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ORIGINAL ARTICLE

Clinical evaluation of a polyacid-modified resin composite (Dyract) in class V carious lesions: 5-year results

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Abstract This study evaluated the 5-year clinical performance of polyacid-modified resin composite, Dyract (DeTrey/Dentsply, Konstanz, Germany), restorations in class V carious lesions. Ninety-two class V carious lesions in 28 patients were restored with Dyract. Restorations were clinically evaluated at baseline, 1-, 2-, 3-, 4-, and 5-year recalls and were evaluated according to the modified Ryge criteria by two experienced calibrated examiners in regard to color match, marginal discoloration, wear or loss of anatomical form, caries, marginal adaptation, and surface texture. The retention rate after 5 years compared to baseline in class V carious restorations was 84%, with only 12 restorations failing. Color change and marginal discoloration in restorations were found to be statistically significant ($p=0.0238$ and $p<0.0001$, respectively) at the end of the 5 years, but did not require replacement of any of the restorations. The results of this study revealed that at the end of 5 years, Dyract exhibited a clinically acceptable success rate but had significant color changes and marginal discoloration in class V carious lesions.

Keywords Class V carious lesion · Dyract · Clinical performance · Polyacid-modified resin composite · PSA Prime/Adhesive

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Introduction

Since the introduction of glass ionomer cements in 1972, some developmental changes in the liquid and powder components of the material have occurred. The goals of these changes were to obtain physical properties similar to amalgam and esthetic properties similar to composite resin. Recently, these changes focused on the liquid part of glass-ionomer cements [18]. By using different chemical approaches, such as combining methacrylate technology with glass ionomer chemistry, a new group of materials were introduced, known as hybrid materials [18]. The new material was divided into two groups: resin-modified glass ionomer and polyacid-modified resin composites [17, 24].

One of the examples of the polyacid-modified resin composite group is Dyract [18], which is a single-component material. The liquid part of the single-component paste has an acid monomer, TCB, which contains two acidic carboxylate groups (COOH) and two polymerizable methacrylate groups within the same molecule [17, 18]. Thus, not only is the monomer able to cross-link when initiated through radical polymerization, it can also undergo an acid–base reaction with the filler and reactive silicate glass particles (72%) that contain fluoride if water is absorbed from the tooth and oral environment [17, 18].

The bonding of Dyract to tooth structure is achieved with a PSA Prime/Adhesive [33]. This adhesive system uses a one-component primer/adhesive on enamel and dentin and combines the primer and bonding resin into a single-component system. One of the components of the PSA Prime/Adhesive is PENTA (dipentacrythritolpenta crylate phosphoric acid monomer) [2, 11, 33]. It is suggested that the hydrophilic phosphate groups in the PENTA molecule react with the tooth surface and forms an ionic bond with the calcium ions of the hydroxyapatite [1, 11, 32, 33].

Dyract has gained increased clinical use with its ease of application, ability to bond to hard tooth tissues, fluoride release, having composite-like esthetics, ease of finishing, and being a light-cured material [3]. Additionally, clinical studies of Dyract show that it is effective in restoring cervical lesions and provides good performance [20, 33, 34].

The current study evaluated the clinical performance of a polyacid-modified resin composite, Dyract (DeTrey/Dentsply), in class V carious cavities at baseline, 1-, 2-, 3-, 4-, and 5-year recalls for color match, marginal discoloration, wear or loss of anatomical form, caries, marginal adaptation, and surface texture.

