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Research / Araştırma Makalesi

Long-Term Esthetic and Functional Success of Two Different Composite Materials in Fractured Anterior Teeth of Children

Çocuklardaki Ön Diş Travmalarında Kullanılan İki Farklı Kompozit Materyalin Uzun Dönem Estetik ve Fonksiyonel Başarısı

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ABSTRACT

Aim: Crown fracture is the most common traumatic dental injury in children's permanent maxillary central incisors. The study aims to evaluate the long-term clinical success of two different composite materials used for the restoration of fractured maxillary central incisors by dental trauma.

Material and Methods: The study was carried out on 132 teeth in 106 patients aged between 7-13 years. Patients with enamel-dentine fractures not involving the pulp, and pulp unaffected were randomly divided into two groups utilizing a composite with nanoceramic particles and a microhybrid composite material. Composite restorations were evaluated according to the Modified Ryge (USPHS) and FDI criteria by two experienced and calibrated examiners at 6, 12, 18, 24-month follow-up visits. Color changes of the restorations were also evaluated by spectrophotometer and color measurements were done by the standardized digital photographs.

Results: At the 24-month follow-up, 3 restorations were lost, and no statistically significant differences were found between composites at all follow-up periods. However significant esthetic and functional changes were observed at 6 and 12-month periods for both materials.

Conclusions: Both microhybrid and nanoceramic composites showed satisfactory clinical results at 24-month follow-up. It could be suggested that longer clinical success of composite restorations could be achieved by polishing, refurbishment, and repair where needed at frequent follow-ups.

Keywords: Dental trauma, enamel-dentine fractures, microhybrid composites

ÖZ

Amaç: Kron kırığı, çocukların daimî maksiller santral kesici dişlerinde en sık görülen travmatik dental yaralanmadır. Bu çalışmanın amacı, çocuklarda gözlenen diş travmaları sonucu kırılmış maksiller santral kesici dişlerin restorasyonunda kullanılan iki farklı içeriğe sahip kompozit restorasyon materyalinin uzun dönem klinik başarısını değerlendirmektir.

Gereç ve Yöntemler: Çalışmamız yaşları 7-13 arasında değişen 106 çocuk hastanın 132 dişi üzerinde gerçekleştirilmiştir. Dişlerinde pulpayı içermeyen, pulpanın etkilenmediği mine-dentin kırığı olan çocuk hastalar rastgele iki gruba ayrılarak nanoseramik partiküllü kompozit ve submikrohibrit kompozit materyali kullanılarak tedavi edilmiştir. Yapılan kompozit restorasyonlar 6, 12, 18, 24 aylık takip dönemlerinde iki deneyimli ve kalibre edilmiş araştırıcı tarafından Modifiye Ryge (USPHS) ve FDI kriterlerine göre değerlendirilmiştir. Restorasyonların renk değişimleri spektrofotometre cihazı ile değerlendirilmiş ve ayrıca renk ölçümleri de destandardize edilmiş dijital fotoğraflar ile gerçekleştirilmiştir.

Bulgular: 24 aylık takip sonucu hastalara yapılan 3 restorasyonun kaybedildiği gözlenmekle birlikte, tüm takip dönemlerinde kompozit restorasyon grupları arasında istatistiksel olarak anlamlı bir fark bulunmamıştır. Ancak her iki kompozit materyali için de 6 ve 12 aylık dönemlerde anlamlı estetik ve fonksiyonel değişiklikler gözlenmiştir ($p< 0.05$).

Sonuçlar: Hem mikrohibrit kompozitler hem de nanoseramik kompozitler 24 aylık takip sonucunda tatmin edici ve başarılı klinik sonuçlar göstermiştir. Dental travma sonrası yapılacak kompozit restorasyonların daha uzun dönem klinik başarısının cilalama, yenileme ve tamir gibi işlemlerle artırılabileceği düşünülmektedir.

Anahtar Kelimeler: Diş travmaları, mine-dentin kırıkları, mikrohibrit kompozitler

INTRODUCTION

Crown fractures account for most traumatic injuries to the permanent teeth. They are relatively common in schoolchildren. They are serious functional, aesthetic, and psychological problems for both children and their parents. The anterior position of fractured teeth gives precondition for easy noticeability which makes esthetics the most important treatment factor. For uncomplicated crown fractures in children, there are several factors for clinicians to consider. These include color, shape, and adhesive protocol. Difficulties may arise because of the age of, the right choice of treatment plan and its fulfillment.[1,2] It is important to note that the pulp chamber in children has a larger volume and in the presence of fracture many open dentin tubules are exposed to the oral environment. This creates a possibility of pulp damage. As we know, children fracture their teeth most often between ages 8 and 11. It is important to bear in mind that in young children eruption is the eruption of the teeth is not complete and the teeth are not in the correct position Another specific feature is the fact that after the trauma teeth should be treated minimally invasively with fewer number of manipulations to avoid pulpal or periodontal damage. For this reason, crown fractures in children cannot be treated with porcelain veneers or crowns.[1]

The lost tooth structure of crown fractures can be restored with restorative materials or by reattaching the fragment. Fragment reattachment can be a simple and very effective procedure with good longevity. Therefore, patients should be advised to bring fractured fragments of teeth with them while presenting for treatment.[2]

Through developments in composites and adhesive systems, which are now equal or superior to some porcelain systems, enhanced optical properties and esthetics can be accomplished by direct restorations. In addition, this treatment option can reduce the cost and duration of treatment.[3-5]

The direct restoration of proximal-incisal (Class IV) defects with composite resin is a challenge for all clinicians. These restorations require knowledge of the color, structures and materials involved, attention to detail, and artistic skill. It is important to mimic nature so that both form and color incorporate seamlessly, producing restorations that not only mimic but are indistinguishable from surrounding natural dentition.[1,5-10]

