Clinical Performance of Nanofilled and Microhybrid Direct Composite Restorations on Endodontically Treated Teeth

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ABSTRACT

This study evaluated the clinical performance of direct restorations made of nanofilled and microhybrid resin composites in endodontically treated teeth. Twenty patients (11 males, 9 females; mean age: 34.2±10) that met the inclusion criteria received a total of 48 restorations. After employing etch-and-rinse adhesive system, one dentist placed all restorations using either a nanofilled (Filtek Ultimate) or microhybrid (Filtek Z250) resin composite. The restorations were clinically reviewed at baseline, 6 months, and up to 2 years using the modified United States Public Health Service (USPHS) criteria. The changes were analyzed using the McNemar test and marginal homogeneity tests (p<0.05). The mean observation period was 17.4 months. With respect to color match, marginal adaptation, secondary caries, and surface texture, no significant differences were found between the two restorative materials (p>0.05). Most restorations yielded alpha or bravo scores with respect to the evaluation criteria. Five restorations failed due to chipping up to 2 years (1 microhybrid at 6 m, and 3 at 2 years; 1 nanofilled at 2 y) and were repaired. One complete replacement and one extraction due to endodontic complications were needed for 2 microhybrid resin group at 2 years.

INTRODUCTION

The selection of direct versus indirect restorations involves aesthetic, economic, mechanical, and anatomical considerations with respect to the restorative materials and the amount of remaining tooth structure.[1] The process of choosing the most suitable restoration for endodontically treated teeth is important as such teeth are highly susceptible to fractures.[2] Endodontically treated teeth are weak due to loss of structure and as a consequence of restorative and endodontic procedures and/or caries.[3] Helfer *et al.* reported that endodontic treatment causes biological changes, rendering treated teeth more susceptible to failure.[4] However, other studies found no significant difference in moisture content and claimed that endodontic procedures do not impair tooth strength.[5,6] Current adhesive technologies enable restorations without posts in many clinical situations that do not further weaken endodontically treated teeth.[2]

The loss of tooth vitality and structure after endodontic treatment has been viewed as an issue for crown placement.[7,8] Today, direct restorations are preferred as a basic treatment protocol for the replacement of lost tooth structure.

Composite resins are good alternatives to amalgam as they adhere to tooth structure and thereby increase fracture resistance.[9] The elastic modulus of resin composites is similar to that of dentin and bear occlusal loads comparable to dentin.[10] However, direct adhesive restorative techniques still present clinical challenges such as difficulty in obtaining proximal contacts. Moreover, such materials lead to high polymerization shrinkage stress.[11,12]

The introduction and development of adhesive technologies has resulted in a variety of restorative materials, including hybrid and nano-filled resin composites decreasing polymerization shrinkage and increasing wear resistance[13,14] Nanocomposites contain a unique combination of two types of nanofillers (5-75 nm) and nano-clusters that are discrete non-agglomerated and nonaggregated particles, 20-75 nm in size. The agglomerates act as a single unit enabling high-filler loading and high strength. As a result of the reduced dimension of the particles and wide-size distribution, increased filler load can be achieved with the consequence of reducing polymerization shrinkage and increasing the mechanical properties such as tensile strength, compressive strength to fracture and better polishability compared to microfilled or hybrid ones.[16-18] Nanohybrid resin composites also demonstrate enamel-like wear behaviour.[15] However, unambiguously improved clinical results have not yet been reported.

The objective of this clinical study therefore was to investigate microhybrid and nanofilled resin composites to restore endodontically treated teeth. The hypothesis tested was nanofilled resin composite would present better clinical performance compared to microhybrid composite.

MATERIALS AND METHOD

STUDY DESIGN

The brands, manufacturers, chemical composition and batch numbers of the materials used in this study are listed in Table 1.

Ethical committee of Istanbul Medipol University approved this clinical study (100840098-63). Patients were given written informed consent to participate the study before treatment and to enrol a recall program at baseline (1 week), 6 months, and thereafter annually.

