified resin composite and the resin composite [25]. In addition, resin-modified glass ionomer materials have been shown to undergo considerably greater wear in comparison to composite resin [26]. It was suggested that the coherence within the interpenetrating matrices of polyalkenoate and poly-HEMA and its coherence with the glass particles are extremely low, which makes the polyalkenoate network vulnerable to erosive wear. Accordingly, the glass fillers are more easily exposed and dislodged, leading to a rough surface [27]. It is likely that the higher surface roughness of the glass ionomer fillings is determined by a third mechanism. Because the resin-modified glass ionomers must be mixed prior to placement, inherent porosity may occur and subsequently contribute to the increased surface roughness of this material [25].

Anatomical contours

Regarding the anatomical contours of the restoration, a considerable number of the resin-modified glass ionomer restorations were evaluated Charlie. In contrast, the anatomical contours of none of the composite restorations and only three of the polyacid-modified resin composite restorations were rated Charlie. Different hypotheses should be taken into account when explaining these observations. First, the physiological, anatomical contours are rather difficult to reproduce with glass ionomers due to their low viscosity and relatively sticky properties [28]. Second, the changes in the anatomical contours of the resin-modified glass ionomer fillings are possibly due to their poor physicomechanical properties, especially the low wear resistance [13, 29, 30]. As already mentioned above, the wear of the resin-modified glass ionomer materials is significantly greater than that for resin composites [26]. Thirdly, the severe alteration of the anatomical contours of the resin-modified glass ionomer fillings might also be caused by the particular elastic properties of these materials. According to Levitch et al. [31], occlusal stresses, leading to flexural distortion of the cervical region, are crucial in the pathogenesis of cervical defects. The flexural strength of Photac Fil and Fuji II LC resin-modified glass ionomers has been reported to be significantly less than those of Dyract and the hybrid composites [29, 32]. Thus, the greater brittleness of the resin-modified glass ionomers possibly causes larger fragments to chip off the bulk under occlusal stress and, therefore, leads to severe changes in the anatomical contours of the restoration [31].

Shade match

Discoloration of the body of the filling is dependent upon the surface conditions and physico-mechanical characteristics. According to Jokstad et al. [33], three main reasons can be responsible for postoperative alterations in the shade match of a filling: (1) the deposition of exogenous, colored pigments on the surface, (2) the alteration of the interface between the organic matrix and the filler particles, and finally (3) chemical reactions of the resin matrix itself. In the present study all materials showed some degree of discoloration. The prevalence of discoloration was significantly higher for the resin-modified glass ionomer cements. The greater surface roughness of the Photac-Fil and Fuji II LC fillings may explain these observations [13]. Additional mechanisms can be proposed explaining the shade changes undergone by Dyract restorations due to their smooth surfaces as shown in this study as well as in in vitro experiments. Probably, further chemical reactions of the resin matrix of the polyacid-modified resin composite after setting, e.g., oxidation of carbonic double bonds or cracking of residual HEMA molecules, trigger the shade changes [14, 34].

Marginal integrity

Regarding marginal integrity, alterations in the margins of numerous Dyract, Fuji II LC, and Photac Fil fillings were observed, whereas the composite restorations showed the lowest frequency of nonperfect margins. The greater tendency for water sorption of Dyract, Fuji II LC and Photac Fil, far exceeding that of composite materials, seems to be the most likely explanation for the excess material observed at the margins [35, 36]. The extremely high prevalence of margins with negative steps on Photac Fil and Fuji II LC fillings is also remarkable. On the one hand, the poor wear resistance of the resin-modified glass ionomer cements in comparison to the composite and polyacid-modified resin composite may explain these results. On the other hand, there was possibly abfraction of the margins caused by the tooth flexing due to occlusal stresses. The two resin-modified glass ionomer cements investigated in the present study exhibited a low flexural fatigue limit and flexural strength in in vitro experiments compared to an ultrafine compact filled composite [25]. In addition, Tetric and Dyract were the only materials for which a dentin bonding system was used prior to placement. The use of a dentin bonding system results in the creation of an elastic intermediate layer between the filling and the cavosurface [37]. It has been claimed that flexural deformation of the tooth in the cervical region is at least partly absorbed by this elastic layer [28].