The challenges to be faced when executing proximal-incisal restorations include the creation of 1) a natural color transition from tooth to restoration, 2) opacification to mask the intraoral background,

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3) a translucent incisal edge, and 4) natural surface texture.[11] Rarely can clinicians achieve excellent aesthetic results in proximal-incisal restorations with a single shade of composite. This can only be achieved when the tooth is relatively mono-chromatic and the selected composite material ''picks up'' the tooth color during both refraction and reflection of incident light. However, good results can often be achieved using a Polychromatic Composite layering technique if the clinician understands the basic concepts of biomimetic dentistry.[5-11] Biomimetic dentistry techniques provide the patient with minimally invasive options that conserve sound tooth structure as a clinical imperative. Biomimetics is essentially described as a mimicking of natural life, which can be accomplished using contemporary composite resins and adhesive dental procedures.[12]

This study aims to evaluate long-term clinical success of two composite materials developed by nanocomposite technology, one having a nanoceramic and the other microhybrid composition used for the restoration of upper middle incisor enamel-dentine fractures by both FDI[13] and Modified Ryge criterias[14].

MATERIAL AND METHODS

The study was performed on 132 teeth in 106 patients aged between 7-13 years without any accompanying medical problems who were referred to the Department of Pedodontics, Ege University, Faculty of Dentistry (Izmir, Turkey). The minimum number of the samples was determined as 130 based on the effect size (0,58) and 95.14% power analysis (G. Power v.3.1, Dusseldorf Universitat, Dusseldorf, Germany). Patients with enamel-dentine fractures on both or one of the upper middle incisors not involving the pulp were included in the study. The Ethical Committee of the Medical Faculty of Ege University reviewed and approved the protocol and consent form for this study (protocol 10-11.1/45). The purpose and clinical procedures of the study were explained to the parents and written informed consent was obtained from all participants before starting treatment. All data were recorded in patients' forms before starting and at the end of the treatment and at every follow-up visit. Patients with symptomatic or devitalized teeth detected clinically or radiographically were excluded from the study. Amputation or endodontic treatments were done in those cases. The teeth were divided into three groups according to the cavity size (**Figure 1**).

Figure 1. Different fractures according to the cavity size the extent of the fracture to incisal third, middle or cervical third of the tooth.

The teeth were divided into two groups for the restoration of the fractured crowns utilizing a composite with nanoceramic particles (Ceram-X Duo; Dentsply/De Trey Konstanz, Germany) and a microhybrid composite material (Esthet-X HD; Dentsply/De Trey Konstanz, Germany). Randomization chart was used in single tooth fractures according to parallel study design. Randomization was achieved by tossing a coin in a split mouth study design which was used in patients with both incisors fractured.

Before initiating tooth color determination, the area was cleaned and polished using water and fluoride-free prophylaxis paste (Clinpro Prophy Powder, 3M ESPE, Seefeld, Germany) with a prophylaxis brush under slow speed and rinsed with water. In this study, tooth color determination was completed before isolation and dehydration in natural daylight a few minutes after the tooth was observed from different angles. The basic color of the tooth (hue-A, B,…) was determined from the cervical third; the degree of hue saturation or the intensity (chroma-A1, A2,..) was determined from the incisal third of the tooth. When uncertainty occurred about the color of the tooth, to properly determine the tooth color 1 mm to 1.5 mm composite layer was applied directly to the tooth without etching and application of an adhesive bonding agent. Tooth color was selected from the Vitapan classical shade guide (Vitalumin, Vita Zahnfabrik, Bad Sackingen, Germany) for Ceram-X Duo; TruMatch Shade Tab (Dentsply, Dentsply/De Trey Konstanz, Germany) for the Esthet-X HD restorations according to the manufacturer's instructions. Isolation, preparation, and adhesive protocol steps were performed by manufacturer's instructions and are shown in **Figures 2-6**.

Figure 2. **a)** Baseline photograph **b)** Color determination using TruMatch Shade Tab (Dentsply, Dentsply/De Trey Konstanz, Germany) for the Esthet-X HD. We decided to use B2-O, A1, CE layers respectively.

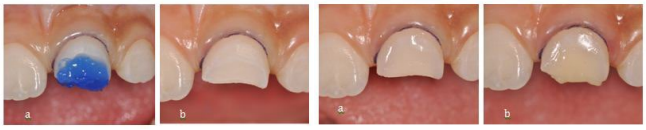

Figure 3. **a)** Etching of the prepared surfaces **b)** After cleaning and drying of the etched surfaces **c)** Applying of the adhesive bonding agent **d)** Covering composite-tooth junction with a thin layer of opaque composite material to produce a nonrecognizable junction area.

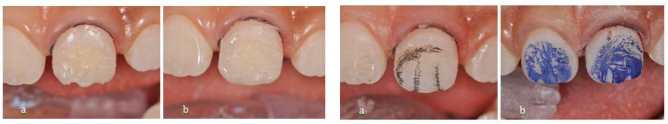

Figure 4. **a)** Restoration of the dentin body **b)** Restoration of the translucent enamel **c)** The surface characteristic properties such as macro or micro texture, enamel growth lines, lobes and grooves were mimicked from neighbouring tooth

Figure 5. View of the restoration after polishing

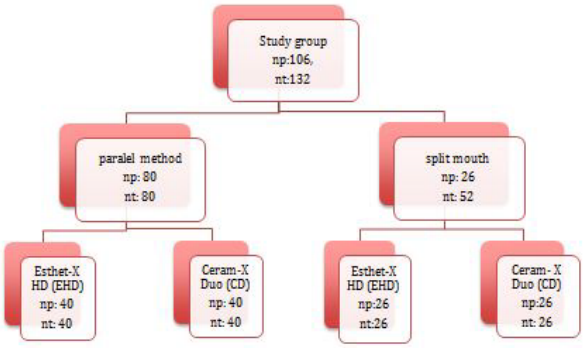

Figure 6. Flow diagram of the participants (np: number of patients)