INCLUSION AND EXCLUSION CRITERIA

Patients having at least two premolar or molar teeth in need of endodontic treatment were recruited to this study. Exclusion criteria included presence of teeth with severe periodontal problems and patients with systemic diseases.

OPERATIVE PROCEDURES

One operator with experience in adhesive dentistry, more than 10 years since graduation, made the cavity preparations and placed the posterior class II restorations (N=48) in the maxilla or mandible in a total of 20 patients (11 males, 9 females; mean age: 34.2±10 years) at the university staff clinics. To allow for an intra-individual comparison, one of the teeth for each patient was restored with a nanofilled resin composite (Filtek Ultimate, 3M ESPE, St, Paul, MN, USA) (n=24) whereas the other was restored with a microhybrid (Filtek Z250, 3M ESPE) one (n=24). Sixteen patients received 1 pair of restorations whereas 4 patients received two pairs. The choice of material was randomly

Table 1. Brands, types, chemical compositions and manufacturers of the main materials used in this study.

Brand	Type	Manufacturer	Chemical Composition
Filtek Ultimate Flow	Flowable resin composite	3M ESPE, St. Paul, MN, USA	Resin matrix: bis-GMA, TEGDMA, Procrylate Filler type: ytterbium trifluoride, silica
Filtek Z2550	Photo-polymerized microhybrid resin composite, universal	3M ESPE	Resin matrix: : bis-GMA, bis-EMA, UDMA, TEGDMA Filler type: Zirconia, silica
Filtek Ultimate	Photo-polymerized nanofilled resin composite, universal	3M ESPE	Resin matrix: : bis-GMA, bis-EMA, UDMA, TEGDMA Filler type: Zirconia, silica
Single Bond 2	Two-step etch and rinse adhesive	3M ESPE	2-HEMA, bis-GMA, di-methacrylates, amines, methacrylate functional co-polymer of polyaacrylic and polyitaconic acid, ethanol, water, photoinitiator

determined by coin toss. Considering the history and frequency of former incipient caries lesions, the operator determined the caries risk for each patient.

ENDODONTIC TREATMENT AND RESTORATIVE PROCEDURES

Root canal treatments were performed under local anesthesia by one endodontics specialist at the Endodontics Department of the same university. After endodontic access was achieved on the pulp chamber wall, canals were prepared using the rotary system (Pro-Taper Ni-Ti Rotary System, Dentsply Maillefer, Ballaigues, Switzerland) and root canals were filled with gutta-percha points (Pro-Taper F3 gutta-percha points, Dentsply Maillefer) and sealer (AH-Plus Sealer, Dentsply Maillefer) within the same session. All teeth received a temporary restoration (Clip, Voco, Cuxhaven Germany). The patients were then scheduled for permanent restorations 1 week after the endodontic treatment. The temporary restoration was removed, the metal matrix band (Adapt SuperCap Matrices, Kerr Corp., CA, USA) and wooden wedge were placed. Subsequently, conditioning was performed with a phosphoric etching gel (3M Etching gel, 3M ESP) for 30 s, followed by through rinsing with water and gentle air drying. The adhesive bottle (Single Bond, 3M ESPE) was shaken and two or three drops of adhesive resin were placed in a clean well. Adhesive was then applied with a disposable brush to dentin surfaces in scrubbing motions for 20 s. This application was repeated with a new drop of adhesive, with a 20 s waiting period between each coat. The surfaces were dried with gentle air blowing for at least 5 s and photo-polymerized for 20 s using an LED polymerization device (Elipar Free Light, 3M ESPE) with output of ≥ 400 mW/cm^2 according to the manufacturer's protocol. A 1-mm thick flowable composite (Filtek Ultimate Flow, 3M ESPE) was applied to the cavity floor close the orifices of the canals. Both restoration types

Table 2. Distribution of cavity characteristics and tooth location.

