ARAŞTIRMA / ORIGINAL ARTICLE

Gülhane Tıp Dergisi 2010; 52: 1-6

Buccal and palatal cusps fracture resistance of root filled teeth using various dentine bonding agents and hybrid composite resin

Elif Aybala Oktay (*), Güneş Şahinkesen (**)

SUMMARY

In this study, we aimed to compare the buccal and palatal cusp fracture resistance of endodontically treated primary maxillary premolars with mesial-occlusal-distal cavity which was restored with composite resin by using different types of bonding adhesives. A hundred extracted double rooted human maxillary premolars were randomly separated into five groups in which 20 teeth were included in each group. Group 1 was restored with total performance hybrid spectrum hybrid composite and Prime&Bond NT, and Group 2 was restorated with total performance hybrid spectrum hybrid composite and Clearfil S-Tri Bond. Group 3 was restorated with total performance hybrid spectrum hybrid composite and Clearfil SE Bond. Group 4 was considered as positive control, and Group 5 was considered as negative control. Also each experimental group was divided into two subgroups of 10 teeth in order to compare the values of buccal and palatal cusp fracture resistance. Group 3, in which Clearfil SE Bond was used showed a higher value of fracture resistance than Group 1, in which Prime&Bond NT was used. When samples were investigated, it was observed that there was no statistically significant difference between buccal and palatal cusps of mesial-occlusal-distal cavities which were restorated with hybrid composite and different bonding adhesives.

Key words: *Cusp fracture resistance, endodontically restorated premolars*

ÖZET

Hibrid-kompozid ve farklı bonding ajanların kullanıldığı kök kanal tedavili dişlerin, bukkal ve palatinal tüberkül kırılma dirençleri

Bu çalışmada, farklı tipte bonding ajan kullanarak kompozit rezin ile restore edilen meziyo-oklüzo-distal kaviteli ve endodontik olarak tedavi edilmiş üst birinci küçük azı dişlerinin bukkal ve palatinal tüberkül kırılma dirençlerini karşılaştırılması amaçlanmıştır. Çekilmiş çift köklü 100 adet üst çene küçük azı (maksillar premolar) dişleri her bir grup 20 diş içerecek şekilde rastgele 5 gruba ayrıldı. Grup 1 total performans hibrid spektrum hibrid kompozit ve Prime&Bond NT ile ve Grup 2 total performans hibrid spektrum hibrid kompozit ve Clearfil S-Tri Bond ile restore edildi. Grup 3 total performans hibrid spektrum hibrid kompozit ve Clearfil SE Bond ile restore edildi. Grup 4 pozitif kontrol ve Grup 5 negatif kontrol grupları olarak belirlendi. Ayrıca deney gruplarının her biri kendi içinde bukkal ve palatinal tüberkül kırılma direnç değerlerini karşılaştırmak için 10 adet dişten oluşan alt gruplara ayrıldı. Clearfil SE Bond'un kullanıldığı Grup 3, Prime&Bond NT'nin kullanıldığı Grup 1'den istatistiksel olarak daha yüksek kırılma direnci değeri gösterdi. Örnekler değerlendirildiğinde, hibrid kompozit ve farklı bonding ajanlar ile restore edilen meziyo-oklüzo-distal kavitelerin bukkal ve palatinal tüberküllerinde kırılma dirençleri arasındaki farklılığın istatistiksel olarak anlamlı olmadığı görüldü.