Evaluation of the restorations

The restorations were evaluated at baseline and after 6-12-18 and 24 months. Two experienced and calibrated dentists, not involved with the placement of the restorations and therefore blinded to the group assignment, performed the evaluations. For calibration training purposes, the examiners observed 10 photographs that were representative of each score for each criterion from 'www.e-calib.info'. An intraexaminer and interexaminer agreement of at least 85% was necessary before the beginning of the evaluations. In this study there was no need to apply all the 16 criteria from FDI, only the clinically relevant measures of the aesthetic resin restorative materials were evaluated. The primary clinical endpoint was the aesthetic category, but the fracture of material and retention which was the following secondary endpoint was also evaluated (**Table 1**).

Table 1. FDI criteria and gradings

	Esthetic properties 1. Surface lustre	**2. Staining a. surface b. margin**	**3. Color match and translucency**	**4. Esthetic anatomical form**	**Functional properties 5. Fracture of material and retention**
1. Clinically excellent / very good	1.1 Lustre comparable to enamel.	2a.1 No surface staining.	3.1 Good color match, no difference in shade and/or translucency.	4.1 Form is ideal.	5.1 No fractures / cracks.
2. **Clinically good** (after polishing probably verygood)	1.2.1 Slightly dull, not noticeable from speaking distance 1.2.2 Some isolated pores.	2a.2 Minor surface staining, easily removable by polishing. 2b.2 Minor marginal staining, easily removable by polishing.	3.2 Minor deviations in shade and/or translucency	4.2 Form is only slightly deviated from the normal.	5.2 Small hairline crack.
3. Clinically sufficient / satisfactory (minor shortcomings, no unacceptable effects but not adjustable w/o damage to the tooth)	1.3.1 Dull surface but acceptable if covered with film of saliva. 1.3.2 Multiple pores on more than one third of the surface.	2a.3 Moderate surface staining that may also present on other teeth, not esthetically unacceptable. 2b.3 Moderate marginal staining, not esthetically unacceptable.	3.3 Distinct deviation but acceptable. Does not affect esthetics: 3.3.1 more opaque 3.3.2 more translucent 3.3.3 darker 3.3.4 brighter	4.3 Form deviates from the normal but is esthetically acceptable.	5.3 Two or more or larger hairline cracks and/or material chip fracture not affecting the marginal integrity or approximal contact.
4. Clinically unsatisfactory (but reparable)	1.4.1 Rough surface, cannot be masked by saliva film, simple polishing is not sufficient. Further intervention necessary. 1.4.2 Voids.	2a.4 Unacceptable surface staining on the restoration and major intervention necessary for improvement. 2b.4 Pronounced marginal staining; major intervention necessary for improvement.	3.4 Localized clinically deviation that can be corrected by repair: 3.4.1 too opaque. 3.4.2 too translucent. 3.4.3 too dark. 3.4.4 too bright.	4.4. Form is affected and unacceptable esthetically. Intervention/correction is necessary.	5.4.1 Material chip fractures which damage marginal quality or approximal contacts. 5.4.2 Bulk fractures with partial loss (less than half of the restoration).
5. Clinically poor (replacement necessary)	1.5 Very rough, unacceptable plaque retentive surface.	2a.5 Severe surface staining and/or subsurface staining, generalized or localized, not accessible for intervention. 2b.5 Deep marginal staining, not accessible for intervention.	3.5 Unacceptable. Replacement necessary.	4.5 Form is unsatisfactory and/or lost. Repair not feasible / reasonable, Replacement needed.	5.5 (Partial or complete) loss of restoration or multiple fractures.
Acceptable / not acceptable (n and %): Overall esthetic score					Overall functional score

The overall rating of a restoration was determined after completion of the assessments of the final scores for both aesthetic and functional properties. The most severe score of the restoration was recorded as the final overall rating for the aesthetic or functional properties of the restoration. According to Modified Ryge criteria marginal adaptation, marginal discoloration, anatomic form, secondary caries, surface roughness of the restorations was evaluated (**Table 2**). The restoration retention rates were calculated according to the Cumulative failure percentage.

Table 2. Modified Ryge criteria and gradings

Criteria/Score	**A (Alfa)**	**B (Bravo)**	**C (Charlie)**	**D (Delta)**
Marginal adaptation	closely adapted, no visible crecive along the margin	visible crevice along the margin into which the explorer will penetrate or catch	visible evidence of a crevice along the margin into which the explorer will penetrate or catch; the dentin is exposed	restoration is fractured, mobile or missing (in part or total)
Marginal discoloration	no discoloration along the margin	slight discoloration along the margin between the restoration and the tooth structure, but the discoloration has not penetrated along the margin in a pulpal direction	discoloration with penetration of pulpal direction	
Anatomic form	continous restoration with existing anatomical form	restoration is not in continuity with the existing anatomical form; the discontinuity in insufficient to expose dentin or lining	sufficient loss of the restoration has occurred to expose dentin or lining; redtoration needs to be replaced	
Secondary caries	no evidence of caries	evidence of caries along the margin		
Surface roughness	surface gloss comparable to enamel	surface is slightly dull with isolated small pores	surface is rough with multible pores and needs to be replaced	

Color measurements with spectrophotometer

Color values of maxillary central incisors were recorded at baseline, and 6-12-18 and 24 months of the restorations. The color measurements were performed using a digital intraoral spectrophotometer (Vita EasyShade, Vita Zahnfabrik GmbH, Bad Säckingen, Germany) according to the CIE-Lab (Commission Internationale de l'Eclairage, L*, a*, b*) coordinates. The color change (ΔE) for each tooth was calculated using the following equation: $\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$ where, ΔL*, Δa* and Δb* are the differences in the respective values at baseline and immediately after and 6-12-18 and 24 month of the restorations. One calibrated operator made three measurements at the same dental unit and the average was recorded. The clinically visible color change values for each tooth were accepted as ΔE data being higher than 3.7 units in this study.

