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Clinical Research

Longevity of Direct Resin Composite Restorations in Maxillary Anterior Crown Fractures: A 4-year Clinical Evaluation

B Korkut • M Özcan

Clinical Relevance

A monochromatic composite layering technique can meet the esthetic and functional expectations over 4-years, even when using microhybrid resins.

SUMMARY

Objectives: To investigate the longevity of direct composites for Class IV restorations and the possible reasons of failure.

Methods and Materials: The longevity of 168 Class IV restorations in 50 adult patients was evaluated, in terms of modified United States Public Health Service criteria, for 4 years. Restorations were performed using a monochromatic layered microhybrid, resin-based composite (RBC) (Essentia, Universal Shade, GC Corporation, Japan; n=76) and polychromatic layered micro/nanohybrid (MD and LE shades, Essentia, GC Corporation, Japan; n=92) RBCs, by a single operator.

Results: The majority of the teeth (n=156) remained acceptable at the end of 4 years, and the overall survival (OS) rate was considered as 92.86%. Survival rates for the monochromatic layering technique (MLT) and polychromatic layering technique (PLT) were 90.8% and 94.6%, respectively. Mean survival was 46 months for MLT and 47 months for PLT, indicating no significant difference (*p*=0.343). Fracture of the restoration was the most common reason for failure (4.2% out of 7.1% of general failures) for both the layering techniques.

Conclusions: Under the conditions of this mid-term clinical study, MLT and PLT as well as microhybrid and nanohybrid resin composite materials, showed similar clinical durability. In terms of simplicity, monochromatic layering can be preferred for Class IV restorations, when the right indication criteria are met.

*Bora Korkut, PhD, DDS, Department of Restorative Dentistry, Dentistry Faculty, Marmara University, Basibuyuk, Maltepe, Istanbul, Turkey

Mutlu Özcan, PhD, DDS, Clinic for Fixed and Removable Prosthodontics and Dental Materials Science, Center for Dental and Oral Medicine, Dental Materials Unit, University of Zurich, Zurich, Switzerland

*Corresponding author: Marmara University, Basibuyuk, Maltepe, Istanbul, Turkey, 34826; e-mail: bora.korkut@marmara.edu.tr

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INTRODUCTION

Clinical conditions such as caries lesions, discoloration, diastemas, crown fractures, and misaligned teeth may cause an undesirable esthetic appearance and smile.[1] Two main esthetic treatment options are available to solve these problems: indirect ceramic and direct resin-based composite (RBC) restorations.[2] With recent developments in adhesive dentistry materials and techniques, direct RBC restoration is now considered a good minimally, or even noninvasive, option.[3,4] Compared to indirect ceramic restorations, direct RBCs have the advantages of single-visit treatment, less preparation time, durability, and repairability.[4] However, periodic checks are mandatory to ensure durability of resin composites, and more of these checks are needed as compared to ceramics. In cases of fracture or chipping of the composite, a simple repair protocol is used to extend the life of the original restoration.[5] Direct restorations reportedly have successful short-term clinical results.[6] Appropriate indications, effective isolation, good optical and mechanical properties of the resin composite, operator experience and skill, accurate shade selection, successful finishing and polishing of the direct restorations, and frequent checkups are needed for long-lasting functional and esthetic outcomes.[4,7] In the literature, there is a lack of long-term evidence of the clinical efficacy of direct RBC restorations placed in the anterior teeth. The most common reason for failure of direct composite build-ups is fracture of the RBC.[6,8] According to previous studies, the 3- to 5-year anterior restoration survival rate varies between 79% and 89%.[5,6,9] Limited longevity has been reported for composite laminate veneers due to their susceptibility to staining, wear, and fracture.[10] However, the potential influence of chemical and physical properties of the resin composite, the size of restoration, and patient- and dentist factors still remain to be determined, especially in long-term clinical trials. A need for information regarding the potential factors influencing long-term failure clearly remains. Kubo and others[11] investigated the main factors associated with the longevity of Class III-V composite restorations, including cavity type, gender, age, dentist factors, and the requirement for retreatment. Dentist factors, cavity type, and retreatment significantly influenced the survival rate.

Two types of veneers comprised of different microhybrid resin composite materials were compared by Gresnigt and others[12], and no significant difference in 3- or 5-year survival was found. A meta-analysis of prospective studies on anterior composite restorations reported median survival rates of 95% and 90% for Class II and IV restorations, respectively, after 10 years.[13] Since esthetics is one of the main concerns regarding anterior teeth, some researchers have recommended using resin composites with a smaller filler size (nanofilled composites) to produce a smoother surface.[14] However, a systematic review comparing nanofilled and submicron composites to microhybrid composites reported no improvement in surface smoothness with use of nanofilled composites.[15]

The aim of this clinical study was to determine the mid-term survival rate of Class IV composite restorations of maxillary anterior teeth and to investigate the possible reasons for failure.

METHODS AND MATERIALS

Study Design and Participants

Patients who had received Class IV restoration(s) of maxillary anterior teeth were selected for this 4-year clinical follow-up study. Fifty patients (22 males and 28 females; total of 168 Class IV restorations) aged between 18 and 56 years (mean age, 31.1 years) were included. A flow diagram of the restorations is shown in Figure 1. All patients provided written informed consent before the restorative procedures. Class IV restorations of maxillary teeth, which were conducted at least 4 years ago, were included. Baseline (1 week) and 1-, 2-, 3-, and 4-year follow-up data were evaluated by two experienced restorative dentistry specialists. The distribution of the restorations according to the layering technique, composite filler type, and tooth number is provided in Table 1.