Anahtar kelimeler: *Tüberkül kırılma direnci, endodontik olarak tedavi edilmiş küçük azı dişleri*

* Dental Service, Turkish Army Land Forces

**Department of Conservative Dentistry and Endodontics, Gulhane Military Medical Academy

Reprint request: Elif Aybala Oktay, Dental Service, Turkish Army Land Forces, Ankara, Turkey

E-mail: eaybala@yahoo.com

Date submitted: August 18, 2009 • **Date accepted:** February 04, 2010

Introduction

Endodontically treated teeth are structurally different from unrestored vital teeth and require specialized restorative treatment (1). Loss of dentin including anatomic structures such as cusps and arched roof of the pulp chamber may result in tooth tissue fracture after the final restoration (2). In particular, occlusal forces may result in cuspal fractures in root-filled posterior teeth (3). Cusps deform due to occlusal forces and lateral excursions, even though intact teeth are stiff (4), and the stress generated during friction between ocluding surfaces is mainly absorbed in the periodontal ligament (5). Caries, trauma and the excessive removal of dentine during root canal treatment produce a substantial reduction in tooth strength and increase cuspal fracture under occlusal load (6,7).

Therefore, intracoronal reinforcement of teeth, especially posterior ones, is important in order to protect them against fracture (8). An optimal tooth restoration material should mimic structural, mechanical and physical characteristics of dentin and enamel (9).

The use of resin composites for restoring posterior stress-bearing cavites has increased significantly in recent years (10). The mechanical properties of resin-based composite mainly depend on its microstructure and composition. The microstructural characteristics involve the type, size and quantity of filler particles. These characteristics are directly related with the composition of the composite (11).

Resin composites with dentin bonding agents are materials that are considered good candidates for the direct restoration of endodontically-treated teeth. When it comes to strengthening the tooth structure and increasing its fracture resistance, the role of resin composites with dentin bonding agents has generally been accepted (12).

Recently self-etch adhesive systems have been widely utilized due to their simplified application procedures and low-technique sensitivity when compared to etch and rinse adhesives (13). Self-etch adhesive systems can generally be classified as either a one-step (all-in-one) adhesive system or a two-step adhesive system, based on whether or not a bonding agent is applied (14). In addition, a two-step adhesive system reportedly exhibited relatively higher bonding performance of resin to tooth than a one-step self-etch adhesive system (15).

Clinically, it is important when replacing significant amounts of tooth structure that the restoration will be functional and not fracture when strong occlusal contacts are present. The purpose of this study was to compare the fracture resistance of the buccal cusps and palatal cusps of root-filled maxillary premolar teeth with mesial-occlusal-distal (MOD) cavities restored with new-generation dentine bonding adhesives.

Material and Methods

A hundred intact, noncarious, nonrestored double rooted human mature maxillary premolar teeth freshly extracted for orthodontic and periodontal reasons were selected. The mesio-distal and bucco-lingual dimension of the crown and the cervico-apical length of the roots were similar. Measurements were made by the help of a hand length meter. Only sound teeth with an average length of 20 mm-21 mm, a bucco-lingual coronal width of 8.5 mm-9 mm and a mesio-distal coronal dimension of 6.5 mm-7 mm were included in the study. Any calculus and soft tissue deposits were removed from the teeth using a hand scaler, and the root surfaces were examined in a stereomicroscope for any root fracture and crack. Canal morphology was verified from standardized apical radiographs (70 kV and 0.08 s) both in the mesial-distal and bucco-lingual directions. Because of anatomic variability, the teeth were prepared free hand. The MOD preparations were prepared using high speed diamond rotating cutting instruments (11161791 QTY) under constant water cooling. The MOD cavities were prepared so that the bucco-lingual width of the occlusal isthmus was one-third of the width between buccal and lingual cusp tips, and the bucco-lingual width of the approximal preparations was one-third of the bucco-lingual width of the crown. The approximal boxes were prepared straight and their depth was limited to 2 mm coronally from the cemento-enamel junction (Figure 1).

