New adhesives in Class V restorations under combined load and simulated dentinal fluid

Krejci, Ivo; Häusler, Tobias; Sägesser, David; Lutz, Felix

How to cite

KREJCI, Ivo et al. New adhesives in Class V restorations under combined load and simulated dentinal fluid. In: Dental materials, 1994, vol. 10, n° 5, p. 331–335. doi: 10.1016/0109-5641(94)90042-6

This publication URL: https://archive-ouverte.unige.ch/unige:84755
Publication DOI: 10.1016/0109-5641(94)90042-6

Dent Mater 10:331-335, September, 1994

New adhesives in Class V restorations under combined load and simulated dentinal fluid

Ivo Krejci, Tobias Häusler, David Sägesser, Felix Lutz

Department of Preventive Dentistry, Periodontology and Cariology, Dental Institute, Zurich University, Zurich, SWITZERLAND

ABSTRACT

Objectives. This study compared the efficacy of three dentinal adhesives using the "all etch" technique (All-Bond 2, Bisco; Scotchbond MP, 3M Dental Products Co.; OptiBond, Kerr) with a dentinal adhesive which still uses phosphoric acid to condition enamel and a self-etching primer for dentin (A.R.T.-Bond, Coltene/Whaledent).

Methods. Eight V-shaped mixed Class V restorations were placed per group in extracted human premolars. The restorations were subjected to 1,200,000 mechanical occlusal cycles (max. force 49 N; frequency 1.7 Hz) and 3,000 simultaneous thermal cycles (5-50-5°C). Dentinal fluid was simulated using 1:3 diluted horse serum and fed into the pulp chamber both during restoration and loading. Percentages of "continuous margin" were assessed on SEM replicas of enamel and dentinal margins at 200x magnification immediately before and after stressing, respectively.

Results. No significant differences were observed before stress between the materials either in enamel or in dentin. After stress, however, OptiBond and A.R.T.-Bond performed significantly better in dentin than the two other adhesives (Kruskal-Wallis, Mann-Whitney; $p < 0.05$). Although high initial values were observed, All-Bond 2 and Scotchbond MP were not stress-resistant under simulated physiological conditions.

Significance. The predicted clinical potential of All-Bond 2 and Scotchbond MP is inferior to that of OptiBond and A.R.T.-Bond.

INTRODUCTION

The higher life expectancy of the population and improved dental prophylaxis in industrialized countries have led to greater numbers of elderly patients retaining more of their natural dentition (Imfeld, 1992). Due to involutive processes of the periodontal tissues and destructive mechanical oral hygiene habits (Bergström and Eliasson, 1988), eventually combined with occlusal stress (Lee and Eakle, 1984; Braem *et al.*, 1992), an increased number of denuded cervical cementum with V-shaped defects are found in this group of patients. In addition, 35-55% of multi-surfaced restorations in posterior teeth have cervical margins located in dentin or in unstructured enamel (Mayer, 1991). The adhesive restoration of such non-retentive defects can only be successfully managed by using highly efficient adhesives which can seal enamel and dentinal margins.

Earlier studies have shown that most of the former dentinal adhesives did not optimize the marginal quality of mixed Class V restorations in dentin (Airoldi *et al.*, 1992). Unfortunately, some of these formulations even compromised enamel adhesion (Airoldi *et al.*, 1992). Consequently, marginal discoloration, hypersensitivity, secondary caries and loss of restorations occured in clinical cases. In addition, the application of most of these commercially available products was complex. Different substances were used to condition enamel and dentin and their application was often restricted to enamel or to dentin without contacting the other hard tissue (Van Meerbeek *et al.*, 1992a). As a further handicap, defined layer thickness was recommended for some formulations (Erickson, 1992).

All-Bond 2, Scotchbond Multipurpose and OptiBond have recently become available to the profession with universal conditioners for both enamel and dentin, which are claimed to simplify handling and shorten the application time. The aim of this study was to evaluate the efficacy of these three adhesives in mixed Class V restorations under stress and simulated dentinal fluid. The results were compared to the new adhesive A.R.T.-Bond which still uses phosphoric acid to selectively condition enamel.

