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Science Met Practice at the IAAD Meeting in Orlando: A Resounding Success

Dear Readers,

At the first biennial IAAD meeting from September 11 to 12, 2015 in Orlando, Florida, a superb program was put together by the organizing team consisting of IAAD president Jean-François Roulet, IAAD President-Elect Markus B. Blatz, and the program co-chairs Sillas Duarte Jr and Jin-Ho Phark (Fig 1). With the general theme being "Science Meets Practice," a total of 25 speakers and 4 moderators translated the latest innovations in dental adhesive technology into the broad and diverse field of clinical applications of adhesive techniques. Almost 180 academics and clinicians from all over the world attended the very intense two-day meeting that was held at the comfortable Renaissance Orlando at SeaWorld hotel. The publisher of the *Journal of Adhesive Dentistry*, The Quintessence International Publishing Group, guaranteed a perfect organization of the meeting.

After an excellent introductory lecture by Roland Goldstein, sketching the historical perspective of adhesive dentistry, five top experts in adhesive technology (J. Tagami, F. Tay, A. Sadr, J. Perdigão, L. Tjäderhane; Fig 2) covered the basics of adhesive dentistry by focusing on the adhesive interface and in particular on the different approaches to maintaining the tooth/restoration bond in the mouths of our patients as long as possible. This morning session was followed by the afternoon program, during which diverse topics were discussed, such as the indispensibility of proper light curing (R. Price), the perpetual problem of polymerization shrinkage of composites (A. Versluis), and the new restoration trend of bulk-filling (R. Hirata). The first meeting day finished with two lectures that elegantly documented how the technical limits of adhesive procedures can be pushed in light of high esthetic demands (D. Terry) and complex multidisciplinary treatment needs (V. Clavijo).

The second meeting day was divided into four themes. The first theme, "Adhesion science meets practice", involved three lectures that covered the ways to digitally replicate natural dentition (P. Kano), the fatigue behavior of dental ceramics and composites (R. Belli), and the implementation of the concept of minimally invasive dentistry into daily practice (D. Gerdolle). Under the second theme, "Adhesion meets CAD/CAM technology", the lecture topics covered were the clinical long-term performance of bonded indirect restorations (R. Frankenberger), the challenging restoration of worn dentition (P. Guess), and the concepts for adhesive full-mouth CAD/

Fig 1 The organizing team, left to right: J-F. Roulet, M. Blatz, S. Duarte, J-H. Phark.

Fig 2 The Friday-morning speakers, left to right: R. Goldstein, L. Tjäderhane, F. Tay, J. Tagami, J. Perdigão, A. Sadr.

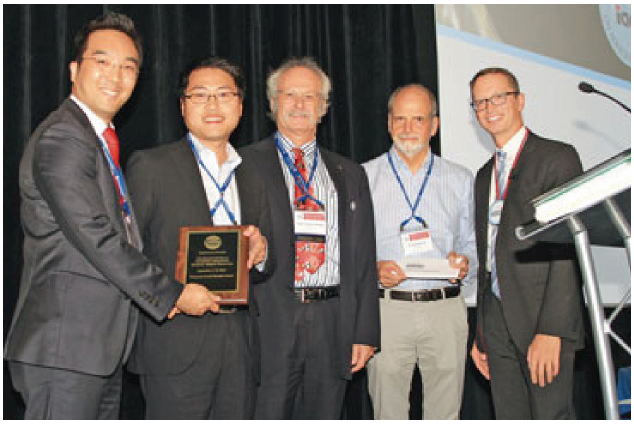

Fig 3 IAAD Fusayama Junior Scientist Award, left to right: J-H. Phark, F-C. Tian, J-F. Roulet, U. Blunck, M. Blatz.

Fig 4 IAAD Presidential Student Scientist Award, left to right: J-H. Phark, B. Yang, J-F. Roulet, U. Blunck, M. Blatz.

CAM reconstructions (a team presentation by J-H. Phark, S. Duarte Jr., and N. Sartori). The third theme, "Adhesion meets prosthodontics", dealt with the challenging bond to zirconia (M. Özcan), the clinically equally challenging resin-bonded FDPs (M. Kern), and the potential of a novel plasma-activated bonding technique (N. Silva). The fourth and last meeting theme, "Adhesion meets implantology", expanded the classical bonding-to-teeth application of modern adhesive technology to applications in implantology, with a lecture on a recipe for clinical success with implant restorations (P. Weigl) and a duo-lecture on the diverse adhesive interfaces involved with implant restorations (M. Blatz, M. Begler).

All lecturers should be congratulated for having excellently covered the diverse topics, as well as for their outstanding presentation skills. The extraordinarily rich lecture program was complemented by a high-level poster session, where student and junior researchers and clinicians presented their most recent cutting-edge research and/or top clinical work. I invite you to read the 2015 IAAD meeting abstracts at the end of this issue.

The Orlando meeting closed with the IAAD 2015 poster award ceremony, during which Fu-cong Tian and co-authors were awarded the IAAD Fusayama Junior Scientist Award (Fig 3) and Bo Yang and co-authors were awarded the IAAD Presidential Student Scientist Award (Fig 4).

Please visit the IAAD website, http://adhesivedentistry.org/, for the names of the other IAAD award winners, a large collection of meeting photos conveying the wonderfully enjoyable meeting atmosphere, and more information on our young academy and its future activities.

We do hope that you can join the IAAD family and attend the second IAAD meeting in 2017, wherever it may take place, as this still needs to be determined.

Sincerely yours,

Bart Van Meerbeek

Meta-Analysis of the Influence of Bonding Parameters on the Clinical Outcome of Tooth-colored Cervical Restorations

Eduardo Mahn[a] / Valentin Rousson[b] / Siegward Heintze[c]

Purpose: To meta-analyze the literature on the clinical performance of Class V restorations to assess the factors that influence retention, marginal integrity, and marginal discoloration of cervical lesions restored with composite resins, glass-ionomer-cement–based materials [glass-ionomer cement (GIC) and resin-modified glass ionomers (RMGICs)], and polyacid-modified resin composites (PMRC).

Materials and Methods: The English literature was searched (MEDLINE and SCOPUS) for prospective clinical trials on cervical restorations with an observation period of at least 18 months. The studies had to report about retention, marginal discoloration, marginal integrity, and marginal caries and include a description of the operative technique (beveling of enamel, roughening of dentin, type of isolation). Eighty-one studies involving 185 experiments for 47 adhesives matched the inclusion criteria. The statistical analysis was carried out by using the following linear mixed model: $\log(-\log(Y/100)) = \beta + \alpha \log(T) +$ error with $\beta = \log(\lambda)$, where β is a summary measure of the non-linear deterioration occurring in each experiment, including a random study effect.

Results: On average, 12.3% of the cervical restorations were lost, 27.9% exhibited marginal discoloration, and 34.6% exhibited deterioration of marginal integrity after 5 years. The calculation of the clinical index was 17.4% of failures after 5 years and 32.3% after 8 years. A higher variability was found for retention loss and marginal discoloration. Hardly any secondary caries lesions were detected, even in the experiments with a follow-up time longer than 8 years. Restorations placed using rubber-dam in teeth whose dentin was roughened showed a statistically significantly higher retention rate than those placed in teeth with unprepared dentin or without rubber-dam ($p < 0.05$). However, enamel beveling had no influence on any of the examined variables. Significant differences were found between pairs of adhesive systems and also between pairs of classes of adhesive systems. One-step self-etching had a significantly worse clinically index than two-step self-etching and three-step etch-and-rinse ($p = 0.026$ and $p = 0.002$, respectively).

Conclusion: The clinical performance is significantly influenced by the type of adhesive system and/or the adhesive class to which the system belongs. Whether the dentin/enamel is roughened or not and whether rubber-dam isolation is used or not also significantly influenced the clinical performance. Composite resin restorations placed with two-step self-etching and three-step etch-and-rinse adhesive systems should be preferred over one-step self-etching adhesive systems, GIC-based materials, and PMRCs.

Keywords: cervical restorations, Class V, adhesives, composite restorations, abfraction lesions, clinical trials.

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Commonly, noncarious cervical lesions (NCCLs, also called Class V defects) are restored with artificial materials, namely, composite resins or GIC-based materials. Clinical studies with NCCLs are also used to examine the efficacy of a given adhesive system[1] or adhesive class to which the system belongs, and to evaluate the efficacy of restorative procedures and modalities for the treatment of NCCLs.

The main reason for the premature failure of Class V composite restorations is retention loss.[5] Marginal caries hardly affects Class V restorations.[6,15] Earlier studies on Class V adhesive systems show that the prevalence of retention loss increases with increasing observation time,[25] but one study published in 2012 showed less retention loss after 13 years of observation[16] than did another study with the same observation period. However, results of other products published in 2007[25] corroborate

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the earlier findings. It is not yet established in routine clinical practice that roughening of the tooth surfaces prior to Class V restorations is essential for the longevity of the restoration. Mechanical preparation removes sclerotic dentin, which impedes the formation of an adequate hybrid layer.[27,28] Although the roughening of tooth surfaces has not been shown to be a significant factor in the annual failure rate in NCCLs with etch-and-rinse adhesives in several studies,[2,23,24] a meta-analysis published in 2010[6] found significant differences when the tooth surfaces were roughened prior to restoration placement. However, this particular meta-analysis included studies with an observation time of 2 to 3 years. It remains to be seen whether longer observation periods confirm this finding.

The influence of absolute vs relative isolation of the treatment field is another topic that is subject to controversy. A systematic review of Class II restorations carried out by Brunthaler et al[3] found no statistical difference between restorations placed with or without rubber-dam. However, a recently published meta-analysis on the efficacy of Class II resin restorations yielded a different result, showing that the use of rubber-dam isolation significantly diminishes the risk of material fractures.[8]

The type or category of adhesive system or the combination with a specific type of restorative material may also play an important role, as shown by Peumans et al[15] and Heintze et al.[6] A systematic review of Class V clinical trials from 1998 to 2004[15] showed lower failure rates (loss of retention) for three-step etch-and-rinse and two-step self-etching adhesive systems. The same research group found similar results when they performed a further review conducted from 2004 to 2009,[7] with the exception of an improvement in performance of one-step self-etching adhesive systems. These results were partially confirmed by a meta-analysis conducted in 2010,[6] which showed that two-step self-etching adhesive systems performed better than three-step etch-and-rinse systems, followed by glass-ionomer cements, resin-modified glass ionomer cements, two-step etch-and-rinse systems and polyacid-modified resin composites (PMRC). The worst clinical performance was observed in the systems belonging to the one-step self-etching group.

Five years have passed since the first study that systematically evaluated clinical factors on the outcome of cervical restorations in vivo was published.[6] In that study, clinical data from 50 studies were included in a systematic review containing 105 in vivo experiments with 40 different adhesives. That study concluded that two-step self-etching and three-step etch-and-rinse systems should be chosen over one-step self-etching systems and GIC-based materials. The same study concluded that dentin (and enamel) surfaces should be roughened before placement of the restoration.

The goal of the present study was to update the results of that meta-analysis on Class V restorations carried out in 2009[6] by including the same studies with a more strict selection and studies published thereafter. The following hypotheses were examined: 1. Roughening of dentin results in higher retention rates. 2. Beveling of enamel results in higher retention rates and less marginal discoloration. 3. The type of isolation does not influence the clinical outcome. 4. The type of adhesive system or restorative material has an influence on the clinical performance of cervical restorations.

