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Clinical Research

Clinical Performance of Ormocer, Nanofilled, and Nanoceramic Resin Composites in Class I and Class II Restorations: A Three-year Evaluation

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Clinical Relevance

Ormocer, nanofilled, and nanoceramic composites exhibited clinical performance similar to that of conventional microhybrid composite in Class I and Class II restorations.

SUMMARY

Purpose: This prospective long-term clinical trial evaluated and compared the three-year clinical performance of an ormocer, a nanofilled, and a nanoceramic resin composite with that of a microhybrid composite placed in Class I and Class II cavities.

Methods: Forty patients, each with four Class I and II restorations under occlusion, were enrolled in this study. A total of 160 restorations were placed, 25% for each material, as follows: an ormocer-based composite, Admira; a nanofilled resin composite, Filtek Supreme XT; a nanoceramic resin composite, Ceram X; and a microhybrid resin composite, Tetric Ceram. A single operator placed all restorations according to the manufacturers' instructions. Immediately after placement the restorations were finished/polished. Clinical evaluation was performed at baseline and at yearly intervals after placement by two other independent examiners using modified US Public Health Service (USPHS) criteria. The changes in the USPHS parameters during the three-year period were analyzed with the Friedman test. Comparison of the baseline scores with those at the recall visits was made

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using the Wilcoxon signed rank test. The level of significance was set at $p < 0.05$.

Results: All materials showed only minor changes, and no differences were detected between their performance at baseline and after three years. Only two ormocer, one nanofilled, and one microhybrid restorations in molars failed because of loss of retention. Regarding the clinical performance, there were no statistically significant differences among the materials used ($p>0.05$).

Conclusions: The ormocer, nanofilled, and nanoceramic composites provided acceptable clinical performance over a three-year period.

INTRODUCTION

In recent years, composite restorations have become a routine procedure for Class I and Class II lesions.[1] However, polymerization shrinkage and associated stresses remain a genuine problem.[2] These stresses may produce defects in the composite-tooth bond, leading to microleakage and bond failure and causing deformation of the surrounding tooth structure, predisposing the tooth to fracture.[3] The performance of a dental composite resin is influenced by many variables, such as resin matrix formulation, filler type and amount, and degree of polymerization.[4]

In an attempt to overcome some of the concerns associated with the traditional composite filling materials a new type of inorganic-organic hybrid restorative material called ormocer (organically modified ceramics) was developed in 1997.[5] Ormocers are characterized by the inorganic-organic copolymers in the formulation that modify the mechanical properties,[6] and ormocers are reported[7] to have increased fracture and wear resistance compared with resin-based composites. The alkoxysilyl groups of the silane form an inorganic Si-O-Si network by hydrolysis and polycondensation reactions, while the (meth)acrylate groups photochemically induce organic polymerization,[7] which may reduce polymerization stress following light irradiation. The ormocer materials are considered amalgam alternatives or even fully adequate substitutes.[1,8] Laboratory studies on ormocer demonstrated good performance of the material with respect to polymerization shrinkage,[9] wear,[10] biocompatibility,[11] and marginal integrity.[12]

Recently, nanofiller particles have been introduced in resin composite materials. Nanotechnology is based on the production of functional materials and structures in the range of 100 nm using various physical and chemical methods. Resin composites based on nanotechnology have certain advantages, such as reduced polymerization shrinkage, increased mechanical properties, better gloss retention, and diminished wear.[13] The organically modified, ceramic-based, nanoceramic composite was also developed through a combination of both the ormocer technology and nanotechnology. This composite contains methacrylate-modified, silicon dioxide–containing nanofiller, and resin matrix that is replaced by a matrix full of highly dispersed methacrylate-modified polysiloxane particles.[14]

Laboratory investigations are crucial for an early assessment of a dental restorative, but only a clinical study[15,16] can take into account all of the potential variables (which vary from patient to patient) influencing the overall performance of a restorative.[17] These variables include mastication forces, abrasive foods, chemically active foods and fluids, temperature fluctuations, humidity variations, bacterial byproducts, and salivary enzymes.[18,19] However, only a few clinical studies[20-23] concerning the performance of ormocer, nanofilled, and nanoceramic composites have been published, and more clinical data are still required. In addition, an increasingly confusing array of promising new materials has now become available. To evaluate the factual clinical worth of a highly branded restorative material without being carried away by its proposed qualities is a challenge that we as clinicians must accept. Therefore, the current study evaluated and compared the three-year clinical performance of an ormocer, a nanofilled, and a nanoceramic resin composite with that of a conventional microhybrid composite placed in Class I and II cavities.