Inclusion and Exclusion Criteria

The medical and clinical history of the patients was taken, and they attended 1-week and 1-, 2-, 3-, and 4-year follow-up appointments. The 168 Class IV restorations of maxillary anterior teeth were done between June 2014 and July 2015. Restorations that were extracted, replaced, repaired, or repolished during this period were not excluded from the study, but were considered failures. Teeth that underwent root canal treatment (RCT) at baseline were excluded from the study; however, endodontically treated teeth were included. The necessity for RCT after treatment was determined based on the assessment results. All patients had full anterior dentition and normal occlusion without generalized periodontal disease, as verified by clinical and radiographic records. The reasons for the Class IV restorations were all uncomplicated crown fractures. Before the restorations, minimally invasive removal of any residues of former restorations and related secondary caries was conducted. Presence of bruxism was also diagnosed based on medical and clinical

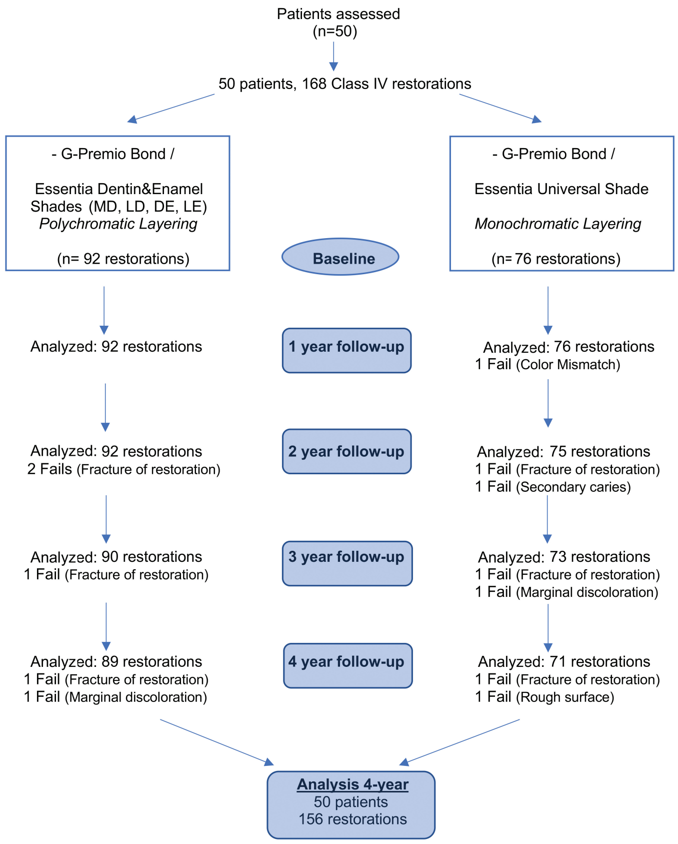

Figure 1. *Flow diagram of history of restorations.*

history. Thirty-seven restorations of eleven patients were not included for the analysis, due to the presence of bruxism.

Restorative Procedures

All restorations were performed using the same procedures by a restorative dentistry specialist in an academic university clinic. A silicone key constructed via either diagnostic wax-up or direct mock-up was used for all restorations. The principle of minimally invasive dentistry guided the preparations. Before tooth preparation, shade matching was performed with the button technique using a digital camera (D750 ; Nikon, Tokyo, Japan) with a 105-mm macro lens (Nikon), the R1C1 Wireless Close-up Speedlight System (Nikon), a flash mounting bracket (Owlbrckt C, Torun & Torun, Ankara, Turkey), and the polar_eyes cross-polarization filter (PhotoMed International, Van Nuys, CA, USA). The most appropriate enamel and dentin shades of the selected composite resin were placed on the labial surfaces of the adjacent teeth and polymerized,

Table 1: *Distribution of Class IV Restorations According to Layering Type, Composite Filler Type, and Tooth Number*

Layering Technique	Composite Filler Type	n	Tooth Number					
			6	7	8	9	10	11
Monochromatic Essentia (Universal shade)	Microhybrid	76	18	9	12	10	11	16
Polychromatic Essentia (MD and LE shades)	Micro-/ nanohybrid	92	5	17	21	24	19	6
Total		168	23	26	33	34	30	22

following which photographs were taken and evaluated by the operator. The selected shades and initial dental photographs were recorded for each patient. Following shade selection, teeth #5-12 were isolated with a rubber dam (Nic Tone, Bucharest, Romania). The teeth to be restored were retracted with either dental floss or rubber dam clamps (Hygenic Brinker Clamps; Coltene, Altstatten, Switzerland). Minimally invasive removal of the former restorations was performed in all cases. Then, 45° beveling of the buccal surface of the fracture lines (including all enamel and up to half of the exposed dentin) was performed using a red diamond needle-shaped bur (Dentsply Maillefer, Ballaigues, Switzerland) under constant water cooling. Following this, 35% phosphoric acid gel (Ultra-Etch, Ultradent Products, Inc, South Jordan, UT, USA) was applied to all of the prepared enamel surfaces for 30 seconds, water-rinsed for 10 seconds, and gently spray-dried. Then a one-step adhesive system (G-Premio Bond, GC Corporation, Tokyo, Japan) was applied to all of the etched enamel and nonetched dentin surfaces, as per the manufacturer's instructions. The adhesive was left undisturbed for 10 seconds after rubbing and air-dried under maximum air pressure for 5 seconds. Polymerization was performed using a light-curing unit (wave length: 430-480 nm; Elipar DeepCure-S LED, 3M Oral Care, Maplewood, MN, USA), applied for 20 seconds at a light intensity of 1370 mW/cm^2 with an irradiated diameter of 10 mm.