MATERIALS AND METHODS

Selection of Clinical Trials on Class V Restorations

The aim of this review was to update the data collected from a previous study[6] in order to evaluate the clinical performance of cervical restorations and to compare the performance of different adhesive systems. Prospective clinical studies on Class V restorations were searched in MEDLINE and SCOPUS (search period 1955 to 2012, search month 07/2012) applying the guidelines of PRISMA (Preferred Reporting Items for Systemic Reviews and Meta-Analyses). A manual search was performed based on the references of all related articles found. The search words were “Class V” or “cervical” or “abfraction lesion” and “clinical”. The inclusion criteria were: 1. prospective clinical trial published in ISI journals involving at least one adhesive system in Class V cavities; 2. minimum duration of 18 months; 3. the study had to report about the outcome variables retention, marginal discoloration, marginal integrity, and marginal caries; 4. the study had to include a description of the operative technique (eg, beveling of enamel, roughening of dentin, or type of isolation). The selected studies after 12/2008 were added to the database created for the meta-analysis published in 2010.[6]

If a clinical trial investigated the effect of etching the enamel by comparing the results with those of etch-and-rinse adhesives, only the data of the etching group were included. The restorative materials and adhesive systems (AS) were grouped as follows:

1. One-step self-etching AS
2. Two-step self-etching AS
3. Two-step etch-and-rinse AS
4. Three-step etch-and-rinse AS
5. Polyacid-modified resin composite (PMRC)

6./7. Resin-modified glass-ionomer cements/glass-ionomer cements (GIC-based materials).

In each experiment, the patients were followed up between 1.5 and 13 years (minimum 1.5 years). The clinical performance was measured via the percentage of retention loss R, the percentage of marginal discoloration MD, and the percentage of detectable margins MI (marginal integrity). The percentage of marginal caries MC was also measured, but since most experiments showed 0% marginal caries, this outcome was not considered in the present analysis. As in Heintze et al,[6] a clinical index defined as $CI = (4R + 2MD + MI)/7$ was calculated to summarize the clinical performance. In the following, all these percentages are expressed as equal to 100% at baseline and decreasing afterwards. They were assessed after 0.5, 1, 1.5, 2, 3, 4, 5, 6, 7, 8, and 13 years (depending on the studies). Since measurements after 13 years were available in only 2 experiments of the same study, and

Table 1 Forty-seven adhesive systems, listed by allocated number, belonging to the 7 different classes (in parentheses) used in 185 experiments from 81 studies included in this meta-analysis

Adhesives systems used			
1 (3) ART Bond	16 (6) GC Conditioner	27 (3) Prime & Bond NT	40 (7) Ketac Conditioner
3 (3) Admira Bond	17 (4) Gluma 2000	29 (1) Prompt-L-Pop	41 (4) Scotchbond 2
5 (4) Clearfil Liner Bond	18 (4) Gluma Solid Bond	30 (3) Single Bond	42 (1) Adper Prompt-L-Pop
6 (2) Clearfil Liner Bond 2	19 (1) Hybrid Bond	31 (4) Scotchbond Multipurpose	43 (3) ALL-BOND 3
8 (2) Clearfil SE Bond	20 (1) iBond	32 (4) Syntac Classic	44 (5) NRC
9 (5) Dyract PSA	21 (3) One Coat Bond	33 (5) Syntac Single Component	47 (1) Clearfil Tri-S-Bond
10 (4) EBS	19 (1) Hybrid Bond	34 (4) Tenure	49 (3) Single Bond Plus
11 (3) Excite	22 (3) One Step	35 (4) Tripton	50 (1) G-Bond
12 (5) F2000 SEP	23 (4) OptiBond FL	36 (1) Tyrian SPE	53 (3) One Step Plus
13 (6) FujiBond L	24 (3) OptiBond Solo	37 (1) Xeno 3	54 (5) PSA Prime/Adhesive
14 (2) ALL-BOND SE	25 (4) Permaquick	38 (6) Vitremer Primer	55 (1) Bond force
15 (1) Futurabond NR	26 (3) Prime & Bond 2.1	39 (7) HTF Conditioner	59 (3) Experimental adhesive (Vericom)

Classes of adhesive systems	Number of experiements
(1) Self-etching 1 step (SE1)	41
(2) Self-etching 2 steps (SE2)	19
(3) Etch-and-rinse 2 steps (ER2)	49
(4) Etch-and-rinse 3 steps (ER3)	37
(5) Polyacid modified resin composites (PMRC)	18
(6) Resin-modified glass ionomer cements (RMGIC)	17
(7) Glass ionomer cements (GIC)	4

since there is a gap of 5 years between 8 and 13 years, the subsequent focus was placed on 8 years of follow-up. In some experiments, an occasional increase rather than a decrease of a percentage was noted over time, which may be due to drop-out of some subjects or to a measurement error.

In Heintze et al,[6] the percentage Y over time T for a given experiment was assumed to decrease linearly according to the following model: $Y = 100 - (\beta + \text{error})^2\, T$, which was equivalent to the linear model $\sqrt{(100-Y) / T} = \beta + \text{error}$, where the parameter β was dependent on the characteristics of the experiment. A linear deterioration was a good approximation in the first analysis from 2009[6] since there were only 3 years of follow-up. As 8 years of follow-up were now considered, this model was no longer suitable, since a linear deterioration over time may imply a percentage below 0, which is by definition not possible. This is why the following model was considered: $(Y/100) = \exp(-\lambda\, T\alpha\ \text{error})$, where the percentage Y also decreases with time, but not linearly, ensuring that the percentage remains above 0. The parameter lambda (λ) must be positive to ensure that the estimated percentages decrease monotonously; with a negative lambda, the percentages would increase with time.

This model is equivalent to the following linear model: $\log(-\log(Y/100)) = \beta + \alpha \log(T) + \text{error}$, with $\beta = \log(\lambda)$ (such that $\lambda = \exp(\beta)$ is positive). In this model, the parameter β is a summary of the deterioration occurring in an experiment. It depends on the fixed characteristics of the experiment, ie, the factor adhesive as well as the factors preparation (no/yes/missing), beveling (no/yes/missing), and rubber-dam (no/yes/missing). To account for the fact that partly the same subjects were used in the different experiments conducted within the same study, a random study effect was included in the model. To take into account the correlations among the different measurements made in the same experiment, a random experiment effect was also included (which is nested in the study effect). The result was a linear mixed effect model as follows: β = reference value + adhesive effect + preparation effect + beveling effect + rubber-dam effect + study random effect + experiment random effect.

Each experiment was weighted according to the number of subjects involved.

The two random effects as well as the error term were assumed to be normally distributed. The reference value refers to the adhesive No 1 of the list of adhesive systems (Table 1, ART Bond) without roughening, without beveling, and without rubber-dam (in an average experiment from an average study). This reference value is thus a summary measure of the deterioration, ie, the clinical performance for this adhesive system. To obtain a summary measure of the clinical performance for the other adhesives, the coefficients corresponding to the different adhesives estimated in the model should be

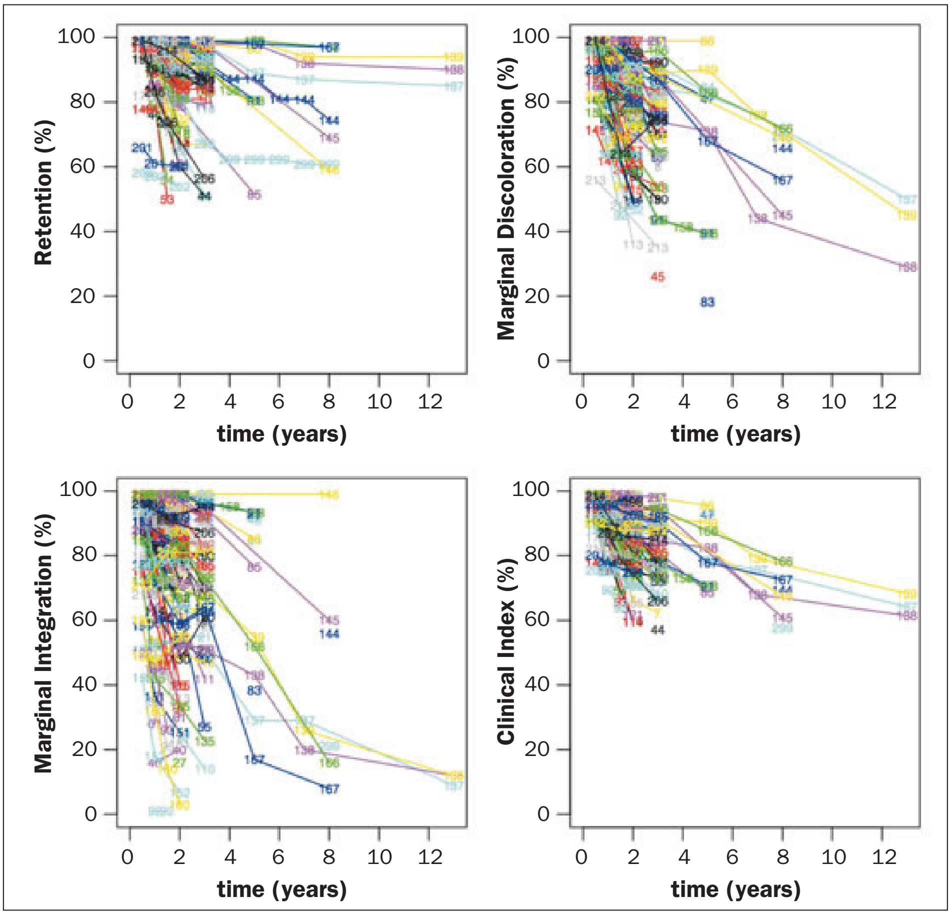

Fig 1 Deterioration of clinical performance (percentage of retention [R], marginal discoloration [MD], marginal integrity [MI], and clinical index [CI] over time) in the different experiments. The numbers indicate the number of each experiment.

added to this reference value (since 47 adhesives were examined, the adhesive effect was represented by 46 coefficients in this model). To fit a linear mixed effect model, the lme routine was used from the package nlme implemented in the free statistical package R. Using this routine, it was possible to weight a percentage Y according to the denominator used for its calculation, ie, the number of patients available at a given point in time. Thus, the percentages calculated from many patients received a higher weight than the percentages calculated from a small sample.

RESULTS

Data on the clinical performance of 47 adhesives were analyzed in patients from 185 experiments conducted in 81 studies (between 20 and 134 patients per experiment and between 1 and 6 experiments per study, each study involving up to 4 different adhesives). Figure 1 shows the deterioration of clinical performance over time in the different experiments included.

Table 1 shows all the adhesive systems used in the studies included in this meta-analysis (see also Appendix 1).

The following distributions for the factors beveling, roughening, and rubber-dam (no/yes/missing) were found in the 185 experiments: beveling: 100/77/8; roughening: 98/75/12; rubber-dam: 98/71/16. No experiment was excluded when fitting our model, where the three factors above were treated as factors with three categories (including a "missing" category).

The mean retention rate of cervical fillings was 90.8%, 87.7%, and 76.2% after 3, 5, and 8 years, respectively. The percentage of restorations without marginal discoloration and without detectable margins was lower, resulting in a value for the clinical index of 84.0%, 82.6%, and 67.7% after 3, 5 and 8 years, respectively.