MATERIALS AND METHODS

Restorative Materials

Brand names, specifications, manufacturers, and compositions of the four tested restorative materials are listed in Table 1. Because composite restoratives are generally marketed as a complete system, including the proprietary etchant, primer, and bonding products, in the present study the clinical evaluation of the investigated restorative materials was performed using each composite with its proprietary adhesive system. The composite restorative systems employed in the current study were an ormocer-based composite, Admira with Admira Bond (Voco GmbH, Cuxhaven, Germany); a nanofilled resin composite, Filtek Supreme with Single Bond (3M ESPE, St Paul, MN, USA); a nanoceramic

Table 1: *Materials Used in the Study*

Restorative System	Manufacturer	Matrix	Filler	Filler Degree
Admira (Ad)	Voco, Cuxhaven Germany	Ormocer, Bis-GMA, UDMA,TEG DMA	Glass ceramic SiO_2 (microfiller), 0.7 μm	56 vol%, 79 wt%
Admira Bond (two-step etch-and-rinse)	Voco	Etchant: 36% phosphoric acid Adhesive: acetone, ormocer matrix, DMA, polyfunctional methacrylate, CQ stabilizer		
Filtek Supreme XT (FS)	3M ESPE, St Paul, MN, USA	Bis-GMA, Bis-EMA, UDMA, and TEGDMA	Dispersed filler particles nonagglomerated/ nonaggregated (5-75 nm), partially calcined porous clusters (~1.3 μm) of agglomerated nanosized particles, with a primary particle size of 5-20 nm, infiltrated with silane	59 vol%, 78.5 wt%
Single Bond (two-step etch-and-rinse	3M ESPE	Etchant: 36% phosphoric acid with colloidal silica Adhesive: Bis-GMA, HEMA, DMA, polyalkenoic acid copolymer, initiator, water, ethanol		
Ceram-X Mono (CX)	Dentsply De Trey GmbH, Konstanz, Germany	Methacrylate modified polysiloxane, dimethacrylate	Barium-aluminum-borosilicate glass, methacrylate functionalized silicon dioxide (nano filler), 10 nm (57 vol%, 76 wt%)	57 vol%, 76 wt%
Prime & Bond NT (two-step etch-and-rinse)	Dentsply Detrey	PENTA, UDMA resin, Resin R5-62-1, T-resin, D-resin, nanofiller, initiators, stabilizer, cetylamine hydrofluoride, acetone		
Tetric Ceram (TC)	Ivoclar-Vivadent, Schaan, Liechtenstein	Bis-GMA, UDMA, and TEGDMA	Barium glass, Ba-Al-fluorosilicate glass, Al_2O_3, YbF3, pyrogenic SO_2. Mean particle size 0.7 μm	60 vol%, 79 wt%
Excite (two-step etch-and-rinse)	Ivoclar-Vivadent	Etchant: 37% phosphoric acid with colloidal silica Adhesive: HEMA, DMA, phosphoric acid acrylate, silicon dioxide, initiator, stabilizers in an alcohol solution		

Abbreviations: Bis-GMA, bisephenol-A glycidyl methacrylate; UDMA, urethane dimethacrylate; TEGDMA, triethylene glycol dimethacrylate; Bis-EMA, *bisephenol-ethyl methacrylate;* DMA*, dimethaacrylate;* HEMA*, hydroxyethyl methacrylate*

composite, Ceram X with Prime & Bond NT (Dentsply DeTrey, Konstanz, Germany); and a microhybrid resin composite, Tetric Ceram with Excite (Ivoclar Vivadent, Schaan, Liechtenstein). They were used in accordance with the manufacturers' instructions.

Patient Selection

Forty patients from the Outpatient Clinic at Mansoura University, Faculty of Dentistry, with a total of 160 posterior lesions were enrolled in this study. Prior to participating in the study, each patient signed a consent form. The form and protocol were approved by our institution's ethics committee. Criteria for their inclusion included the presence of primary caries. Each patient received four posterior restorations. They were required to have complete and normal occlusion as well as good oral hygiene. The patient population was selected to achieve a

Table 2: *Number of Evaluated Restorations by Location (Tooth) and Extension (Class) for Each Material*

Group	No. of Evaluated Restorations	Tooth Type		Type of Restoration	
		Premolars	Molars	Class I	Class II
Ad	40	14	26	28	12
FS	40	11	29	31	9
CX	40	14	26	30	10
TC	40	13	27	29	11
Total	160	52 (33%)	108 (67%)	118 (74%)	42 (26%)

Abbreviations: Ad, Admira; CX, Ceram X; FS, Filtek Supreme; TC, Tetric Ceram.

balance in age from 20 to 54 years, with a median age of 33 years.

Clinical Procedures

One experienced operator who was familiar with adhesive dentistry prepared, restored, and finished 160 posterior restorations, 40 with each restorative composite material used. The restorations were 118 Class I and 42 Class II restorations. The number of posterior teeth restored were as follows: 14 premolars and 26 molars (28 Class I and 12 Class II) with ormocer; 11 premolars and 29 molars (31 Class I and 9 Class II) with nanofilled composite; 14 premolars and 26 molars (30 Class I and 10 Class II) with nanoceramic composite; and 13 premolars and 27 molars (29 Class I and 11 Class II) with microhybrid composite (Table 2).

Before restorative procedures, periapical radiographs of the teeth to be treated were taken. Vitality test scores of the teeth were recorded with a vitality tester (Parkell Pulp Vitality Tester, Parkell Electronics DN, Farmingdale, NY, USA).