Attributes			Filtek Z250			Filtek Ultimate		
Cavity characteristics and tooth location			Baseline	6 month	Final Recall	Baseline	6 month	Final Recall
Maxillary Premolar		OM/OD	1	1	1	1	1	1
		MOD	2	2	2	3	3	3
Mandibular Premolar		OM/OD	2	2	2	1	1	1
		MOD	1	1	1	-	-	-
Maxillary Molar		OM/OD	7	7	6	9	9	9
		MOD	2	2	2	3	3	3
Mandibular Molar		OM/OD	9	9	8	5	5	4
		MOD	-	-	-	2	2	2
Tooth Location	contact	present	21	21	20	22	22	21
		absent	2	2	2	2	2	2
		porcelain	1	1	-	-	-	-
	antagonist	present	18	18	17	19	19	18
		absent	2	2	2	2	2	2
		porcelain	4	4	3	3	3	3

Table 3. List of modified United States Public Health Service (USPHS) criteria used for the clinical evaluations of the restorations.[19]

Category	Scoring characteristics
Anatomical form	A: Restoration's contour is continuous with existing anatomical form and margins. B: Restoration is slightly over contoured or under contoured. C: Marginal overhang or tooth structure (dentin or enamel) is exposed. D: Restoration is missing, traumatic occlusion or restoration causes pain in tooth or adjacent tissue.
Secondary caries	A: No visible caries. C: Caries continuous with the margin of the restoration.
Color match	A: No mismatch in color, shade or translucency between restoration and adjacent tooth structure. B: Mismatch between restoration and tooth structure within the normal range of tooth. C: Mismatch between restoration and tooth structure outside the normal range of tooth. D: Esthetically displeasing color, shade and translucency.
Retention	A: Present. B: Partial loss. C: Absent.
Marginal adaptation	A: Excellent continuity at resin-enamel interface; no ledge formation, no discoloration. B: Slight discoloration at resin-enamel interface; ledge at interface. C: Moderate discoloration at resin-enamel interface measuring 1 mm or greater. D: Recurrent decay at margin.
Polishability	A: Smooth and highly shiny, similar to enamel. B: Smooth and satin, highly reflective. C: Rough and shiny, satin, somewhat reflective. D: Rough and dull or satin, not reflective.
Surface staining	A: Absent. C: Present.
Soft tissue health	A: Excellent response-no inflammation. B: Slight inflammation of gingival tissue. C: Moderate to severe gingival inflammation.
Proximal contact points	A: Present. C: Absent.

A,:Alpha; B: Bravo; C: Charlie; D: Delta.

were built up incrementally in 2 mm thick layers and polymerized according to the manufacturer's instructions. Occlusal adjustment was controlled using carbon paper and interproximal contacts were checked using dental floss. The restorations were finished under water-cooling with finishing burs; polishing was performed with polishing discs (Opti Disc, Kerr Corp, Orange, CA, USA) and rubbers (HiLuster PLUS Polishing, Kerr Corp). Patients were instructed to call upon any kind of complaint.

RESULTS

The distribution of 28 restored teeth and restoration types in the maxilla and mandible are presented in Table 2. Description of evaluation criteria are listed in Table 3 and 4.[19]

The drop-out rate of patients at final recall was 4.2%. One patient with one pair of restorations could not be evaluated at the final recall as he moved to another city. The mean observation period was 17.4 months. The overall success rate was 95.8% and

Table 4. Definitions for clinically acceptable, functionally present and failed restorations.

Clinically acceptable	Functionally present	Clinically unacceptable/failed
Restorations with Alfa and Bravo scores	If the tooth with the restoration received crown for reasons purely unrelated to materials. e.g. cracked tooth pathology, trauma	Restorations with Delta scores
Restorations in need of simple maintenance treatments (prophylaxis and polishing) to upgrade their scores back to Alfa or Bravo	If the tooth with the restoration received a new direct restoration adjacent to the existing restoration.	If the tooth with the restoration received additional treatment (endodontic, crown) purely related to materials.
	Repaired restorations due to chipping defects.	Complete replacement of restoration due to fracture/loss, serious color mismatch and allergic side-effects and evaluator-detected secondary caries, fracture, periodontal side effects and marginal degradation.