Regarding the restorative materials and technique, a microhybrid RBC (Universal Shade Essentia, GC Corporation) with a chameleon effect was used for monochromatic Class IV restorations (n=76). A combination of microhybrid and nanohybrid RBCs (Medium Dentin [MD] and Light Enamel [LE] Essentia shades, GC Corporation) were used for polychromatic Class IV restorations (n=92). The brand, type, manufacturer, and chemical compositions of the materials are listed in Table 2. Mono- or polychromatic layering was performed according to the necessity for incisal translucency of the incisal edge. If the adjacent or symmetrical tooth had these features, the polychromatic layering technique (PLT) was considered. All restorations were gradually built-up under silicone index guidance. The incremental layering technique (≤2-mm thickness) was used for monochromatic layering of the microhybrid resin and for polychromatic layering of the micro/nanohybrid resin. A nanohybrid translucent shade (LE) was used to mimic the natural enamel tissue, whereas microhybrid, opaque, and chromatic shades (MD) were used to mimic the natural dentin tissue. Marginal walls of the restorations were completed using self-contoured, kidney-shaped posterior metal matrix bands (No. 1298, Tor VM, Moscow, Russia). All shades were polymerized for 20 seconds at an irradiation of 1370 mW/cm^2. The light intensity of the curing unit was evaluated before each restoration using a radiometer (Hilux Curing Light Meter, Benlioglu Dental, Ankara, Turkey). The final labial surface layers of the restorations were polymerized under a glycerin gel cover (Air Barrier, GC Corporation) to eliminate the oxygen inhibition layer.

The final occlusion was adjusted by protrusive and lateral movements of the mandible. Interproximal surfaces were polished with interdental polishing strips (Epitex strips; GC Corporation) with three different grits (medium #500, fine #800, and extrafine #1200). Labial and incisal embrasures were adjusted using aluminum oxide-embedded abrasive polishing discs (Sof-Lex, 3M Oral Care) with three different grains (medium [40 μm], fine [24 μm], and superfine [8 μm]) under dry conditions at 15,000 rpm, as per the manufacturer's instructions. Finishing of the restorations was performed using a 12-blade bur (Diatech, Dental AC, Heerbrugg, Switzerland) at 30,000 rpm under water cooling. Diamond particle-embedded medium- and fine-grit rubber wheels (Twist Dia; Kuraray Noritake Dental, Tokyo, Japan) were operated at 10,000 rpm without water cooling to polish the labial surfaces. Additional polishing was performed using a medium-grit diamond bur (Diatech), operated horizontally at 5000 rpm. All patients were scheduled for repolishing 24 hours later. Only the high-shine (fine-grit) polisher was used for final surface polishing. Patient's medical/dental histories, as well as dental photographs, and radiography records, if necessary, were collected at the 1-week and 1-, 2-, 3-, and 4-year follow-up appointments. No repair or repolishing procedure was performed at any of follow-up visits.

Evaluations and Statistical Analyses

Medical history, radiographic and clinical data, were collected for each patient by the operator. Variables such as age and gender were recorded. Patients were also questioned regarding postoperative sensitivity. Radiographs were only taken when indicated by clinical examination, and when it was a necessity to complete the examination, to minimize radiation exposure. The necessity was judged by the operator during the annual follow-up visits. Intraoral frontal bite, frontal view with contrast enhancement (Owlcntrst, Torun & Torun), frontal close-up view, and occlusal photographs were taken using the equipment described in Section 2.3. The arms of the mounting bracket were set at a 45° angle for all photographs. All photographs were taken under the same conditions (1/250 shutter speed, f:28

Table 2: *Brands, Types, Manufacturers, and Chemical Compositions of the Materials*

Brand	Type	Manufacturer	Chemical Composition
Essentia Universal Shade	Microhybrid composite	GC Corp, Japan	Matrix: UDMA, Bis-MEPP, Bis-EMA, Bis-GMA, TEGDMA Filler: prepolymerised fillers (17 μm): strontium glass (400nm), lanthanide fluoride (100nm), fumed silica (16 nm) FAlSi glass (850 nm) [81 wt%]
Essentia Medium Dentin (MD) Shade	Microhybrid composite	GC Corp, Japan	Matrix: UDMA, Bis-MEPP, Bis-EMA, Bis-GMA, TEGDMA Filler: prepolymerised fillers (10 μm):barium glass (300nm), fumed silica (16 nm), silica glass (850 nm) [76 wt%]
Essentia Light Enamel (LE) Shade	Nanohybrid composite	GC Corp, Japan	Matrix: UDMA, Bis-MEPP, Bis-EMA, Bis-GMA, TEGDMA Filler: prepolymerised fillers (10 nm): barium glass (300 nm), fumed silica (16 nm) [81 wt%]
G-Premio Bond	Self-etch / Universal adhesive agent	GC Corp, Japan	4-MET, MDP, MDTP, dimethacrylate monomers, water, acetone, silicone dioxide, photoinitiators
Ultra-Etch	Etching gel	Ultradent Products, US	35% phosphoric acid
Twist Dia Prepolisher	Polishing material / rubber spirals	Kuraray Noritake, Japan	Diamond grains embedded synthetic rubber spirals. Medium grit (325-400 mesh)
Twist Dia High-shine Polisher	Polishing material / rubber spirals	Kuraray Noritake, Japan	Diamond grains embeded synthetic rubber spirals. Fine grit (4-8 μm)
Sof-Lex Discs	Four step polishing discs	3M Oral Care, Japan	Aluminium oxide paticles embedded round polishing discs in different girts. (Coarse: 55 μm; Medium: 40 μm; Fine: 24 μm; Ultrafine: 8 μm)
Epitex Polishing Strips	Four step interdental polishing strips	GC Corp, Japan	Diamond particles embeded interdental polishing strips in 4 different grains. (Coarse #300; Medium #500; Fine #800; Extra fine #1200)
Air Barrier	Oxygen inhibition layer inhibitator	GC Corp, Japan	Glycerine gel in high viscosity

Abbreviations: MDP, methacryloyloxydecyl dihydrogen phosphate; 4-MET, methacryloyloxyethyl trimellitic acid; MDTP, thiophosphate ester monomer; Bis-GMA, bisphenol A diglycidl ether dimethacrylate; UDMA, diurethane dimethacrylate; TEGDMA, triethylene glycol dimethacrylate.

diaphragm, ISO 200); the distance to the patient was also kept constant. The white balance was adjusted for each patient using gray paper. The surfaces of the teeth and restorations were spray-dried before the photographs were taken. The photographs were taken as quickly as possible to avoid de-hydration for precise shade matching. Frontal photographs were also taken to aid in shade matching and identification of any discoloration. The photographs were saved as JPEG and RAW files.