MATERIALS AND METHODS

Sixteen intact, caries-free upper premolars with completed root formation, stored in 0.1 % thymol solution, were cleaned and randomly assigned to four groups with four teeth each. After sealing the apices with two coats of nail varnish, the roots were fixed in the center of custom-made specimen holders using a cold-polymerizing resin (Paladur, Kulzer & Co., Wehrheim, Germany). The pulpal tissue was not removed. A

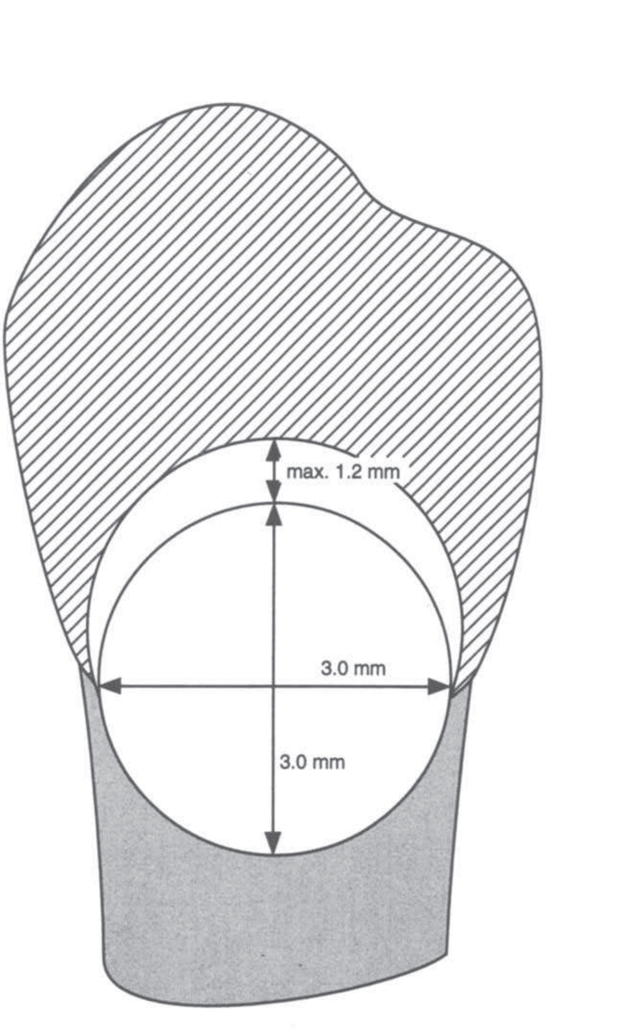

Fig. 1. **Schematic representation of the V-shaped mixed Class V cavity. The maximum depth is 1.5 mm.**

cylindrical hole was made into the pulpal chamber approximately at the middle third of the root. A metal tube (1.4 mm diameter) was inserted into the hole and luted in place using a dentin adhesive (Syntac, Vivadent, Schaan, Liechtenstein). This metal tube was connected by a flexible silicone hose to a serum infusion bottle placed vertically 34 cm above the sample. The infusion bottle was filled with 1:3 diluted horse serum (Pashley *et al.,* 1981; Maita *et al.,* 1991) to simulate the dentinal fluid under the normal hydrostatic pressure of about 25 mm Hg (Mitchem *et al.,* 1988; Tao and Pashley, 1989). With the aid of a three-way valve, the whole system was evacuated with a vacuum pump and finally filled bubble-free with the diluted horse serum.

Two V-shaped Class V cavities were then prepared on the buccal and lingual surfaces in all teeth using 80 µm diamond burs (Amalgam Prep Set, Intensiv SA, Lugano, Switzerland) under continuous water cooling. The cavities prepared at the cemento-enamel junction extended 50% into enamel and 50% into dentin. The dimensions were as follows: diameter 3.0 mm, depth 1.5 mm (Fig. 1). The enamel margin was beveled to a crescent shape with a maximal breadth of 1.2 mm, and the entire cavity was finished using 25 µm diamonds (Universal Prep Set, Intensiv SA, Lugano, Switzerland). The preparations were checked for imperfections under a stereo microscope (M5, Wild AG, Heerbrugg, Switzerland) at 12x magnification.

