Long-Term Clinical Performance of Direct Composite Resin for Anterior Space Closure

: A Retrospective Evaluation

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감사의 글

석사 과정의 여정을 마무리하며, 이 논문을 완성하기까지 제가 받은 따뜻한 가르침과 응원에 마음 깊이 감사드립니다. 부족한 점이 많았던 저에게 아낌없는 조언과 진심 어린 격려를 보내주신 모든 분들께 이 글을 통해 존경과 감사의 마음을 전합니다.

먼저, 본 논문의 지도 교수님 이신 박정원 교수님께 깊이 감사드립니다. 항상 따뜻한 시선으로 이끌어 주시고, 세심한 피드백과 열정적인 지도 덕분에 끝까지 배움의 여정을 이어가며 논문을 완성할 수 있었습니다. 또한, 바쁘신 일정 가운데서도 논문 심사를 맡아 주시고, 보다 깊이 있는 방향으로 나아갈 수 있도록 귀중한 조언을 아끼지 않으신 신유석 교수님과 전미정 교수님께도 진심으로 감사드립니다. 교수님들의 섬세한 통찰과 격려는 학문을 대하는 자세를 다시금 돌아보게 해 주셨습니다.

더불어, 대학원 수련의로써 보존학의 기반을 다지는 데 있어 큰 가르침을 주신 신수정 교수님께도 진심으로 감사드립니다. 교수님께서 전해주신 보존학에 대한 진중한 태도와 따뜻한 관심은 늘 제 마음에 남아 있을 것입니다. 또한, 늘 제자들의 성장을 위해 아낌없이 헌신하시는 김의성 교수님, 정일영 교수님, 김선일 교수님, 김도현 교수님께도 감사의 마음을 전합니다.

항상 곁에서 서로 의지하며 함께 수련의 시간을 보낸 소중한 동기 윤희원 선생님에게도 고마운 마음을 전합니다. 동기와 함께한 날들은 치열했던 나날 속에서도 따뜻한 위로이자 든든한 힘이 되어 주었습니다. 그리고 늘 따뜻하게 응원해주시고 힘이 되어 주신 의국의 선후배 선생님들께도 깊이 감사드립니다.

마지막으로, 말로 다 표현할 수 없는 사랑과 응원으로 늘 든든한 힘이 되어 주신 부모님과 오빠에게 깊이 감사드립니다. 힘들 때마다 조건 없이 곁을 지켜준 가족의 존재는 언제나 가장 큰 힘이었습니다. 또한, 특유의 유쾌함으로 웃음을 주고, 현실적인 조언으로 늘 힘이 되어준 성원이에게도 진심으로 감사를 드리며 이 글을 마칩니다.

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ABSTRACT

Long-Term Clinical Performance of Direct Composite Resin for Anterior Space Closure

: A Retrospective Evaluation

This retrospective study evaluated anterior space closure with respect to its long-term clinical performance using direct composite resin, with a particular focus on restoration survival and the types of complications encountered over time. Spacing in the anterior region, such as diastema and black triangle, is frequently managed for esthetic reasons, and direct composite resin restoration offers a conservative, cost-effective and minimally invasive treatment option. However, current research remains insufficient data regarding the long-term clinical success and failure patterns of such treatments in actual clinical practice.

The study included 53 patients and 147 treated teeth that underwent anterior space closure at the Department of Conservative Dentistry in Gangnam Severance Dental Hospital from April 2007 to December 2021. Each restoration was assessed using the modified FDI criteria. The lowest clinical score across the evaluation parameters was used to determine the overall performance of each case. Follow-up durations were statistically analyzed in relation to these performance classifications.

The mean period of follow-up was 7.05 years, ranging from 2 to 17 years, allowing for a robust analysis of both short and long-term outcomes. Survival analysis using the Kaplan-Meier method revealed a cumulative success rate of 96%, with only six restorations classified as “clinically unacceptable”, indicating failure. Cases of failure included material fracture, poor color match and

translucency, and one case involving both marginal discoloration and esthetic anatomical form.

Among all restorations, marginal discoloration (n=49) was the most prevalent finding issue, followed by changes in the modified gingival index (n=37) and deterioration in esthetic anatomical form (n=31). A distinct trend was noted wherein lower clinical scores were associated with longer follow-up durations, suggesting progressive degradation over time. However, fracture-related failures showed a non-linear pattern. Restorations rated as clinically good had longer follow-up durations than those rated as very good, while restorations considered clinically satisfactory demonstrated the shortest follow-up period before increasing again in clinically unsatisfactory cases.

In conclusion, this study demonstrated that direct composite resin restorations for anterior space closure exhibited a 96% long-term success rate, with sustained esthetic and functional outcomes over time. The minimally invasive nature of this technique contributed to its favorable prognosis. Moreover, regular clinical follow-up may further enhance long-term outcomes by enabling early detection and management of potential complications. This study contributed valuable clinical evidence supporting the application of direct composite techniques in esthetic anterior treatments.