For cavity preparation, local anesthesia was applied to prevent patient discomfort during the restorative procedures. The cavities were prepared using round diamond and fissure burs (Komet, Brasseler GmbH & Co. KG, Lemgo, Germany) at high speed with water cooling. Hand instruments and slow-speed tungsten carbide burs were used to remove the caries. Control of the excavated preparation floor was mainly conducted by probing with a sharp explorer and by means of the color of the underlying dentin. Adhesive preparation design was used according to the principles of minimally invasive dentistry. The common characteristics of this preparation design were the following: 1) none of the cavity preparations involved one or more cusps; 2) all of the gingival margins included sound enamel and were placed above the gingival sulcus; and 3) no beveling was applied to the preparation walls and margins. The buccolingual width of the preparations did not exceed one-third of this distance.

After cavity preparation and shade selection, the operative field was isolated with cotton rolls together with suctioning. Calcium hydroxide–based material (Dycal, Dentsply/Caulk, Milford, DE, USA) was only used in deep preparations and was applied directly over the deep portion of the preparation and then sealed with a glass ionomer cement lining (Vivaglass Liner, Ivoclar Vivadent). All Class II preparations were restored using a sectional metal matrix fixed with a ring (Palodent, Dentsply DeTrey) in order to reestablish the anatomical shape and proximal contacts of the teeth. For all restorations, two-step etch-and-rinse adhesive systems were used (Admira Bond, Voco) for ormocer, Single Bond (3M ESPE) for nanofilled composite, Prime & Bond NT (Dentsply DeTrey) for nanoceramic, and Excite (Ivoclar Vivadent) for microhybrid composite.

The preparations in which ormocer was to be placed were etched with 36% phosphoric acid gel (Vococid, Voco). The acid gel was first placed on the enamel and then the dentin was conditioned during the last 15 seconds of the 30-second etching time. Each preparation was then thoroughly rinsed with water for 10 seconds. The adhesive was applied for 30 seconds, the solvent was removed using a gentle stream of air, and light-curing was then performed for 10 seconds with a halogen light-curing unit (Astralis 5, Ivoclar Vivadent). The wavelength of the unit measured between 400 and 500 nm. Light intensity was 530 mW/cm^2, as measured by a radiometer (Optilux Radiometer Model 100, SDS Kerr, Danbury, CT, USA).

For nanofilled composite restorations, the preparation was etched with 36% phosphoric acid gel (Scotchbond Etchant, 3M ESPE) for 15 seconds. The preparation was then thoroughly rinsed for 10 seconds and gently dried. The adhesive was applied two times followed by light-curing for 10 seconds.

The preparations in which nanoceramic (Ceram-X mono) composite was to be placed were etched with 34% phosphoric acid (Caulk 34% Tooth Conditioner Gel), as for the ormocer group. The preparation was then rinsed thoroughly with water for 10 seconds, and a generous amount of Prime & Bond NT adhesive was applied to thoroughly wet all of the preparation surfaces. The solvent was removed using a gentle stream of air, and light-curing was performed for 20 seconds.

Where microhybrid composite was used, the preparation was etched with 37% phosphoric acid gel (Total Etch, Ivoclar Vivadent), as for the ormocer group. The preparation was then thoroughly rinsed with water for 15 seconds. The adhesive was applied with a microbrush. After 10 seconds, the solvent was evaporated with a gentle air stream followed by polymerization for 20 seconds.

Restoration of preparations was incrementally made in oblique layers with ormocer, nanofilled, or nanoceramic composite materials or microhybrid resin composite. Each increment was light-cured for 40 seconds. Following removal of the matrix band, the proximal regions of the restorations were additionally polymerized buccally and lingually/palatally for 40 seconds. Contouring and finishing of the restorations was performed at the same appointment using a water-cooled, fine-grit diamond finishing instrument (Komet, Lemgo, Germany). Articulating paper (Bausch, Nashua, NH, USA) was used to establish appropriate occlusal morphology and contact. Flexible points impregnated with silicone dioxide were used to obtain smooth surfaces (Astropol, Ivoclar Vivadent). For finishing and polishing of the proximal surfaces, aluminum oxide finishing strips (Dentonics Inc, Monroe, NC, USA) were used. The quality of the interproximal contacts was checked with dental floss.

Evaluation Procedures

All restorations were clinically evaluated immediately following finishing and polishing (baseline) and after one year, two years, and three years by two independent examiners. The Cohen Kappa index was used as a measure of interexaminer agreement. Examiners were not involved in the filling procedures. When disagreement occurred during evaluations, the restorations were reevaluated by both examiners and a consensus was obtained. Restorations were evaluated using the US Public Health Service (USPHS) modified Ryge[24] criteria for retention, color match, cavosurface marginal discoloration, anatomic form, secondary caries, surface roughness, marginal adaptation, and postoperative sensitivity (Table 3). Restorations were given the score "Alpha" for the ideal clinical situation, "Bravo" for clinically acceptable, "Charlie" for clinically unacceptable and in need of replacement, or "Delta," representing fractured, mobile, or missing restorations in need of immediate replacement. In addition, each restoration was assessed for postoperative sensitivity by blowing a stream of compressed air for three seconds at a distance of 2-3 cm from the restoration and by moving the probe over the restored tooth surface. To detect secondary caries, the presence of softness, opacity, etching, or white spots are considered as evidence of undermining or demineralization in areas where the explorer catches or resists removal after insertion. Furthermore, bitewing radiographs (Kodak, Rochester, NY, USA) were taken at each follow-up appointment. A magnifying aid was used for examination of marginal adaptation. Retention loss, severe marginal defects, discoloration that needed repair or replacement, and the occurrence of caries along the restoration margins were considered to represent clinical failures.