Materials and methods

This study was performed at the Department of Conservative Dentistry, Istanbul University. Ninety-two class V carious lesions in 28 patients were selected. The average age of the patients was 34.8 years (range 13–70 years). All patients were free of any active periodontal disease. Before restorative treatment, the patients received information about dietary habits, especially carbohydrate ingestion, and were instructed in standard oral hygiene procedures, with a demonstration of brushing techniques and the use of dental floss. Each patient received two oral hygiene checkups per year using oral health progress record or OHPR. This record uses a simple criterion-based scoring for plaque, stain/calculus, tissue (bleeding), and program acceptance. According to OHPR, "0"or "1" indicates excellent to good oral health, a score of "2" indicates borderline problems, and a score of "3" or higher signifies a definite problem in that area, requiring further evaluation or intervention with soft scaling of teeth for calculus, food impaction, or plaque [27]. Poor oral hygiene and evidence of heavy occlusion and/or tooth wear were considered causes of exclusion from the study. When the study started, the Ethics Committee of Istanbul University Faculty of Dentistry had not been established. However, informed consent was obtained from each patient before starting the treatment. All cavities were prepared, and restorations were placed by the same operator in 42 maxillary teeth (23 anterior, 16 premolar, 3 molar) and 50 mandibular teeth (23 anterior, 18 premolar, 9 molar). Each patient received approximately three restorations. Cavity preparations were limited to the removal of caries, and the exact cavity form and size were obtained after the removal of caries. All of the cavities were prepared using round and cylindrical tungsten carbide burs (Komet, Lemgo, Germany) under water cooling. Deep caries, if found, was removed with a round bur at low speed, and a thin layer of calcium hydroxide (Dycal, DeTrey/Dentsply, Konstanz, Germany) was placed on the deep portion of the cavity. The cavity margins were not beveled, and unsupported enamel was removed. The margins of the cavities were mainly located in enamel. The cervical margins of the cavities were located at the cemento-enamel junction.

The operative field was isolated with cotton rolls and saliva ejectors. Gingival retraction cords were carefully placed to prevent sulcular fluid or blood from contaminating the cavity surface, especially at the cervical margins. The restorations were placed according to the manufacturer's instructions. After drying the cavity, one coat of PSA Prime/Adhesive (DeTrey/Dentsply, Konstanz, Germany) was applied for 30 s, gently air-dried, and then light-cured for 10 s. A second coat of adhesive was applied, immediately air-dried and light-cured for 10 s. Tooth and resin colors were matched using a Vita shade guide (Vita Zahnfabrik, Bad Sackingen, Germany), and the material, delivered in compules, was injected into the cavities. With restoration depths exceeding 2 mm, the material was applied using an incremental technique. The first material layer was applied on the pulpal walls and was light-cured for 40 s. Then, a second layer was applied and light-cured for an additional 40 s. In shallow cavities, the material was placed in a single increment and light-cured for 40 s. The intensity of the curing light (XL3000, 3 M Dental Products, St. Paul, MN, USA) was measured before and after use, with the light output never going below 450 Mw/cm^2. After the removal of excess material with fine diamond burs and strips, the restorations were finished and polished with Sof-Lex abrasive disks (3 M Dental Products).

The restorations were evaluated by two experienced calibrated examiners according to the modified Ryge criteria [31] (Table 1). Inter- and intra-examiner agreement for the evaluated criteria was 91%. The two examiners examined each patient independently and, when rating disagreements were encountered, the examiners conferred to agree on an acceptable score for each evaluation before the patient was dismissed. At baseline, 1-, 2-, 3-, 4-, and 5-year recalls, color match, marginal discoloration, wear or loss of anatomical form, caries, marginal adaptation, and surface texture were evaluated.

Restoration retention rates were calculated according to ADA Guidelines: cumulative failure %=[(PF+NF)/(PF+RR)]×100%. PF is the number of previous failures before the current recall; NF is the number of new failures at the current recall; and RR is the number of restorations at the current recall [10].