100% observed at the 6-month recall and 78.3% and 95.7% at final recalls for the microhybrid and nano-filled resin composite, respectively. Most restorations received alpha or bravo scores with respect to the evaluation criteria. Five restorations failed due to chipping up to 2 years (1 microhybrid at 6 m, and 3 at 2 years; 1 nanofilled at 2 years) and were repaired. Restorations underwent repair procedures due to chipping and missing proximal contacts (*Table 5*). Repaired restorations were not considered as complete failures as they were functional.

One complete replacement and one extraction due to endodontic complications were needed for 2 microhybrid resin group at 2 years.

All restorations in both groups received alpha (A) scores at the baseline assessment; at the 6 month recall, as regards for secondary caries, retention, surface polish, staining and proximal contact. One restoration in each group was scored with bravo (B) for anatomical form. One restoration in the microhybrid group and three in the nano-filled group received bravo scores for color match and for soft tissue health which were repolished (*Table 6*).

Only one restoration needed to be restored due to caries that occurred independent from the restoration at the 2-year recall. Secondary caries was not observed in any of the restored teeth at the final recall.

Between the two resin composite groups, the evaluated restorations showed no statistically significant difference with respect to any of the criteria over the observation period (p>0.05).

DISCUSSION

In this clinical study, clinical performance of microhybrid and nanofilled resin composites on endodontically treated teeth were compared. When USPHS criteria outcome were considered, the two material types showed no significant difference. Thus, the hypothesis could be rejected.

Since in most endodontically treated teeth, there is missing tooth structure caused by caries or endodontic access preparation,[20] the remaining tooth tissue and the restorative material chosen may have a significant effect on tooth survival. Due to the small sample of 48 restorations in 20 patients, this study could be considered as observational trial. In this study, restorations that could be repaired were categorized as functionally present based on a report of Palaniappan *et al.*[21] whereas those that were completely replaced were considered as real failures. According to our observations, restorations were deemed to have failed whenever they were completely retreated or judged as delta due to material-related factors. In cases needing intervention, the observer and operator decided on repair or on partial or complete replacement. In this regard, microhybrid and nano-filled resin materials showed similar performance providing that microhybrid ones required 4 repair actions and 1 replacement. On the other hand, only one restoration with nanohybrid needed a repair at 2 year follow up.

Subjective decision-making to assess restoration failures such as staining may be graded as charlie and a complete absence as alpha, without a bravo score according to the modified USPHS criteria. This limitation in scoring for some criteria, such as staining and proximal contacts, has forced investigators to assign a charlie score for limited surface staining. Subjectively, restorations scored charlie were not always considered to be failures in our study; extrinsic surface staining was removed through prophylactic measures.

The type of cavity in endodontically treated teeth plays a significant role on the prognosis of resin composite restorations. For instance for amalgam restorations, MO/OD cavity preparations were considered more favorable as opposed to MOD preparations in endodontically treated teeth.[20] On the contrary, the type of cavity preparations, be it MO/OD or MOD, did not affect the clinical survival of resin composite materials.[21]

Table 5. Categories of clinical status and distribution of results up to 2 years of clinical service.

Category		Filtek Z250			Filtek Ultimate		
		Baseline n (%)	6 months n (%)	Final Recall n (%)	Baseline n (%)	6 months n (%)	Final Recall n (%)
Clinically acceptable		24 (100)	23 (95.8)	18 (78.3)	24 (100)	24 (100)	22 (95.7)
	Without maintenance	24 (100)	21 (83.3)	11 (47.8)	24 (100)	21 (87.5)	14 (60.9)
	With maintenance	-	3 (12.5)	7 (30.4)	-	3 (12.5)	8 (34.8)
	Maintained criteria	-	Marginal adaptation, soft tissue health, color match	Marginal adaptation, soft tissue health, color match, proximal contact, retention	-	Marginal adaptation, soft tissue health, color match	Marginal adaptation, soft tissue health, color match, proximal contact, retention
Functionally present		-	1 (4.2)	3 (13.4)			1 (4.3)
	Repaired	-		3 (13.4)	-	-	1 (4.3)
	Nature of repair/ additional treatment	-		Restorations were repaired due to chipping defect and to achieve proximal contact	-	-	Restorations were repaired due to chipping defect and to achieve proximal contact
Failed		-	-	2 (8.7)	-	-	-
	Reason			Tooth extraction due to periapical inflammation New direct restoration with fiber post due to the loss of restoration			