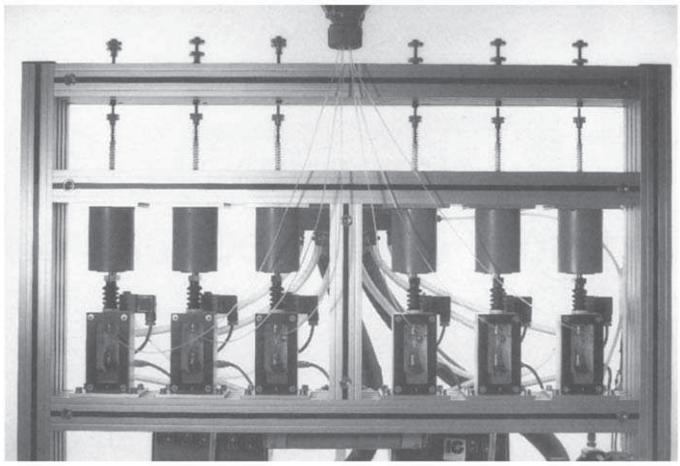

Fig. 2. **The apparatus for simultaneous simulation of chewing loads and thermal cycling under dentinal fluid.**

Four teeth with a total of eight cavities were randomly assigned to one of the four tested adhesive systems (Table 1). The bonding to enamel and dentin was done meticulously following the manufacturer's recommendations for each product, except that the light curing of the adhesive was extended to 60 s for all products. The cavities were then filled with composite in a two-step technique. The first layer, about 1.3 - 1.5 mm thick, was placed into the cervical half of the cavity. Each layer was cured for 60 s with visible light (Optilux 400, Demetron Research Corporation, Danbury, CT, USA). Immediately after curing the restorations were finished and polished using flexible discs (Sof-Lex, 3M Dental Products Co., St. Paul, MN, USA). The polishing was checked with a stereo microscope at 12x magnification and perfected where necessary. An impression was made of each restoration with a vinyl polysiloxane impression material (President light body, Coltène AG, Altstätten, Switzerland) immediately after polishing and prepared for the subsequent quantitative margin analysis in a scanning electron microscope (Amray 1810 T, Amray Inc., Bedford, MA, USA).

After storage in the dark in a 0.9% saline solution at 37°C for 1 wk, the restored teeth were simultaneously loaded with repeated thermal and mechanical stresses in a chewing machine (Krejci *et al.,* 1990a; 1990c; 1993) (Fig. 2). Thermal cycling was carried out in flushing water with the water temperatures changing 3,000x from 5° to 50°C and a dwell time of 2 min each. The mechanical stress consisted of 1,200,000 load cycles in the center of the occlusal surface with a frequency of 1.7 Hz and a maximal load of 49 N applied by using the natural lingual premolar cusp prepared from another extracted human tooth.

The dentinal fluid simulation under stress was achieved by a modification of the stress apparatus test chambers. A correspondingly higher position of the serum infusion bottle compensated for the slight pressure generated by the circulating water in the test chambers. After the stress tests, replicas were again taken of the restorations. Together with the replicas made initially, they were subjected to quantitative marginal analysis under 200x magnification (Krejci *et al.,* 1993). Percentages of "continuous margin" were reported separately for the enamel and dentin margins. Differences in the percentages of "continuous margin" were tested

TABLE 1: DESCRIPTION OF THE EXPERIMENTAL GROUPS				
	Group 1	Group 2	Group 3	Group 4
Cavity	———V-shaped mixed Class V———			
Adhesive System	All-Bond 2 (0290/029192/029292) Bisco, Itasca, IL, USA	Scotchbond MP (Exi 78/79) 3M Dental Products Co., St. Paul, MN, USA	Optibond (112492/750150) Kerr, Glendora, CA, USA	A.R.T. Bond (9204288) Coltene/Whaledent, Mahwah, NJ, USA
Bonding Technique	Enamel & Dentin Etch 15 s Rinsing & "Drying" Mix Primer A & B 5x Primer Application Primer Air Drying - - D/E-Bond Application D/E-Bond Light Curing 60 s	Enamel & Dentin Etch 15 s Rinsing & "Drying" - 1x Primer Application Primer Air Drying - - Adhesive Application Adhesive Light Curing 60 s	Enamel 30 s & Dentin Etch 15 s Rinsing & "Drying" - 1x Primer Application Primer Air Drying Primer Light Curing 60 s Mix DC Paste & Activator DC Paste Application DC Paste Light Cure 60 s	Enamel & Dentin Etch 30 s Rinsing & "Drying" Mix Primer A & B 1x Primer Application Primer Air Drying - - Bond Application Bond Light Curing 60 s
Composite	Bis Fill M (099181) Bisco	Z-100 (1/92) 3M Dental Products Co.	Herculite XR V (21142) Kerr	Brilliant Dentin (9204274) Coltene/Whaledent
Composite Insertion	———2-step———			
Composite Light Curing	———60 s / Layer ———			