Endodontic access cavity preparation and root canal treatment were performed in three experimental

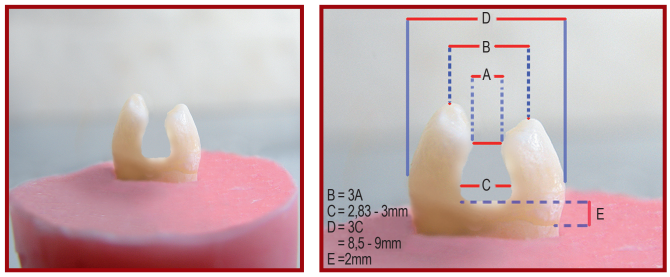

Figure 1. Shape of open MODE. D: Bucco-lingual distance, B: Distance between cusps, A: Width of occlusial cavity, C: Approximate width of cavity

groups. After endodontic access cavities preparation, a size 15 K-file was inserted into the canals until it was visible at the apical foramen for determination of the working length. The working length of each canal was calculated to be 1 mm less than the length obtained with this initial file. Root canal preparations were performed using Hero 642 NiTi rotary instruments. The recommended working speed was 300 RPM. All canals were prepared to ISO size 30-0.04 taper. The instrumentation was performed strictly according to the manufacturer's instructions. The canals were irrigated with 3 mL of 2.5% NaOCl solution after the use of each instrument. Following biomechanical preparation, the canals were irrigated with 3 mL of 15% EDTA solution for 30 seconds to remove smear layer. Final canal irrigation was accomplished with 3 mL of 2.5% NaOCL solution. Instruments were withdrawn when resistance was felt and changed for the next instrument. Canals were dried with absorbent paper points. Root fillings were completed using gutta percha (4200A-B Grenoble France) and AH Plus (Dentsply De Trey GmbH 78467 Konstanz, Germany) root canal sealer using lateral condensation. After root canal fillings were completed, the test specimens were restored in the following manner: the material used in this study and their composition are shown in Tables I and II).

Group 1: According to application procedure of 36% phosphoric acid, Prime&Bond NT (Dentsply, Caulk, Milford, DE, USA) acid was applied. After washing with pressured water spray for 15 seconds extra water was removed with light air. The surface was moist. Prime&Bond NT was applied with single usage brush for 20 seconds. It was applied on all cavity with light air for 5 seconds. Light was applied for ten seconds. Total performance hybrid (TPH) spectrum composite resin was applied on MOD cavity with mouth spatula. Filling was polymerized by applying light on it for 20 seconds.

Group 2: Cearfil Tri–S Bond (Clearfil S^3 Bond); (Kuraray Medical Inc. Okayama, Japan) was used as a one-step adhesive for the all-in-one adhesive sys-

Table I. Materials used and their composition

Adhesive system	*Primer (Self etching primer)*	*Adhesive Resin*	*Manufacturing firm*
Clearfil SE Bond (two-step adhesive system) (self-etch)	10-Methacryloyloxydecyl dihydrogen phosphate (MDP) 2-Hydroxyethyl methacrylate (HEMA) Hydropilicdimethacrylate dl-Camphoroquinone N,N-Dietanol p-toluidine water	Methacryloyloxydecyl dihydrogen phosphate (MDP) Bis-PhenolA diglycidylmethacrylate (Bis GMA) Hydroxyethyl methacrylate (HEMA) Hydropilic dimethacrylate dl-Camphorquinone N,N –Dietanol p-toluidine Silanated kolloidal silica	Kuraray, Osaka, Japan
Clearfil S Bond (all-in one adhesive system) (self-etch)	10- Methacryloyloxydecyl dihydrogen phosphate (MDP) Bis-Phenol diglycidylmethacrylate (Bis-GMA) 2- Hydroxyethyl methacrylate (HEMA) dl- Camphoroquinone Etil alcohol, WaterSilanated kolloidal silica		Kuraray, Osaka, Japan
Prime&Bond NT one bottle (Total-etch)	Conditioner	Dipentaeritilol pantaakrilt monofosfat (PENTA), UDMA, Resin R5-62-1 T-Resin, D-Resin Nanafiller Acetone	Dentsply

Table II. The composite material used and its composition

TPH Spectrum	0.8 (Baglass) 0.5 (SIO)	0.04-2 (SIO)	Barium glass, silica	78 to 79	Modified Bis-GMA urethane, boron silicate of silanated aluminum and barium, silanated pyrolytic silica, camphoroquinone, EDAB, butylated hydroxytoluen, and mineral dyes	Dentsply Latin America Petropolis, RJ, Brazil	554143

tem. After applying air in high pressure for 5 seconds it was polymerized with light for 10 seconds. Later, spectrum TPH composite was placed in cavity and polymerized with light for 20 seconds.