According to the modified Ryge criteria [31], a rating of Alpha (A) represents a clinically ideal situation, and a rating of Bravo (B) indicates a clinically acceptable situation. The rating of Charlie (C) represents an unacceptable situation where the restoration requires replacement. A rating of Delta (D) indicates a situation where the res-

Table 1 Direct clinical evaluation criteria (modified Ryge criteria)

Rating	Aspect	Method
Color match		
Alpha(A)	There is no mismatch in color, shade, and/or translucency between the restoration and the adjacent tooth structure	Visual inspection
Bravo(B)	There is a mismatch in color, shade, and/or translucency between the restoration and the adjacent tooth structure, but the mismatch is within the normal range of tooth color, shade, and/or translucency	Visual inspection
Charlie(C)	The mismatch is between restoration and adjacent tooth structure outside the normal range of tooth color, shade, and/or translucency	Visual inspection
Cavosurface marginal discoloration		
Alpha(A)	There is no discoloration anywhere on the margin between the restoration and the tooth structure	Visual inspection
Bravo(B)	There is discoloration anywhere on the margin between the restoration and the tooth structure, but the discoloration has not penetrated along the margin of the restorative material in a pulpal direction and can be polished away	Visual inspection
Charlie(C)	The discoloration has penetrated along the margin of the restorative material in a pulpal direction	Visual inspection
Wear/anatomic form		
Alpha(A)	The restoration is not under-contoured, that is, the restorative material is not discontinuous with existing anatomic form	Visual inspection and explorer
Bravo(B)	The restoration is under-contoured, that is, the restorative material is discontinuous with existing anatomic form, but sufficient restorative material is not missing so as to expose the dentin or base	Visual inspection and explorer
Charlie(C)	Sufficient restorative material is missing so as to expose the dentin or base	Visual inspection
Caries		
Alpha(A)	There is no evidence of caries contiguous with the margin of the restoration	Visual inspection
Bravo(B)	There is evidence of caries contiguous with the margin of the restoration	Visual inspection
Marginal adaptation		
Alpha(A)	There is no visible evidence of a crevice along the margin into which the explorer will penetrate	Visual inspection and explorer
Bravo(B)	There is visible evidence of a crevice along the margin into which the explorer will penetrate. The dentin or base is not exposed	Visual inspection and explorer
Charlie(C)	There is visible evidence of a crevice along the margin into which the explorer will penetrate. The dentin or base is exposed	Visual inspection and explorer
Delta(D)	The restoration is fractured or missing in part or in toto	Visual inspection and explorer
Surface texture		
Alpha(A)	Surface of restoration is smooth	Explorer
Bravo(B)	Surface of restoration is slightly rough or pitted, can be refinished	Explorer
Charlie(C)	Surface deeply pitted, irregular grooves (not related to anatomy), cannot be refinished	Explorer
Delta(D)	Surface is fractured or flaking	Explorer

toration is missing, mobile, or fractured and has to be replaced, as the restoration is clinically unacceptable. Data obtained by evaluating each assessment criteria were statistically analyzed using the Friedman test for the comparison of years followed by Wilcoxon matched pairs test (Bonferroni corrected) for multiple comparisons.

Results

At the end of 1 year, the recall rate was 100%. After 2, 3, 4, and 5 years, the recall rates were 96.7, 94.6, 80.4, and 79.3%, respectively (Table 2).

At the end of 1 year, 2 of the 92 restorations were completely lost, and one restoration had a rating of C for anatomic form and marginal adaptation and had to be replaced. The rate of retention was 96.7%. After 2 years, three restorations were completely lost, and the rate of retention was 93.5%. After 3 years, one restoration was lost due to crown treatment and the rate of retention was 92.1% (Table 2). At the end of 4 years, four restorations were lost (one restoration had a caries lesion adjacent to its margin; two restorations were completely lost, and one restoration received a crown), and the rate of retention was 87.4%. After 5 years, one restoration was completely lost, and the rate of retention was 83.8%.

Table 2 History of the restorations between baseline and 5 years

	Missing (due to patient dropout)	Evaluated	Lost since last evaluation
Baseline	–	92	–
1 year	–	92	3
2 years	3	86	3
3 years	5	81	1
4 years	18	67	4
5 years	19	62	1

Direct clinical evaluation results at baseline, 1-, 2-, 3-, 4-, and 5-year recalls are shown in Table 3. Except the lost restorations, none of the restorations were clinically unacceptable regarding color match, marginal discoloration, wear or loss of anatomical form, caries, marginal adaptation, and surface texture after the 5-year evaluation period. However, color change in 5 years was statistically significant (p=0.0238), with a substantial shift from clinically ideal color match (Alpha) to clinically acceptable color match (Bravo), but did not require the replacement of any of the restorations. Color change was more pronounced, especially in the first year of the study. In the following 2 years, the color change was less pronounced, and especially during the third, fourth and fifth years, the color change in restorations decreased predominantly. In addition, except between years 2 and 3, 2 and 4, 2 and 5, 3 and 4, 3 and 5, and 4 and 5, there was statistically significant color change among all of the evaluation periods.