"Drying" means water removal without desiccating dentin.

statistically using specific statistical software (Stat View II, Brain Power Inc., Calabasas, CA, USA) on a personal computer (Macintosh IIfx, Apple Computer Inc., Cupertino, CA, USA) using non-parametric tests (Kruskal-Wallis, Mann-Whitney U-test and Wilcoxon signed rank-test).

RESULTS

Less than 2% of the specimens exhibited overfilled margins, underfilled margins, marginal tooth fractures or marginal restoration fractures either before or after loading. These marginal qualities are therefore not reported in detail. Buccally and palatally the values for "continuous margin" before and after stress were not significantly different in all groups. The enamel margins showed good initial marginal adaptation in all groups, ranging from 89% to 100% of "continuous margin". In Group 4, the percentage of "continuous margin" in enamel remained stable after stress. Group 3 showed an insignificant decrease, Groups 1 and 2 a significant decrease of the "continuous margin" scores in enamel after stress (Fig. 3). Before loading, no significant difference was found between the enamel and the dentin scores of "continuous margin" within each group. There were also no significant differences among the four test groups in dentin before loading. After loading, however, Groups 1 and 2 performed significantly worse than Groups 3 and 4 (Fig. 4), and their marginal adaptation in dentin was significantly adversely influenced by loading. No significant difference was found after stress between Groups 3 and 4.

One restoration was lost in Group 2 during stressing. It was not included in the mean values after loading because no evaluation of the marginal adaptation was possible. However, because the restoration was lost, the percentage of "continuous margin" after loading was obviously 0%. If this value was included in the mean, this group rated 66.8 ± 30.2% in enamel and 54.8 ± 29.7% in dentin after loading.

DISCUSSION

The high values of "continuous margin" observed in all four test groups indicated that adhesive systems are currently available which bond to tooth structure under the effects of physiological dentinal fluid flow. Because no significant differences were found, it was irrelevant whether enamel or dentin was the bonding substrate, at least when the adhesives were light-cured for 60 s before composite insertion. These results would confirm the high bond strengths generated on flat dentinal surfaces by other researchers (Perdigao *et al.,* 1993; Swift *et al.,* 1993). However, in this investigation, the situation completely changed after loading. In particular, the percentage of "continuous margin" of All-Bond 2 in dentin was extremely low with a wide range. While less pronounced, similar behavior was observed with Scotchbond MP. In contrast, OptiBond and A.R.T.-Bond showed only a moderate decrease in marginal adaptation in dentin. Besides the influence of dentinal fluid, the discrepancy between shear bond strengths and marginal adaptation in Class V cavities may be attributed to several factors (Davidson *et al.,* 1993). While V-shaped cavities have a rather low C-factor — which is the ratio of the restoration's bonded to unbonded surface (Feilzer *et al.,* 1987) — some residual stresses due to polymerization shrinkage were anticipated. They may have stressed the marginal adaptation under load. The three-dimensional cavity configuration may additionally have contributed to a pronounced

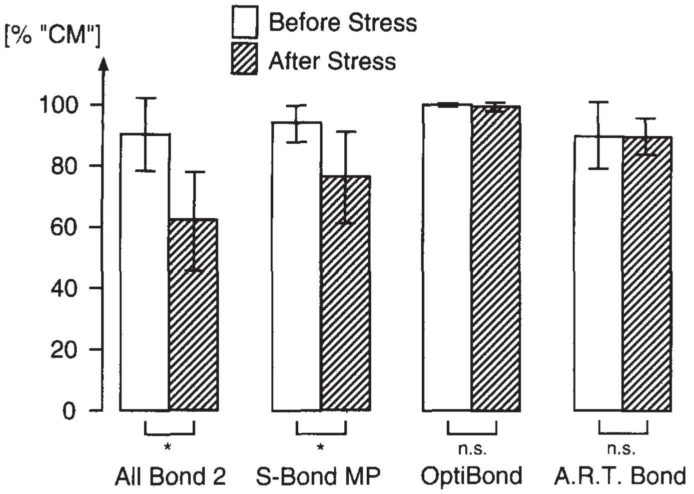

Fig. 3. **Percentages of "continuous margin" [CM] at enamel margins of mixed Class V restorations (* p < 0.05).**