Group 3: Clearfil SE Bond; Two-step adhesive system. Premier (Kuraray Medical Inc. Okayama, Japan) was applied on cavity with single usage brush for 20 seconds and applied on cavity homogenously. Its polymerization was ensured with light for 10 seconds. Later, spectrum TPH composite was placed in cavity and polymerized with light for 20 seconds.

Group 4: (Negative control)

Group 5: (Positive control)

The teeth were randomly divided into three experimental groups and two control (positive and negative) groups of 20 teeth each. Negative control group did not receive endodontic cavity preparation or root canal treatment. Positive control group received endodontic cavity and MOD cavity preparation. Positive and negative experimental control groups were also divided into two subgroups of 10 teeth each. While the buccal cusp fracture resistance was observed in one of the subgroups, the palatinal cusp fracture resistance was observed in the other subgroup.

The teeth were stored in an incubator at 37 C° in 100% humidity until the execution of the mechanical tests. All specimens were thermocycled for 500 cycles between 5 and 55 C° using a dwell time of 30 s. Copper rings, 25 mm in length and 10 mm in diameter, were filled with self-curing acrylic resin to the level 2 mm apical to the cemento-enamel junction. The copper rings with the teeth were placed into a universal testing machine (Llyod, LRX, Fareham, Hants, England). The buccal walls of the teeth were then subjected to a slowly increasing force (1 mm/min) at the junction of the buccal cusp and the filling material. The force was applied at the middle mesio-distal width of the buccal cusp and at a 135° angle to the long axis of the teeth. Same procedures were applied for palatinal cusps of the teeth. The force necessary to fracture each tooth was recorded (Figure 2).

For statistical analysis, SPSS for Windows Ver.15.0 (SPSS Inc., IL, USA) and NCSS 2007 (NCSS Inc., Utah, USA) were used. All descriptive statistics are shown as mean±standard deviation. The normality of the data from all teeth and from subgroups was assessed

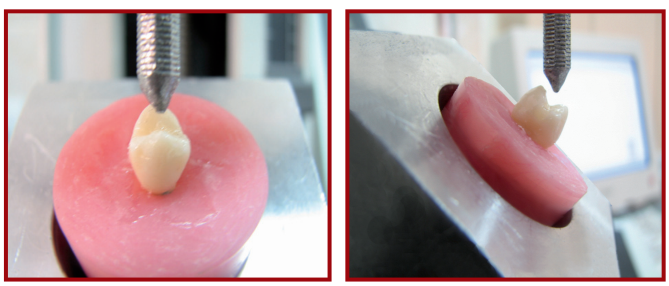

Figure 2. The state of teeth placed on fracture plan

graphically and by using the Shapiro-Wilk Test results. To find differences between specimens, a one-way analysis of variance (ANOVA) test was conducted on data that were normally distributed, and the Kruskall–Wallis tests were used for non-normal data. When significant differences were found, the reasons for these differences were analyzed by post-hoc pairwise tests.

Results

The difference between buccal cusp 351 kgf and palatal cusp 320 kgf for fracture resistance was found statistically insignificant (z=1.035; p=0.301). There was statistically significant difference in fracture resistance between adhesives in hybrid composite group (F=7.962; p=0.001) (Figure 3).