Keywords**:** diastema closure, direct composite resin, FDI criteria, longevity, long-term evaluation, survival

1. Introduction

Esthetic management of anterior spacing, including diastema and black triangle closure, is a critical aspect of restorative dentistry, as gaps in the anterior dentition can significantly impact a patient's smile and overall facial harmony. Various treatment modalities are available for anterior spacing correction, including direct composite resin restorations, prosthetic approaches, and orthodontic treatment.[1,2] Prosthetic options, such as porcelain veneers and full-coverage restorations like crowns or bridges, provide superior esthetics, durability, and stain resistance. However, these treatments require varying degrees of tooth reduction, making them irreversible. Orthodontic treatment, while preserving natural tooth structure, is often time-consuming and may not be suitable for patients seeking immediate esthetic improvements. Among these options, direct composite resin restorations provide a minimally invasive and cost-effective solution that maintains tooth structure while allowing for immediate esthetic enhancement. Despite their susceptibility to wear, discoloration, and marginal degradation over time compared to ceramic restorations, advancements in adhesive systems and composite resin materials have significantly improved their longevity and clinical performance.[3]

Several clinical investigations have assessed the outcomes of direct composite restorations used for anterior teeth, reporting survival rates typically exceeding 80-90% over 4-7 years. Korkut et al. documented a 4 year survival rate of 90.3% in 216 restorations, with an annual failure rate of 0.9-3.4%.[5] Lempel et al. found a 7.2 year survival rate in 163 restorations.[6] Frese et al. observed an 84.6% survival rate after 5 years in 176 cases.[1] Peumans et al. noted a 5 year survival rate of 89%, further supporting the long-term viability of these restorations.[7] These findings suggest that direct composite restorations in the anterior region demonstrate favorable longevity, with variations

influenced by material properties, patient factors, and clinical techniques.[8,9]

However, despite the broad clinical practice of direct composite resin restorations for anterior space closure, existing studies are limited by relatively short follow-up periods-with follow-up durations commonly under 10 years, making it difficult to fully assess their long-term performance and durability.[4]

Additionally, there is inconsistency in the evaluation criteria across studies, as the definition of restoration failure – such as discoloration, wear, marginal integrity, and retention – varies, making direct comparisons between studies challenging. Clinical evaluation of resin restorations is commonly performed using standardized criteria such as the FDI system and modified USPHS criteria, which assess esthetic, functional, and biological properties.[10] However, these criteria may not fully capture certain aspects specific to diastema closure. To enhance clinical relevance and provide a more precise evaluation of anterior composite restorations, modifications were made in this study.

This study aims to assess the clinical reliability and longevity of direct composite resin restorations for anterior space closure for a long-term follow up. By assessing key clinical parameters and analyzing survival rates using robust statistical methods, this research intends to offer valuable perspectives on the long-term efficacy of this restorative approach. Understanding the factors that influence restoration success will aid in optimizing clinical protocols and improving patient outcomes in esthetic dentistry.

2. Materials and Methods

2.1. Study design and participants

Ethical approval for this study was obtained from the Institutional Review Board of Gangnam Severance Hospital (IRB approval number: 3-2024-0316). Patients who visited the Department of Conservative Dentistry in Gangnam Severance Dental Hospital and underwent anterior space closure using direct composite resin, including diastema closure and black triangle closure, from April 2007 to December 2021 were included in the study. The final treatment outcomes were evaluated during follow-up appointments. To ensure reliable follow-up data, patients must have consistently attended clinical recall visits at least two years post-treatment with available clinical photographs and had not received treatment from other dentists during the observation period. Complete clinical photographic records were essential for inclusion, covering pre-treatment, immediate post-treatment, and routine follow-up visits. Cases lacking follow-up photographic documentation were excluded to maintain data reliability.

At our clinic, 137 patients underwent diastema and black triangle closure more than 2 years ago. Among them, 57 patients had a follow-up time longer than 2 years with available clinical photographs. A retrospective study was conducted on these 57 patients. In total, 147 composite resin restorations were placed across this patient group, including 139 cases of diastema closure, 6 cases involving black triangle closure combined with resin veneer placement, and 2 cases of black triangle closure alone. Details regarding the gender, age, and tooth number of the cases are presented in Table 1. Data on re-polishing, repairs, and replacement of restorations were meticulously collected from patient records.

Table 1. Distribution of the restorations based on the gender, age, tooth number

Sex	N(%)	Age	N(%)	Tooth number	N(%)
Male	36 (24)	14~19	31 (21)	11, 21	36 (24)
Female	111 (76)	20~29	50 (34)	12, 22	63 (43)
		30~39	8 (5)	13, 23	33 (22)
		40~49	29 (20)	14, 24	2 (1)
		50~59	17 (12)	31, 41	7 (5)
		60~69	8 (5)	32, 42	5 (3)
		70~73	4 (3)	44	1 (1)
total	147(100)	total	147(100)	total	147(100)

2.2. Restorative procedure

All procedures were conducted by a specialist in restorative dentistry, who also holds a teaching position at a university, ensuring a high standard of expertise and consistency across all treatments.

In adherence to the principles of minimally invasive dentistry, all restorations were designed to preserve as much natural tooth structure as possible. The surfaces of the teeth were prepared by roughening them with abrasive discs (Sof-Lex™ Discs, 3M ESPE, St. Paul, MN, USA) to create an ideal surface for bonding. For restorations limited to enamel, 37% phosphoric acid (Etch-37, Bisco, Schaumburg, IL, USA) was applied for 15 seconds, rinsed, and dried, followed by bonding agent application per manufacturer's protocol. When dentin was involved, a selective-etch approach was utilized, in which the enamel surface was treated with phosphoric acid for 15 seconds while avoiding excessive etching of the dentin. After rinsing, the cavity was gently dried to maintain slight dentin moisture before applying the adhesive. Three adhesive systems were used: Clearfil SE bond

(Kuraray Noritake Dental, Tokyo, Japan; 124 cases), XP bond (Dentsply Sirona, York, PA, USA; 22 cases), and OptiBond FL (Kerr Corporation, Orange, CA, USA; 4 cases). Table 2 provides details on the brand names, types, manufacturers, and chemical compositions of the materials used in the study. All adhesive steps were performed in accordance with the manufacturers' instructions.