When clinical studies are evaluated, endodontically treated premolars with limited tooth structure restored with a fiber post and a direct resin composite restoration, with or without complete crown coverage, showed similar success rates after 3 years with no fracture or tooth loss.[22] In a different study, Nagasiri *et al.*[8] evaluated the survival rate for endodontically treated molars without crown coverage and concluded that the amount of remaining tooth structure and type of restorative material significantly affected the longevity of endodontically treated molars without prosthetic restorative treatment. In our study, two failures were observed due to fracture of the restoration and the tooth itself and as a result of endodontic complications. The only fractured and failed tooth was a mandibular premolar with an MOD cavity. This tooth was restored with a new restoration with fiber post. One retrospective clinical study also reported more incidence of fractures in premolars.[23]

Table 6. Summaries of USPHS scores and percentages for nanofilled (Filtek Ultimate) and microhybrid composite (FiltekZ250) materials at baseline and final follow-up up to 2 years

USPHS criteria		FiltekZ250			Filtek Ultimate		
		Baseline n (%)	6 months n (%)	Final Recall n (%)	Baseline n (%)	6 months n (%)	Final Recall n (%)
Anatomical form	A	24 (100)	23 (95.83)	21 (95.5)	24 (100)	23 (95.8)	22 (95.7)
	B	0 (0)	1 (4.17)	1 (4.6)	0 (0)	1 (4.2)	1 (4.6)
	C	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)
Secondary caries	A	24 (100)	24 (100)	22 (100)	24 (100)	24 (100)	23 (100)
	B	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Color match	A	24 (100)	23 (95.8)	14 (63.6)	24 (100)	21 (87.5)	15 (65.2)
	B	0 (0)	1 (4.17)	8 (36.4)	0 (0)	3 (12.5)	8 (34.8)
	C	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)
Retention	A	24 (100)	24 (100)	19 (86.4)	24 (100)	24 (100)	21 (91.3)
	B	0 (0)	0 (0)	2 (9.01)	0 (0)	0 (0)	2 (8.7)
	C	0 (0)	0 (0)	1 (4.6)	0 (0)	0 (0)	0 (0)
Marginal adaptation	A	24 (100)	21 (87.5)	11 (50)	24 (100)	23 (95.8)	12 (52.2)
	B	0 (0)	2 (8.3)	10 (45.5)	0 (0)	1 (4.2)	11 (47.8)
	C	0 (0)	1 (41.7)	1 (4.6)	0 (0)	0 (0)	0 (0)
	D	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Polishability	A	24 (100)	24 (100)	17 (77.3)	24 (100)	24 (100)	17 (73.9)
	B	0 (0)	0 (0)	5 (22.7)	0 (0)	0 (0)	6 (26)
	C	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)
Surface staining	A	24 (100)	24 (100)	21 (95.5)	24 (100)	24 (100)	21 (91.3)
	C	0 (0)	0 (0)	1 (4.6)	0 (0)	0 (0)	2 (8.7)
Soft tissue health	A	24 (100)	23 (95.83)	21 (95.5)	24 (100)	22 (91.7)	22 (95.7)
	B	0 (0)	1 (4.17)	1 (4.6)	0 (0)	2 (8.3)	1 (4.4)
	C	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Proximal contact points	A	24 (100)	24 (100)	21 (95.5)	24 (100)	24 (100)	22 (95.7)
	C	0 (0)	0 (0)	1 (4.6)	0 (0)	0 (0)	1 (4.4)