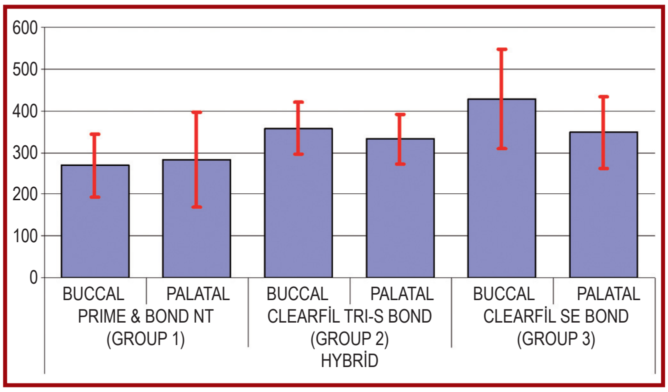

Figure 3. The fracture resistance to buccal and palatal adhesives in hybrid composite group

The difference (69 kgf) between Prime&Bond NT and Clearfil Tri-S Bond was statistically insignificant (p=0.051), whereas 112 kgf of difference between Prime&Bond NT and Clearfil SE Bond was statistically significant (p=0.001). There was no statistically significant difference between Clearfil Tri-S Bond and Clearfil SE Bond (p=0.421).

When subgroups of buccal and palatal cusp in which restorative materials with dental adhesives were applied to teeth together compared, buccal cusp showed a lower fracture resistance than palatal cusp. However 14 kgf difference in terms of fracture resistance was not statistically significant (t=0.328; p=0.746).

Also buccal cusp showed higher fracture resistance than palatal group in hybrid restorative material Clearfil Tri-S Bond group; but 25 kgf difference had no statistically significance (t=0.949; p=0.355).

In Clearfil SE Bond group, buccal cusp was found more resistant than palatal cusp in hybrid restorative material. The difference in resistance was statistically significant (z=1.436; p=0.165).

When control group was investigated internally, 578 kgf difference between control (-) group and control (+) group was found to be important (t=9.729; p<0.001). Control (-) group had 5 times more fracture resistance than control (+) group. In the control (-) group the fracture resistance of buccal cusp was 973 kgf, whereas the fracture resistance of palatal cusp was 492 kgf. A fracture resistance difference of 480 unit between buccal and palatal cusp was statistically significant (Z=3.780; p<0.001) (Figure 4).

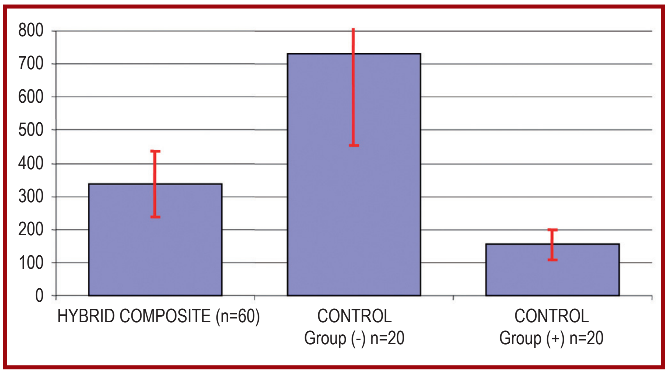

Figure 4. Investigation and comparison of hybrid composite and control groups

In the control (+) group fracture resistance of buccal cusp was 169 kgf, whereas fracture resistance of palatal cusp was 138 kgf. Buccal cusp had higher fracture resistance than palatal cusp. However the difference between two groups was not statistically significant (Z=1.587; p=0.123).

Discussion

Fracture of teeth is a frequent dental problem (16). Clinicians often experience the clinical fracture of endodontically treated teeth (17). Many factors, such as caries, abrasion, erosion, malocclusion, trauma, masticatory stresses, aging and dessication caused by endodontic therapy contribute to the fracture of cusps (18). In addition, the tooth anatomy itself can be partially responsible for susceptibility to cuspal fracture (19).