Table 2. Details of the materials used in this study, including brand names, types, manufacturers, and chemical compositions

Brand	Type	Manufacturer	Chemical composition
Etch-37	37% phosphoric acid etchant	Bisco, Inc., USA	Phosphoric acid (H_3PO_4) 37%, water, silica-thickened gel, polyethylene glycol, dye
OptiBond FL	3-step etch-and-rinse adhesive	Kerr, USA	**Primer:** GPDM (Glycerophosphate dimethacrylate), HEMA, ethanol, water, photoinitiator **Adhesive:** HEMA, Bis-GMA, barium aluminosilicate glass, fumed silica, camphorquinone, photoinitiators, stabilizers
XP bond	2-step etch-and-rinse adhesive	Dentsply Sirona, USA	PENTA (dipentaerythritol penta acrylate monophosphate), TCB resin, UDMA, HEMA, TEGDMA, butylated hydroxytoluene (BHT), acetone, camphorquinone, photoinitiators, stabilizers
Clearfil SE bond	2-step self-etch adhesive	Kuraray Noritake, Japan	**Primer:** MDP (10-Methacryloyloxydecyl dihydrogen phosphate), HEMA, hydrophilic dimethacrylates, water, **Bonding:** Bis-GMA, MDP, HEMA, UDMA, silica fillers, camphorquinone, photoinitiators, accelerators
Tetric N-Ceram	Nano-hybrid composite	Ivoclar Vivadent, Liechtenstein	Bis-GMA, UDMA, TEGDMA, Bis-EMA, barium glass filler, ytterbium, mixed oxides, prepolymer fillers, silane coupling agents, camphorquinone
Filtek Supreme	Nanocomposite	3M ESPE, USA	Bis-GMA, UDMA, TEGDMA, Bis-EMA, zirconia/silica nanofillers, aggregated zirconia/silica clusters, photoinitiators, stabilizers
Estelite Sigma Quick	Supra-nano-filled composite	Tokuyama Dental, Japan	Bis-GMA, TEGDMA, UDMA, spherical silica-zirconia fillers, silane-treated fillers, camphorquinone, photoinitiators
Esthet-X HD	Nano-hybrid composite	Dentsply Sirona, USA	Bis-GMA, TEGDMA, UDMA, barium glass filler, silica nanoparticles, ytterbium fluoride, photoinitiators, stabilizers
Filtek Z350 XT	Nanocomposite	3M ESPE, USA	Bis-GMA, UDMA, TEGDMA, Bis-EMA, zirconia/silica nanofillers, aggregated zirconia/silica clusters, photoinitiators, stabilizers

The composite resin was placed employing the free-hand layering technique. In most cases, Tetric-N-Ceram was primarily used to construct the lingual wall, while a combination of different composite resins was selected as needed. Light curing was performed for 10 seconds on each resin layer, with the last labial layer receiving a prolonged curing time of 40 seconds. A high-light LED curing unit (Satelec Mini-LED, Acteon, France, or 3M Light Curing Unit, 3M ESPE) was used.

After the resin layers were fully cured, the finishing process was systematically carried out in the following sequence: occlusal adjustment, shape refinement, margin trimming, and final polishing. Any excess material along the margins was precisely trimmed using a No. 12 blade, allowing for precise removal of overhangs or irregularities without compromising the restoration's margins or contours. Shape refinement was performed using an extra-fine diamond point to achieve natural anatomy and seamless integration. The final polishing sequence involved the use of Sof-Lex discs (3M ESPE) for initial smoothing, followed by Enhance (Dentsply Sirona) and PoGo (Dentsply Sirona) for further surface refinement. To achieve a superior natural gloss, the Ultradent Jiffy polishing system (Ultradent) was additionally utilized.

Table 3. Modified FDI evaluation criteria and gradings (Esthetic properties : 1-6, Functional properties : 7-8, and Biological properties : 9)