Marginal discoloration was statistically significant (p= 0.00001) after 5 years compared to baseline and among all of the evaluation periods except between years 3 and 4 and 4 and 5, but the discoloration was clinically acceptable (Bravo) and did not require the replacement of any of the restorations (Table 3). Marginal discoloration was minimum, superficial, and only located on an unspecific point on the enamel surrounding the restoration. The discoloration could be polished away, indicating that it did not progress towards the pulp (Bravo).

Statistical analysis showed no significant difference in wear or loss of anatomical form, caries, marginal adaptation, and surface texture between baseline and 5-year results. Secondary caries was detected only in one restoration during the 5-year period. At baseline, 1-, 2-, 3-, 4-, and 5-year recalls, none of the patients reported sensitivity.

Discussion

After 4 and 5 years, the retention rates were 87 and 84% when compared to baseline. In agreement with the present study, Di Lenarda et al. [12] reported that the success rate was 82.8% in cervical compomer restorations after 48 months. On the other hand, Folwaczny et al. [16] determined that 4 of 20 Dyract restorations were lost and a total 5 of 20 restorations failed (Charlie and Delta) within a 5-year period. Loguercio et al. [22] reported a retention rate of 78.5% for Dyract in non-carious cervical lesions after 5 years. Their retention rate was lower than in the present study. In contrast, Van Dijken [36] found fewer failures with Dyract and replaced only three restorations, one restoration fractured and two restorations had secondary caries, in class III cavities at the at the end of 5 years. This difference observed between the present study and these other studies may be due to cavity or lesion type. Additionally, the shape and size of the restoration lesions, operator variability, occlusal factors, the bonding capacity of the restorative system, application and curing technique used, and factors during aging of the restoration, like temperature and pH cycles in the mouth [38], are factors that could account for the differences between the studies.

Table 3 Results of clinical evaluation of Dyract restorations (observation are in percent)

	Color match			Marginal discoloration			Wear/anatomic form			Caries		Marginal adaptation				Surface texture			
	A	B	C	A	B	C	A	B	C	A	B	A	B	C	D	A	B	C	D
Baseline n=92	95.7	4.3	0	100	0	0	97.8	2.2	0	100	0	100	0	0	0	100	0	0	0
1 year n=89	74.2	25.8	0	83.1	16.9	0	94.5	4.4	1.1	100	0	97.8	1.1	1.1	0	100	0	0	0
2 years n=83	66.3	33.7	0	59	41	0	89.2	10.8	0	100	0	98.8	1.2	0	0	96.4	3.6	0	0
3 years n=80	65	35	0	43.7	56.3	0	82.5	17.5	0	100	0	96.2	3.8	0	0	95	5	0	0
4 years n=63	63.5	36.5	0	41.3	58.7	0	81.3	18.8	0	98.4	1.6	95.2	4.8	0	0	93.7	6.3	0	0
5 years n=61	60.7	39.3	0	39.3	60.7	0	80	20	0	100	0	93.4	6.6	0	0	91.8	8.2	0	0
P	p=0.0238(S)			p=0.00001 (S)			p=0.5955 (NS)			p=1.00 (NS)		p=0.9894 (NS)				p=0.9703 (NS)			

S Significant (the statistically significant alpha value was set at $p \leq 0.05$. The p values were calculated using Friedman's two-way ANOVA), *NS* not significant, *A* Alpha, *B* Bravo, *C* Charlie, *D* Delta