Color measurements on digital dental photographs

Photographs were taken before and after restorations and on 6-12-18 and 24 months of the restorations after the same digital camera (105 mm macrolens, Sigma, Sigma Corp., NY, ABD) and ring flash (EM-140DG Macro Flash, Sigma Corp., NY, ABD). The camera's settings were done manually according to the dental photography settings guide (f:22, E:1/125, ISO:200, WB: flash)[15]. At every appointment, 9 standardized photographs were taken from each patient. The colour measurements of the restorations on baseline and control photographs which had the same magnification ratio were performed by an experienced dentist using Adobe-Photoshop CS6 PC program according to the CIE-Lab coordinates.

All statistical analyses were performed with the IBM SPSS (Statistical Package for Social Sciences Statistics version 20.0 for Windows) computer program. Statistical data were evaluated using the Mann-Whitney U test, McNemar, Wilcoxon Test, t-test, and chi^2-test. Compatibility of the evaluations by spectrophotometer and digital photos were achieved by intraclass correlation analysis. Cumulative survival rates of restorations were analyzed by the Kaplan-Meier test ($p < 0.05$).

RESULTS

A total of 132 (67 right, 65 left central incisors) fractured teeth were restored in 106 patients mean age of 10,14 (±1,55). The distribution of restorations according to age and gender was shown in **Table 3**. Crown fractures distribution according to the cavity sizes were found to be equal in both groups (**Table 4**).

Table 3. Distribution of restorations according to age and gender

Gender	Number of patients (%)
Male	46 (%43,4)
Female	60 (%56,6)
Age (year)	**Number of patients (%)**
7-9	45 (%42,4)
10-11	38 (%35,8)
12-13	23 (%21,7)

Table 4. Distribution of restorations according to materials and fracture size

Restoration material	Cavity sizes of crown fractures			Total
	1 (n,%)	2 (n,%)	3 (n,%)	
Esthet-X HD	8	46	12	66
Ceram-X Duo	10	42	14	66
Total	18 (%13,6)	88 (%66,7)	26 (%19,7)	132 (%100)

After 24 months a total of 122 restorations' follow-up could be achieved. Whilst the 2-year follow 2 restorations were excluded due to non-returning patients and 5 restorations due to devitalization. The flow diagram of the participants was shown in **Figure 6**. Overall Cohen's kappa statistics showed good agreement between the examiners. Esthetic and functional interkappa scores of two examiners were found 0,82 and 0,97 respectively. During the two years, it was observed that at 6 months 2 restorations in the CD group; at 18 months 1 restoration in the EHD group was lost. At the end of two years, the esthetic properties of Esthet-X HD restorations and functional properties of Ceram-x Duo restorations had better scores than each other but there was not a significant difference among the two composites.

At the end of the study, regarding the FDI criteria, 12 restorations (6 CD, 6 EHD) were recorded as clinically not acceptable according to the final overall rating for the aesthetic and functional properties. When the restorations in the Split-mouth group were evaluated alone, similar results with the complete study were found.

For both materials, statistically significant differences were observed at both functional and esthetic parameters starting from 6 and 12th-month follow-ups respectively ($p<0.05$). When the Split-mouth group was evaluated separately; for both materials statistically, significant differences were observed at both functional and esthetic parameters starting at 6th month follow-up. The reasons for the changes during time in esthetic properties of the restorations were found as surface staining, marginal staining, and deviation of esthetic anatomical form.

At the end of 2 years, the cumulative survival time of the restorations was found 23.9 and 23.5 months in the EHD and CD groups respectively. In the CD groups 3%, and in the EHD group 1,5% failure was recorded according to the fracture of material and retention. There was no statistically significant difference between groups according to cumulative survival rate. Secondary caries was only observed in one restoration for the EHD group at 6 months according to modified ryge criteria, and no significant difference was found between groups for 2 years. The results for Modified Ryge criteria of restoration were like FDI criteria. The number of restorations for the two groups according to the FDI and Modified Ryge criteria scores were shown in **Tables 5, 6** respectively.

Table 5. Number of restorations for two groups according to the FDI criteria score at baseline, 6-12-18-24 months follow-ups. (*): retention loss of restoration: absolute failure