	Esthetic properties						Functional properties		Biological properties
	1. Surface luster	2. Surface staining	3. Marginal discoloration	4. Color match and translucency	5. Esthetic anatomical form	6. emergence profile	7. fracture of material and retention	8. marginal adaptation	9. modified gingival index(MGI)
1. Clinically very good	1.1 Luster comparable to enamel	2.1 No surface staining	3.1 No discoloration at the margins	4.1 good color match, no difference in shade and/or translucency	5.1 Form is ideal	6.1 Ideal profile, proper angle	7.1 Restoration retained, no fracture/crack	8.1 Harmonious outline, no gaps, no discoloration	9.1 normal gingiva(no inflammation / healthy pink color)
2. Clinically good	1.2 Slightly dull, not noticeable from speaking distance (Some isolated pores)	2.2 Minor surface staining, easily removable by polishing	3.2 Minimal discoloration present, only detectable upon close inspection (~1/3)	4.2 Minor deviations in shade and/or translucency	5.2 Form is only slightly deviated from the normal	6.2 Mostly appropriate, some correction needed	7.2 Small hairline crack	8.2 Small marginal fracture/gap removable by polishing	9.2 mild inflammation (slight redness / no noticeable swelling)
3. Clinically satisfactory	1.3 Dull surface but acceptable if covered with film of saliva (Multiple pores on more than 1/3 of the surface)	2.3 Moderate surface staining, not esthetically unacceptable	3.3 Mild discoloration noticeable but not affecting overall appearance (1/3~1/2)	4.3 Distinct deviation but acceptable not affecting esthetics (More opaque, more translucent, lighter or darker)	5.3 Form deviates from the normal but is esthetically acceptable	6.3 acceptable but need more minor improvements	7.3 Two or more or larger hairline cracks and/or chipping	8.3 Several small enamel or dentin fractures / gap<150um not removable	9.3 moderate inflammation (redness / no swelling or minimal swelling)
4. Clinically unsatisfactory (but repairable)	1.4 Rough surface, cannot be masked by saliva and simple polishing is not sufficient (intervention is necessary)	2.4 Pronounced surface staining, major intervention necessary	3.4 Noticeable discoloration at the margins affecting appearance (1/2 ~2/3)	4.4 Localized clinically deviation that can be corrected (Too opaque, too translucent, too light or too dark)	5.4 Form is effected and unacceptable esthetically (intervention/correction is necessary)	6.4 Inadequate, significant adjustments required	7.4 Chipping or bulk fractures with or without partial loss (less than half of the restoration)	8.4 Notable enamel or dentine wall fracture / gap>250um or dentine/base exposed	9.4 moderate to severe inflammation (redness / obvious swelling)
5. clinically poor (replacement necessary)	1.5 Very rough unacceptable plaque retentive surface	2.5 Deep surface staining not accessible for intervention	3.5 Severe discoloration present, significantly affecting appearance (2/3~overall margin)	4.5 Unacceptable color match, Replacement is necessary	5.5 Partial or complete loss of restoration	6.5 Very poor, needs replacement	7.5 Partial or complete loss of restoration	8.5 Filling is loose but in situ	9.5 severe inflammation (Severe redness, swelling / possible ulceration)

2.3. Clinical examination

Patient information was collected through medical and dental records and clinical examinations. Additionally, photographic records were meticulously reviewed, serving as a critical tool in evaluating the restorations. A standardized photography protocol was implemented to maintain consistency and accuracy. The photographic equipment consisted of a full-frame camera body (D200, Nikon, Tokyo, Japan), a macro lens (AF Micro-Nikkor 105mm, Nikon, Tokyo, Japan) and a ring flash (EM-140DG, Sigma, Kawasaki, Japan). These high-quality tools allowed for detailed and uniform intraoral images across all cases. Clinical photographs were taken at all time points - pre-treatment, post-treatment and follow-up visits, with the same equipment and settings.

The evaluation of the restorations was conducted by two examiners who were properly trained and calibrated before the study was conducted. In cases where the two examiners disagreed, the final assessment was determined by a third examiner, who had also undergone the same training and calibration process to ensure consistency in evaluation.

They assessed the restorations using a modified version of the FDI clinical criteria, which evaluate three major categories: esthetic properties (parameters 1-6), functional properties (parameters 7-8), and biological properties (parameter 9), as summarized in Table 3. Several modifications were made to the original framework. In the esthetic domain, marginal discoloration and emergence profile were added. Notably, marginal discoloration is not included in the original FDI criteria but is a parameter commonly assessed in the USPHS (United States Public Health Service) system. In the functional domain, wear and proximal contact were excluded, while in the biological domain, post-operative hypersensitivity and tooth vitality, recurrence of caries, and erosion, abfraction, and tooth integrity were removed. Additionally, adjacent mucosa was replaced with the Modified Gingival

Index (MGI) to provide a standardized assessment of gingival health.

At both baseline and the last follow-up, the restorations' clinical condition was assessed in detailed using these criteria. Dental records were reviewed to trace the history of each restorations, focusing on events such as repairs, replacements or any failure. Any restoration deemed a failure, either due to replacement or repair, was excluded from further follow-up analyses. Reasons for failure, such as marginal discoloration, chipping, or other adverse events, were carefully documented. In some cases, minor damage went unnoticed by the patients and was identified only during recall examinations. If the exact date of such events was unknown, the date of the recall visit was used as a reference point.

2.4. Statistical Analysis

All statistical analyses were performed using version 9.4 of the SAS program (SAS Institute, Cary, NC, USA). A descriptive statistical approach was applied to outline the frequency distributions of the clinical evaluation scores and document the reasons for failure. Each of the nine parameters from the modified FDI criteria was analyzed to provide a detailed understanding of the restorations' performance across different aspects.

To account for the clustering of multiple restorations within the same patient, the generalized estimating equations (GEEs) method was used to adjust for intra-patient correlations. Additionally, p-values were calculated using the GEE method to compare failure rates across evaluation criteria.

The main outcome assessed in the study was the survival time of the restorations, which refers to the period from placement to the occurrence of any failure or unfavorable clinical event. Kaplan-Meier analysis was used to generate survival curves, providing a visual representation of restoration

longevity.

3. Results

A total of 147 anterior direct composite resin in 57 patients were evaluated. The follow-up time varied between 2 and 17 years, with a mean duration of 7.05 years and a median duration of 6.24 years. The distribution of follow-up durations is illustrated in Figure 1.