Marginal discoloration

Concerning marginal discoloration, three main causes can be taken into account: the presence of excess filling material, a deficit of filling material at the margin and, finally, the formation of gaps [2, 8, 14].

Advanced marginal discoloration was observed on numerous resin-modified glass ionomer fillings, which corresponds to the high frequency of non perfect restoration margins showing a surplus or a deficit of material. In addition, the bond strength of the glass ionomer materials investigated in this study is only moderate and, therefore, may lead to the formation of marginal gaps [18, 38]. Moreover, compared to Dyract or hybrid composite material, higher polymerization shrinkage has been reported for Photac Fil and Fuji II LC, which may also promote the occurrence of marginal gaps [35]. It was previously noted that shrinkage stress is a particular problem for cervical restorations [38]. Because large portions of the restorative are in contact with the cavity, only a small free surface area is capable of flowing and releasing shrinkage stress. However, regarding shrinkage stress, the relatively slow development of shrinkage in the resin-modified glass ionomer materials in comparison to the resin composites was suggested to be advantageous [39]. A high proportion of marginal discoloration was noted in the enamel of Dyract fillings. No acid etching of the cavity margins was carried out prior to placing the Dyract fillings. According to the results produced by Fritz et al. [3], the bond strength of Dyract on enamel without acid etching was 5 MPa on average. The formation of gaps at the margins placed in enamel may be responsible for the high rate of discoloration.

Survival rate

Overall, the total loss of fillings may mainly be determined by the bond strength of the material on dentin. Comparing the shear bond strengths of Photac Fil, Fuji II LC, and Dyract, the latter was strongest whereas the adhesion of the resin-modified glass ionomers was poor [38]. The bond strength of composites placed in combination with a dentin bonding agent was reported to be approximately 20 Mpa, dependent on the product – which is quite similar to that of Dyract [41]. But despite the use of a dentin bonding agent, 10% of the Dyract restorations still failed, indicating the second highest rate of all materials investigated in this study. As mentioned above, there was no acid etching prior to applying the polyacid-modified resin composite fillings, leading Dyract having a very low shear bond strength on enamel [3]. It appears very likely that the weak bond strength of Dyract on enamel is the major reason for the high rate of failed fillings. Furthermore, the rate of retention of the fillings probably also depends on the elastic modulus of the material used. According to Heymann et al. [12], materials with a lower elastic modulus were better retained in cervical lesions than materials showing a higher elastic modulus. The higher elastic modulus prevents the material deforming with the tooth during occlusal stress-induced deformation and results in a higher rate of restoration displacement. Dyract has previously been reported to have a significantly higher elastic modulus than Fuji II LC and Photac Fil [32]. Finally, explaining the rate of total filling failure, the above-mentioned intermediate elastic layer produced by the dentin bonding agent may probably exert some influence by absorbing deformation stress at the interface between the material and the cavosurface [37].

Statistical procedure

The results of the clinical evaluation of the restorations were analyzed with the Chi-square test. Since a considerable number of patients received more than one restoration, the analysis was carried out with non-independent observation units. Treating several cervical lesions in one patient with the same material might cause similar changes of the clinical quality in all restorations which were related to the patient rather than to the restoration material. In addition, very uneven distribution of restorations was observed, which were not available for assessment at the 3-year recall among the four study groups. This fact might also have influenced the results of this study. Regarding the survival analysis, the type of material did not significantly influence the rate of retention. However, when drawing conclusions from this result one has to consider that the size of the experimental groups in the present study was quite unevenly distributed which might have influenced the probability of retention of the four materials.

Conclusions

Regarding the retention of the restorations, no significant difference was achieved among the four materials tested in the present study. However, the clinical performance of the restorations being retained over the 3-year period showed distinct differences for the four materials. The best clinical performance was observed for the resin composite whereas the quality of the Dyract restorations without enamel etching was inferior. The poorest results were obtained with those restorations fabricated with resin-modified glass ionomers.

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