Time		Baseline		6. month		12. month		18. month		24. month	
FDI criteria and gradings *Esthetic and functional properties*		*Ceram-X duo n:66*	*Esthet-X HD n:66*	*Ceram-X duo n:66*	*Esthet-X HD n:66*	*Ceram-X duo n:66*	*Esthet-X HD n:66*	*Ceram-X duo n:66*	*Esthet-X HD n:66*	*Ceram-X duo n:66*	*Esthet-X HD n:66*
Surface lustre	1.clinically excellent	47	53	46	53	44	53	42	52	40	50
	2. clinically good	17	12	17	12	17	11	17	11	18	12
	3. clinically sufficient	2	1	1	1	1	1	1	1	1	1
	4. clinically unsatisfactory	-	-	-	-	-	-	-	-	-	-
	5. clinically poor	-	-	-	-	-	-	-	-	-	-
Surface staining	1.clinically excellent	65	65	60	59	51	56	46	51	42	49
	2. clinically good	1	1	4	7	11	9	13	13	16	14
	3. clinically sufficient	-	-	-	-	-	-	1	-	1	-
	4. clinically unsatisfactory	-	-	-	-	-	-	-	-	-	-
	5. clinically poor	-	-	-	-	-	-	-	-	-	-
Margin staining	1.clinically excellent	65	64	62	60	54	52	46	45	40	39
	2. clinically good	1	2	2	6	8	13	14	19	19	24
	3. clinically sufficient	-	-	-	-	-	-	-	-	-	-
	4. clinically unsatisfactory	-	-	-	-	-	-	-	-	-	-
	5. clinically poor	-	-	-	-	-	-	-	-	-	-
Color match and translucency	1.clinically excellent	45	50	44	50	44	50	43	50	42	49
	2. clinically good	21	16	20	16	18	15	17	14	17	14
	3. clinically sufficient	-	-	-	-	-	-	-	-	-	-
	4. clinically unsatisfactory	-	-	-	-	-	-	-	-	-	-
	5. clinically poor	-	-	-	-	-	-	-	-	-	-
Esthetic anatomical form	1.clinically excellent	57	57	53	54	50	53	48	52	47	50
	2. clinically good	9	9	10	10	9	10	9	11	8	10
	3. clinically sufficient	-	-	-	1	-	-	-	-	-	1
	4. clinically unsatisfactory	-	-	1	1	3	2	3	1	4	2
	5. clinically poor	-	-	2*	-	-	-	-	1*	-	-
Fracture of material and retention	1.clinically excellent	66	66	57	54	49	49	47	43	40	38
	2. clinically good	-	-	4	3	6	5	6	8	9	9
	3. clinically sufficient	-	-	2	6	4	6	4	9	6	11
	4. clinically unsatisfactory	-	-	1	3	3	5	3	4	4	5
	5. clinically poor	-	-	2*	-	-	-	-	1*	-	-

Table 6. Number of restorations for two groups according to the modified Ryge criteria scores at baseline, 6-12-18-24 months follow-ups. (*): retention loss of restoration: absolute failure

		Baseline		6. month		12. month		18. month		24. month	
Modifiye Ryge criteria		*Ceram-X duo n:66*	*Esthet-X HD n:66*	*Ceram-X duo n:64*	*Esthet-X HD n:66*	*Ceram-X duo n:62*	*Esthet-X HD n:65*	*Ceram-X duo n:60*	*Esthet-X HD n:64*	*Ceram-X duo n:59*	*Esthet-X HD n:63*
Marginal adaptation	A	66	66	58	60	56	56	54	54	51	49
	B	-	-	5	6	5	8	5	10	7	13
	C	-	-	1	-	1	1	1	-	1	1
	D	-	-	2*	-	-	-	-	1*	-	-
Marginal discoloration	A	66	66	64	65	57	60	51	52	49	50
	B	-	-	-	1	5	5	9	12	10	13
	C	-	-	-	-	-	-	-	-	-	-
Anatomic form	A	66	66	60	58	53	55	52	53	44	49
	B	-	-	3	8	8	9	7	11	14	13
	C	-	-	1	-	1	1	1	-	1	1
Sekondary caries	A	66	66	64	65	62	64	60	63	59	62
	B	-	-	-	1	-	1	-	1	-	1
Surface roughness	A	66	65	64	64	60	63	59	62	57	59
	B	-	1	-	2	2	2	1	2	2	4
	C	-	-	-	-	-	-	-	-	-	-

Color evaluations by spectrophotometer and digital photos were found to be compatible. According to the results of color measurements done by these two methods, an increase in color change within time was found in both groups. Although the color change was more prominent in Esthet-X HD restorations at the end of one and two years there was not a significant difference among the two composites (**Table 7,8**). Intraoral view of the restorations which got different scores at baseline and 6-12-18-24 months follow-ups according to the FDI criteria are demonstrated in **Figures 7-12**.

Table 7. Mean ΔE values

	ΔE 0-12		ΔE 0-24	
	mean±standart deviation		mean±standart deviation	
	Esthet-X HD	Ceram-X Duo	Esthet-X HD	Ceram-X Duo
ΔE spectrophotometer	1,71±1,35	1,45±0,97	2,22±1,59	2,07±0,97
ΔE digital photograph	2,07±1,13	1,97±1,17	2,93±1,19	2,54±1,28

Table 8. Number of restorations according to visible colour change obtained or not.

	ΔE 0-12 n				ΔE 0-24 n (%)			
	Esthet-X HD		Ceram-X Duo		Esthet-X HD		Ceram-X Duo	
	≤3,7	>3,7	≤3,7	>3,7	≤3,7	>3,7	≤3,7	>3,7
ΔE photograph	58	7	56	6	46 (%73)	17 (%27)	49 (83,1)	10 (%16,9)
ΔE spectrophotometer	59	6	60	2	54 (%85,7)	9 (%14,3)	54 (%91,5)	5 (%8,5)

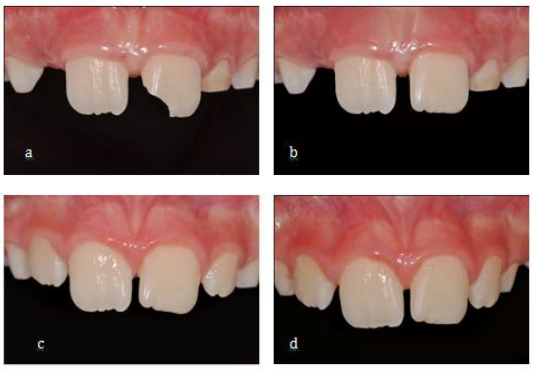

Figure 7. Labial views of the fractured left upper central incisor restored by EHD at baseline and follow-ups. The restoration scored 'Clinically excellent / very good' both esthetically and functionally at baseline and every controls.