The 168 Class IV restorations were evaluated between August and November 2018 by two experienced and fully blinded examiners using a dental mirror and explorer. Before evaluating the data, the examiners were provided with a set of reference photographs illustrating the scoring criteria. Cohen kappa coefficient (κ) was calculated as a measure of observer agreement. The intraobserver (κ=0.74 and 0.77) and interobserver (κ=0.67) agreements were both substantial. The restorations were examined and scored individually in accordance with modified United States Public Health Service (USPHS) criteria at the 1 week and 1-, 2-, 3-, and 4-year follow-ups.[16] The patient and restoration histories were obtained from the dental records. Failed restorations were excluded from the analysis, and reasons for failure were recorded. Caries in nonfilled tooth surfaces with acceptable composite resin restoration were not considered as reasons for failure.

Data collection and statistical analysis were performed using software SPSS Statistics for Windows (Version 23.0; IBM Corporation, Armonk, NY, USA). Descriptive statistics for the evaluation criteria and failure rates were generated. Qualitative analysis based on the modified USPHS criteria was performed separately for each of the nine clinical characteristics evaluated. Kaplan-Meier survival analysis was performed to obtain survival curves for the two layering techniques. An additional survival analysis of the restorations was performed using Cox regression analysis. The associations of survival with factors including tooth number, patient age and gender, and layering technique (independent variables) were evaluated. The layering techniques were compared in terms of the proportion of acceptable USPHS scores by year using the chi-squared test and Cochran Q test.

RESULTS

In total, the outcomes of 156 teeth were acceptable after 4 years, and the overall survival (OS) rate was 92.86%. The failure rates for the monochromatic layering technique (MLT) and PLT were 9.2% and 5.4%, respectively. The survival rate for the first year was 99% for MLT and 100% for PLT, and 99% overall; the respective rates for the second year were 96%, 98%, and 97%, while those for the third year were 93%, 97%, and 95%, and those for the fourth year were 91%, 95%, and 93%. Restorations requiring any repair or replacement were considered as failures. Repolishing was not performed during the follow-up period. Of the 168 restorations, 12 (7.14%) were failures. No restoration had more than one clinically unacceptable score, and no patients were lost to follow-up, so the number of unacceptable scores was equal to the number of failed restorations. The reasons for failure included fractured restoration (n=7), marginal discoloration (n=2), color mismatch (n=1), surface roughness (n=1), and caries (n=1). Fracture occurred in seven restorations (4.2% of the 7.1% of restorations that failed) and was the most common reason for failure in both the MLT (3.9%) and PLT (4.3%) groups. Only 2 teeth (2.6%) in the MLT group and 21 (22.3%) in the PLT group showed no detectable changes (score of 0). In 145 (86.3%) restorations, at least one change was detected (score of 1-4). Postoperative sensitivity (USPHS score of 1) was noted in 20 restorations (11.9%) in only eight patients, all at baseline (1 week after the restoration); all of these were considered recovered at the first-year follow-up.

Figure 2 shows the Kaplan-Meier survival curves for the restorations performed with the two layering techniques. The MLT (microhybrid RBC) and PLT (micro/nanohybrid RBC) groups showed no significant difference in mean survival time (p=0.343). The mean survival time was 46.026 and 46.957 months for the MLT and PLT groups, respectively. According to the chi-squared (χ^2) test, the proportion of acceptable USPHS scores did not differ between the two layering techniques in any year ($p \geq 0.05$); this was also the case in the Cochran Q test analysis ($p \geq 0.05$). There was no significant difference in failure rate among years in the MLT group ($p \geq 0.05$), whereas, in the PLT group there was a significant difference, attributable to the rate in the second year (p=0.042). For all restorations, second-year scores (p=0.018) differed significantly from the first-, third-, and fourth-year scores (p=0.433, p=0.151, p=0.302, and $p<0.05$, respectively).

Cox regression analysis of the restorations was also performed to evaluate the effect of four independent variables (tooth number, patient age and gender, and layering technique). None of the variables were associated with survival ($p \geq 0.05$) (Table 3).

DISCUSSION

In this clinical follow-up study, the long-term performance of maxillary Class IV composite restorations was investigated. The restoration outcomes using two layering techniques (MLT and PLT) were

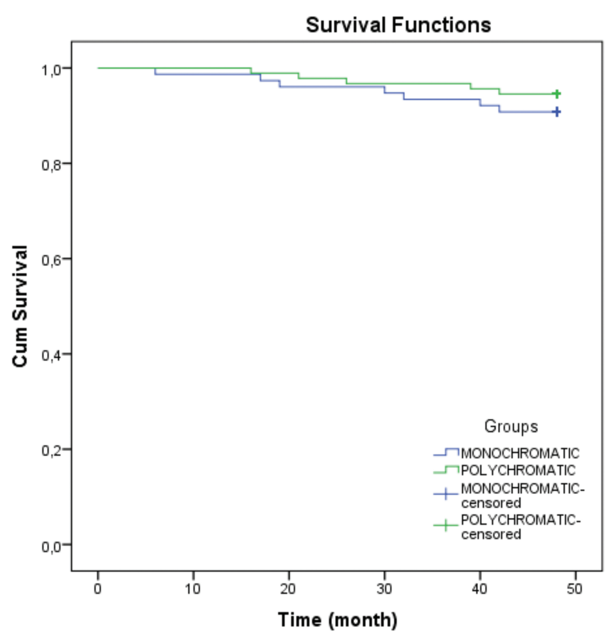

Figure 2. *Kaplan-Meier survival curve for survival of restorations with monochrome and polychrome layering techniques during the mean observation period.*

Table 3: *Cox Regression Analysis of the Restorations Regarding the Independent Variables*