Statistical Analysis

A statistical analysis was performed using an SPSS (version 17) software program (SPSS, Chicago, IL, USA). Since the assessment of the restorations yielded clearly ordinal structural data, only nonparametric procedures were used. The changes in the parameters during the three-year period were analyzed using the Friedman test, which is a nonparametric analysis of variance. The baseline scores were compared with those at the recall visits using the Wilcoxon signed rank test. The level of significance was set at $p < 0.05$.

RESULTS

The results of this study are summarized in Table 4. All patients attended the three-year recall visit, and no patient reported any negative appreciation for restorative procedures that were performed. The Cohen Kappa statistics (Kappa = 0.90) showed strong examiner agreement, and no statistical difference was observed in patients' answers ($p > 0.05$).

The scores for all of the performance criteria were either Alpha or Bravo. At baseline examination, postoperative sensitivity of two ormocer and three microhybrid restorations was scored as Bravo, but it disappeared by the one-year evaluation. No secondary caries were observed after three years of clinical

Table 3: *US Public Health Service (USPHS) Modified Ryge Direct Evaluation Criteria Rating System*

Category and Rating	Criteria
Retention	
Alpha	Restoration is present.
Delta	Restoration is partially or totally missing.
Color match	
Alpha	The restoration matches the adjacent tooth tissue in color, shade, or translucency.
Bravo	There is a slight mismatch in color, shade, or translucency, but within the normal range of adjacent tooth structure.
Charlie	There is a slight mismatch in color, shade, or translucency, but outside of the normal range of adjacent tooth structure.
Marginal discoloration	
Alpha	There is discoloration anywhere along the margin between the restoration and the adjacent tooth structure.
Bravo	Discoloration is present but has not penetrated along the margin in a pulpal direction.
Charlie	Discoloration has penetrated along the margin in a pulpal direction.
Anatomic form	
Alpha	The restoration is continuous with existing anatomic form.
Bravo	The restoration is discontinuous with existing anatomic form, but missing material is not sufficient to expose the dentin or base.
Charlie	Sufficient restorative material is missing to expose the dentin or base.
Secondary caries	
Alpha	No caries are present at the margin of the restoration, as evidenced by softness, opacity, or etching at the margin.
Bravo	There is evidence of caries at the margin of the restoration.
Surface roughness	
Alpha	The restoration surface is as smooth as surrounding enamel.
Bravo	The restoration surface is rougher than the surrounding enamel.
Charlie	There are a crevice and fracture on the restoration.
Marginal adaptation	
Alpha	There is no visible evidence of a crevice along the margin into which the explorer penetrates.
Bravo	There is visible evidence of a crevice along the margin into which the explorer penetrates or catches.
Charlie	The explorer penetrates the crevice, and dentin or base is exposed.
Delta	The restoration is mobile, or missing, either in part or total.
Postoperative sensitivity	
Alpha	Normal reaction to cold spray compared to that of nonrestored teeth
Bravo	Increased cold sensitivity
Charlie	Spontaneous pain
Delta	Nonvital

service. With regard to retention criterion, two restorations from ormocer, one restoration from nanofilled, and one restoration from microhybrid groups were lost at the three-year recall, resulting in a retention rate of 95% for ormocer, of 97.5% for nanofilled, of 100% for nanoceramic, and of 95% for microhybrid composite restorations, with no significant differences ($p>0.05$) noted.

For color match criterion, slight differences were observed in two ormocer, two microhybrid, one nanofilled, and one nanoceramic restorations after three years. These shade mismatches were clinically acceptable (Bravo), with no significant differences noted between the materials investigated ($p>0.05$).

According to the cavosurface marginal discoloration and surface roughness criteria, there were no significant differences among the restorative materials ($p>0.05$). Marginal adaptation rate was 100% for nanofilled and nanoceramic, 97.5% for the microhybrid, and 95% for ormocer restorations at both one and two years. However, after three years this criterion was 97.5% for nanofilled and nanoceramic

Table 4: *Results of the Clinical Evaluation as Number of Restorations for Which This Score Was Given*[a]