a) Before restoration b) After restoration c) At 12 months
d) At 24 months

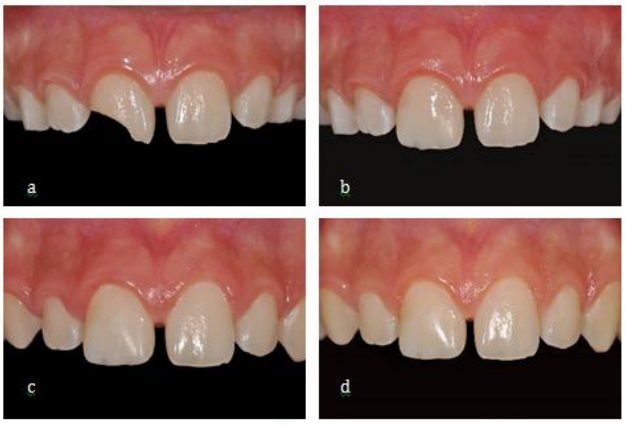

Figure 8. Labial views of the fractured right upper central incisor restored by CD at baseline and follow-ups. The restoration scored 'Clinically excellent / very good' both esthetically and functionally at baseline and every controls.

a) Before restoration b) After restoration

c) At 12 months d) At 24 months

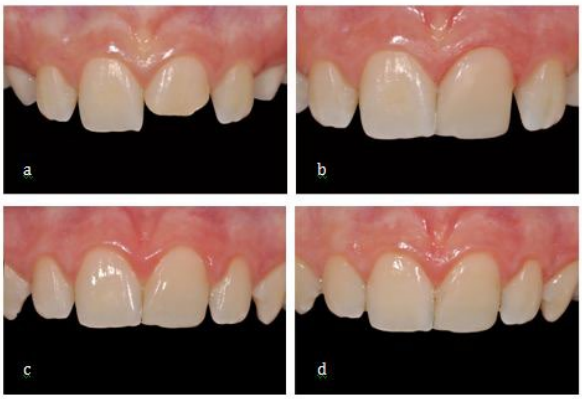

Figure 9. Labial views of the fractured left upper central incisor restored by CD at baseline and follow-ups. The restoration scored 'Clinically excellent / very good' functionally, 'Clinically good - Scor 1.2.1' esthetically at baseline. The scores did not change at folllow-ups.

a) Before restoration b) After restoration c) At 12 months

d) At 24 months

Figure 10. Labial views of the fractured left upper central incisor restored by EHD at baseline and follow-ups. The restoration scored 'Clinically excellent / very good' both esthetically and functionally at baseline.

a) Before restoration b) After restoration c) At 12 months d) At 18 months e) Small hairline crack existed at 18 months (Clinically good – Score 5.2) f) At 24 months

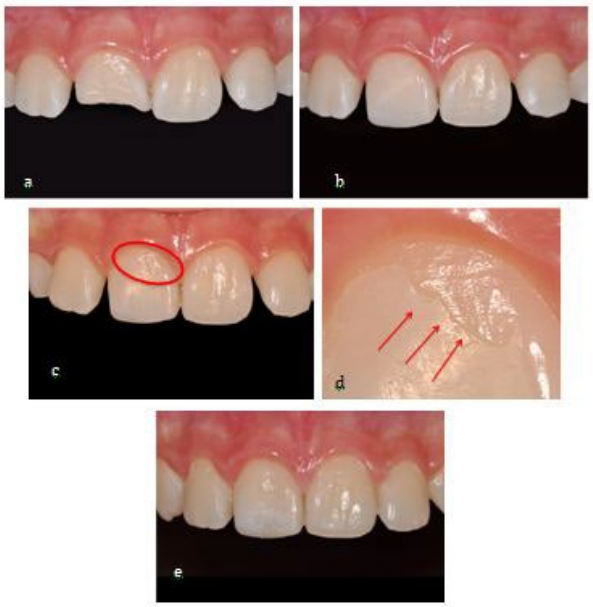

Figure 11. Labial views of the fractured right upper central incisor restored by EHD at baseline and follow-ups. The restoration scored 'Clinically excellent / very good' functionally, 'Clinically good - Score 4.2' esthetically at baseline.

a) Before restoration b) After restoration c) At 6 months d) Material chip fracture not affecting the marginal integrity or approximal contact existed at 6 months (Clinically sufficient – Score 5.3) e) At 24 months

Figure 12. Labial views of the fractured left upper central incisor restored by CD at baseline and follow-up. The restoration scored 'Clinically excellent / very good' both esthetically and functionally at baseline.

a) Before restoration b) After restoration c) At 12 months; the restoration scored 'Clinically unsatisfactory (but reparable)' because of the partial loss of the restoration. (Esthetic Score 4.4, Functional Score 5.4.1)

DISCUSSION

Crown fractures are relatively common among schoolchildren. They create serious functional, esthetic, and psychological problems for both children and their parents. In recent years, techniques and materials used in the restoration of crown fractures have improved due to increased demand for aesthetic crown fracture restoration also in children.[1-3] Our study aims to evaluate the long-term clinical success of two composite materials developed by nanocomposite technology, one having a nanoceramic and the other microhybrid composition used for the restoration of upper middle incisor enamel-dentine fractures.

The prognosis of the pulp in uncomplicated crown fractures is very good. Long-term clinical studies show very little pulpal response to enamel dentin fractures and subsequent restorative procedures, if there is no concomitant periodontal injury, and the restoration is efficiently sealed: prevalence of pulp survival equals 94-98%.[2] Those results are by experimental studies; histological observations show very little changes in the pulp, after induced traumatic fractures. In our study prevalence of pulp vitality after 2 years of clinical follow-up is 96% and it is deemed compatible with other conducted studies.