	OR (95% CI)	*p*
Tooth number	0.985 (0.881-1.101)	0.788
Age	1.047 (0.992-1.106)	0.096
Layering technique	0.807 (0.237-2.752)	0.732
Gender	1.147 (0.363-3.62)	0.815

compared over a 4-year period. The methodology employed has been used in many other clinical studies.[7,11,17,18] Also, the clinical evaluations in our study were performed by two independent observers, similar to previous studies.[1,19,20] Challenges to clinical studies include standardization of indications and treatment protocols, achieving operator agreement, and dealing with missing data.[16] As the cases in this study were to be used in laboratory demonstrations for undergraduate and postgraduate students, a high-quality operator was required; the operator was a university instructor with 15 years of clinical experience specializing in restorative dentistry. The modified USPHS criteria were used for evaluating the selected restorations in this study, allowing for a standardized and detailed longitudinal assessment of the restorations. Although there is a need for a more definitive method,[21] this evaluation method has nevertheless been used in many clinical studies, to which our results could thus be compared.[11,12,16,22,23]

Substantial intraobserver (κ=0.74 and κ=0.77) and interobserver (κ=0.67) agreements were obtained for the fully blinded observers. The observers agreed with all the unacceptable scores, and the disagreements were not related to the acceptable/unacceptable decisions. Disagreements occurred regarding the acceptable scores of 0 and 1 for marginal discoloration, color match, and surface roughness criteria. It might be difficult to make a decision between these scores using only dental photographs, particularly for segmental deterioations from ideal in some of these criteria. Previously, Peumans and others[9] reported that the photographic evaluation may mask imperfections on the restoration surface and thereby lead to misjudgements, especially for the assessment of color match. Therefore, the obtained minor disagreements were considered to not effect the targeted outcomes of the present study. The evaluations of the first observer were taken into consideration for the statistical analyses.

A high OS rate of 92.84% after 4 years was obtained for the Class IV restorations in this study. For survival analysis, the Kaplan-Meier method is the gold standard and was therefore used in this study instead of the log-rank test, which has limited utility for analyzing multivariate datasets. Nevertheless, an additional survival analysis (Cox regression) of the restorations was performed. Four independent variables (tooth number, patient age and gender, and layering technique) were not associated with survival ($p \geq 0.05$) (Table 3). The OS rate observed in our study was higher than that in the studies of Coelho-de-Souza and others[1] (3.5-year survival rate of 80.1%), Frese and others[3] (5-year survival rate of 84.6%), Lempel and others[16] (7-year survival rate of 88.3%), Khayatt and others[24] (7-year survival rate of 85%), and Gresnigt and others[12] (3.5-year survival rate of 87.5%). This may be because all of the restorations in our study were done by a single restorative dentistry specialist under the same clinical conditions, and not by undergraduate students or inexperienced operators (which can affect restoration longevity).[20,21] Although all of the patients in this study were dental school applicants with low socioeconomic status, this was not associated with negative outcomes in our study, unlike some other clinical studies.[1,21]

In this study, a microhybrid RBC (81 wt%) was used in conjunction with the MLT, and a combination of microhybrid and nanohybrid RBC (76 wt%) in conjunction with the PLT. Coelho-de-Souza and others[1] reported that microfilled composite veneers had better surface gloss, color matching, anatomical, marginal adaptation, and surface staining properties compared to universal composites. However, nanofilled resin was not evaluated. Accordingly, gloss retention and polishability were previously reported to be better for resins including nanofiller (0.005-0.01 μm) compared to those including microfiller (0.01-0.1 μm).[14,25] More incisal chipping and a 3.7-fold higher risk of failure were reported by Lempel and others[16] for build-up restorations of anterior teeth when using microhybrid resin compared to nanofilled resin. Massano and others[23] reported good clinical performance of Class III and Class IV restorations using nanofilled resin over a 2.7-year period (failure rate of 2.4%). However, microfilled resins were also reported to have the advantages of high surface hardness and high resistance to wear, fracture, and shrinkage.[19,26,27] As well as the size, both the shape and amounts of particles were reported to affect the performance of resin composites.[7]

In the present study, the respective failure rates when using the MLT and PLT were 9.2% and 5.4%. The Kaplan-Meier survival analysis revealed that the mean survival durations of the restorations were not different at 46.026 and 46.957 months, respectively, ($p=0.343$) nor were the survival rates for each year or the OS rate (based on the proportion of acceptable USPHS scores; $p \geq 0.05$). Both RBCs (microhybrid and nanohybrid) applied to the top surface layer of the restorations exhibited satisfactory performance. While nanofilled composites only use nanosized particles, nanohybrids combine nano- and microsized particles, similar to microhybrid composites.[14] Thus, becoming microhybrid or nanohybrid is directly related to the distribution of the nano- and microparticles.[26] Moraes and others[14] reported that microhybrid and nanofilled composites with similar matrix components yielded similar polymer network structures and thus similar hardness despite noticeable differences in filler size. According to their results, the behavior of nanohybrid composites was more similar to that of microhybrid, rather than nanofilled composites. Also, in previous studies, nano- and microhybrid resins were reported to have similar physical characteristics, depending on the filler content.[14,27] The RBCs used in this study were micro- and nanohybrids of the same brand, with similar contents including almost the same filler type and the same amount of filler particles (81 wt% for both) (Table 2). Therefore, this similarity might be the reason for no significant difference between the restorative materials, for marginal discoloration, color matching, surface roughness, and restoration wear in our study. It may also explain the lack of difference in mean survival duration at any time point or in OS between the two resin composites used. In addition, performing the restorations by a single specialist, under the same restoration protocols and clinical conditions, might be related to the similar clinical performances of the restorations with different RBC materials.[20]

The restoration failure rates of the two layering techniques used in this study did not differ by time point ($p \geq 0.05$), except for the rate at the 2-year follow-up in the PLT group ($p=0.042$). Considering both groups together, the failure rate at the 2-year follow-up was different to those of the other time points ($p=0.018$). Two unacceptable "fractured restoration" USPHS scores during the second year may explain this result. Fracture occurred in seven restorations and was the most common reason for failure when using either the MLT (3.9%) or PLT (4.3%). These results were similar to those of previous clinical trials.[5,21]

Fracture and chipping were the most frequent reasons for failure in microhybrid anterior RBC restorations in the studies of Frese and others,[3] van Dijken and others,[8] Coelho-de-Souza and others,[1] Gresnigt and others,[12] and Milosevic and Burnside.[28] In their systematic review Heintze and others[13] reported that Class IV restorations, including of the incisal edge, had a higher risk of failure compared to Class III restorations. All of the fractured restorations had a USPHS score of 2 ("partial fracture in restoration>1/4"). The fracture rate was not statistically different between the two layering techniques ($p \geq 0.05$). No fracture was observed using either technique during the first 2 years of follow-up.