Evaluation Criteria Materials	Score	Baseline				1 y				2 y				3 y			
		AD	FS	CX	TC	AD	FS	CX	TC	AD	FS	CX	TC	AD	FS	CX	TC
Retention	A	40	40	40	40	40	40	40	40	40	40	40	40	38	39	40	38
	D	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	2
Color match	A	40	40	40	40	40	40	40	40	40	40	40	40	37	39	38	38
	B	0	0	0	0	0	0	0	0	0	0	0	0	3	1	2	2
	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Marginal discoloration	A	40	40	40	40	39	40	40	39	39	40	40	39	38	39	39	38
	B	0	0	0	0	1	0	0	1	1	0	0	1	2	1	1	2
	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Marginal adaptation	A	40	40	40	40	38	40	40	39	38	40	40	39	38	39	39	38
	B	0	0	0	0	2	0	0	1	2	0	0	1	2	1	1	2
	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Surface roughness	A	40	40	40	40	38	40	40	38	38	40	40	38	37	40	40	38
	B	0	0	0	0	2	0	0	2	2	0	0	2	3	0	0	2
	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anatomic form	A	40	40	40	40	39	40	40	38	37	40	40	38	37	40	40	37
	B	0	0	0	0	1	0	0	2	3	0	0	2	3	0	0	3
	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Postoperative sensitivity	A	39	40	40	38	40	40	40	40	40	40	40	40	40	40	40	40
	B	2	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Secondary caries	A	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
	B	0	0	0	0	0	0	0	O	0	0	0	0	0	0	0	0

Abbreviations: Ad, Admira; CX, Ceram X; FS, Filtek Supreme; TC, Tetric Ceram.
[a] *The scores for each composite material include their proprietary adhesive systems.*

and 95% for ormocer and microhybrid composite restorations, with no significant differences noted among the restorative materials ($p>0.05$). The marginal defects recorded were small detectable V-shaped defects at the enamel margin of the restorations. In addition to hand instruments, a magnifying aid was used for investigation of the restoration margins. According to the anatomic form criterion, there were no significant differences among the restorative materials ($p>0.05$). All of the restorative materials were clinically successful.

DISCUSSION

The current study evaluated the first marketed resin composite based on ormocer matrix technology (Admira), resin composite containing only nanofillers (Filtek Supreme XT), and the composite based on both ormocer and nanofiller technology (Ceram X). Microhybrid resin composite (Tetric Ceram) was used as a control. Clinical trials require objective, reliable, and relevant criteria with which to assess the performance of restorations. Composite restoration quality is evaluated using a system of clinical parameters developed by Gunnar Ryge[24] and known as the USPHS Criteria or Ryge Criteria. These criteria were adapted by the California Dental Association for quality evaluation and referred to as Modified USPHS Criteria or USPHS/CAD Criteria.[25] However, this evaluation technique was designed to reflect differences in acceptability (yes/no) rather than degree of success. In the present study, the performance of the tested restorative systems was different at three years compared to at baseline.

The scores for color match, cavosurface marginal discoloration, marginal adaptation, surface roughness, and anatomic form for all restorative systems changed from Alpha to Bravo; both of the scores were considered acceptable. On the other hand, the retention rate of the ormocer and microhybrid composite restorations was 95%, and 97.5% for the nanofilled and 100% for the nanoceramic after three

years. According to the American Dental Association (ADA) acceptance criteria,[26] the clinical evaluation of restorations must show a failure rate of less than 5% at two years. Based on that, ormocer and microhybrid restorations were considered acceptable. This was in contrast with the findings of Oberländer and others,[1] who reported that ormocer (Definite) did not attain ADA acceptance criteria for restorative materials. A clinically satisfactory performance was reported for the nanofilled resin composite in two one-year and one three-year follow-ups.[21,27,28] In a recent two-year clinical evaluation,[29] Class II restorations of the nanofilled resin composite were compared in a similar intraindividual comparison with the well-known Tetric Ceram. Both restorative materials showed acceptable clinical performance, and the nanofilled resin composite showed no significant difference in overall clinical performance compared to Tetric Ceram. A failure rate of 1.9% was observed for both materials after two years, confirming the clinical performance in the present study, with a clinical failure rate of 2.5% for nanofilled composite and 5% for microhybrid composite after a three-year clinical evaluation period. Recently published controlled clinical longitudinal studies[30,31] of hybrid resin composites showed annual failure rates varying between 1.1% and 7.0% after two to four years. Tetric Ceram showed 5% failure rates, indicating a good clinical effectiveness of the nanofilled and nanoceramic resin composite studied.

A hybrid resin composite system was reported[32] to exhibit a statistically better marginal integrity along the occlusal and cervical margins of unloaded and loaded restorations than did ormocer. Consistent with this finding, the clinically ideal marginal adaptation (Alpha) rate in the present study was 100% for the nanoceramic composite and nanofilled composite and 97.5% for microhybrid composite, while the rate for the ormocer at both one and two years was 97.5%. However, this criterion was changed after three years for all materials without clinically significant differences. Long-term clinical studies[32,33] demonstrated good clinical performance of Tetric Ceram in posterior teeth, as well as for its predecessor, Tetric resin composite. Rosin and others[34] examined the clinical performance of ormocer restorations and reported excellent results regarding marginal integrity and marginal discoloration after six months. Bottenberg and others[35] stated that in occlusal stress-bearing cavities, the ormocer-based composite materials tested (Definite and Admira) performed comparably to the conventional microhybrid bisphenol A diglycidyl ether dimethacrylate–based composite, with the exception that ormocer had a poor color match.