In another previous clinical study, the success rate of 39 Class II restorations in endodontically treated teeth, with the same microhybrid material used in this study without any post presented similar results with our clinical study.[24] In that study, at the 2-year recall only marginal discoloration exhibited a significant change, decreasing from alpha to bravo scores. In this study, three restorations at 6 months and 21 restorations at final recall received bravo scores for marginal adaptation. While marginal defects were observed for both materials, only limited number of restorations showed marginal discoloration with both materials. Marginal defects are attributed to the fractures of thin flashes of resin composite, extended on non-prepared enamel surfaces adjacent to the restoration margins.[25] Interestingly, regardless of the variations in the filler content of the two materials tested in this study, marginal adaptation scores were similar at 2 year follow up. Similarly, colour match and polishability, surface staining parameters were almost identical with the two materials, Thus, when 2 year clinical scores are considered, no big differences were observed between the two materials tested. These results are contradictory with some other studies[26,27] where significantly better polishability for nano-filled composite resins were reported compared to microhybrid ones.[26,27] The benefits of the exclusive incorporation of nanofillers are generally related to the translucency and the polishability of the material[26,38] but apparently, under function, this advantage may not be persistent.

In the literature, assessing the clinical outcome of direct posterior resin composite restorations, evaluation periods vary between 1 and 17 years with an annual failure rate ranging between 0 and 45%.[29,30] In this study, four 'functionally present' restorations were not considered as failures. Because failure rates generally increase with longer evaluation periods,[31] the relatively short period of our clinical investigation could be considered as limitation of this observational trial and the results should be confirmed with long-term analysis on a larger sample with more operators in a randomized controlled clinical trial.

CONCLUSIONS

From this study, the following could be concluded:

1. The clinical performance of nanofilled and microhybrid resin composites applied for restoring endodontically treated teeth were similar up to 2 years in function with respect to color match, marginal adaptation, surface texture and secondary caries.
2. The incidence of repairs and replacement were more common in microhybrid resin composite compared to nanofilled one but except for one all of them were repairable.

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DISCLOSURE

The authors declare that they have no conflict of interest.

REFERENCES

1. Soares PV, Santos-Filho PC, Martins LR, Soares CJ. Influence of restorative technique on the biomechanical behavior of endodontically treated maxillary premolars. Part I: fracture resistance and fracture mode. *J Prosthet Dent* 2008;**99**:30-37.
2. Nothdurft FP, Seidel E, Gebhart F, Naumann M, Motter PJ, and Pospiech PR. The fracture behavior of premolar teeth with class II cavities restored by both direct composite restorations and endodontic post systems. *J Dent* 2008;**36**:444-449.
3. Helfer AR, Melnick S, and Schilder H. Determination of the moisture content of vital and pulpless teeth. *Oral Surg Oral Med Oral Pathol* 1972;**34**:661-670.
4. Taha NA, Palamara JE, Messer HH. Cuspal deflection, strain and microleakage of endodontically treated premolar teeth restored with direct resin composites. *J Dent* 2009;**37**:724-730.
5. Reeh ES, Messer HH, Douglas W. Reduction in tooth stiffness as a result of endodontic and restorative procedures. *J Endod* 1989;**15**:512-516.
6. Papa J, Cain C, Messer HH. Moisture content of vital vs endodontically treated teeth. *Endod Dent Traumatol* 1994;**10**:91-93.
7. Tidmarsh BG. Restoration of endodontically treated posterior teeth. *J Endod* 1976;**2**:374-375.
8. Nagasiri R, Chitmongkolsuk S. Long-term survival of endodontically treated molars without crown coverage: a retrospective cohort study. *J Prosthet Dent* 2005:93;164-170.
9. Lohbauer U, von der Horst T, Frankenberger R, Krämer N, Petschelt A. Flexural fatigue behavior of resin composite dental restoratives. *Dent Mater* 2003;**19**:435-440.
10. Abe Y, Lambrechts P, Inoue S, Braem MJ, Takeuchi M, Vanherle G, van Meerbeek B.Dynamic elastic modulus of 'packable' composites. *Dent Mater* 2001;**17**:520-525.
11. Suliman AA, Boyer DB, Lakes RS. Cusp movement in premolars resulting from composite polymerization shrinkage. *Dent Mater* 1993;**9**:6-10.
12. Touati B, Aidan N. Second generation laboratory composite resins for indirect restorations. *J Esthet Dent* 1997;**9**:108-118.
13. Clelland NL, Pagnotto MP, Kerby RE, Seghi RR. Relative wear of flowable and highly filled composite. *J Prosthet Dent* 2005:93;153-157.
14. Lohbauer U, Frankenberger R, Krämer N, Petschelt A. Strength and fatigue performance versus filler fraction of different types of direct dental restoratives. *J Biomed Mater Res B Appl Biomater* 2006;**76**:114-120.
15. Palaniappan S, Elsen L, Lijnen I, Peumans M, Van Meerbeek B, Lambrechts P. Three-year randomised clinical trial to evaluate the clinical performance, quantitative and qualitative wear patterns of hybrid composite restorations. *Clin Oral Investig* 2010;**14**:441-458.