The factors roughening, beveling, and rubber-dam are presented in Fig 2. Experiments with roughening had significantly less retention loss and a better marginal integrity than experiments without (eg, $p = 0.001$ for the clinical index CI, 0.004 for MI, and 0.005 for R). No significance was found for MD ($p = 0.279$). Experiments with rubber-dam had significantly less retention loss than experiments without rubber-dam (eg, $p = 0.011$ for CI, and 0.002 for R), although no significance was observed for the outcomes MI ($p = 0.852$) and MD ($p = 0.138$). Experiments with beveling did not significantly differ from experiments without beveling for any factor ($p = 0.62$ for CI, 0.08 for MI, 0.43 for MD, and 0.194 for R). Interaction between the factors roughening and rubber-dam was tested (based only on those experiments where both factors were present): no significance was found ($p = 0.096$,

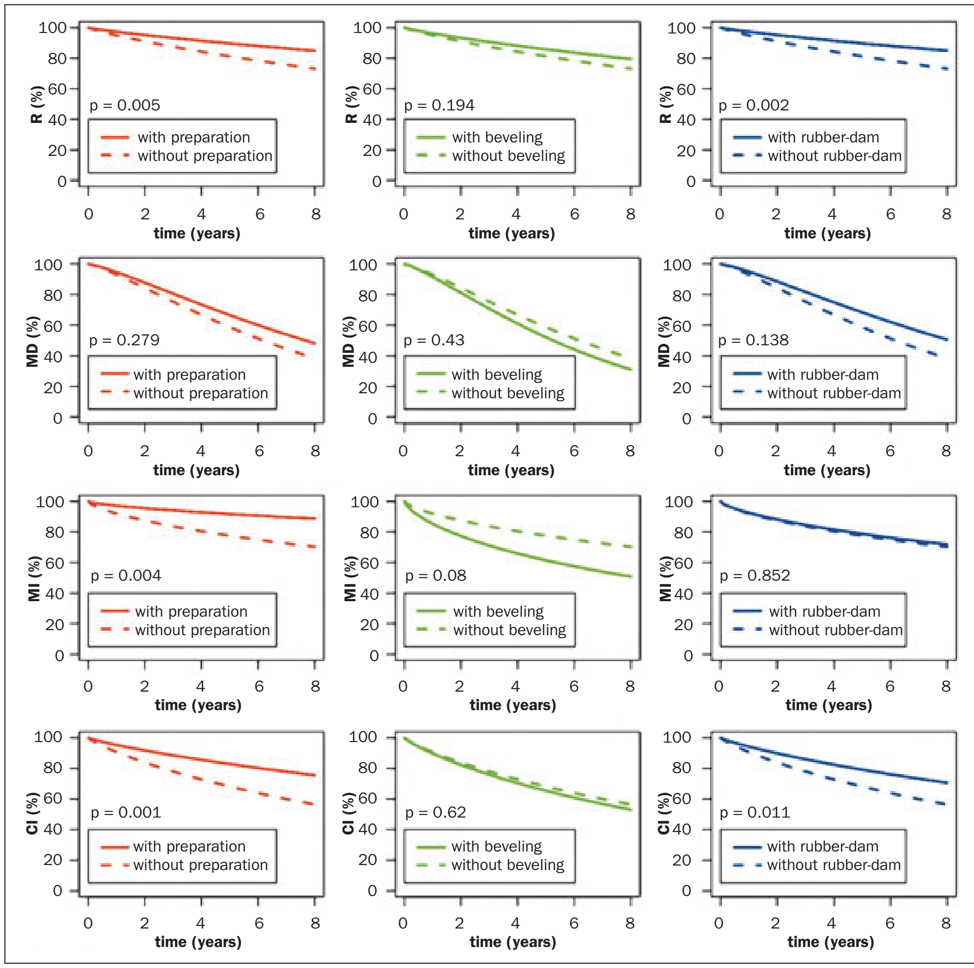

Fig 2 Estimation of the median deterioration over time of the clinical performance (percentage of retention [R], marginal discoloration [MD], marginal integrity [MI], and clinical index [CI]) according to the linear mixed model as a function of the factors preparation or roughening (left panels), beveling (middle panels), and rubber-dam (right panels).

p = 0.747, p = 0.260, and p = 0.813 for R, MD, MI, and CI, respectively).

The deterioration was better estimated for those adhesives evaluated by several studies than for those adhesives evaluated only in a few studies. To avoid an overinterpretation of the results of these plots (Fig 3), only 12 adhesives with measurements from at least 5 studies are shown (adhesives No. 8, 9, 16, 22, 23, 27, 29, 30, 31, 38, 40, 47). For instance, it is evident that adhesive No. 8 (Clearfil SE Bond) was the best and adhesive No. 22 (One-Step) was the worst with respect to the clinical index (CI).

Figure 3 shows the median deterioration estimated for the different adhesives with respect to R, MD, MI and CI, which were tested in at least 5 different clinical trials.

Table 2 shows the distribution regarding the factors rubber-dam, beveling, and roughening.

The adhesive systems/restorative materials were grouped in 7 different classes. Classes 6 and 7 (RMGIC and GIC) were considered as one class for the statistical analysis. The factor "class of adhesive" was globally significant for each outcome, except MI, in a likelihood ratio test ($p < 0.001$, $p = 0.006$, $p = 0.054$, and $p = 0.002$ for R, MD, MI, and CI, respectively). When comparing two by two the classes of adhesive in a post-hoc test applying a Bonferroni correction, one-step self-etching adhesives had a significantly worse clinical index than did two-step self-etching and three-step etch-and-rinse adhesives ($p = 0.026$ and $p = 0.002$), whereas GIC-based materials had a significantly better retention rate than did one-step self-etching, two-step etch-and-rinse, and PMRC ($p = 0.005$, $p < 0.001$, and $p < 0.001$), see also Fig 4.

Interaction between the factors "class of adhesive" and "beveling" was also tested (based only on the experiments where the factor "beveling" was present), and was significant for most outcomes: $p < 0.001$, $p = 0.001$, $p = 0.497$, and $p = 0.001$ for R, MD, MI, and CI, respectively. In fact, this was because the factor "beveling" was significantly associated with an acceleration of the deterioration for GIC-based materials (Class 6/7). No significant interaction was found between the factors "class of adhesive" and "rubber-dam" (based only on the experiments where the factor rubber-dam was present): $p = 0.933$, $p = 0.053$, $p = 0.434$, and $p = 0.620$ for R, MD, MI, and CI, respectively.

Figure 5 shows the Spearman correlations "rho" among the four measures of clinical performance (R, MD, MI, CI) obtained via the coefficients estimated in the linear mixed model (here parameterized so that a higher value means better clinical performance) calculated over the 47 adhesives. Interestingly, although the clinical index places more weight on R and MD than on MI, the correlation

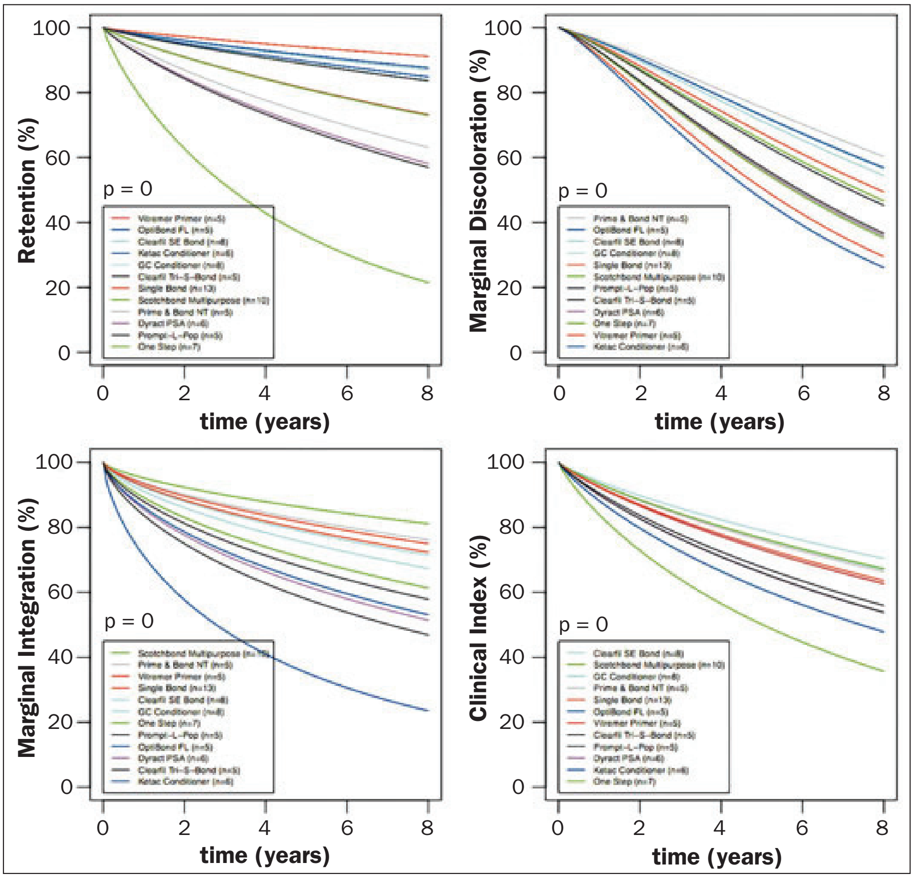

Fig 3 Estimation of the median deterioration over time of the clinical performance (percentage of retention [R], marginal discoloration [MD], marginal integrity [MI], and clinical index [CI]) according to the linear mixed model for the 12 adhesives with measurements from at least 5 studies (where n refers to the number of studies available for each adhesive).

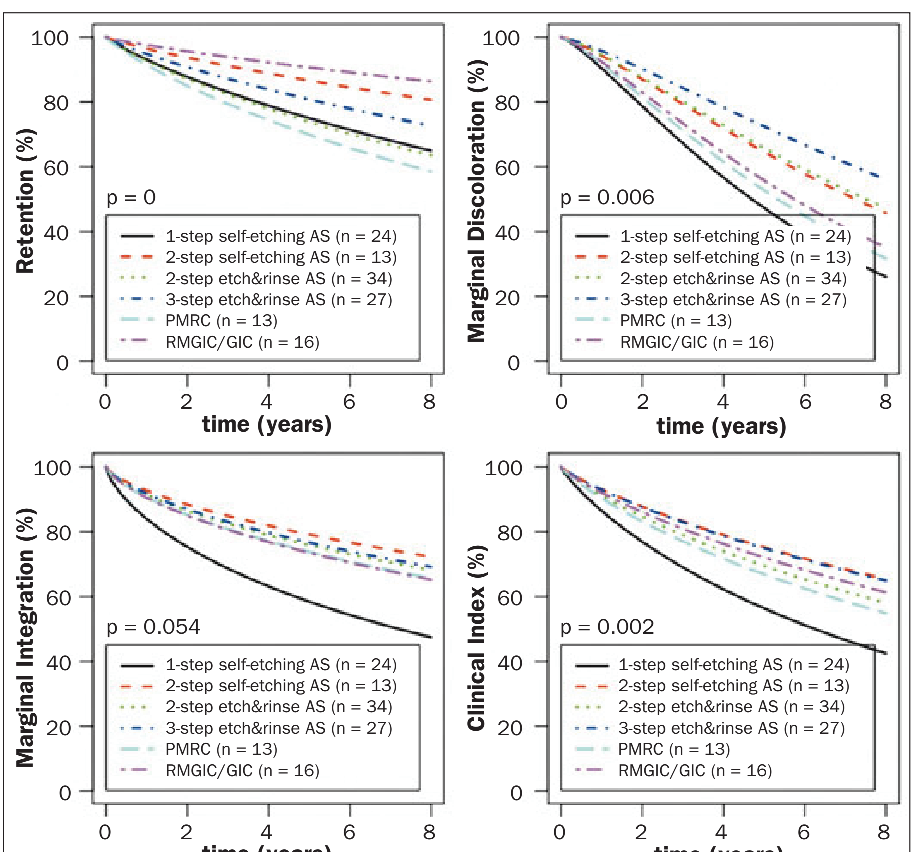

Fig 4 Estimation of the median deterioration over time of the clinical performance (percentage of retention [R], marginal discoloration [MD], marginal integrity [MI], and clinical index [CI]) according to the linear mixed model as a function of the class of adhesive (where n refers to the number of studies available for each class of adhesive).