The clinical performance of ormocer and nanofill composite material lined or not lined with flowable composites after two years was tested by Efes and others.[36] They reported that neither of the restorative materials exhibited postoperative sensitivity or secondary caries, and both showed ideal clinical performance. In this study, no secondary caries were detected in all of the tested restorative systems. Furthermore, postoperative sensitivity was observed at the baseline examination in two ormocer restoration and three microhybrid restorations. No secondary caries were reported in the earlier-discussed two-year study of Ernst and others either.[29]On the other hand, one has to realize that a three-year evaluation is far too short to observe the formation of secondary caries. This condition will develop mainly after four to six years of intraoral aging, as shown in earlier, longer follow-ups.[37] The operative field in the present study was isolated with cotton rolls and suction device, simulating operative dental procedures in most general clinics. No difference in annual failure rate was observed compared to the study of Ernst and others,[29] in which all restorations were placed under rubber dam isolation after application of the matrix system, 1.1% and 1.0%, respectively. This confirms the nonsignificant clinical differences observed in an earlier study[38] comparing the two isolation methods; in particular, in box-like preparations with high configuration factor, polymerization stresses may cause cohesive and/or adhesive failures.

At the three-year evaluation, all of the restorative materials demonstrated good color stability. Bravo scores were recorded for only two ormocer, two microhybrid, one nanoceramic, and one nanofilled composite restorations. These scores were insignificantly different. However, a slight color mismatch in tooth-colored restorations in posterior teeth might be desirable so that enamel adjacent to a composite restoration is not damaged during finishing.

Regarding the cavosurface marginal discoloration criterion, the majority of the scores were Alpha. Bravo scores were only recorded at the one-year examination in one ormocer and one microhybrid restoration. These scores had not changed during the two-year period. However, after three years, two microhybrid, two ormocer, one nanoceramic, and one nanofilled restorations recorded Bravo scores. All of the discoloration was located at the enamel margin; hence, it was clinically acceptable. This discoloration

might be due to the patients' food choices and smoking habits. Cavosurface marginal discoloration might indicate a breakdown of the bond between restorative material and tooth structure and, consequently, marginal leakage. In composite restorations, polymerization shrinkage is one of the main factors causing marginal discoloration,[39] especially in occlusal cavities with a high C-factor, the ratio between bonded walls to free walls.[40]

In the present study, the score of the surface roughness criterion of all the nanoceramic and nanofilled restorations was Alpha, while the score was Bravo for two ormocer and two microhybrid restorations at the one-year examination. These scores did not change during the three-year period, except for in the case of one ormocer restoration, which then received a Bravo rating. However, there were no significant differences among the materials. A laboratory study[41] evaluated the effect of several finishing and polishing procedures on the surface roughness of nanofilled composite (Filtek Supreme), nanohybrid (Grandio) composite, and ormocer-based (Admira) dental restorative materials. This study showed that nanofilled and nanohybrid composites achieved a smoother surface than did ormocer against Mylar strip finishing and polishing methods. Therefore, the slightly rough surface texture of the ormocer restoration observed in this study could be attributed to its particle size, yielding to the effects of masticatory forces and some abrasive foods. Ergucu and Turkun[42] analyzed the surface roughness of five novel nanocomposites (Ceram X, Filtek Supreme XT, Grandio, Premise, and Tetric EvoCeram) after polishing with three different one-step systems. They reported that differences between polishing systems were significant and that their effectiveness depends on material properties.

None of the tested restorative composites showed an unacceptable wear pattern, as evaluated by the USPHS criteria (anatomical form).These results could be attributed to filler size and content of the tested materials. The presence of nanoparticles and clusters in the nanofilled resin composite provide higher filler loading and distinct mechanical and physical properties compared with those of nanohybrid resin composites. Theoretical and experimental considerations of the wear and mechanical properties of nanofilled and nanohybrid composites, as compared with materials containing fillers in the micrometer range, have indicated the improved performance of the nanofilled and nanohybrid composites.[13] Recently, Palaniappan and others[43] tested the null hypothesis that there are no differences between the clinical-wear performances of nanofilled, microfilled, and conventional hybrids placed in Class I and Class II cavities. The findings of the five-year clinical trial revealed that operators and preparation type can affect restoration wear magnitude but do not contribute to increased functional risk of fracture or harmful effects on pulp and periodontal biocompatibility. However, one has to realize that this scoring system has no optimal wear evaluation method, and, therefore, no direct conclusions can be made concerning the suggested lower wear properties of the material. More sophisticated replicas involving evaluation methods and longer evaluation periods are necessary.[21]

In this study, ormocer, nanoceramic, and nanofilled composites performed as well as the microhybrid composite in posterior teeth. These results were in agreement with those of other clinical studies. For example, Rosin and others[34] evaluated the clinical performance of an ormocer (Definite, Degussa) in combination with a self-conditioning adhesive after one year and observed that ormocers are clinically effective in a private practice setting.