Marginal discoloration, the second most common reason for failure, was observed in two cases in each layering technique group, all of which had a USPHS score of 2 ("obvious staining could not be polished away"). The rate of marginal discoloration was not significantly different between the layering techniques ($p \geq 0.05$). Heintze and others[13] and Lempel and others[16] reported that adhesion to enamel and 37% phosphoric acid etching were important for good sealing and prevention of discoloration. Selective enamel etching was performed for all restorations in our study. Additionally, 45° beveling of the labial surface of the teeth prior to conditioning the enamel was performed, to ensure that the transition between the restoration and enamel was not visible. Beveling prevents marginal staining[16,23,29] and improves fracture resistance at the tooth-restoration interface.[16,29]

Color mismatch was the least common reason for failure in this study and the rate thereof did not differ between the two layering techniques ($p \geq 0.05$). Only one restoration in the MLT group had an unacceptable ("slight mismatch in color or shade") USPHS color mismatch score; 51 restorations in the MLT group and 32 in the PLT group had a score of 1 ("good color match") during the 4-year follow-up period. Nasim and others[26] reported that the rate of discoloration was the highest for nanofilled RBCs among the microhybrid and microfilled RBCs tested. Tekçe and others[30] reported similar findings *in vitro*. Superficial degradation of restorative materials and absorption of staining agents are responsible for discoloration.[16] Vichi and others[25] reported that low triethylene glycol dimethacrylate (TEGDMA) content in the resin matrix may limit water uptake and, by extension, the color variation induced by absorption of the staining solution. In this study, both RBCs contained TEGDMA, which may explain the staining results. Additionally, filler particle type, size, and distribution are important physical properties of composite fillers[27] and may affect color stability. A previous study reported that smaller filler particle size led to low visual opacity,[27] while, in another study, it decreased staining and enhanced esthetics.[25] Lempel and others[16] reported no long-term positive effects of nanoparticles on color stability or surface gloss *in vivo*. This was supported by a recent systematic review, which concluded that nanofilled and submicron RBCs did not yield superior color stability or gloss retention outcomes compared to microhybrids.[15] In addition to material factors, patient factors (such as diet) and operator factors (operating environment, isolation, adhesion, finishing and polishing protocols, and recall frequency) may also influence RBC staining outcomes. In our study, the experienced operator, standardized restorative technique, and high patient motivation may have been responsible for the very low rate of color mismatch failures.

The surface roughness USPHS score was unacceptable only in one case, at the 4-year follow-up in the MLT group. In total, 36 restorations performed using the MLT, and 32 using the PLT, had a score of 1 ("slightly rough or pitted") on the surface roughness USPHS criterion during the 4-year follow-up period. Repolishing was not performed for any restoration. There was no statistically significant difference in surface roughness between the two layering techniques ($p \geq 0.05$). Caries related to the restoration was considered unacceptable in only one case and no significant difference in caries was found between the two layering techniques ($p \geq 0.05$).

While clinical examinations were performed only during the fourth year of follow-up, postoperative sensitivity data were obtained from the medical histories of the patients at baseline; 20 restorations (11.9%) in only eight patients had a score of 1 for this USPHS criterion, all of which had recovered at the first-year follow-up. As the etching of dentin with phosphoric acid is considered a risk factor for postoperative sensitivity,[31] the use of the selective etch technique in this study may explain the low postoperative sensitivity scores, which also showed no difference between the layering techniques ($p \geq 0.05$). In accordance with the results of Gresnigt and others[12] and Lempel and others[16] regarding restoration wear, no wear was detected in our cases.

Some researchers have suggested that the failure criteria should be revised, where some repaired restorations remain functional and therefore should not be considered as complete failures.[16,32,33] Those studies concluded that if repaired restorations are not classified as failures, annual failure rates would drop, such that repairability could be considered as a predictor of better survival of RBC restorations.[16,34] Frese and others[3] classified repaired cases as restoration survival rather than failure. Reparability of the RBC materials was considered the most important factor in extending the life of their restorations, which had a functional survival rate of 100%. Van de Sande and others[34] reported 69% survival and 2.4% annual failure rates for Class III and IV restorations, respectively, when repair was not considered as failure, compared to 64% and 2.9%, respectively, when it was considered as failure. Composite repair is a suitable alternative to Class III-IV and veneer restorations, since it may increase the survival rate of anterior restorations.[16,34] However, in our study, restorations needing repair, retreatment, or even repolishing were considered as failures. Considering this, the 92.84% OS rate can be considered very high.