Table 2 Distribution regarding the factors rubber-dam, beveling, and roughening

	Rubber-dam			Beveling			Roughening		
	Yes	No	Missing	Yes	No	Missing	Yes	No	Missing
Number of experiments	71	98	16	77	100	8	75	98	12

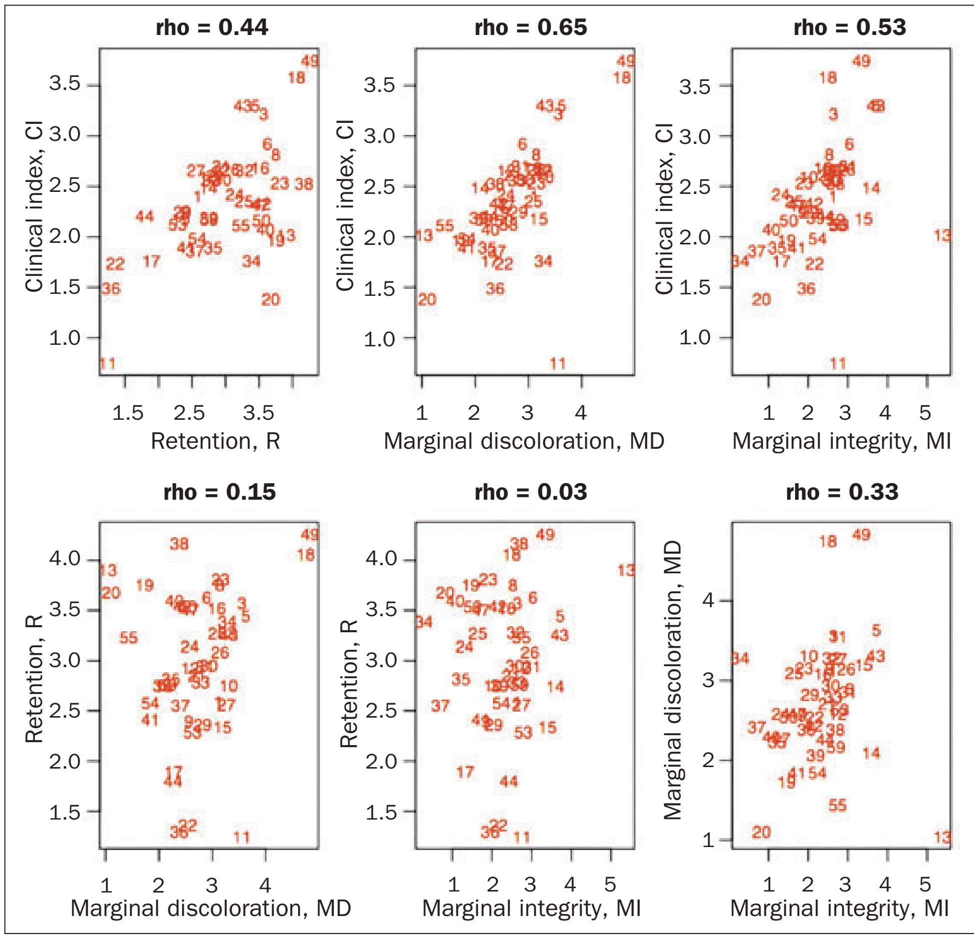

Fig 5 Spearman correlations among the four measures of clinical performance (R, MD, MI, CI) obtained via coefficients estimated in a linear mixed model (the higher the value, the better the clinical performance) calculated for the 47 adhesive systems. The numbers refer to the adhesive system (see Table 1).

was higher between CI and MI than between CI and R or between CI and MD. This is due to the fact that R showed a lower variability among the adhesive systems than did MD and MI. Correlations between R and MD and between R and MI were not significant, whereas the correlation between MD and MI was (rho = 0.33, p = 0.024).

DISCUSSION

The present meta-analysis systematically evaluated the influence of bonding parameters on the clinical outcome of cervical restorations in vivo. Clinical evaluation of this type of restorations is important due to their use as evaluators for clinical performance of dental adhesives and because of an emerging public health issue: the prevalence of NCCLs is increasing in the population, especially in industrialized countries. where more patients retain their own teeth well into old age. It is known that the etiology of NCCLs depends on multiple factors,[12] and the patient's risk factors vary considerably. Therefore, several factors can directly influence the retention and general clinical performance of Class V restorations, for example, occlusion, dentin sclerosis, and patient age.[4,17,23]

In the present study, data on the clinical performance of 47 adhesives was measured on subjects from 185 experiments conducted in 81 studies, which means that compared to the first meta-analysis,[6] 35 studies with 80 experiments were added. Eight new adhesives which fulfilled the inclusion criteria were tested in this period. The same clinical index used in the first publication[6] was used in this study (CI= (4 x R+ 2 x MD + 1 x MI)/7). The rationale for creating a clinical index is that a better statistical analysis can be conducted. The weighing of the three outcome variables (4x for R, 2x for MD, 1x for MI, and all divided by 7) was based on the following considerations: retention loss is the most obvious sign of failure of a cervical restoration and is the most reliable diagnostic evaluation criterion with little variability between different evaluators, and marginal discoloration and marginal integrity are outcome variables which may show a greater variability between different evaluators; although they are not generally regarded as primary failure, they deserve attention. It is true that retention is objective and the other parameters rather subjective, but the results are also reported separately for each parameter. Since the main reason for the treatment of NCCLs is the unpleasant esthetic appearance of cervical defects (followed by hypersensitivity), discoloration of restoration margins and marginal integrity should also be included, as many practitioners confound marginal discoloration with marginal caries and replace the restorations unnecessarily. Furthermore, marginal discoloration may impair the esthetic appearance, which again might be a reason for replacement. No other clinical parameters, such as color match or post-operative hypersensitivity, were included in the present analysis, because most of the studies did not report them. With regard to marginal caries, the prevalence was close to 0, even after 8 years; therefore, this parameter was excluded from the statistical analysis.

Although great care was taken to reduce bias and perform a precise collection of the data, the present meta-analysis had some limitations, as described below.

During the last 30 years, there have been many “generations” and types of adhesive product designs. In the collection of data, major efforts were made to correctly classify each adhesive system, most often by Internet search.

The different assessment criteria (eg, USPHS, A-B-C; USPHS, A-B-C-D; FDI 1-5.) were normalized as far as possible by combining scores, eg, FDI 1 and 2 were combined with USPHS A, FDI 3 was allocated to USPSH B, and FDI 4 and 5 were combined with USPHS C.

Over the past decades, several techniques have been used with more or less enthusiasm by clinicians and tested in clinical trials. They have certainly had an impact on the bonding performance. The best example concerns dentin moisture vs dryness, with methods that require drying of dentin, leaving dentin wet, leaving dentin moist, or slightly drying and then rewetting dentin. Since many studies do not report about the exact operative procedure, it was not possible to take these parameters into account.

To facilitate the inclusion of clinical trials, it would be desirable if they examined restorations of similar size, geometry, and extent; if not, at least differences should be reported as well as failures related to those differences. However, the size and precise characteristics of each restoration are usually not reported in the studies. Therefore, it is impossible for us to categorize and account for these parameters. In addition, since we included a large number of studies, we may assume that the variability of cavity size and hard tissue characteristics from one study to another study is great enough to justify general conclusions that do not need restrictions with regard to the above-mentioned parameters.

As a rule, the introduction of new adhesive systems onto the market is based on laboratory tests, ie, bond strength tests of various kinds, while clinical evaluations tend to be exceptions.[26,29] Although several adhesive systems showed good bond strength values (μTBS) to dentin,[11] high loss rates were reported only after some years of clinical service.[14,17] Only three publications on the correlation of bond strength tests and the clinical performance of restorations placed with adhesive systems have been published so far. In one of these studies,[7] the microtensile bond strength data of 15 adhesive/restorative systems placed by the same operator were correlated with the clinical studies of noncarious cervical Class V restorations. No correlation was found between the retention rate of cervical restorations after three years and the microtensile test results after 8 h or 6 months of water storage. Some moderate correlation was found between marginal staining and bond strength values after 6 months of water storage, and another study showed some correlation between retention rates of Class V restorations after 5 years with laboratory specimens that were submitted to artificial aging, including mechanical stressing of bonded bars.[30]

Since the success of Class V restorations mainly relies on adhesion to the cavity with almost no mechanical retention, the impregnation of the dentin substrate by the resin monomers and the stability of the bonded interface (homogeneous hybrid layer) are of paramount importance for their clinical performance.[13] Many influential factors have been mentioned in the literature, such as roughening of the surface, beveling of enamel, use of rubber-dam, type of the adhesive, and the technique used to apply it. For example, vigorous agitation of the adhesive (rubbing technique) seems to increase retention rates,[13] since a better impregnation of the dentin substrate improves the durability of the hybrid layer. This factor seems to be especially critical for resin monomers with a high molecular weight, such as those present in simplified etch-and-rinse adhesives. Due to their limited diffusion into the wet demineralized dentin,[14,31] these monomers produce an uneven resin penetration with a high concentration at the surface and a lower concentration in the deepest area of the demineralized zone. In accordance with the results published in 2010,[6] adhesives belonging to adhesive class 1 (one-step self-etching) performed poorest and adhesives belonging to class 2 (two-step self-etching) performed the best. Another factor that has been disregarded in the literature is the performance of flowable composites in NCCLs compared to high-viscosity resin composite. Their use is very rare in NCCL restorations. Only seven studies that used flowable composites fulfilled the inclusion criteria. Not enough data were found to perform a meaningful analysis exclusively for them.

The results of the same adhesive system in different studies vary considerably. To date, it is not clear whether the high variability (also shown in in vitro studies[7]) is due to operator-related factors, patient related-factors, or the technique sensitivity of the product. It has been shown that the operator plays an important role in in vitro studies, since differences between experienced and inexperienced operators influenced the results in some studies irrespective of the adhesive system.[20,22] When instructions for use were followed, even the more complicated adhesive systems (three-step etch-and-rinse) produced better and more predictable bond strength results with inexperienced operators than did the simplified systems (one-step self-etching),[20] and two-step self-etching adhesive systems produced better results than did two-step etch-and-rinse systems.[22] These results corroborate the data found in the present meta-analysis: three-step etch-and-rinse and two-step self-etching performed better for all clinical parameters than did simplified systems, such as two-step etch-and-rinse and one-step self-etching. Regarding retention, the analysis for different classes of adhesives revealed that both the two-step self-etching adhesive systems and the glass-ionomer cements showed the best retention rate over time, whereas the one-step self-etching adhesives and the compomers had the lowest retention rate (Fig 3).

Variable sample sizes, different operative techniques, and lack of calibration between the evaluators need to be added to the variation in operator experience. Due to the reasons mentioned before, it is necessary to standardize the design of clinical trials, since many clinical variables are simultaneously involved and the Ryge criteria are no longer precise enough.[10] New clinical criteria for the evaluation of restorations were published in 2007 by a board of experienced clinicians; these criteria were also accepted by a FDI committee.[10] Unfortunately, more recent studies could not use these new criteria because they had already started at the time of the publication.[13]

It is well known that the type of dentin and especially the degree of sclerosis can have an effect on the clinical performance. Some studies classified the defects with a dentin sclerosis scale,[9,18,19] but unfortunately most of the studies did not relate the failures to the age of the patients or to the level of sclerosis previously classified, which makes the correlation of these factors impossible.

In order to improve the bonded surface, many investigators roughen the surfaces of NCCLs prior to restoration. The idea is to remove contaminated and hypermineralized dentin surfaces that can have a negative effect on the formation of the hybrid layer. However, early studies showed that this factor was not significant with regard to annual failure rates.[2,23,24] The present meta-analysis confirmed the earlier meta-analysis.[6] Both showed that the effect of dentin/enamel roughening significantly increased the retention rate of Class V restorations. This effect did not necessarily apply to each class of adhesive system, because not enough data was available to perform a meaningful analysis for each adhesive class separately.