However, cavity preparation procedures for tooth restorations seem to be the major cause in most cuspal fractures (20). In particular, several studies have been performed to assess the mechanical resistance to fracture of root-filled maxillary premolars (21,22).

The resistance of teeth to fracture and the stiffness of cusps are reduced by cavity preparation, and the degree of reduction is related to the depth and width of the occlusal cavity as well as to the additional preparation of interproximal surfaces (23-25). Access preparation for endodontic treatment causes a more severe loss of stability, especially in combination with MOD cavities (26). In the present studies, it has been demonstrated that with the MOD preparation cuspal rigidity decreases by 50% and with an additional endodontic access this diminution reaches to 80%. These reports are in parallel with the result of our study.

The mechanical behavior of intact and healthy teeth is different from that of restorated teeth under the same occlusal loading conditions. Healthy teeth distribute load-generated stress more homogeneously, because enamel is not appreciably deformed and the deformation is transferred to the more resilient dentin (27). When the continuity of the enamel is lost due to crack or cavity preparation, the properties of dentin play a major role in cusp behavior (28).

Test designs of laboratory studies can only partially simulate the clinical situation. Clinical loading of teeth is a dynamic process, in which loading force, frequency and direction vary greatly. The choices made in laboratory tests result in a large variation. Also due to a large number of other variables involved (i.e. tooth condition, tooth type, procedures and restorative materials). It is almost impossible to compare fracture resistance data between laboratory studies (29,30). In most static mechanical fracture test reported in the literature, the premolars were loaded on the palatal cusp at 130–150 degree angles to the longitudinal axis of the tooth, generating a compressive load prependicular to the cuspal side. On the contrary, during function, the occlusion generates non-axial forces resolved in to their vectors along the cuspal side following the paralleogram of forces (31). In this study, static load was applied at the middle mesiodistal width of the buccal cusp, palatinal cusp and at a 135 C°angle to the long axis of the teeth.

In this study, the applying force speed was 1 mm/min as stated that lower speeds are accompanied by greater plastic deformation, thus, higher fracture resistance measurements will be recorded (32).

Dentine bonding agent splint the cusps and reduce cuspal flexure, which reduces stress that generate on tooth crowns (33). Several previous studies have shown that restoration with resin composite provided substantial recovery of tooth stiffness, especially when coupled with dentin etching. Etching both enamel and dentine provided additional mechanical retantion and additional surface area for the dentine bonding adhesive, enhancing stiffness recovery (34). These reports are in accordance with the results of this study.

Because of its good bonding efficacy (35) a two-step self-etching priming system, Clearfil SE Bond, was chosen as the reference material in this study. Clearfil SE Bond also has been used in other studies in comparison with all-in-one adhesives (36). Therefore, it is appropriate to use the material for a standard bonding system, and the evaluation will prove reliability of the test material.

In this study, no significant difference was found between buccal and palatal cusp fracture in test groups. However, Clearfil SE Bond had statistically higher fracture resistance than Prime&Bond NT. Although Clearfil SE Bond had higher fracture resistance than Clearfil S-Tri Bond, there was no statistically significance between these two groups.

Prime& Bond NT we used in our study showed the least buccal and palatal fracture resistance when compared with the other groups. The cause of the difference was that in total-etching (Prime&Bond NT) adhesive system phosphoric acid was used to etch the smear layer following rinsing. A moist surface is required in order to maintain a noncollapsed demineralized collagen network etched dentine. Usually these one-bottle adhesive systems contain ethanol or acetone as a solvent. Prolonged and intensive contact with acetone-containing products may lead to minute dissolution of the outermost surface of calcium hydroxide materials.

The use of strong 36% phosphoric acid with Prime&Bond NT, according to the manufacturer's instructions, may be excessive in the absence of a smear layer and smear plugs, possibly causing "over etching" and subsequent collapse of the collagen network. This situation may inhibit the penetration of adhesive resin and result in a weak hybrid layer.