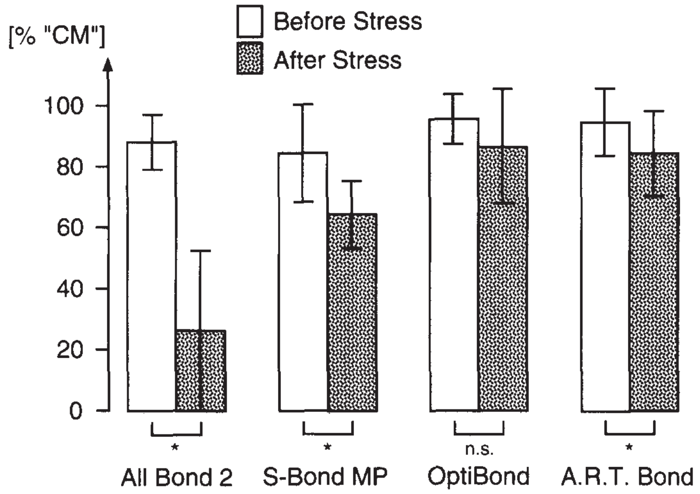

Fig. 4. **Percentages of "continuous margin" [CM] at dentinal margins of mixed Class V restorations (* p < 0.05).**

thermal cycling effect (Haller *et al.,* 1991). Finally, the superimposed long-term mechanical loading, which has been omitted in shear bond strength tests, may further have stressed the adhesive bond (Davidson and Abdalla, 1993; Krejci *et al.,* 1993).

The loading conditions applied in the present study did not exceed the physiological range. The maximal and minimal physiological oral temperatures were recently reported as 67°C and 0°C, respectively (Palmer *et al.,* 1992). The chewing forces (Anderson, 1956; Eichner, 1963), the chewing frequency (Anderson, 1956; Bates *et al.,* 1975) and the simulation of dentinal fluid were also chosen according to physiological data (Pashley *et al.,* 1981; Maita *et al.,* 1991). The high number of load cycles represented a clinical service time of about 5 y (Krejci and Lutz, 1990). Therefore, in predicting long-term behavior, the results of this study may be clinically more relevant than shear bond strength studies where no attempt was made to simulate cavity geometry, or investigations where only the thermal cycling or short mechanical loading with extremely high chewing forces, but without thermal cycling and without simulation of dentinal fluid (Davidson and Abdalla, 1993) were applied.

Because different results may be generated when an adhesive is tested with composites from different manufacturers (Krejci *et al.,* 1990b), composite material from the identical manufacturer was used. In addition, composites with similar coefficient of thermal expansion and modulus of elasticity were chosen for all groups to eliminate the undesirable influence of the extremely different physical properties of the composite brands (Braem, 1985; Gordon *et al.,* 1986).

It was obvious in this study that universal conditioning using weak acids such as 10% phosphoric acid or 10% maleic acid for 15 s negatively influenced marginal adaptation under load in enamel. Although there are other formulations that may successfully condition enamel (Krejci *et al.,* 1993), 37% phosphoric acid may be the most reliable enamel conditioner to date. Therefore, if a so-called total etch is required, 37% phosphoric acid may be preferred because of enamel margins, which are present in most clinical cases. While controversy still exists on phosphoric acid etching of dentin, the topic currently needs a more refined approach. If dentin is etched with phosphoric acid and a good marginal adaptation of the subsequent restoration can be established, the situation is biologically uncritical (Pashley *et al.,* 1992). However, the crucial point is the establishment of sufficient stress-resistant adhesion. This in turn is not only a function of the conditioner. It also involves the wetting properties and the penetration ability of the adhesive into the conditioned surface, both depending among others on the polarity and solubility parameters of the formulation (Asmussen and Uno, 1993). Furthermore, its curing ability in the "hybrid layer" (Nakabayashi *et al.,* 1982; Zidan *et al.,* 1991; Erickson, 1992), the time needed for adhesion establishment (Komatsu and Finger, 1986) and its chemical stability (Bassiouny *et al.,* 1989; Reeves *et al.,* 1990; Crim, 1991) are of importance. All these factors are influenced by the chemistry of the appropriate product. In addition, the physical properties of the restorative system such as flow capacity, elasticity, water sorption or coefficient of thermal expansion determine the stability of the bond under load (Van Meerbeek *et al.,* 1992b).