The present study confirmed that beveling of the enamel did not improve the clinical performance on a general basis. In restorations placed with GIC-based materials (RMGIC/GIC), beveling was significantly associated with an acceleration of the deterioration of marginal integrity. If enamel is beveled, glass ionomer is placed in thin layers on the beveled enamel, and due to the low mechanical properties of glass ionomer and the low bond strength to enamel, marginal fractures may occur over time, compromising the marginal seal.

Experiments in which rubber-dam was used were related to significantly less retention loss and marginal discoloration than experiments without rubber-dam (eg, $p = 0.011$ for the clinical index CI; no significance was found for the outcome variable MI) (Fig 2). This result was in contrast to the first meta-analysis published in 2010,[6] which showed no significant impact of rubber-dam isolation on any of the examined variables. On the other hand, the present results agree with a meta-analysis on direct posterior Class II restorations,[23] which found that the application of rubber-dam (absolute isolation) compared to cotton rolls and suction (relative isolation) significantly enhanced the longevity of the restorations by reducing material fractures. In this situation, moisture during application and polymerization of the composite could have reduced the mechanical properties of the posterior restorations. In the case of the cervical restorations, moisture may promote the infiltration of saliva and/or sulcular fluid along the restoration interface, which creates more microleakage and thus compromises the bond to dentin. However, no evidence in the literature has been found to substantiate this hypothesis. However, a possible confounder is the operator. Dentists who place rubber-dam may be more skilled and/or are more careful and pay more attention to the operative procedures than those dentists who work only with cotton rolls and saliva ejector. Thus, a higher level of operator skill combined with more careful operative procedures can enhance the longevity of composite resin restorations both in posterior and cervical restorations. To elucidate the influence of absolute vs relative isolation on clinical parameters, we need well-designed, prospective, long-term multicenter clinical studies, also with general practitioners, using a split-mouth design in which the restoration on one side of the mouth is placed with absolute isolation and on the other side with relative isolation.

Clinical Recommendations

Within the limitations of the present analysis, the following recommendations can be made.

The clinician should roughen the dentinal (and enamel) surface, as this measure increases the durability of the cervical restoration. The first hypothesis was accepted (eg, $p = 0.001$ for the clinical index CI, 0.004 for MI, and 0.005 for R). The additional beveling of the enamel can be omitted, as this procedure does not influence the clinical performance of the restoration ($p = 0.62$ for CI, 0.08 for MI, 0.43 for MD, and 0.194 for R). Thus, the second hypothesis – positive correlation of enamel beveling with clinical performance – was rejected. For glass-ionomer cement restorations, beveling of enamel should be completely omitted, since it decreases the longevity of this material in Class V restorations.

If the clinical situation allows it, absolute isolation with rubber-dam should be applied, since the use of rubber-dam positively influences the performance of Class V restorations. Experiments which employed rubber-dam had significantly less retention loss than experiments which did not, although no significance was observed for marginal integrity ($p = 0.852$) and marginal discoloration (p = 0.138); the third hypothesis was therefore rejected. One-step self-etching adhesives had a significantly worse clinical index than did two-step self-etching and three-step etch-and-rinse adhesives (p = 0.026 and p = 0.002). This finding allowed the 4th hypothesis to be accepted. Not enough evidence exists for the use of flowable composites in combination with any kind of adhesive system. Although GIC-based materials perform well with regard to retention, their rather poor esthetic properties may make them inadequate for this indication, especially in the anterior and premolar region.

CONCLUSIONS

Due to the increased number of patients reaching higher ages, noncarious cervical lesions and dentin hypersensitivity (DH) are increasing in prevalence. In the absence of DH, cervical defects should only be restored if the esthetic appearance is compromised and if the patient has a strong desire to have the lesion restored. If the application of fluoride or desensitizer fails to reduce sensitivity, cervical defects should be restored. Traditionally, cervical defects are restored with artificial materials, namely, composite resins or glass-ionomer cements and their modifications. Since the success of Class V restorations mainly relies on adhesion to the cavity with almost no mechanical retention, the adhesive system plays the most important role. The clinician should select an adhesive system with proven good clinical performance for this indication.

This analysis revealed that the clinical performance of cervical restorations is significantly influenced by the type of adhesive system and/or the adhesive class the systems belongs to and by the fact if the dentin is roughen or not, as previously proven in a meta-analysis performed 5 years ago.[6] Beveling of the enamel had no significant influence on any clinical parameters and was independent of the adhesive class, with the exception of glass-ionomer cements, which performed worse when the enamel had been beveled. The type of isolation had a significant influence on the long-term result: restorations placed with rubber-dam performed significantly better in the long run than those placed without rubber-dam.

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APPENDIX 1

Adhesive systems and their allocated number evaluated in 81 clinical trials (for details of references, see Appendix 2 and references above)

Allocated number and adhesive system	Clinical trial
1. A.R.T. Bond	18,72
3. Admira Bond	1,23
5. Clearfil Liner Bond	8,46,79
6. Clearfil Liner Bond 2	7,39,75,
8. Clearfil SE Bond	1,3,16,53,54,57,69,74
9. Dyract PSA	4,19,29,33,42
10. EBS	19,73
11. Excite	30
12. F2000 SEP	25,27,32,49
13. Fuji Bond LC	54
14. ALL-BOND SE	41
15. Futurabond NR	6,36
16. GC Conditioner	4,12,15,19,30,33,71
17. Gluma 2000	8,35,79
18. Gluma Solid Bond	64
19. Hybrid Bond	1,66
20. iBond	64
21. One Coat Bond	19,38,75
22. One Step	10,11,13,61,65,73,81
23. OptiBond FL	24,30,56,76,78
24. OptiBond Solo	27,63,68
25. Permaquick	56,74,78
26. Prime & Bond 2.1	2,48,63,68
27. Prime & Bond NT	23,27,45,51,69

Allocated number and adhesive system	Clinical trial
29. Prompt-L-Pop	22,43,58,75
30. Single Bond	9,12,21,22,32,39,43,51,61, 62,65,80,81
31. Scotchbond Multipurpose	8,9,17,37,47,49,50,52,72,79
32. Syntac Classic	8,29
33. Syntac Single Component	2,4,15,27
34. Tenure	77
35. Tripton	77
36. Tyrian	13,44
37. Xeno III	66,67
38. Vitremer Primer	4,30,33,42,49
39. HTF Conditioner	33
40. Ketac Conditioner	5,14,24,20,59,71
41. Scotchbond II	25,59
42. Adper Prompt-L-Pop	37
43. ALL-BOND 3	60
44. NRC	49
47. Clearfil Tri-S Bond	16,20,26,28,38,40
49. Single Bond Plus	52
50. G-Bond	20,38,76
53. One Step Plus	31,46
54. PSA Prime/Adhesive	23,52
55. Bond Force	52
59. Experimental adhesive (Vericom)	37

APPENDIX 2

Literature: Studies used in the previous meta-analysis (b), studies added to this meta-analysis (c)

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One-year Clinical Evaluation of Resin Composite Restorations of Noncarious Cervical Lesions in Smokers

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Purpose: To evaluate the one-year clinical performance of composite restorations in noncarious cervical lesions placed in smoking and non-smokers using a multimode adhesive system with two adhesive strategies.

Materials and Methods: Among the selected cervical lesions, four experimental groups were formed based on the patients' smoking habit and bonding strategies with a multimode adhesive system (n = 38): G1: etch-and-rinse in non-smokers; G2: selective enamel etching in non-smokers; G3: etch-and-rinse in smokers; G4: selective enamel etching in smokers. The restorations were paired, ie, each patient received at least two restorations. A nanofilled resin composite was applied and light cured incrementally in all groups by one operator. Two calibrated examiners evaluated the restorations at baseline, 6 and 12 months after placement. The modified USPHS criteria were used for evaluation. Data were analyzed using the chi-square (for associations between groups) and McNemar tests.

Results: No statistically significant difference was found between groups for the criteria of retention, marginal discoloration, color match, marginal integrity, or sensitivity after 6 and 12 months. The assessments over time showed a statistically significant difference only for marginal discoloration at 12 months for groups 1, 3, and 4 when compared to baseline ($p = 0.031$). There were no statistical differences for any criteria evaluated among smokers and non-smokers, except for color match, where a difference was found after the baseline evaluation. Regarding the adhesive strategy, etch-and-rinse resulted in a clinical performance similar to that of selective enamel etching over 12 months.

Conclusion: Neither cigarette smoking habit nor adhesive strategy influenced the clinical performance of resin composite cervical restorations over the first year.

Keywords: resin composite, clinical trial, dentin bonding system, multimode adhesive system, universal adhesive system, enamel bonding, enamel etching, phosphoric acid, smoking habit, cigarette, tobacco, NCCL.

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Restorative materials and their ability to bond to tooth substrates are one of the most investigated topics in dental research. Regarding composite bonding agents, there has been great progress since Buonocore[10] suggested enamel surface treatment with an acid to promote the formation of microporosities on its surface, leading to penetration of acrylic resins and an effective mechanical union. Since then, enamel adhesion is considered a stable, predictable, and clinically proven procedure. In contrast, dentin bonding has always been a challenge, due to the properties of dentin tubular tissue, with a large proportion of organic components and water in its composition.[44,46] However, adhesive systems have improved such that dentin bonding has become a routine procedure.[12]

Bonding between the adhesive biomaterial and the tooth structure can be achieved micromechanically (etch-and-rinse adhesive systems) or chemically (self-etching adhesive sytems or glass-ionomer materials).[51] The etch-and-rinse systems promote surface demineralization and micromechanical retention between the adhesive and dental tissue. Mild self-etching systems, as well as glass-ionomer materials, promote a chemical bond with

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Table 1 Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
• More than 20 natural teeth in mouth • At least two cervical NCCLs in different quadrants (1 mm to 3.5 mm occluso-gingival distance and less than 2 mm in depth) • The nonretentive NCCL has less than 50% of margin in enamel and makes up over 50% of the total area in dentin • 50% smokers: consumption of 20–30 cigarettes/day • 50% non-smokers • Medically compromised patients	• Severe bruxism • Severe tooth sensitivity • Active periodontal disease • Poor oral hygiene • Carious lesions associated with cervical lesions • Pregnancy • Debilitated patients (physical or mentally) • Patients undergoing orthodontic treatment or bleaching of teeth • Nonvital teeth

the tooth structure. Although chemical bonding is not as strong as micromechanical retention, it ensures a good long-term interfacial seal. Recently, a new generation of one-bottle dental adhesives was introduced. The literature refers to this new generation of adhesives as universal or multimode adhesives and they are indicated for use with or without prior etching. In other words, these new adhesives may be used as a simplified etch-and-rinse adhesive system or as a simplified self-etching system. Additionally, manufacturers also recommend an alternative "selective enamel etching" technique.[36] However, few studies on the clinical and laboratory behavior of these new adhesives are available in the literature.[35,38]

Class V resin composite restorations in noncarious cervical lesions (NCCLs) have been used to evaluate the clinical efficacy of adhesive systems, after bonding to enamel and dentin in vitro.[4,9] The main factors related to the success of Class V restorations are bonding agent properties and substrate characteristics.[17] However, the dentin in NCCLs is often exposed and some of its original structural characteristics may be changed through contact with several substances.[7]

Many types of contamination may affect the tooth structure and restorative materials. Oral fluids, such as saliva, blood, and crevicular fluid, may be chemically incompatible with some dental materials, damaging the adhesion.[55,56] Cigarette smoke is considered a dentin contaminant. In addition to the large body of evidence that cigarette smoking is responsible for much damage to general health,[14] its consumption is related to a higher rate of tooth loss, periodontal diseases, restoration staining, and cancerous lesions in the oral cavity.[5,6,24,31] Moreover, tooth staining caused by cigarette smoking is one of the main complaints of smokers.[2]

Considering that approximately 20% of the global adult population are smokers[14] and that tobacco consumption has reached epidemic proportions worldwide, the relevance of research on this topic has increased. However, there has been little research on the influence of smoking on direct adhesive resin composite restorations. One in vitro study showed that exposure to cigarette smoke decreased the resin composite bond strengths to dentin.[3]

Therefore, the aim of this study was to evaluate the clinical performance, primarily through the retention and visible color change, of resin composite restorations using different adhesive strategies (etch-and-rinse or selective enamel etch) with a multimode adhesive system. The null hypotheses tested were: 1) smoking does not influence the clinical performance of cervical resin composite restorations; and 2) bonding strategies (etch-and-rinse and selective enamel etching) do not influence the clinical performance of a multimode adhesive system in resin composite restorations over 12 months.