16. de Andrade AK, Duarte RM, Guedes Lima SJ, Passos TA, Lima KC, Montes MA. Nanohybrid versus nanofill composite in class I cavities: margin analysis after 12 months. *Microsc Res Tech* 2011;**74**:23-27.
17. Assif D, Nissan J, Gafni Y, Gordon M. Assessment of the resistance to fracture of endodontically treated molars restored with amalgam. *J Prosthet Dent* 2003;**89**:462-465.
18. Bassir MM, Labibzadeh A, Mollaverdi F. The effect of amount of lost tooth structure and restorative technique on fracture resistance of endodontically treated premolars. *J Conserv Dent* 2013;**16**:413-417.
19. van Dijken JW. A clinical evaluation of anterior conventional, microfiller, and hybrid composite resin fillings. A 6-year follow-up study. *Acta Odontol Scand*1986;**44**:357-367.
20. Swanson K, Madison S. An evaluation of coronal microleakage in endodontically treated teeth. Part I. Time periods. *J Endod* 1987;**13**:56-59.
21. Palaniappan S, Bharadwaj D, Mattar DL, Peumans M, Van Meerbeek B, Lambrechts P. Three-year randomized clinical trial to evaluate the clinical performance and wear of a nanocomposite versus a hybrid composite. *Dent Mater* 2009;25;1302-1314.
22. Mannocci F, Bertelli E, Sherriff M, Watson TF, Pitt Ford TR. Three-year clinical comparison of survival of endodontically treated teeth restored with either full cast coverage or with direct composite restoration. *J Prosthet Dent* 2002; **88**:297-301.
23. Mannocci F, Bertelli E, Sherriff M, Watson TF, Pitt Ford TR. Three-year clinical comparison of survival of endodontically treated teeth restored with either full cast coverage or with direct composite restoration. *J Prosthet Dent* 2002; **88**:297-301.
24. Mannocci F, Bertelli E, Sherriff M, Watson TF, Pitt Ford TR. Three-year clinical comparison of survival of endodontically treated teeth restored with either full cast coverage or with direct composite restoration. *J Prosthet Dent* 2002; **88**:297-301.
25. Tamse A, Fuss Z, Lustig J, Kaplavi J. An evaluation of endodontically treated vertically fractured teeth. *J Endod* 1999; 25;506-508.
26. Hansen EK, Asmussen E. In vivo fractures of endodontically treated posterior teeth restored with enamel-bonded resin. *Endod Dent Traumatol* 1990;**6**:218-225.
27. Mannocci F, Bertelli E, Sherriff M, Watson TF, Pitt Ford TR. Three-year clinical comparison of survival of endodontically treated teeth restored with either full cast coverage or with direct composite restoration. *J Prosthet Dent* 2002; **88**:297-301.
28. Tamse A, Fuss Z, Lustig J, Kaplavi J. An evaluation of endodontically treated vertically fractured teeth. *J Endod* 1999; 25;506-508.
29. Can Say E, Kayahan B, Ozel E, Gokce K, Soyman M, Bayirli G. Clinical evaluation of posterior composite restorations in endodontically treated teeth. *J Contemp Dent Pract* 2006;**7**:17-25.
30. Raskin A, Setcos JC, Vreven J, Wilson NH. Influence of the isolation method on the 10-year clinical behaviour of posterior resin composite restorations. *Clin Oral Investig* 2000;4;148-152.
31. Sornkul E, Stannard JG. Strength of roots before and after endodontic treatment and restoration. *J Endod* 1992;**18**:440-443.