Due to a lack of inherent macro-mechanical retention, adhesion is the most important factor in the retention of restorations in cervical abrasion/erosion lesions [23]. On the other hand, in class V carious cavities, a more retentive cavity form with undercuts is obtained, as the surface area of the cavity is increased with the removal of the caries. A further explanation of the lack of micro-mechanical retention is that a more inhomogenous, thinner and void rich hybrid layer is found in old sclerotic dentin, explained by the inability of the acid conditioners to uniformly demineralize the sclerotic dentin [30]. Duke et al. [14], in a clinical trial of class V resin composite restorations with Scotchbond 2, stated that the greatest failure rate was in the more sclerotic lesions. Moreover, one hypothesis expressed that sclerotic dentin in non-carious cervical lesions was less receptive to adhesive treatment [13].

During the 5 years, 12 restorations were lost, resulting in 83.4% acceptable restorations. The durability of the restorations depends on the effectiveness of the bond between the restoration and both the enamel and dentin interfaces. Bonding of Dyract to tooth structure could be explained by the adhesion mechanism of PSA Prime/Adhesive to dentin and enamel. Adhesive potential is achieved by ionic bonding of carboxyl and phosphate groups; the acetone component improves this potential by wetting the tooth surface [1, 11, 32, 33].

It is suggested that the clinical retention of an adhesive restoration depends not only on the retention capacity of the adhesive system used but also on the viscoelastic properties of the restorative material used [39]. It has been reported that the elastic modulus of Dyract is higher than microfilled resin composites but lower than those of hybrid resin composites [5, 17]. The materials with lower modulus of elasticity that are used in cervical restorations tend to bend more like tooth structure when subjected to a masticatory load and may flex and be retained [19]. The use of a dentin bonding system results in the creation of an elastic intermediate layer between the filling and the cavosurface [40]. It has been claimed that flexural deformation of the tooth in the cervical region is at least partly absorbed by this elastic layer [8].

It was stated that poor bond strength of Dyract to unetched enamel was probably responsible for lost restorations. When comparing the retention rate of Dyract with those of a composite resin and two resin-modified glass ionomers in class V lesions, Folwaczny et al. [15] found no statistically significant differences after 3 years. On the other hand, it was determined that the retention rate of a resin-modified glass ionomer was higher than Dyract in restorations of non-carious cervical lesions at the end of a 5-year period [16].

After 4 and 5 years, the rates of ideal color match were 63.5 and 60.7%, respectively. These results are consistent with Di Lenerda et al. [12] who found the ideal color match rates (Alpha) to be 63.3% after 4 years. They stated that there was a reduced ability to match the composites with the tooth color because of the lower aesthetic properties of compomers and available limited shades of Dyract that were available at the beginning of their study. On the other hand, Folwaczny et al. [16] and Loguercio et al. [22] determined that the rate of ideal color match in Dyract restorations of non-carious cervical lesions was 81.3 and 81.8% after 5 years, respectively. Their finding was higher than the present study. These differences between the current and those studies might be from the type of lesion and the higher number of restorations in the current study. The reasons given for color changes include the retention of extrinsic pigments, surface roughness, incomplete polymerization, residual monomer after light activation, water sorption, and desiccation [16, 22, 23]. Additionally, the esthetic restorations are exposed to the combined effects of light, moisture, stain, and mechanical wear under oral conditions, often resulting in visibly detectable and esthetically undesirable color changes [21]. Moreover, it was reported in an in vivo study that potential reasons for the change in color match are caused by the extent of the acid–base reaction, water sorption, early disruption of both the polymerization reactions and surface characteristics [37]. Van Dijken [35] reported that the high content of hydrophilic monomer in hybrid materials causes a high rate of water sorption, resulting in a color change. Cattani-Lorente et al. [7] reported that the water absorption of Dyract continued for at least 3 months in vitro. In addition, the absorption of water after photopolymerization initiates an acid–base reaction which causes a continuation of the setting process [3, 11, 18, 33, 34]. These factors might explain the color change in the current study.