There were some limitations to our survival analysis, including the relatively low number of cases, mid-term follow-up period, and lack of generalizability, as only one operator was involved. The results of survival analyses for different dental materials should be interpreted with care, as the numbers of cases (including failures) and follow-up periods tend to be limited.[1] Demarco and others[5] noted a lack of long-term clinical results regarding the performance of anterior RBC restorations in a systematic review. The reasons for this include poor patient compliance and follow-up visit attendance.[22] Regarding our results, in case of a long-term evaluation period, perceptible major differences might have occurred in nano- and microhybrid restorations, therefore similar longevity outcome might have also changed. Recently, Dietschi and others[20] identified several factors influencing outcomes in a systematic review including; patient hygiene, caries risk, age, socioeconomic status, operator characteristics, treatment environment, observation period, and evaluation method. Use of composite filler materials and the type of curing light had little to no impact on clinical success at any time point, whereas treatment environment and number of operators affected the restoration failure rate. According to their results, a single operator yielded the optimum results.[20] In the present study, all restorations were performed by a single operator at the same clinic under consistent conditions and using the same materials. However, the effect of operator's skill, experience, and the operation environment still remained unclear. The outcomes of this study represent patients without bruxism. Therefore, the high success rate might also be associated with patients with low-risk factors. In spite of that, some patients might have developed slight or severe bruxism during its course, and this was not assessed. Differences among patients in oral parafunctions, malocclusion, dietary habits, and oral hygiene might have also affected the outcome. Because bruxism is a self-reported behavior that is difficult for patients to identify, diagnoses based on patient histories can be inaccurate. There is evidence that bruxism is a major risk factor for fracture.[8] However, in many other clinical trials, bruxism was not associated with survival. Coehlo-de-Souza and others[1] reported no correlation between tooth fracture and the longevity of build-up restorations. In the study of Milosevic and Burnside,[28] bruxism was not associated with tooth fracture or restoration failure. Further clinical long-term studies are needed to assess the effect of bruxism on survival rate. Also, studies including more than one operator, larger sample size, and a variety of RBC materials are necessary to verify the findings of this study.

CONCLUSIONS

From this study, the following conclusions were drawn:

1. Class IV direct composite resin restorations showed good clinical outcomes, with a survival rate of 92.84% after 4 years.
2. Use of both the MLT and PLT for Class IV anterior restorations provided acceptable durability, with mean survival periods of 46 and 47 months, respectively.
3. Fracture was the most common reason for restoration failure in both the MLT (3.9%) and PLT (4.3%) groups.
4. Micro-/nanohybrid composite restorations showed a slightly higher survival rate (94.6%) than the microhybrid composite restorations (90.8% survival), but the difference was not statistically significant.
5. Monochromatic layered microhybrid and polychromatic layered micro-/nanohybrid Class IV restorations showed no significant difference in optical properties over the 4-year study period.

Regulatory Statement

This retrospective study was approved by Ethics Committee of Marmara University Faculty of Dentistry (Approval no: 2018-198 and approval date: 24.05.2018).The approval code issued for this study is 2018-198.

Conflict of Interest

The authors of this manuscript certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this manuscript.

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REFERENCES

1. Coelho-de-Souza FH, Gonçalves DS, Sales MP, Erhardt MCG, Correa MB, Opdam NJM, & Demarco FF (2015) Direct anterior composite veneers in vital and non-vital teeth: A retrospective clinical evaluation *Journal of Dentistry* **43(11)** 1330-1336. http://dx.doi.org/10.1016/j.jdent.2015.08.011

2. Demirci M, Tuncer S, Öztaş E, Tekçe N, & Uysal Ö (2015) A 4-year clinical evaluation of direct composite build-ups for space closure after orthodontic treatment *Clinical Oral Investigations* **19(9)** 2187-2199. https://doi.org/10.1007/s00784-015-1458-8

3. Frese C, Schiller P, Staehle HJ, & Wolff D (2013) Recontouring teeth and closing diastemas with direct composite buildups: A 5-year follow-up *Journal of Dentistry* **41(11)** 979-985. https://doi.org/10.1016/j.jdent.2013.08.009

4. Ferracane JL (2011) Resin composite-state of the art *Dental Materials* **27(1)** 29-38. https://doi.org/10.1016/j.dental.2010.10.020

5. Demarco FF, Collares K, Coelho-de-Souza FH, Correa MB, Cenci MS, Moraes RR, & Opdam NJM (2015) Anterior composite restorations: A systematic review on long-term survival and reasons for failure *Dental Materials* **31(10)** 1214-1224. https://doi.org/10.1016/j.dental.2015.07.005

6. Wolff D, Kraus T, Schach C, Pritsch M, Mente J, Staehle HJ, & Ding P (2010) Recontouring teeth and closing diastemas with direct composite buildups: A clinical evaluation of survival and quality parameters *Journal of Dentistry* **38(12)** 1001-1009. https://doi.org/10.1016/j.jdent.2010.08.017

7. Baldissera RA, Corrêa MB, Schuch HS, Collares K, Nascimento GG, Jardim PS, Moraes RR, Opdam NJ, & Demarco FF (2013) Are there universal restorative composites for anterior and posterior teeth? *Journal of Dentistry* **41(11)** 1027-1035. https://doi.org/10.1016/j.jdent.2013.08.016

8. Van Dijken JWV & Pallesen U (2010) Fracture frequency and longevity of fractured resin composite, polyacid-modified resin composite, and resin modified glass ionomer cement Class IV restorations: An up to 14 years of follow-up *Clinical Oral Investigations* **14(2)** 217-222. https://doi.org/10.1007/s00784-009-0287-z

9. Peumans M, Van Meerbeek B, Lambrechts P, & Vanherle G (1997) The 5-year clinical performance of direct composite additions to correct tooth form and position. II. Marginal qualities *Clinical Oral Investigations* **1(1)** 19-26. https://doi.org/10.1007/s007840050003

10. Meijering AC, Creugers NHJ, Roeters FJM, & Mulder J (1998) Survival of three types of veneer restorations in a clinical trial: A 2.5-year interim evaluation *Journal of Dentistry* **26(7)** 563-568. https://doi.org/10.1016/S0300-5712(97)00032-8

11. Kubo S, Kawasaki A, & Hayashi Y (2011) Factors associated with the longevity of resin composite restorations *Dental Materials* **30(3)** 374-383. https://doi.org/10.4012/dmj.2010-191

12. Gresnigt MM, Kalk W, & Ozcan M (2012) Randomized controlled split-mouth clinical trial of direct laminate veneers with two micro-hybrid resin composites *Journal of Dentistry* **40(9)** 766-775. https://doi.org/10.1016/j.jdent.2012.05.010