An adhesive interface represents the transition area between materials with different moduli of elasticity; as a consequence, the adhesive interfaces are considered the weak link of adhesive restorations which can fail under load, leading to the mechanical failure of the buccal and palatal. This kind of fracture pattern was due to morphology of the MOD preparations, leaving limited amounts of residual tooth structure at level of the cervical margin of the specimens.

Clearfil SE Bond showed the best fracture resistance among all bonding agents. Considering the clinical advantages of the simplified all-in-one adhesive systems, the bond to enamel requires further improvement. When a self-etch adhesive two step in hybride composite was used the increase in cuspal rigidity was significantly greater than total-etch adhesive whereas combination of nano composite and adhesives need further investigation. We believe that further studies should be made to investigate the accordance between adhesives and composites. Thus, the use of composite resin and a bonding system has become widely accepted for restorative treatment of nonvital teeth. Clinical studies should be performed keeping in mind the accordance between composites and adhesives.

References

1. Wagnild G, Muller K. Restoration of endodontically treated teeth. In: Cohen S, Hargreaves KM (eds). Pathways of the Pulp. 9th ed. St Louis: Mosby Co, 2006: 786-821.
2. Belli S, Erdemir A, Özcopur M, et al. The effect of fibre insertion on fracture rersistance of root filled molar teeth with MOD preparations restored with composite. Int Endod J 2005; 38: 73-80.
3. Eissman HF, Radke RA. Postendodontic restoration. In: Cohen S, Burns RC (eds). Pathways of the Pulp. St Louis: Mosby Inc, 1984: 701-749.
4. Jantarat J, Palamara J, Msser H. An investigation of cuspal deformation and delayed recovery after occlusal loading. J Dent 2001; 29: 363-370.
5. Doyglas WH, Sakaguchi RL, DeLong R. Frictional effects between natural teeth in an artificial mouth. Dental Mater 1985; 1: 115-119.
6. El-Badrawy WA. Cuspal deflection of maxillary premolars restored with bonded amalgam. Oper Dent 1999; 24: 337-343.
7. Mannocci F, Bertellii E, Sherriff M, Watson TF, Ford TR. Three-year clinical comparison of survival endodontically treated teeth restored with either full cast coverage or with direct composite restoration. J Prosthet Dent 2002; 88: 297-301.
8. Belli S, Erdemir A, Yildirim C. Reinforcement effect of polyethylene fiber in root filled teeth: comparison of two restoration techniques. Int Endod J 2006; 39: 136-142.
9. Sabbagh J, Vreven J, Leloup G. Dynamic and static moduli of elasticity of resin-based materials. Dent Mater 2002; 18: 64-71.
10. Manhart J, Kunzelmann KH, Chen HY, Hickel R. Mechanical properties and wear behavior of light cured packable composite resins. Dent Mater 2000; 16: 33-40.
11. Al-Sharaa KA, Watts DC. Stickiness prior to some light cured resin composites. Dent Mater 2003; 19: 182-187.
12. Trope M, Tronstad L. Resistance to fracture of endodontically-treated premolars restored with glass ionomer cement or acid etch resin composite. J Endod 1991; 17: 257-259.
13. Peumans M, Kanumilli P, De Munck J, Van Landuyt K, Lambrechts P, Van Meerbeek B. Clinical effectiveness of contemporary adhesives: A systematic review of current clinical trials. Dental Mater 2005; 21: 864-881.