Summarizing the results of this and a previous study, where additional adhesives were tested under similar conditions (Krejci *et al.,* 1993) and including unpublished data on Clearfil Liner Bond, OptiBond seems to be the only commercial adhesive system with a universal conditioner where these factors have been most thoroughly addressed. As the only representative of this group of products, it was able to seal dentinal and enamel margins successfully. However, because the application of phosphoric acid, primer and dual-cured paste is time consuming, there is no relevant time-saving effect compared to A.R.T.-Bond, which provides similar performance with fewer application steps (Table 1). Therefore, at least under the conditions of this study, there seems to be currently no reason for preferring the "total etch technique" with phosphoric acid to the selective etching of enamel.

Received January 26, 1994 / Accepted April 23, 1994

Address correspondence and reprint requests to:
Ivo Krejci, DDS, PhD
Department of Preventive Dentistry, Periodontology and Cariology
Dental Institute, Zurich University
Plattenstrasse 11
CH-8028, Zurich, SWITZERLAND

REFERENCES

Airoldi RL, Krejci I, Lutz F (1992). *In vitro* evaluation of dentinal bonding agents in mixed class V cavity preparations. *Quintessence Int* 23:355-362.

Anderson PJ (1956). Measurement of stress in mastication. *J Dent Res* 35:664-670.

Asmussen E, Uno S (1993). Solubility parameters, fractional polarities, and bond strengths of some intermediary resins used in dentin bonding. *J Dent Res* 72:558-565.

Bassiouny MA, Kamel IL, Ellison SR (1989). Simulated oral environmental effect on stability of dentin adhesion promotors. *J Dent Res* 68:344, Abstr. No. 1299.

Bates JF, Stafford GD, Harrison A (1975). Masticatory function: A review of the literature. II. Speed of movement of the mandible, rate of chewing and forces developed in chewing. *J Oral Rehab* 2:349-361.

Bergström J, Eliasson S (1988). Cervical abrasion in relation to toothbrushing and periodontal health. *Scand J Dent Res* 96:405-411.

Braem M (1985). An *in vitro* investigation into the durability of dental composites. Thesis, Leuven.

Braem M, Lambrechts P, Vanherle G (1992). Stress-induced cervical lesions. *J Prosthet Dent* 67:718-722.

Crim GA (1991). Microleakage of three dentinal bonding systems: A 6-month evaluation. *Quintessence Int* 22:387-389.

Davidson CL, Abdalla AI (1993). The effect of occlusal load cycling on marginal integrity of adhesive Class V restorations. *J Dent Res* Spec Issue: 114, Abstr. No. 87.

Davidson CL, Abdalla AI, DeGee AJ (1993). An investigation into the quality of dentin bonding systems for accomplishing a durable bond. *J Oral Rehab* 20:291-300.

Eichner K (1963). Messung der Kräfte bei Kauvorgängen. *Dtsch Zahnärztl Z* 18:915-924.

Erickson RL (1992). Surface interactions of dentin adhesive materials. *Oper Dent Suppl* 5:81-94.

Feilzer AJ, de Gee AJ, Davidson CL (1987). Setting stress in composite resin in relation to configuration of the restoration. *J Dent Res* 66:1636-1639.

Gordon M, Plasschaert AJM, Saiku JM, Pelzer RB (1986). Microleakage of posterior composite resin materials and an experimental urethane restorative material, tested *in vitro* above and below the cementoenamel junction. *Quintessence Int* 12:817-820.

Imfeld T (1992). Zahnbestand in Relation zum Alter: Erhebungen in der Schweiz 1980-1990. *Schweiz Monatsschr Zahnmed* 102:549-551.