MATERIALS AND METHODS

Study Design

As far as possible, this study design followed CONSORT guidelines.[42] A randomized double-blind clinical study regarding the adhesive strategy was performed. However, half of the restorations were carried out in smokers and half in non-smokers. The study was conducted in the Dental Clinics of the Federal University of Santa Catarina, Florianopolis, Brazil. Before starting, the study proposal was submitted to the Ethics Committee for Research in Humans and approved.

Participant Selection

The first examination of volunteers was conducted among patients seen by undergraduate and graduate students at the School of Dentistry. Patients of different gender, smokers and non-smokers, with at least two NCCLs of similar size present in the oral cavity and who met the inclusion criteria were selected (Table 1).

All selected patients were informed about the purpose of the research, nature of the study, procedures and relevant technical risks involved, as well as the treatment evaluation model. They were then given an informed consent form to sign, in accordance with Resolution 196 of October 10, 1996, National Board of Health / Ministry of Health, Brazil. Despite being aware of the restorative technique that would be performed, the patients did not know which tooth would receive which adhesive technique.

The participants' age, gender, and the distribution and characteristics of the NCCLs selected for study (location, shape, degree of sclerosis, wear facets) are described in Table 2.

Group Distribution

In total, 62 patients presenting NCCLs were evaluated. Only 26 of those who met the research inclusion and exclusion criteria were able to participate. The selected patients were divided into two groups: smokers (20–30 cigarettes/day) and non-smokers. Each patient had to have at least one pair of NCCLs of similar size and depth to receive the different adhesive strategies. The maximum number of restorations/patient was 8 and the average was 6 (3 pairs). In total, 152 NCCLs were selected, 76 teeth in smokers and 76 in non-smokers. The lesions were divided into four groups, each one with 38 lesions: group 1: etch-and-rinse adhesive strategy in non-smokers; group 2: selective enamel etching strategy in non-smokers; group 3: etch-and-rinse adhesive strategy in smokers; group 4: selective enamel etching strategy in smokers.

The restorations were performed between May and October, 2012. The randomization procedure for the adhesive technique was done by tossing a coin (with the pairs previously defined).

Restorative Procedures

All restorations were performed by a single operator using the universal adhesive (Scotchbond Universal Adhesive, 3M ESPE; St Paul, MN, USA) in etch-and-rinse mode for groups 1 and 3 and with a self-etching approach on dentin (selective enamel etching) in groups 2 and 4. A nanofilled resin composite (Filtek Z350 XT, 3M ESPE) was selected as the restorative material for all groups (Table 3). The restorative procedures were performed as follows:

1. Tooth prophylaxis with pumice/water and rubber cup at low speed.
2. Resin composite shade selection.
3. Relative isolation of operating field with lip retractor, cotton rolls, and retraction cords (Ultrapack, Ultradent; South Jordan, UT, USA).
4. Tooth etching with 37% phosphoric acid (Condac 37, FGM; Joinville, Brazil), 30 s for enamel (all groups) and 15 s for dentin (only in groups 1 and 3).
5. Cavity rinsing with water for 30 s. The excess dentin moisture was removed using sterile cotton pellets, which protected this tissue while enamel drying was performed using compressed air for 10 s at a distance of 2 cm.
6. Application with agitation of one layer of the universal adhesive on enamel and dentin for 20 s.
7. Air application for 5 s to volatilize the solvent, followed by light curing for 20 s using an LED unit with an intensity of 1100 mW/cm^2 (Flashlite 1404, Discus Dental/Philips; Stamford, CT, USA).
8. First composite increment applied to the cervical and axial walls, light cured for 40 s.
9. Second resin composite increment applied to the occlusal wall, light cured for 40 s.
10. Final increment applied, filling the remaining cavity depth, adapted with a brush to restore the tooth contour, and light cured for 40 s.
11. Initial finishing with scalpel.
12. Retraction cord removal with an explorer.
13. Finishing and polishing with diamond points and sequential finishing disks (Sof-Lex Pop-on, 3M ESPE).
14. Final polishing with diamond paste and felt disks.

Table 2 Characteristics of the participants and cervical lesions in the study

Participants' characteristics				
	Non-smoker		Smoker	
Total	13		13	
Male	6		7	
Female	7		6	
Age				
20–39	4		2	
40–59	6		10	
> 59	3		1	
NCCL characteristics				
Location	**G1**	**G2**	**G3**	**G4**
Anterior	11	10	15	16
Incisor	6	6	8	9
Canine	5	4	8	8
Posterior	27	28	21	20
Premolar	21	23	21	20
Molar	6	5	1	1
Superior	24	18	28	27
Inferior	14	20	8	9
Dentin sclerosis				
None	16	16	13	6
Mild	12	10	14	20
Moderate	10	11	9	10
Severe	0	1	2	2
Angle				
< 90 degrees	5	4	2	3
> 90 degrees	33	34	36	35
Cervico-incisal dimensions				
1.0 to 2.0 mm	12	10	9	8
2.0 to 3.5 mm	23	25	28	29
> 3.5 mm	3	3	1	1
Wear facets				
Present	9	11	17	16
Absent	29	27	21	22

Table 3 Restorative materials used in the study

Material	Composition	Manufacturer	Batch number
Condac 37	37% Phosphoric acid	FGM; Joinville, Brazil.	210109
Scotchbond Universal Adhesive	MDP phosphate monomer, dimethacrylate resins, HEMA, Vitrebond copolymer, filler, ethanol, water, initiators, silane	3M ESPE; St Paul, MN, USA	468647
Filtek Z350XT shades A1, A2, A3, A3.5	Bis-GMA, UDMA, TEG-DMA, bis-EMA6, TEG-DMA, fillers (non-agglomerated 20-nm silica and 4- to 11-nm zirconia filler) and aggregated zirconia/ silica cluster filler (20-nm silica and 4- to 11-nm zirconia particles)	3M ESPE	N187661, N181254, N187396, N185192

Table 4 USPHS modified criteria scores

Criteria	Score	Description
Retention: restoration is still present	Alfa Charlie	Restoration present Restoration partially or completely lost
Marginal integrity: evidence of cracks along the tooth/restoration interface	Alfa Bravo Charlie	No visible evidence of cracks Visible evidence of cracks, but no exposed dentin Visible evidence of cracks with exposed dentin
Marginal discoloration: changes in the color of the restoration margin	Alfa Bravo Charlie	No discoloration present Presence of localized discoloration Presence of generalized discoloration
Color match: restoration color corresponds to the color of the remaining tooth structure	Alfa Bravo Charlie	Restoration color matches the tooth color Restoration color slightly different from the tooth color Restoration color highly different from the tooth color, esthetically unacceptable
Sensitivity: sensitivity described by the patient	Alfa Bravo Charlie Delta	No sensitivity reported Minimal discomfort reported Moderate discomfort reported Great discomfort reported

Table 5 Results in percentage of Alfa score at each evaluation period

	Recall periods												
	Baseline				6 months				12 months				p-value at 12 months
	G1	G2	G3	G4	G1	G2	G3	G4	G1	G2	G3	G4	
Retention rate	100	100	100	100	100	100	100	100	100	97.4	100	100	0.400
Marginal integrity	100	100	100	100	100	92.1	97.2	100	94.7	91.9	94.4	100	0.258
Marginal discoloration	100	100	100	100	89.5	92.1	86.1	86.1	84.2	89.2	83.3	83.3	0.878
Color match	92.1	94.7	80.6	86.1	92.1	94.7	80.6	86.1	92.1	91.9	77.8	86.3	0.477
Sensitivity	92.1	89.5	94.4	94.4	100	94.7	100	100	100	94.7	100	100	0.112

G1: etch-and-rinse in non-smokers; G2: selective enamel etching in non-smokers; G3: etch-and-rinse in smokers; G4: selective enamel etching in smokers. Percentages of the parameters evaluated refer to retained restorations.

Patients were instructed regarding proper brushing and flossing for adequate healing of the gingival tissue of the restored area. The first evaluation was performed after adequate tooth rehydration, one week after dental restoration procedures.

Evaluation Criteria

The evaluations were performed at baseline, 6 and 12 months using a dental mirror and explorer under adequate light by two evaluators previously calibrated and blinded to the treatments (adhesive techniques). The inter- and intra-examiner agreement level was assessed using the Kappa test. The methodology used for evaluation in this study was based on the United States Public Health Service criteria (USPHS), with modifications adapted for this study, based on information from other clinical studies of similar nature.[9,21,54] The evaluation criteria and the scores considered are reported in Table 4.

The results were analyzed (IBM SPSS 19, IBM; Chicago, IL, USA) using the chi-square (for associations between groups), McNemar, and Cochran's Q tests. The significance level was set at 5%.

RESULTS

Table 5 shows the comparisons between groups and times for each independent criterion analyzed. The McNemar test, comparing each group at the different periods, showed a significant difference for marginal discoloration in groups 1, 3, and 4 between baseline and 12 months ($p = 0.031$ for the three groups).

The comparison between non-smokers and smokers showed no statistically significant difference (chi-square test). Color match was the only criterion that showed significant differences between smokers and non-smokers at baseline, 6 months, and 12 months (p = 0.033). The comparison between etch-and-rinse and selective enamel etching showed no statistical difference between the groups at the evaluation periods.

DISCUSSION

Since dental adhesives have improved greatly in the past decades and have been widely studied, it can be said that the bonding efficacy depends not only on the material's chemistry, but also on proper clinical management and knowledge of the morphological changes in dental tissues caused by the action of the components used in the different adhesive techniques.[25] The adhesive system selected for this study is part of a new generation of bonding systems in which the main difference is not in the chemistry, but in the possibility of varying the adhesive technique with the same product; they are thus called universal or multimode adhesives. After good laboratory results[29] and a short-term clinical study showing good performance,[35] this adhesive system was designed for use in self-etching, etch-and-rinse, or selective enamel etching mode. Even if important failures were not expected with materials from reliable companies, clinical trials are nevertheless essential to prove their performance. The self-etching approach of these multimode adhesive systems on dentin may improve the bond stability over time.[23] However, the literature on the use of self-etching adhesives is controversial, especially concerning single-step systems, as the results have usually been product dependent.[34,53]

Two techniques were applied in the present study for each pair of restorations, using the same universal adhesive, comparing the etch-and-rinse and selective enamel etching strategies. Since Scotchbond Universal (SBU) contains methacryloyloxydecyl dihydrogen phosphate (MDP) molecule and polyalkenoic acid polymer, it is assumed to adhere to dentin and bond chemically with hydroxyapatite.[12,57,58] This chemical interaction contributes to the bond durability.[11] The clinical efficacy of adhesives containing 10-MDP has long been proven, and Clearfil SE Bond (Kuraray) is the gold standard in this bonding strategy, as it is considered clinically reliable, predictable, and easy to use.[18,34,39,43,46] The choice of prior enamel etching with phosphoric acid for all restorations in our study was based on the limited enamel demineralization by self-etching adhesives with a higher pH (2.7 for SBU), which might promote an ineffective long-term bond. Enamel etching with phosphoric acid is preferred due to micromechanical interaction, and some studies showed that the effectiveness of single-step self-etching adhesives could be improved by etching enamel margins with this acid.[11,16] Although prior dentin etching does not reduce the immediate resin composite bond strengths to dentin, the bond stability may be lower than that produced when the adhesive is applied to dentin in the self-etching approach.[15,51] Apparently, this does not occur with SBU.[29]