The split-mouth design is popular in oral health research. In the most common split-mouth study design, each of the two treatments is randomly assigned to either the right or left halves of the dentition. The attractiveness of the design is that it removes a lot of inter-individual variability from the estimates of the treatment effect.[16] However, since enamel dentin fractures are limited to one tooth in most of the patients, our study has been conducted together with a parallel group study design and split-mouth study design to increase the number of participants.

The rigidity and corrosion of the composite materials also affect their performance. Factors like particle content, size, resin matrix type and polymerization are also effective. In the comparison of nanoceramic structured Ceram X Duo with nanohybrid, microhybrid and nanofiller composites Sağsoz et al[17] have found that it showed good results in rigidity and corrosion. In a study assessing mechanical features of the microhybrid and nanohybrid composites Ilie et al[18] have found that microhybrid and nanohybrid composites showed similar results. In the same study, Esthet-X HD and Ceram-X Duo showed similar mechanic features and showed close results to the average value of the material group to which they belong. And this is compatible with our study.

The challenges to be faced when executing proximal-incisal restorations include the creation of (1) a natural color transition from tooth to restoration, (2) opacification to mask the intraoral background, (3) a translucent incisal edge, and (4) natural surface texture. The clinician can master these challenges using a Polychromatic Composite layering technique. With the layering technique opaque colors of the enamel, dentin can be applied layer by layer and the thickness of the enamel and dentin can be adjusted according to the crown of the natural tooth, and therefore color features of the neighboring tooth can be imitated.[8-11] Natural composite restorations can be attained by imitating the morphological features of the tooth via layering technique when the morphology of the tooth is understood.[8,9] Today different layering techniques are suggested according to the composition of various composite systems developed.[4,6,8,9] There is however no study comparing the layering techniques. Materials used in this study are Ceram-X Duo and Esthet-X HD and they are two- and three-layered composite materials respectively. We think that hiding the fracture line and masking the intraoral background is easier with the opaque material in Esthet-X HD. In a study on the translucency and the masking effects of the composite materials Kim et al[19] have reported that the optical properties of the Esthet-X HD are suitable for the restorations of the Class III and IV cavities. In the study comparing the translucency and opacities of the different composite materials and natural tooth structures, Ryan et al[20] have reported that the color of the Ceram-X Duo is more translucent than the natural tooth and the Esthet-X HD enamel and has similar enamel colors, but the opaque color of the Esthet-X HD showed more opacity than the natural tooth. Since Ceram-X Duo does not contain opaque material but a more translucent enamel color we think it is hard to attain enough opacity to hide the fracture line and mask intraoral background. Therefore, in our study for the restorations with Ceram-X Duo, we started with a 1 or 2 high saturation dentin composite of selected crown color. This shows the importance of the polychromatic layering technique, the imitation of the anatomic structures of the tooth, and the usage of materials having different chromas, in attaining aesthetic success.[6]

Although aesthetic properties of the restorative materials are one of the most important subjects, biomechanical properties are also of upmost importance and define the functionality, retention, and life span of the restoration. High resistance to cracking is needed in incisors due to exposure to the high impact forces. Suitable restorative material, suitable adhesive, and cavity preparation are a must to improve the biomechanical features. Needs for preparation for retention is decreasing due to the developments in adhesive systems. Considering preparation methods, bevel techniques are one of the suggested methods since they increase the adhesion area increase the wettability with the adhesive area and provide better marginal cover. Also, bevel preparation is needed to provide a natural color transition from tooth to filling. Many studies support that broad bevel preparation increases the binding surface and provides more mechanical resistance and better color transition and therefore gives more aesthetic appearance.[8,9] Some papers suggest different types and amounts of bevel usage to prepare the incisor fractures. For aesthetic and biomechanical reasons Felippe et al[10] suggest 1-2 mm; Fahl7 suggests broad and thick; Manhart[21] suggests broad on the labial side (2.5mm), 0.5-1mm bevel on the lingual side; and Mopper[22] suggests broad bevel. *In vitro* studies emphasize the importance of bevel amount for the resistance of the restoration. In their *in vitro* studies Xu et al[23] have found that 2 mm bevel application provides more fracture resistance than 1 mm bevel. In our study, during the preparation of fractured teeth broad (2-2.5 mm) and wavelike bevel is used. Thus, it is aimed to attain a natural appearance with the reduction of the sharpness between the restoration and the natural tooth; and increase the fracture resistance by increasing the surface area where filling binds the tooth.

Mena Serrano and colleagues[24] reported that Modified Ryge and FDI criteria had similar results however FDI evaluation criteria are more sensitive than the Modified Ryge criteria. Clinical evaluations for the two methods were also consistent with each other in our study for two years.

Coloration and surface roughness depend on the composition of the material used and the polishing process. In this study, restorations have a gloss surface, and we think it is due to the usage of microhybrid and nanoceramic structured materials and a successful polishing system.

Surface properties have important effects on the success and durability of the restorations. Features like plaque accumulation, physical features, endurance to water and abrasive, surface roughness for patient comfort, aesthetic appearance, and resistance to staining are all related to surface quality. Studies showed that nanocomposites gain more proper surface features than hybrid composites after the finishing process is done.[25] In their study, de Moraes et al[26] have found that nanohybrids show similar or slightly better surface features than microhybrids. This conclusion is compatible with our conclusion; microhybrid structured Esthet-X HD has shown slightly more color change than Ceram-X Duo however there is no statistically significant difference between them.