13. Heintze SD, Rousson V, & Hickel R (2015) Clinical effectiveness of anterior restorations - A meta-analysis *Dental Materials* **31(5)** 481-495. https://doi.org/10.1016/j.dental.2015.01.015

14. Moraes RR, Goncalves LDS, Lancellotti AC, Consani S, Correr-Sobrinho L, & Sinhoreti MA (2009) Nanohybrid resin composites: Nanofiller loaded materials or traditional microhybrid resins? *Operative Dentistry* **34(5)** 551-557. https://doi.org/10.2341/08-043-L

15. Kaizer MR, de Oliveira-Ogliari A, Cenci MS, Opdam NJM, & Moraes RR (2014) Do nanofill or submicron composites show improved smoothness and gloss? A systematic review of *in vitro* studies *Dental Materials* **30(4)** 41-78. https://doi.org/10.1016/j.dental.2014.01.001

16. Lempel E, Lovász BV, Meszarics R, Jeges S, Tóth Á, & Szalma J (2017) Direct resin composite restorations for fractured maxillary teeth and diastema closure: A 7 years retrospective evaluation of survival and influencing factors *Dental Materials* **33(4)** 467-476. http://dx.doi.org/10.1016/j.dental.2017.02.001

17. Kanzow P & Wiegand A (2020) Retrospective analysis on the repair vs. replacement of composite restorations *Dental Materials 36*(**1**) 108-118. https://doi.org/10.1016/j.dental.2019.11.001

18. Da Rosa Rodolpho PA, Donassollo TA, Cenci MS, Loguercio AD, Moraes RR, Bronkhorst EM, Opdam NJM, & Demarco FF (2011) 22-year clinical evaluation of the performance of two posterior composites with different filler characteristics *Dental Materials* **27(10)** 955-963. https://doi.org/10.1016/j.dental.2011.06.001

19. Van de Sande FH, Opdam NJ, Da Rosa Rodolpho PA, Correa MB, Demarco FF, & Cenci MS (2013) Patient risk factors' influence on survival of posterior composites *Journal of Dental Research* **92(7)** 78-83. https://doi.org/10.1177/0022034513484337

20. Dietschi D, Shahidi C, & Krejci I (2019) Clinical performance of direct anterior composite restorations: A systematic literature review and critical appraisal *International Journal of Esthetic Dentistry* **14(3)** 252-270.

21. Manhart J, Chen H, Hamm G, & Hickel R (2004) Buonocore memorial lecture. Review of the clinical survival of direct and indirect restorations in posterior teeth of the permanent dentition *Operative Dentistry* **29(5)** 481-508. https://doi.org/10.2341/1559-2863-29-5-1

22. Massano G, Comba A, Garombo E, Baldi A, Alovisi M, Damiano P, Multani S, & Scotti N (2019) Direct composite restorations of anterior teeth: A retrospective clinical study *Journal of Adhesive Dentistry* **21(5)** 465-456.

23. Al-Khayatt AS, Ray-Chaudhuri A, Poyser NJ, Briggs PFA, Porter RWJ, Kelleher MGD, & Eliyas S (2013) Direct composite restorations for the worn mandibular anterior dentition: A 7-year follow-up of a prospective randomized controlled split-mouth clinical trial *Journal of Oral Rehabilitation* **40(5)** 389-401. https://doi.org/10.1111/joor.12042

24. Vichi A, Ferrari M, & Davidson CL (2004) Color and opacity variations in three different resin-based composite products after water aging *Dental Materials* **20(6)** 530-534. https://doi.org/10.1016/j.dental.2002.11.001

25. Nasim I, Neelakantan P, Sujeer R, & Subbarao CV (2010) Color stability of microfilled, microhybrid and nanocomposite resins—an *in vitro* study *Journal of Dentistry* **38** 137-142. https://doi.org/10.1016/j.jdent.2010.05.020

26. Mitra SB, Wu D, & Holmes BN (2003) An application of nanotechnology in advanced dental materials *Journal of American Dental Association* **134(10)** 1382-1390. https://doi.org/10.14219/jada.archive.2003.0054

27. Milosevic A & Burnside G (2016) The survival of direct composite restorations in the management of severe tooth wear including attrition and erosion: A prospective 8-year study *Journal of Dentistry* **44** 13-19. https://doi.org/10.1016/j.jdent.2015.10.015

28. Tan DE & Tjan AH (1992) Margin designs and fracture resistance of incisal resin composite restorations *American Journal of Dentistry* **5(1)** 15-18.

29. Tekce N, Tuncer S, Demirci M, Serim ME, & Baydemir C (2015) The effect of different drinks on the color stability of different restorative materials after one month *Restorative Dentistry and Endodontics* **40(4)** 255-261. https://doi.org/10.5395/rde.2015.40.4.255

30. Gordon JC (2002) Preventing postoperative tooth sensitivity in Class I, II and V restorations *Journal of American Dental Association* **133(2)** 229-231. https://doi.org/10.14219/jada.archieve.2002.0149

31. Kanzow P & Wiegand A (2020) Retrospective analysis on the repair vs. replacement of composite restorations *Dental Materials* **36(1)** 108-118. https://doi.org/10.1016/j.dental.2019.11.001

32. Casagrande L, Laske M, Bronkhorst EM, Charlotte M, Huysmans DNJM, & Opdam NJM (2017) Repair may increase survival of direct posterior restorations-a practice based study *Journal of Dentistry* **64** 30-36. https://doi.org/10.1016/j.jdent.2017.06.002

33. van de Sande FH, Moraes RR, Elias RV, Montagner AF, Rodolpho PA, Demarco FF, & Cenci MS (2019) Is composite repair suitable for anterior restorations? A long-term practice-based clinical study *Clinical Oral Investigation* **23(6)** 2795-2803. https://doi.org/10.1007/s00784-018-2722-5