Schirrmeister and others[14] reported that after two years of clinical service, 96.8% of the Ceram·X/K-0127 and 100% of the Tetric Ceram/Syntac Classic restorations were in place and performed clinically well. Efes and others[36] compared the clinical performance of packable ormocer, nanofilled, and hybrid composites in occlusal cavities prepared with a minimally invasive technique. They reported that despite the high configuration factor of the cavity, both materials were clinically acceptable. In a recent two-year clinical evaluation, Class I ormocer, nanofilled, and nanohybrid resin composites were compared with microhybrid composite. All of the restorative materials showed acceptable clinical performance.[20] In addition, the evaluation of Stefanski and van Dijken[23] of 54 Class II nanofilled restorations with and without the intermediary of a nanofilled flowable resin composite showed a good clinical performance with a 2.2% failure rate after two years, and no differences were observed between the restorations with and without the nanofilled flowable resin intermediary layer.

CONCLUSIONS

On the basis of the results of this study, and despite the limitations of the small sample size, it seems reasonable to conclude that ormocer (Admira), nanofilled (Filtek Supreme XT), nanoceramic (Ceram X),

and the microhybrid composites (Tetric Ceram) exhibited excellent clinical performance over an evaluation period of three years. However, longer evaluations are necessary.

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 article.

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REFERENCES

1. Oberländer H, Hiller KA, Thonemann B, & Schmalz G (2001) Clinical evaluation of packable composite resins in Class-II restorations *Clinical Oral Investigations* **5(2)** 102-107.
2. Yap AU, Wang HB, Siow KS, & Gan LM (2000) Polymerization shrinkage of visible-light-cured composites *Operative Dentistry* **25(2)** 98-103.
3. Versluis A, & Tantbirojn D (1999) Theoretical considerations of contraction stress *Compendium Continuing Education in Dentistry Supplement* **25(11)** S24-S32; quiz, S73.
4. Lim BS, Ferracane JL, Condon JR, & Adey JD (2002) Effect of filler fraction and filler surface treatment on wear of microfilled composites *Dental Materials* **18(1)** 1-11.
5. Moszner N, & Salz U (2001) New developments of polymeric dental composites *Progress in Polymer Science* **26(4)** 535-576.
6. Wolter H, Storch W, & Ott H (1994) New inorganic/organic copolymers (ORMOCERs) for dental applications *Materials Research Society Symposium Proceedings* **346**143-149.
7. Manhart J, Kunzelmann K-H, Chen HY, & Hickel R (2000) Mechanical properties and wear behaviour of light-cured packable composite resins *Dental Materials* **16(1)** 33-40.
8. Lutz F, & Krejei I (1999) Resin composites in the post amalgam age *Compendium Continuing Education in Dentistry* **20(12)** 1138-1144.
9. Fleming GJP, Hall DP, Shortall ACC, & Burke FJT (2005) Cuspal movement and microleakage in premolar teeth restored with posterior filling materials of varying reported volumetric shrinkage values *Journal of Dentistry* **33(2)** 139-146.
10. Lutz F, & Krejei I (2000) Amalgam substitutes: A critical analysis *Journal of Esthetic Dentistry* **12(3)** 146-159.
11. Wataha JC, Rueggenberg FA, Lapp CA, Lewis JB, Lockwood PE, Ergie JW, & Bettenburg DJ (1999) In-vitro cytotoxicity of resin-containing restorative materials after aging in artificial saliva *Clinical Oral Investigations* **3(3)** 144-149.
12. Erdilek D, Dorter C, Koray F, Kunzelmann K, Efes BG, & Gomec Y (2009) Effect of thermo-mechanical load cycling on microleakage in Class II ormocer restorations *European Journal of Dentistry* **3(3)** 200-205.
13. Mitra SB, Wu D, & Holmes BN (2003) An application of nanotechnology in advanced dental materials *Journal of the American Dental Association* **134(10)** 1382-1390.
14. Schirrmeister JF, Huber K, Hellwig E, & Hahn P (2006) Two-year evaluation of a new nano-ceramic restorative material *Clinical Oral Investigations* **10(3)** 181-186.
15. El-Mowafy OM, Lewis DW, Benmergui C, & Levinton C (1994) Meta-analysis on long-term clinical performance of posterior composite restorations *Journal of Dentistry* **22(1)** 33-43.
16. Turkun LS, Turkun M, & Orate F (2003) Two-year clinical evaluation of a packable resin-based composite *Journal of the American Dental Association* **134(9)** 1205-1212.
17. Ernst CB, Martin M, & Willershausen B (2001) Clinical performance of a packable resin composite for posterior teeth after 3 years *Clinical Oral Investigations* **5(3)** 148-155.
18. de Gee AJ, Wendt SL, Werner A, & Davidson CL (1996) Influence of enzymes and plaque acids on in vitro wear of dental composites *Biomaterials* **17(13)** 1327-1332.
19. Sarrett DC, Coletti DP, & Peluso AR (2000) The effects of alcoholic beverages on composite wear *Dental Materials* **16(1)** 62-67.
20. Mahmoud SH, El-Embaby AE, AbdAllah AM, & Hamama HH (2008) Two-year clinical evaluation of ormocer, nanohybrid and nanofill composite restorative systems in posterior teeth *Journal of Adhesive Dentistry* **10(4)** 315-322.
21. Palaniappan S, Bharadwaj D, Mattar DL, Peumans M, Van Meerbeek B, & Lambrechts P (2009) Three-year randomized clinical trial to evaluate the clinical performance and wear of a nanocomposite versus a hybrid composite *Dental Materials* **25(11)** 1302-1314.
22. Sadeghi M, Lynch CD, & Shahamat N (2010) Eighteen-month clinical evaluation of microhybrid, packable and nanofilled resin composites in Class I restorations *Journal of Oral Rehabilitation* **37(7)** 532-537.
23. Stefanski S, & Van Dijken JWV (2012) Clinical performance of a nanofilled resin composite with and without an intermediary layer of flowable composite: A 2-year evaluation *Clinical Oral Investigations* **16(1)** 147-153.
24. Ryge G, & Cvar JF (1971) Criteria for the Clinical Evaluation of Dental Restorative Materials *San Francisco, Calif: US Government Printing Office Publication* Publication 7902244.
25. Sarrett DC (2005) Clinical challenges and the relevance of materials testing for posterior composite restorations *Dental Materials* **21(1)** 9-20.
26. ADA Council on Scientific Affairs (1996) American Dental Association Acceptance Program Guidelines—Restorative Materials. American Dental Association, Chicago, pp 1-10.
27. Cetin AR, & Unlu N (2009) One-year clinical evaluation of direct nanofilled and indirect composite restorations in posterior teeth *Dental Materials Journal* **28(5)** 620-626.