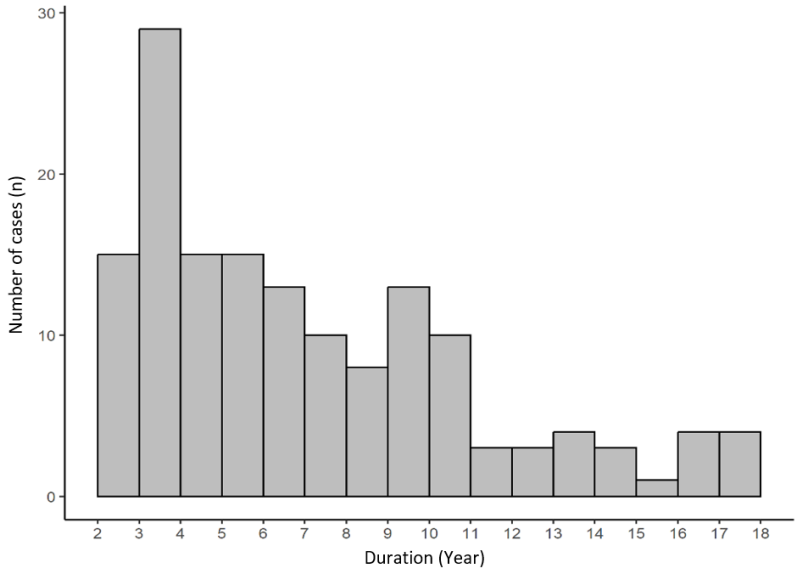

Figure 1. Histogram illustrating the distribution of cases based on follow-up duration (in years).

Restorations classified as clinically very good, good, or satisfactory were considered as survival, and restorations undergoing repair or replacement were classified as clinically unacceptable (FDI

scores of 4 or 5) and categorized as failures in the analysis. The overall survival rate of the restorations over the observation period was 96%.

Some examples of the restorations are shown in Figure 2, 3 and 4. Figure 2 shows a case with a follow-up duration of 16 years, demonstrating an excellent long-term outcome. In contrast, Figure 3 presents a case with an 11-year follow-up, in which gingival recession over time resulted in an altered emergence profile.

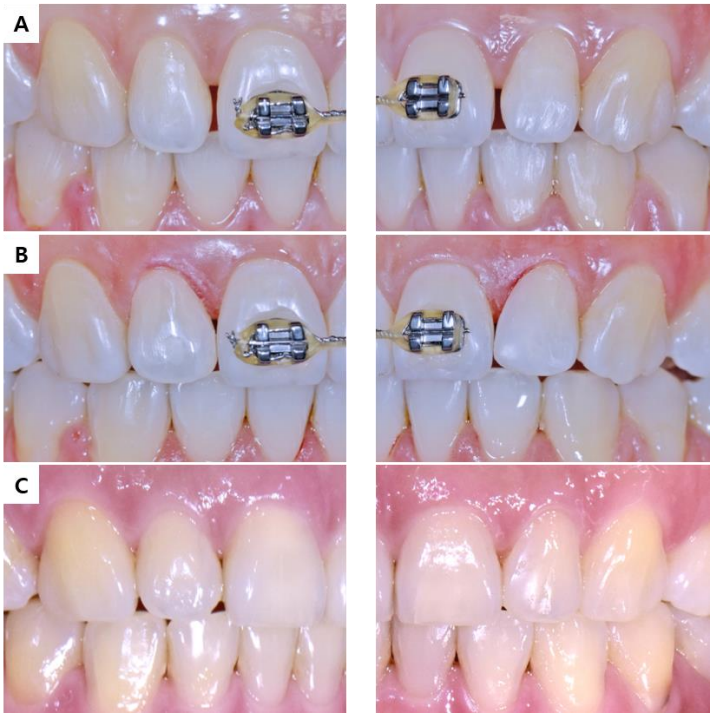

Figure 2. Clinical photographs with 16 years of follow-up showing excellent long-term outcomes (A: pre-treatment, B: post-treatment, C: follow-up stages)

Figure 3. Clinical photographs with 11 years of follow-up, showing gingival recession over time and a resulting alteration in the emergence profile (A: pre-treatment, B: post-treatment, C: follow-up stages)

Figure 4 shows a clinical case classified as clinically unacceptable due to a fracture of the material. The follow-up duration for this case was 2.5 years. Upon detection of the fracture, resin replacement was performed on the same day.

Figure 4. Clinical photographs with failed case due to fracture of restorative material (A: follow-up stage, B: after resin replacement)

Figure 5 presents a comprehensive visualization of restoration by combining a histogram of follow-up cases with a Kaplan Meier survival curve. The histogram categorizes restorations based on their follow-up duration, showing the cumulative number of cases at each time interval while distinguishing between successful and failed restorations, with failed cases marked in red. The overlaid Kaplan-Meier curve provides a survival analysis by estimating the probability of restoration success over time.