14. Knobloch LA, Gailey D, Azer S, Johnton WM, Clelland N, Kerby RE. Bond strengths of one-and two-step self-etch adhesive systems. J Prosthet Dent 2007; 97: 216-222.
15. De Munck J, Van Meerbeek B. The current status of bonding to dentinanno. Int J Oral Med Sci 2007; 6: 45-60.
16. Eakle WS, Maxwell EH, Braly BV. Fractures of posterior teeth in adults. J Am Dent Assoc 1986; 112: 215-218.
17. Ferrari M, Vichi A, Mannocci F, Mason PN. Retrospective study of the clinical performance of fiber posts. Am J Dent 2000; 13: 9B-13B.
18. Ulusoy N, Nayyar A, Morris CF, Fairhurst CW. Fracture durability of restored functional cusps on maxillary nonvital premolar teeth. J Prosthet Dent 1991; 66: 330-335.
19. Cavel WT, Kelsey WP, Blankenau RJ. An in vito study of cuspal fracture. J Prosthet Dent 1985; 53: 38-42.
20. Goel VK, Khera SC, Gurusami S, Chen RSC. Effect of cavity depth on stresses in a restored tooth. J Prosthet Dent 1992; 67: 174-183.
21. Trope M, Langer I, Maltz D, Tronstad L. Resistance to fracture of restored endodontically treated premolars. Endod Dent Traumatol 1986; 2: 35-38.
22. Grandini S, Goracci C, Tay FR, Grandini R, Ferrari M. Clinical evaluation of the use of fiber posts and direct resin restorations for endodontically treated teeth. Int J Prosthodont 2005; 18: 399-404.
23. Blaser PK, Lund MR, Cochran MA, Potter RH. Effects of designs of class 2 preparations on resistance of teeth to fracture. Oper Dent 1983; 8: 6-10.
24. Caron GA, Murchison DF, Cohen RB, Broome JC. Resistance to fracture of teeth with various preparations for amalgam. J Dent 1996; 24: 407-410.
25. Hood JA. Biomechanics of the intact, prepared and restored tooth: some clinical implications. Int Dent J 1991; 41: 25-32.
26. Panitvisia P, Messr HH. Cuspal deflection in molars in relation to endodontic and restorative procedures. J Endod 1995; 21: 57-61.
27. Ausiello P, Apicella A, Davidson CL. Effect of adhesive layer properties on stress distribution in composite restorations – a 3D finite element analysis. Dent Mater 2002; 18: 295-303.
28. Sakaguchi RL, Brust EW, Cross M, DeLong R, Douglas WH. Independent movement of cusps during occlusal loading. Dent Mater 1991; 7: 186-190.
29. Maccari PCA, Conceicao EN, Nues MF. Fracture resistance of endodontically treated teeth restored with three different prefabricated esthetic posts. J Esthet Restor Dent 2003; 15: 25-30.
30. Fokkinga WA, Kreulen CM, Vallittu PK, Creugers NHJ. A structured analysis of in vitro failure loads and failure modes of fiber, metal and ceramic post-and-core systems. Int J Prosthodont 2004; 17: 476-482.
31. Akkayan B, Gülmez T. Resistance to fracture of crowned teeth restored with different post systems. Eur J Prosthodont Restor Dent 1998; 6: 13-18.
32. Espevik S. Stress/strain behavior of dental amalgams. Acta Odontol Scand 1978; 36: 103-111.
33. Salis SG, Hood JA, Stokes AN, Kirk EE. Patterns of indirect fracture in intact and restored human premolar teeth. Endod Dent Traumatol 1987; 3: 10-14.
34. Hernandez R, Bader S, Boston D, Trope M. Resistance to fracture of endodontically treated premolars restored with new generation bonding systems. Int Endod J 1994; 27: 281-284.
35. Toledano M, Osorio R, De Leonardi G, Rosalles-Leal'JL, Ceballos L, Cabrerizo-Vilchez MA. Influence of self-etching primer on the resin adhesion to enamel and dentin. Am J Dent 2001; 14: 205-210.
36. Ibarra G, Vargas MA, Armstrong SR, Cobb DS. Microtensile bond strength of self-etching adhesives to ground and unground enamel. Adhesive Dent 2002; 4: 115-124.