After 12 months, all restorations evaluated at baseline were examined using the same five USPHS-based criteria adapted for this study. These made it possible to evaluate the short-term influence of smoking on adhesion (retention, marginal integrity, and marginal discoloration), resin composite behavior (marginal discoloration and color stability), and potential reduction of hypersensitivity after the restorative procedure. The difficulty of finding smokers who met the research inclusion criteria in the present study design made it necessary to search for patients who needed a higher number of restorations. The number of restorations per patient was based on other clinical studies conducted at our University.[13,15]

There was no statistical difference in the retention criteria among the groups. This criterion is the most basic and objective for the assessment, since the restoration cannot be evaluated in terms of other criteria if it is not present. Sometimes, the decrease in the resin composite bond strength to dentin may occur after smoking contamination, mainly because of the impregnation of dentin with substances in the smoke.[3] Although it is conceivable that this may reduce the bond ability, it was not observed in our study. After one year, only one restoration was lost, from a non-smoking patient. This could be explained by the dynamic nature of the oral environment, with the presence of saliva and the patients' daily oral hygiene, which might dilute the smoke components over the NCCL. The adhesive technique was not found to influence retention, since 100% of the restorations performed using the etch-and-rinse technique and 98% performed using the selective etching technique were present at the 12-month evaluation. This high retention rate is in agreement with a recent 18-month clinical trial[35] which showed a retention rate of 98% for the same adhesive strategies employed, comparable to those obtained with Scothbond Multi-Purpose (3M ESPE) and Adper Single Bond 2 (3M ESPE) over the same period.[33] The high retention rates in the present study may decrease over further evaluation, as reported in studies with longer follow-ups.[28,54]

The marginal discoloration evaluated in this study was at the tooth/restoration interface. The individual assessments for each group for this criterion found a significant increase in Bravo ratings (which generally could be removed by polishing procedures) in groups 1, 3, and 4 at the 12-month evaluation when compared to baseline. Group 2 exhibited a non-significant increase in discoloration. However, this difference could not be directly related to smoking, since discoloration occurred similarly in smokers and non-smokers. Some authors have demonstrated the staining ability of cigarette smoke on resin composites, sometimes irreversibly.[8,24] However, our study showed that discoloration seemed to be more related to patient hygiene and food habits. Although the resin composite (Filtek Z350 XT, 3M ESPE) used in the present study showed an excellent gloss, which was not overlooked during the clinical procedures, such failures were more visible in the proximal areas, where the polishing procedures and access for hygiene measures are more difficult. This also occurred in others studies evaluating resin composite restorations, showing that rates tended to increase over the years.[21,39] The absence of gloss increases the staining of some methacrylate resin composites and, normally, a new polishing procedure could reverse these color alterations.[1]

The color match in this study was evaluated by comparing the resin composite and the tooth color. When the composite was somehow evident, even if clinically acceptable, it was classified as Bravo. The color change over the months could be caused both by intrinsic composite modification or superficial discoloration. Regarding this criterion, although some authors have reported irreversible color changes in composites in the presence of cigarette smoke, especially when combined with stain-inducing beverages,[24] this change was not visible in the present study. Likewise, in this study, marginal integrity failures were insignificant and when present, did not require replacement of the restorations.

It was also observed that the sensitivity caused by thermal stimuli observed at baseline was reduced by nearly 100% over time, which is in agreement with other clinical studies evaluating this criterion.[19,25,35,49,59]

Therefore, we fail to reject the null hypotheses, since there were no differences between the restorations in smokers and non-smokers, nor between the etch-and-rinse and selective etching techniques. The excellent performance of the nanofilled resin composite associated with SBU resulted in restorations with little changes over the 12 months. These resin composites combine favorable physical and mechanical properties and have demonstrated good clinical performance, with wear similar to the microhybrid composites and esthetic characteristics comparable to the microfilled composites.[20,22,30,32,48] The reduced evaluation time may have contributed to the favorable outcome. Despite the high quality materials used and the precisely performed technique, it was observed that smoking did not affect the good results obtained during the first year.

This study is currently in the follow-up stage, and the resulting data are being analyzed. The restorations under continued evaluation will be able to validate the current observations.

CONCLUSIONS

Based on the results obtained over the 12-month evaluation in this study, it was concluded that 1. etch-and-rinse and selective enamel etching techniques are indicated for NCCL restorations when Scotchbond Universal adhesive is used with the nanofilled resin composite Filtek Z350XT, and 2. cervical restorations in smokers and non-smokers had similar excellent clinical performance over the period evaluated.

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Clinical relevance: Neither smoking habit nor bonding strategy (etch-and-rinse or selective enamel etch) influenced the retention rate and color stability of resin composite restorations in NCCL after one year.

Aging Effect of Atmospheric Air on Zirconia Surfaces Treated by Nonthermal Plasma

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Purpose: The purpose of this study was twofold: 1) to characterize the zirconia (Y-TZP) surfaces through scanning electronic microscopy associated with energy-dispersive spectroscopy and atomic force microscopy after the deposition of a thin organosilicon film by nonthermal plasma (NTP) treatment, and 2) to determine the zirconia surface hydrophilicity, before and after aging, through surface energy analysis.

Materials and Methods: Surfaces of 16 zirconia disks (10 x 3 mm) were treated for 30 min each with hexamethyldisiloxane and argon plasmas, followed by oxygen plasma. Disks were analyzed before NTP treatment, immediately after NTP treatment, and after aging for 7, 15, and 30 days. The surface energy of the Y-TZP disks was measured with a goniometer. Quantitative data were submitted to statistical analysis using ANOVA and Tukey's test ($p < 0.05$).

Results: Immediately after NTP treatment, the surface energy of the zirconia disks was significantly higher than at any other tested period ($p < 0.001$), and the water contact angle on the zirconia disks was reduced to 0 degrees. Similar surface energy results were obtained before NTP treatment and after 15 or 30 days of aging ($p > 0.05$; Tukey's test). Energy-dispersive spectroscopy results revealed the presence of carbon, oxygen, and silicon on the surface after NTP treatment.

Conclusion: NTP treatment was useful for treating the zirconia surface for cementation procedures, as it produced a high level of hydrophilicity on the zirconia surface. However, this high level of hydrophilicity did not persist after aging.

Keywords: Y-TZP, contact angle, nonthermal plasma, surface energy, surface topography, microstructure.

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Increasing patient demand for esthetic treatments has led to the development of durable and resistant ceramic systems, such as yttria-tetragonal zirconia polycrystal (Y-TZP).[10,19,22] Nevertheless, improvements of the zirconia composition have made it highly inert and resistant to hydrofluoric (HF) acid etching. As a result, it can be difficult to achieve satisfactory cementation of zirconia-based restorations to resin cements.[9,10,17,22] Modification of the zirconia surface is necessary to improve their interaction with those cements. Proposed methods for improving the roughness of the inner surface of zirconia-based restorations have included aluminum oxide (Al_2O_3) sandblasting and tribochemical silica coating.[9,10,19,21] However, there is scientific evidence that these treatments may create critical defects on the ceramic surface. The accumulation of stresses on a defective surface may lead to clinical complications, including catastrophic fracture of the zirconia infrastructure and failure of the prosthesis.[10,22]

As an alternative to sandblasting, the nonthermal plasma (NTP) technique has been used as a promising

Table 1 Properties of the materials used in this study

Material	Composition	Commercial brand	Manufacturer	Batch number
Y-TZP (zirconia)	Y_2O_3, HFO_2, Al_2O_3, other oxides	Ceramill	Amann Girrbach; Vorarlberg, Austria	1306002
Hexamethyldisiloxane $(CH_3)_3SiOSi(CH_3)_3$	C, Si, O, H	-	Sigma Aldrich; St Louis, MO, USA	USLY001027
Ar (argon)	Ar	-	White Martins; Danbury, CT, USA	15116/12
O_2 (oxygen)	O_2	-	White Martins	07036/12

option to treat the zirconia surface.[9,17] The NTP method can induce modifications of the surface hydrophilic properties of dental ceramics, making them superhydrophilic, or even create thin organosilicon films with the same chemical behavior.[12,14,23] These changes may improve the intimate contact of the adhesive agent or resin cement with the all-ceramic restoration, without causing physical damage to these materials.[9,12,13,17,18,23] Among the methods available for plasma treatment, plasma-enhanced chemical vapor deposition is an interesting and commonly applied technique that may be easily used in dental laboratories.[23]

In vitro studies suggest that to obtain satisfactory bond strength results during the cementation procedure, the inner surface of the all-ceramic prosthesis should be kept clean, regardless of the surface treatment.[25] Some clinical situations, such as surface contamination by saliva or blood, might cause impurities to be incorporated in the final product, thereby significantly reducing the bond strength.[25] After NTP application, the surface of the restorations to be cemented may be easily contaminated by organic impurities when in contact with atmospheric air, owing to the high reactivity that is obtained through the deposition of thin superhydrophilic films.[25,26] Thus, the duration of the thin-film hydrophilicity after exposure to ambient air is as important as the microtensile bond strength for determining the suitability of the NTP-treated surface for bonding procedures. Contamination of the treated surface might affect the intimate contact of the cement to the prosthesis.

To the authors' best knowledge, no study in the literature has evaluated the aging effect of atmospheric air on the organosilicon films deposited by NTP treatment on zirconia surfaces, nor has any study characterized the abovementioned ceramic system after this treatment. Therefore, the purposes of this study were as follows: 1) to characterize the zirconia surface through scanning electron microscopy (SEM) associated with energy-dispersive spectroscopy (EDS) and atomic force microscopy (AFM) analyses before NTP treatment (baseline), immediately after NTP treatment, and after 7, 15, and 30 days of aging in atmospheric air, and 2) to evaluate the hydrophilicity of the treated surface at each aging period through surface energy analysis. The tested periods of aging were chosen in order to simulate the possible interval between the deposition of the thin organosilicon film on the surface of the zirconia-based restoration and the cementation procedure. The null hypotheses were that 1) deposition of the thin organosilicon film by NTP treatment is not resistant to aging in atmospheric air, undergoing degradation or detachment, and 2) there is no significant increase in the surface energy or a significant reduction in the water contact angles on zirconia after periods of aging in atmospheric air.

MATERIALS AND METHODS

Sixteen Y-TZP disks (Ceramill Amann Girrbach; Vorarlberg, Austria), measuring 10 mm in diameter and 3 mm in thickness, were provided by the manufacturer. All materials used in the present study are listed in Table 1. Disk surfaces were polished sequentially with metallographic sandpapers and cleaned in ultrasonic baths.[23] The proposed analyses were performed initially (T0), immediately after NTP treatment (T1), and after aging in atmospheric air for 7 days (T2), 15 days (T3), and 30 days (T4).

The surface energy of the Y-TZP disks was measured with a goniometer (Ramé-Hart 100-00, Ramé-Hart Instruments; Succasuanna, NJ, USA) by the sessile drop technique in a temperature-controlled room (23°C). Ten Y-TZP disks were used, with 10 measurements performed per disk (n = 100 readings total). Surface energy was calculated by the Owens-Wendt-Rabel-Kaelble method, which calculates the contact angle between drops of two liquids with different polarities and the Y-TZP disk. A 0.5-µl drop of deionized water (polar component) and diodomethane (dispersive component) were dropped through a 50-µl glass syringe. The combination of these components is commonly used for the calculation of surface energy, because these components provide information regarding the intermolecular interactions of a substrate.

To perform surface characterization, five disks were submitted to SEM (JSM 610LA, JEOL; Tokyo, Japan). One disk was examined in each test period (T0–T4). Disks were metallized at the moment of the reading. Images were captured at 300X, 10,000X, and 25,000X magnification. Simultaneously, the same disk used for SEM analysis was submitted to elemental chemical composition analysis on the order of 1 µm^3 using EDS. The goal of EDS was to characterize the principal chemical elements of the disk surface before and immediately after NTP treatment and after each test period of aging.