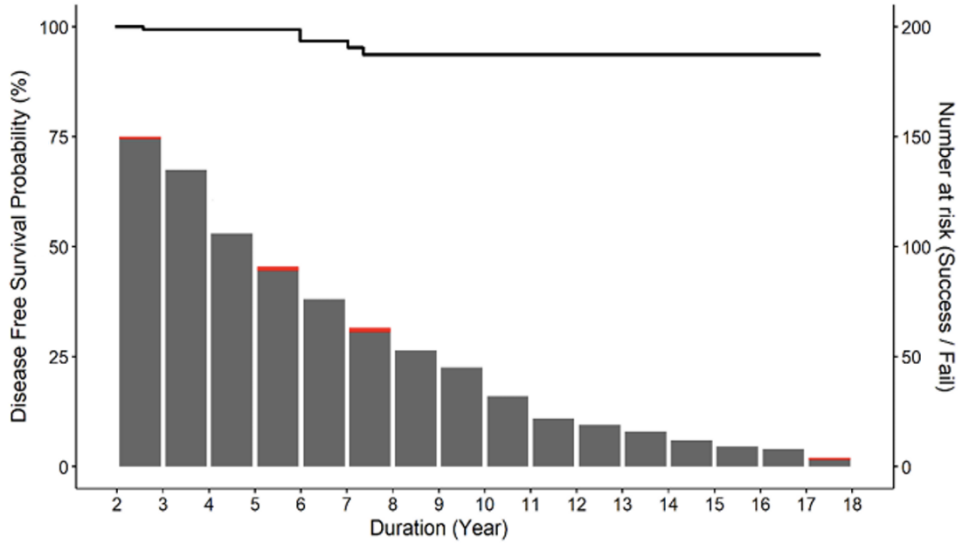

Figure 5. Histogram displaying the number of restorations followed over time in one-year intervals, with successful and failed cases differentiated, where failed cases are marked in red. The Kaplan-Meier curve is overlaid to illustrate the cumulative success rate, accounting for censored data.

Tables 4 and 5 summarize the relationship between clinical performance and follow-up duration. Table 4 provides a comprehensive overview of the observation periods associated with different

levels of clinical evaluation, with the follow-up duration for each case aligned with its lowest recorded score. Table 5 details the distribution of evaluation scores across nine assessment parameters based on the modified FDI criteria, presenting both the number of cases per score category and their respective follow-up durations. This allows for an analysis of the clinical outcomes in relation to time.

Table 4. Summary of the overall follow-up duration(years) for all evaluated restorations, based on the lowest FDI grade assigned during the follow-up period.

		Clinically very good	Clinically good	Clinically satisfactory	Clinically unsatisfactory	Clinically poor	Total
Overall	Median (Min-Max)	5.10 (2.13-16.28)	6.88 (2.69-17.14)	10.69 (2.53-17.27)	6.50 (2.57-17.27)		6.24 (2.13-17.27)
	Mean (SD)	6.28 (3.64)	7.19 (4.01)	9.61 (4.23)	7.69 (4.99)		7.05 (3.99)

Among the 147 restorations assessed, 63 restorations (43%) were classified as clinically very good with no detectable changes or remarks. Conversely, cases rated as clinically good, satisfactory, or below were most frequently associated with marginal discoloration (n=49), followed by issues related to the modified gingival index(n=37) and esthetic anatomical form (n=31). Among them, 6 restorations (4%) were deemed clinically unacceptable and categorized as failures. Contributing factors to failure included fractures of the restoration (n=3), color match and translucency (n=2), marginal discoloration and esthetic anatomical form (n=1). Notably, no restoration received the lowest score, indicating that none were classified as clinically poor.

Table 5. The distribution of evaluation scores and corresponding follow-up duration across 9 evaluation parameters based on the modified FDI criteria.

		Clinically very good	Clinically good	Clinically satisfactory	Clinically unsatisfactory	Clinically poor
Aesthetic properties						
Surface luster	Median (Min-Max)	6.24 (2.13-17.27)	4.91	17.27		
	N (%)	145 (98.7)	1 (0.7)	1 (0.7)		
Surface staining	Median (Min-Max)	6.24 (2.13-17.27)	17.27			
	N (%)	146 (99.3)	1 (0.7)			
Marginal discoloration	Median (Min-Max)	5.15 (2.13-17.14)	7.07 (2.89-17.27)	10.69 (6.88-13.74)	17.27	
	N (%)	98 (65.3)	41 (29.3)	7 (4.7)	1 (0.7)	
Color match and translucency	Median (Min-Max)	5.65 (2.13-16.28)	7.30 (2.69-17.14)	9.15 (2.89-17.27)	5.98	
	N (%)	128 (87.3)	11 (7.3)	6 (4.0)	2 (1.3)	
Esthetic anatomical form	Median (Min-Max)	5.15 (2.13-16.28)	8.02 (2.57-17.14)	11.09 (4.91-17.27)	17.27	
	N (%)	116 (79.3)	28 (18.7)	2 (1.3)	1 (0.7)	
Emergence profile	Median (Min-Max)	6.11 (2.13-17.27)		10.69		
	N (%)	145 (98.7)		2 (1.3)		
Functional properties						
Fracture of material	Median (Min-Max)	6.24 (2.13-17.27)	10.95	2.89	7.02 (2.57-7.35)	
	N (%)	142 (96.7)	1 (0.7)	1 (0.7)	3 (2.0)	
Marginal adaptation	Median (Min-Max)	6.24 (2.13-17.27)				
	N (%)	147 (100.0)				
Biological properties						
Modified gingival index (MGI)	Median (Min-Max)	5.67 (2.13-17.27)	7.30 (2.89-14.38)	8.46 (2.53-14.38)		
	N (%)	110 (73.3)	35 (25.3)	2 (1.3)		

4. Discussion

This retrospective study demonstrates the high long-term clinical success of direct composite resin restorations for anterior space closure, with a 96% success rate over follow-up period ranging from 25 months to 17 years (mean: 7.05 years). Compared to previously reported survival rates of 84.6% to 90.3% over 4-7 years,[1,5,6,7] these results further validate the durability, functionality, and esthetic stability of composite resin in anterior space closure when performed under standardized clinical protocols. Direct composite resin techniques provide a minimally invasive and cost-effective alternative to ceramic veneers or crowns, particularly for patients seeking conservative treatment options[4]. In addition to their favorable mechanical and esthetic performance, composite resin exhibits excellent biocompatibility, especially in cases like diastema and black triangle closure. Given the predictable success, clinicians may consider direct composite resin restorations as a first-line treatment for anterior space closure. The findings encourage a shift towards minimally invasive dentistry while maintaining patient satisfaction through high-quality esthetic outcomes.