The resin matrix ingredient in the resin composites affects the coloration significantly. It has been reported that TEGDMA, which has a hydrophilic structure affects the color durability. In their study Ertaş et al.[27] have reported that color changes in composites can change according to monomer content and composites containing TEGDMA have more color change. Also, in our study, we have observed less color change in restorations with the Ceram-X Duo which does not contain TEGDMA.

In *in vitro* studies, nanohybrid and microhybrid composites showed better results than conventional composites in all categories in terms of mechanical endurance. Similar results have been attained between nanohybrid and microhybrid composites, but it has been found that nanohybrid composites have better mechanical features.[19,26] In their study Badakar et al.[28] assessed fracture resistance of the incisor incisal edge restorations and found that Esthet-X HD and Ceram-X Duo restorations have similar resistance.

In our study, although no difference was found between the two materials concerning esthetic and functional properties according to clinical assessment criteria in all control periods, after two years Ceram-X Duo scored better in terms of functionality while Esthet-X HD scored better in terms of aesthetics.

In time, statically similar results have been found in both groups according to starting scores obtained according to FDI and Modified Ryge Criteria. There are no studies assessing the clinical long-term aesthetics and functional performances of these two materials. In formerly conducted in vitro studies it has been shown that microhybrid and nanoceramic structured composites have close mechanic and aesthetic features like surface roughness, and coloration.[21,26,28] This is compatible with our in vivo conclusions.

Features of the composite materials, adhesives, and application techniques however are very different from the current conditions. It's been considered that current composites, adhesives, preparation, and application techniques increase the endurance of Class IV restorations and intraoral period. In their study with nearly 14 years of follow-up periods, van Dijken and Pallasen[29] have reported that in the tenth-year composite resin restorations are 82% successful and fracture is the most common reason for failure. In another study, after 5 years 7.5% of the incisor fracture composite restorations needed replacement.[29]

According to a review study evaluating composite restorations of permanent incisors with crown fractures.[30] One study compared 4 different anterior composite restoration types over 5 years and reported that Class IV restorations showed the highest failure rate when compared to Class III or V restorations. The longevity of large Class IV composite restorations placed in anterior fractured teeth has also been shown to be relatively short. More recently, Robertson and colleagues evaluated 140 Class IV restorations over 15 years and found that all restorations had been replaced at least once throughout the study, while many had been replaced several times. Roberts and Moffa noted no retention failures or other postoperative complications in a study with 60 sample sizes at the end of 2 years. Fucks and Saphira reported a 91% retention rate; 76% of the restorations were rated good and excellent; 14% of the restorations were rated poor in class IV restorations. Poor marginal integrity, color mismatch, and marginal discoloration were noted in some of the restorations; the survival rate was not reported numerically after 2 years in another study by Geitel and colleagues.[30] In our study, we assessed the cumulative success ratios after two years and consequently, 97% success and 98.5% success were observed in the Ceram-X Duo group and Esthet-X HD group respectively.

In a long-lasting clinical trial, the authors found the need for intervention at 3-year-old restorations from polishing to repair. In a period of 3 to 5 years all the restorations needed to be repaired. The results show that restorations have been changed 3 or 4 times before the significant decrease in tooth adhesive recourses. According to the author composite resin restorations cannot be long lasting. He concluded that prosthetic restorations are an obligatory therapeutic alternative after finishing of child's development.1 However, in our study after 2 years, only 5 Esthet-X HD and 4 Ceram-X Duo restorations have been repaired by material insert.

CONCLUSION

The both microhybrid and nanoceramic composites used for anterior teeth fracture restorations where esthetics and mechanical strength are very important showed satisfactory esthetic and functional results at the 24-month follow-up. Proper systematic application steps and appropriate polishing system selection have an important place in achieving excellent results for the composite restorations. It could be suggested that periodic clinical examinations every 6 months were the whole point for the long-term clinical success of the composite restorations to determine whether it needs polishing, refurbishment, or repair.

Değerlendirme / Peer-Review

İki Dış Hakem / Çift Taraflı Körleme

Etik Beyan / Ethical statement

Bu çalışma Prof.Dr. Nazan ERSİN danışmanlığında 16.01.2015 tarihinde Çocuklarda üst orta keser dişlerin mine dentin kırıklarının restorasyonunda iki farklı kompozit materyalin uzun dönem estetik ve fonksiyonel klinik başarısının araştırılması başlıklı yüksek lisans/doktora tezi esas alınarak hazırlanmıştır.

Bu çalışmanın hazırlanma sürecinde bilimsel ve etik ilkelere uyulduğu ve yararlanılan tüm çalışmaların kaynakçada belirtildiği beyan olunur.

This study was prepared under the supervision of Prof. Dr. Nazan ERSİN on the basis of the master's/doctoral thesis titled "Investigation of long-term esthetic and functional clinical success of two different composite materials in the restoration of enamel-dentin fractures of maxillary central incisors in children" dated 16.01.2015.

It is declared that during the preparation process of this study, scientific and ethical principles were followed and all the studies benefited are stated in the bibliography.

Benzerlik Taraması / Similarity scan

Yapıldı – ithenticate

Etik Bildirim / Ethical statement

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Çıkar Çatışması / Conflict of Interest

Yazarlar çıkar çatışması bildirmemiştir. | The authors have no conflict of interest to declare.

Yazar Katkıları / Author Contributions

Çalışmanın Tasarlanması | Design of Study: MM (%10), NE (%90)
Veri Toplanması | Data Acquisition: MM (%90), NE (%10)
Veri Analizi | Data Analysis: MM (%50), NE (%50)
Makalenin Yazımı | Writing up: MM (%60), NE (%40)
Makale Gönderimi ve Revizyonu | Submission and Revision: MM (%10), NE (%90)

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