28. Dresch W, Volpato S, Gomes JC, Ribeiro NR, Reis A, & Loguercio AD (2006) Clinical evaluation of a nanofilled composite in posterior teeth: 12-Month evaluation *Operative Dentistry* **31(4)** 409-417.

29. Ernst CP, Brandenbusch M, Meyer G, Canbek K, Gottschalk B, & Willerhausen B (2006) Two-year clinical performance of a nanofiller vs a fine-particle hybrid resin composite *Clinical Oral Investigations* **10(2**) 119-125.

30. van Dijken JWV, & Sunnegårdh-Grönberg K (2005) A four-year clinical evaluation of a highly filled hybrid resin composite in Class II cavities *Journal of Adhesive Dentistry* **7(4)** 343-349.

31. Poon ECM, Smales RJ, & Vip KHK (2005) Clinical evaluation of packable and conventional hybrid posterior resin-based composites. Results at 3.5 years *Journal of the American Dental Association* **136(11)** 1533-1540.

32. Kournetas N, Chakmakchi M, Kakaboura A, Rahiotis C, & Geis-Gerstofer J (2004) Marginal and internal adaptation of Class II ormocer and hybrid resin composite restorations before and after load cycling *Clinical Oral Investigations* **8(3)** 123-129.

33. Schafers F, & Krantz-Schafers C (2003) Clinical evaluation of Class II composite restorations—30 Month results *Journal of Dental Research* **81(Special Issue)** 1480.

34. Rosin M, Steffen H, Konschake C, Gersse U, Teichmann D, & Hartmann A (2003) One-year evaluation of an ormocer restorative—A multipractice clinical trial *Clinical Oral Investigations* **7(1)** 20-26.

35. Bottenberg P, Alaerts M, & Keulemans F (2007) A prospective randomized clinical trial of one bis-GMA-based and two ormocer-based composite restorative systems in Class II cavities: Three-year results *Journal of Dentistry* **35(2)** 163-171.

36. Efes BG, Dorter C, Gomec Y, & Koray F (2006) Two-year clinical evaluation of ormocer and nanofill composite with and without a flowable liner *Journal of Adhesive Dentistry* **8(2)** 119-126.

37. van Dijken JWV, & Sunnegårdh-Grönberg K (2006) Fiber reinforced packable resin composites in Class II cavities *Journal of Dentistry* **34(10)** 763-769.

38. van Dijken JWV, & Hörstedt P (1987) Effect of the use of rubber dam versus cotton rolls on marginal adaptation of composite resin fillings to acid etched enamel *Acta Odontologica Scandinavica* **45(5)** 303-308.

39. Rosin M, Urban AD, Gartner C, Bernhardt O, Splieth C, & Meyer G (2002) Polymerization shrinkage-strain and microleakage in dentin-bordered cavities of chemically and light-cured restorative materials *Dental Materials* **18(7)** 521-528.

40. Feilzer AI, de Gee AJ, & Davidson CI (1987) Setting stress in composite resin in relation to configuration of the restoratives *Journal of Dental Research* **66(11)** 1636-1639.

41. Baseren M (2004) Surface roughness of nanofill and nanohybrid composite resin and ormocer-based tooth-colored restorative materials after several finishing and polishing procedures *Journal of Biomaterial Applications* **19(2)** 121-134.

42. Ergucu Z, & Turkun S (2007) Surface roughness of novel composites polished with one-step systems *Operative Dentistry* **32(2)** 185-192.

43. Palaniappan S, Elsen L, Lijnen I, Peumans M , Van Meerbeek B, & Lambrechts P (2012) Nanohybrid and microfilled hybrid versus conventional hybrid composite restorations: 5-Year clinical wear performance *Clinical Oral Investigations* **16(1)** 181-190.