The restorations were evaluated according to the FDI evaluation criteria, systematically categorized into three key domains: esthetic, functional, and biologic properties.[11,12] To better align the assessment with the study objectives, modifications were made to enhance clinical relevance by emphasizing the durability, functional stability, and structural integrity of the resin restorations. A detailed examination of each category reveals the following. Marginal discoloration was added to distinguish between superficial staining and deep bonding interface discoloration, improving early detection of adhesive failure or microleakage.[13] Emergence profile was introduced to assess the transition between the restoration and gingival margin, ensuring better gingival health and plaque control. Conversely, wear and proximal contact were excluded as separate criteria because wear is

multifactorial and assessed under occlusion, while proximal contact is already considered under form and contour. Post-operative hypersensitivity and tooth vitality were removed since they are not a primary indicator of restoration quality, and recurrence of caries was excluded as it is already assessed under marginal adaptation and caries at restoration margins, eliminating redundancy. Similarly, erosion, abfraction, and tooth integrity were removed because they are primarily host-related rather than restoration-related.[14] Lastly, adjacent mucosa was replaced with the Modified gingival index to provide a more standardized and structured assessment of gingival response, aligning the criteria more effectively with clinical and periodontal considerations. These modifications ensure a streamlined yet comprehensive assessment of restorations, improving applicability in both clinical practice and research settings. Additionally, this study supports the use of modified FDI criteria as an effective tool for evaluating restorative outcomes across multiple domains.

The esthetic parameters are essential for patient satisfaction, particularly in anterior restorations where visual appearance is paramount. Surface luster and staining scored particularly well, with 98-99% of cases classified as clinically very good or good. The high gloss retention of nano-filled composite resin like Filtek Z350 (3M ESPE) also contributed to these outcomes. As previous studies have demonstrated, nano-filled composite exhibits enhanced gloss retention due to their smaller filler sizes and uniform distribution, which reduce diffuse reflection and contribute to a smooth, highly reflective surface. This material property, combined with meticulous finishing and polishing procedures, likely played a key role in maintaining long-term esthetic outcomes.[15, 16] However, both marginal discoloration and esthetic anatomical form exhibited a trend of gradual deterioration over time. Restorations initially rated as clinically very good for marginal discoloration had shorter follow-up durations, reflecting their initial aesthetic acceptability. As discoloration progressed,

restorations transitioned to lower grades with longer follow-up periods. The greater susceptibility of composite resins to staining and discoloration over time, in comparison with ceramics, underscores the importance of appropriate finishing, regular maintenance, and patient compliance for long-term esthetic success.[17] Similarly, color match and translucency were rated as clinically very good or good in over 70% of cases, yet this parameter exhibited the highest sensitivity to degradation, with clinically poor ratings often observed after shorter follow-up durations. Intrinsic factors such as dentin sclerosis and extrinsic factors may have contributed to shade discrepancies, but the aging of composite resin itself remains a significant factor.[17, 18] The gradual mismatch between restoration and natural tooth shade over time further emphasizes the limitations of composite materials in long-term esthetic harmony. And the decline in esthetic anatomical form over time underscores the gradual wear or deformation, stressing early detection and intervention for minor defects to prevent significant compromise.[19]

The functional parameters showed excellent marginal adaptation scored, with 100% of cases falling into the clinically very good, reflecting precise finishing. In contrast, fracture of material presented an atypical pattern, indicating that minor fractures of chipping may remain clinically acceptable for an extended period, as they do not immediately compromise the restoration's function. However, over time, mechanical stresses and material limitations can lead to progression, with more substantial failures requiring earlier intervention.[20] Among the six failed restorations in this study, three were due to fracture of the composite material. These findings are in line with those of Lempel et al.,[6] Peumans et al.,[7] van Dijken et al.,[22] all of whom emphasized material fracture as a principal failure mode in long-term evaluation of direct resin restorations. Preventive measures, such as occlusal adjustments and regular monitoring, are critical to identifying early signs of material deterioration, ensuring timely intervention before restoration failure occurs.

The biologic response, assessed through the modified gingival index (MGI) with over 73% of cases maintained clinically very good gingival health. Most assessments were performed 1 to 3 months after treatment, with additional polishing applied when irritation occurred, helping to reduce plaque accumulation and soft tissue inflammation. The increasing follow-up durations for lower-grade restorations suggest that mild gingival issues are often tolerated unless function or aesthetic concern were affected. These findings underscore the importance of optimizing marginal adaptation and plaque control. Regular professional cleanings and patient education on oral hygiene remain essential to maintain biologic compatibility over time.[4, 6, 21]