After 1 year, only 1.1% of the restorations had unacceptable marginal adaptation (Charlie) with a crevice along the margin, it exposed dentin, requiring replacement. However, at the end of 5 years, only 6.6% of the restorations had a crevice (Bravo). However, in the restorations that had a crevice along the margin, dentin was not exposed, which was a clinically acceptable situation. After 5 years, marginal discoloration was seen in 60.7% of the restorations. Marginal discoloration was detected in a relatively high percentage of the cases, but was located on enamel and was clinically acceptable. Marginal discoloration may indicate bond breakdown and a leaking margin, allowing ingress of exogenous stain from food and drink [23]. The manufacturer has claimed that the bond strength to dentin (14.5 MPa) for Dyract is higher than its bond strength to enamel (9.6 MPa) [11]. It was suggested that this difference in bond strengths may be the factor which causes discoloration at the enamel level [33]. On the other hand, the manufacturer recommends using the material without

acid etching the enamel, as the bond strength should be adequate with the use of only PSA Prime [11]. As Dyract is a composite material [34], polymerization shrinkage may be one of the main reasons for marginal discoloration. Miyazaki, et al. [26] reported the rate of polymerization shrinkage of Dyract to be 2.7%. Bonding of resin composite to enamel is markedly improved by acid etching the enamel to create retentive microporosites [34]. It is reported that the bond strength increases by three times when enamel is etched, with respect to unetched enamel [9]. Microleakage studies also indicate that when enamel is not etched, compomers show poor marginal sealing [4, 28]. The increase in leakage of Dyract could be attributed to a thermal expansion mismatch with tooth substance, with Dyract reported to be significantly higher than that of conventional cements and less than that of composites [6, 25] perhaps due to its different chemical composition [32]. Moreover, Dyract has a composition closely related to the microfilled composites and has a coefficient of thermal expansion of 40.52 ppm/°C [32]. Di Lenarda et al. [12] observed in vivo marginal discoloration in 40% of the non-etched and in 16.7% of the etched cervical restorations after 48 months, with a statistically significant difference between these two groups. The rating of Bravo for marginal discoloration was 60.7% in the current study after 5 years. This result is consistent with those of Folwaczny et al. [16] who found a marginal discoloration rate of 56.3% in restorations of non-carious cervical lesions after 5 years. They determined that Dyract showed higher marginal discoloration than a resin-modified glass ionomer cement (42.9%) at enamel margins. Loguercio et al. [22] found a higher frequency of a Bravo rating for marginal discoloration (81.8%) at all enamel margins in restorations of non-carious cervical lesions after 5 years. In addition, Van Dijken determined that Dyract showed more marginal discolorations (40.8%) than a resin-modified glass ionomer (14.3%) and a resin composite (5.8%) in class III restorations after 5 years [36]. These differences may be due to lesion type and the number of restorations. Tyas [34] stated that although Dyract has now been superseded by Dyract AP with a finer filler particle, a cross-linking resin, and optimized initiator system, the manufacturers should still consider specifying mandatory enamel etching before the application of Dyract. After acid etching, Prati et al. [29] found that Dyract exhibited less marginal discoloration than a composite resin, although not statistically significant.

At the 5-year recall, 80% of the restorations were clinically ideal (Alpha) for anatomical form, while only 20% were clinically acceptable (Bravo), showing that 17.8% of the restorations had lost their anatomical form present at baseline. Wear was only limited to the restorative material and did not extend to the sound tooth structure.

At the 5-year recall, secondary caries was detected in 1.6% of the restorations. In addition, 8.2% of the restorations were slightly pitted and had a rough surface texture (Bravo), which could be restored by repolishing.

Conclusions

At the end of 5-year evaluation period, a total 12 restorations were lost (retention rate of 83.8%). However, statistical analysis showed no significant difference in wear, loss of anatomical form, marginal adaptation, and surface texture between baseline and 5-year results. At the end of 5 years, Dyract exhibited a clinically acceptable success rate, but exhibited significant color change and marginal discoloration in class V carious lesions.

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