Haller B, Klaiber B, Betz T, Dobersch S (1991). Shear bond strength to dentin by simulation of three-dimensional Class V cavity configuration. *Dent Mater* 7:206-210.

Komatsu M, Finger W (1986). Dentin bonding agents: Correlation of early bond strength with marginal gaps. *Dent Mater* 2:257-262.

Krejci I, Lutz F (1990). *In vitro*-Testverfahren zur Evaluation dentaler Restaurationen: 3. Korrelation mit *In vivo*-Resultaten. *Schweiz Monatsschr Zahnmed* 100:1445-1449.

Krejci I, Albertoni M, Lutz F (1990a). *In vitro*-Testverfahren zur Evaluation dentaler Restaurationssysteme. 2. Zahnbürsten-/Zahnpastaabrasion und chemische Degradation. *Schweiz Monatsschr Zahnmed* 100:1164-1168.

Krejci I, Picco U, Lutz F (1990b). Dentinhaftung bei zahnfarbenen adhäsiven MOD-Sofortinlays aus Komposit. *Schweiz Monatsschr Zahnmed* 100:1151-1159.

Krejci I, Reich T, Lutz F, Albertoni M (1990c). *In vitro*-Testverfahren zur Evaluation dentaler Restaurationssysteme. 1. Computergesteuerter Kausimulator. *Schweiz Monatsschr Zahnmed* 100:953-960.

Krejci I, Kuster M, Lutz F (1993). Influence of dentinal fluid and stress on marginal adaptation of resin composites. *J Dent Res* 72:490-495.

Lee WC, Eakle WS (1984). Possible role of tensile stress in the etiology of cervical erosive lesions of teeth. *J Prosthet Dent* 52:374-380.

Mayer R (1991). Ästhetisch-adhäsive Füllungstherapie im Seitenzahngebiet eine Illusion? *Dtsch Zahnärztl Z* 46: 468-470.

Maita E, Simpson MD, Tao L, Pashley DH (1991). Fluid and protein flux across the pulpodentine complex of the dog *in vivo*. *Arch Oral Biol* 36:103-110.

Mitchem JC, Terkla LG, Gronas DG (1988). Bonding of resin dentin adhesives under simulated physiological conditions. *Dent Mater* 4:351-353.

Nakabayashi N, Kojima K, Masuhara E (1982). The promotion of adhesion by the infiltration of monomers into tooth substrates. *J Biomed Mater Res* 16:265-273.

Palmer DS, Barco MT, Billy EJ (1992). Temperature extremes produced orally by hot and cold liquids. *J Prosthet Dent* 67:325-327.

Pashley DH, Horner JA, Brewer PD (1992). Interactions of conditioners an the dentin surface. *Oper Dent Suppl* 5:137-150.

Pashley DH, Nelson R, Williams EC, Kepler EE (1981). Use of dentin-fluid protein concentrations to measure pulp capillary reflection coefficients in dogs. *Arch Oral Biol* 26:703-706.

Perdigao J, Swift EJ, Cloe BC (1993). Effects of etchants, surface moisture, and resin composite on dentin bond strengths. *Am J Dent* 6:61-64.

Reeves GW, Fitchie JG, Scarbrough AR, Hembree JH (1990). Microleakage of Gluma Bond, Scotchbond 2 and a glass ionomer/composite sandwich technique. *Am J Dent* 3:195-198.

Swift EJ, Denehy GE, Beck MD (1993). Use of phosphoric acid etchants with Scotchbond Multi-Purpose. *Am J Dent* 6:88-90.

Tao L, Pashley DH (1989). Dentin perfusion effects on the shear bond strengths of bonding agents to dentin. *Dent Mater* 5:181-184.

Van Meerbeek B, Inokoshi S, Braem M, Lambrechts P, Vanherle G (1992a). Morphological aspects of the resin-dentin interdiffusion zone with different dentin adhesive systems. *J Dent Res* 71:1530-1540.

Van Meerbeek B, Lambrechts P, Inokoshi S, Braem M, Vanherle G (1992b). Factors affecting adhesion to mineralized tissues. *Oper Dent Suppl* 5:111-124.

Zidan O, Ross G, Lee IK, Gomez-Marin O, Yeh SH (1991). The effect of dentin pre-treatment and heat-augmented cure on marginal gap formation of a dentin bonding agent. *Dent Mater* 7:174-178.