The remarkable success of anterior space closure using direct composite resin in this study can be attributed to several critical factors: operator expertise, standardized clinical protocols, material properties, and patient compliance. Operator expertise played a significant role, as all procedures were performed by a specialist with advanced skills in restorative dentistry. This high level of technical proficiency may have minimized potential procedural errors – such as suboptimal bonding, contouring, or polymerization – that could affect long-term outcomes. Nevertheless, the consistently high success rate observed also suggests that when standardized protocols are rigorously followed - including meticulous bonding, finishing and polishing procedures – the outcomes can be favorable and clinically predictable, even when performed by less experienced clinicians.[8] Therefore, while the operator factor cannot be completely excluded, the structured approach described in this study provides a reproducible framework for achieving successful outcomes in broader clinical settings. Advances in composite resin formulations - particularly in filler particle size and distribution – have improved the material's physical and optical properties, which are especially important in anterior restorations where shade matching, translucency, and surface texture are critical. In this regard, the findings provide evidence that nano-fill type composites are sufficient for maintaining long-term

esthetic stability.[15, 16] Additionally, patient compliance, including regular maintenance and good oral hygiene, played a key role in long-term success. Periodic follow-ups enabled early detection and management of minor defects, while patient education on diet and parafunctional habits like bruxism helped reduce functional stress on restorations.[4, 23]

Although the results are favorable, this study has some limitations. The retrospective design inherently introduces certain biases, such as variations in follow-up duration and potential gaps in restoration history. While efforts were made to standardize data collection, retrospective studies inherently rely on the accuracy and completeness of historical records. The sample size, although adequate for statistical analysis, might restrict the generalizability of the findings to wider populations. Factors such as age, occlusal habits, and oral hygiene compliance can vary among patients and may influence restoration longevity. Additionally, inter- and intra-examiner variability, though minimized through calibration, remains a potential source of inconsistency.[24] Disagreements requiring third-examiner evaluation could introduce subtle scoring variations. Lastly, while clinical and photographic assessments were effective for evaluating outcomes, additional methods such as patient-reported satisfaction scores or quantitative surface analysis could provide further insights into restoration quality and longevity.[25]

5. Conclusion

This study provided evidence of the long-term clinical performance of direct composite resin restorations in closing diastemas and black triangles when implemented under standardized clinical

protocols. The consistent outcomes across esthetic, functional, and biological aspects highlighted the importance of a systematic and minimally invasive approach in anterior restorative treatment. In addition, regular clinical follow-up supported the durability of results by allowing for the timely identification and management of potential complications. Overall, these findings supported the use of direct composite techniques as a reliable and conservative option for anterior esthetic rehabilitation.

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Abstract in Korean

전치부 공간 폐쇄를 위한 직접 복합 레진 수복의 장기적 임상 결과에 관한 후향적 연구

본 후향적 임상 연구는 직접 복합 레진 수복을 이용한 전치부 공간 폐쇄 치료의 장기적인 임상 성과를 평가하고, 시간 경과에 따른 수복물의 생존율 및 발 생 가능한 합병증의 양상을 분석하고자 하였다. 정중부 이개(diastema)는 주로 심미적 이유로 치료되며, 직접 복합 레진 수복은 보존적이고 비용 효율적이며 최소 침습적인 치료 방법으로 널리 사용되고 있다. 그러나 실제 임상 환경에서 이러한 치료의 장기적인 성공률 및 실패 양상에 대한 데이터는 아직 부족한 실정이다.

본 연구는 2007년 4월부터 2021년 12월까지 강남 세브란스 치과병원 보존과에서 직접 복합 레진으로 전치부 공간 폐쇄 치료를 받은 53명의 환자, 총 147개 치아를 대상으로 하였다. 모든 수복물은 수정된 FDI 평가 기준에 따라 평가되었으며, 9개 평가 항목 중 가장 낮은 점수를 해당 수복물의 전반적인 평가 등급으로 사용하였다. 이후, 각 등급별로 추적 관찰 기간을 통계적으로 분석하였다.

평균 추적 관찰 기간은 7.05년(범위: 2-17년)으로, 단기 및 장기 성과를 모두 평가하기에 충분한 기간이었다. Kaplan-Meier 생존 분석 결과, 누적 성공률은 96%로 나타났으며, ‘임상적으로 부적합(clinically unacceptable)’으로 분류된 실패 사례는 6건에 불과했다. 이들 실패 사례는 수복물 파절, 색조 및 투명도의 부조화, 그리고 변연 변색 및 해부학적 형태의 손상이 복합적으로 나타난 경우를 포함하였다.

전체 수복물 중 가장 흔하게 관찰된 문제는 변연 변색(n=52)이었으며, 그 외에는 변형된 치은 지수(n=40), 심미적 해부학적 형태의 저하(n=31) 순으로 나타났다. 추적 관찰 기간이 길수록 임상 평가 점수가 낮아지는 경향이 뚜렷하게 확인되었으며, 이는 시간이 지남에 따라 수복물의 질이 점차 저하됨을 시사한다. 하지만, 수복물의 파절은 이러한 경향과는 다르게 비선형적인 양상을 보였으며, 임상적으로 보통

(clinically satisfactory) 등급으로 분류된 경우 가장 짧은 기간 내에 문제가 발생하였다.

결론적으로, 직접 복합 레진 수복을 이용한 전치부 공간 폐쇄는 장기적으로도 높은 성공률을 유지하며, 심미적 기능적으로도 양호한 결과를 보이는 치료 방법임이 입증되었다. 이 치료법은 최소 침습적 접근으로 인해 예후가 우수하며, 개별화된 치료 계획과 정기적인 추적 관찰을 통해 잠재적인 합병증을 조기에 발견하고 관리하는 것이 중요하다. 본 연구는 전치부 심미 치료에서 직접 복합 레진 수복의 예측 가능한 장기적 적용을 지지하는 유의미한 임상 근거를 제공했다.

핵심 되는 말 : 생존율, 장기 지속성, 장기 평가, 정중부 이개 폐쇄, 직접 복합 레진, FDI 평가 기준