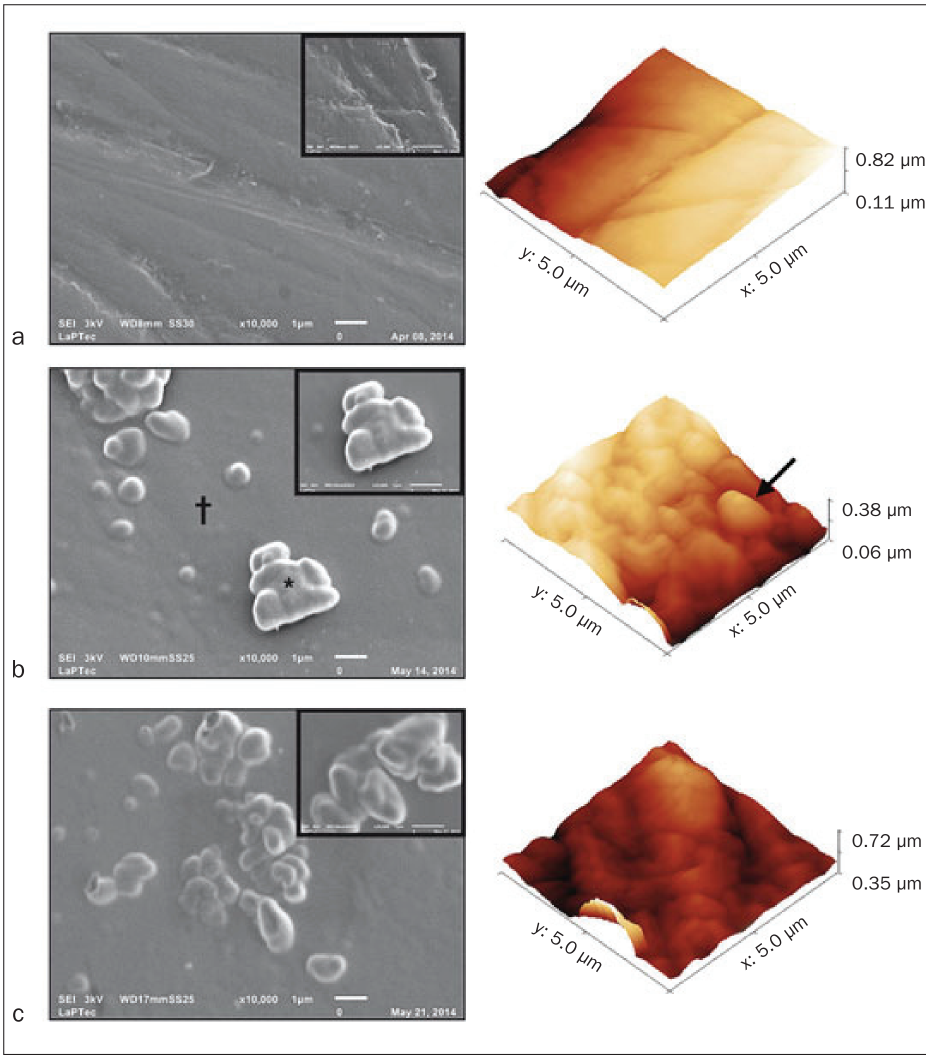

Fig 1 SEM (10,000X and 25,000X magnifications) and AFM images of Y-TZP disks before (a) and immediately after nonthermal plasma treatment (b), and after 30 days of aging (c). † identifies the thin organosilicon film on the zirconia surface, * and the black frame in (c) identify granular structures (agglomeration regions). The thin film deposited produced a standard zirconia surface.

One zirconia disk was submitted to AFM analysis under the same conditions mentioned above, at T0, T1, T2, T3, and T4. AFM images were initially obtained and transferred to the Gwyddion 2.33 program (2013; Department of Nanometrology, Czech Metrology Institute, Okružní; Lesná, Czech Republic) for three-dimensional image acquisition. The images were standardized to 10 µm to enable a visual comparison between the periods.

Plasma treatment was performed inside a stainless glass chamber by using a custom-made instrument from the Technological Plasma Laboratory (LapTec, Sao Paulo State University Engineering College) evacuated to a background pressure of 9×10^{-2} Torr. Deposition plasmas were prepared from mixtures of 85% hexamethyldisiloxane (HMDSO) vapor and 15% Ar at a radiofrequency of 13.56 MHz (50 W) for 30 min under a constant working pressure of 15×10^{-2} Torr. Immediately after this deposition, HMDSO composites and Ar were stopped, and O_2 was admitted to the system at 13.56 MHz (50 W) for 30 min under 10.1×10^{-2} Torr. Parameters for plasma deposition were stipulated according to a previous study.[23] The disks were removed from the stainless glass chamber at a temperature of 33°C, thereby preserving the surface integrity.

During aging in atmospheric air, the disks were positioned in a Petri dish until analysis, in the same test room with controlled temperature. The effect of the time (aging) on the surface energy of the tested ceramic was evaluated by one-way ANOVA. The mean surface energy results were compared by Tukey's Honestly Significant Difference test ($\alpha = 0.05$). Statistical analysis was performed with the Statistical Package for the Social Sciences (SPSS), version 19.0 (IBM SPSS, v19.0; Armonk, NY, USA).

RESULTS

The SEM images (Fig 1) revealed that the NTP deposition promoted topographic modifications on the zirconia disk surface which were observable only at magnifications of 10,000X and 25,000X. At those magnifications, NTP treatment with HMDSO monomer produced areas where the thin organosilicon film agglomerated in a granular pattern, characteristic of such treatment. The

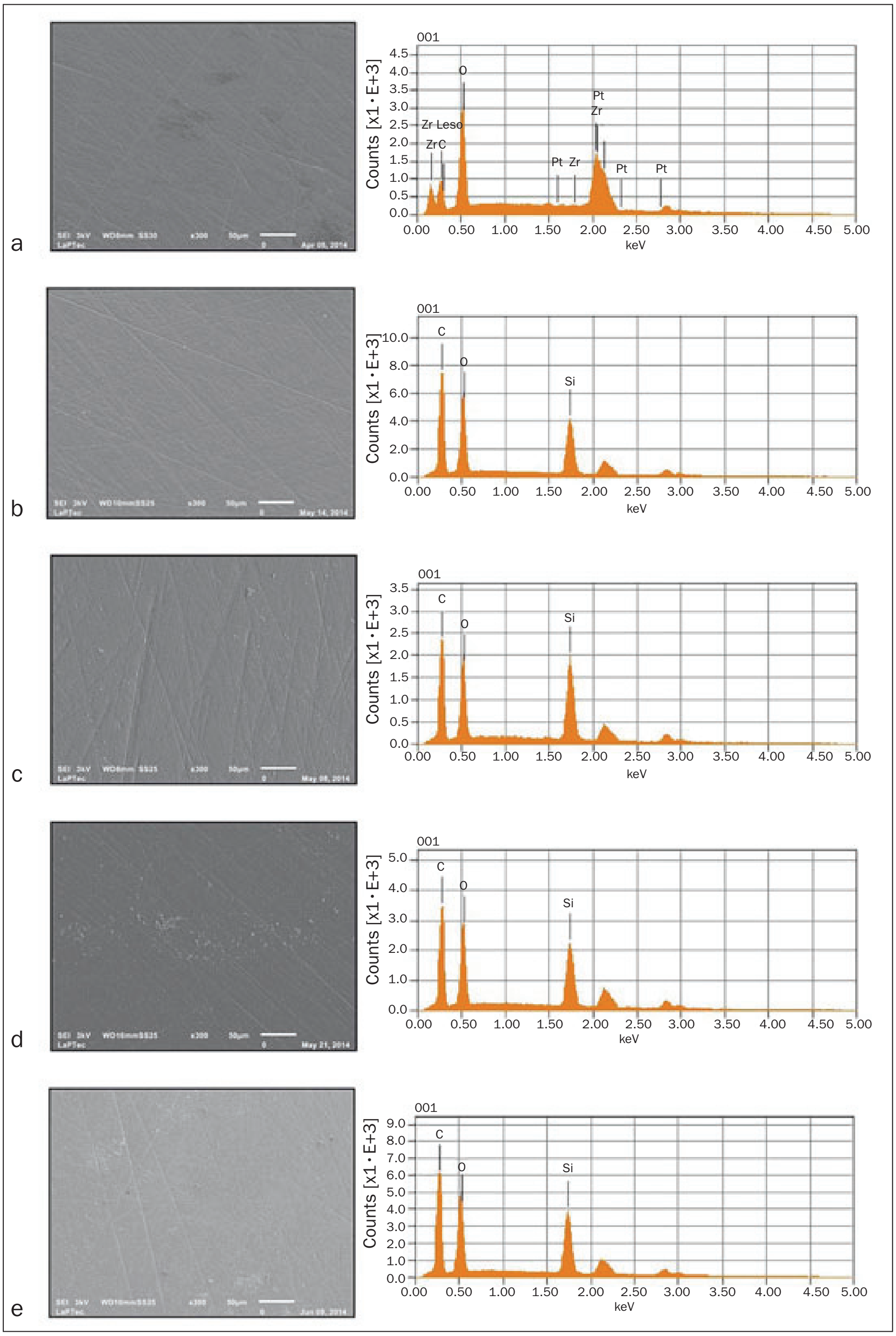

Fig 2 SEM images (300X magnification) and EDS analysis of Y-TZP (a) before nonthermal plasma treatment; (b) after treatment with HMDSO plasma, and after aging for 7 days (c), 15 days (d), or 30 days (e).

AFM images verified the presence of the surface agglomerations (Fig 1). The image of the surface after aging (Fig 1c) showed the preservation of the surface integrity; valley formations and irregularities similar to surface deteriorations were not observed. As there were no morphological alterations of the thin film after aging, representative SEM-EDS images at 300X magnification are shown for each test period (T0–T4, Fig 2).

Regarding the chemical elementary composition of the disk surface, elemental zirconium (Zr) was apparent on the untreated surface (Fig 2a). After NTP treatment (T1) and after aging (T2–T4), the EDS mapping results showed the presence of high quantities of carbon (C), oxygen (O), and silicon (Si). These findings suggested that the thin organosilicon film was adherent on the Y-TZP surface, and that its composition was stable during aging in atmospheric air. EDS analysis did not indicate the presence of Zr on the surface with the thin film (Figs 2b to 2e), suggesting that the thin film was thicker than the maximum depth that the x-ray can penetrate.

Table 2 Results of one-way ANOVA for surface energy

Source	DF	Seg SS	Adj SS	Adj MS	F	p
Time	4	13007.0	13007.0	3251.8	339.13	< 0.001*
Error	45	431.5	431.5	9.6		
Total	49	13438.5				

*Statistically significant difference between factors (p < 0.000).

Table 2 shows that the time factor affected the surface energy of the zirconia disks ($p < 0.001$ by ANOVA). As shown in Fig 3, immediately after NTP treatment (T1), the surface energy of the Y-TZP disks was increased. However, after aging in atmospheric air, the surface energy diminished significantly. The surface energy values after the three periods of aging were statistically similar to each other. The mean surface energy obtained after 7 days of aging (T2) was significantly higher, but the mean values obtained after the other periods of aging (T3 and T4) were statistically similar to the mean value obtained at baseline (T0).

Figure 4 reveals that the lowest water contact angles were present immediately after NTP treatment (T1), thereby qualitatively illustrating the higher surface energy of the treated Y-TZP disks at T1. Polar components on the Y-TZP disks were greatly increased immediately after NTP treatment and then decreased with aging, resembling the baseline results (T0).

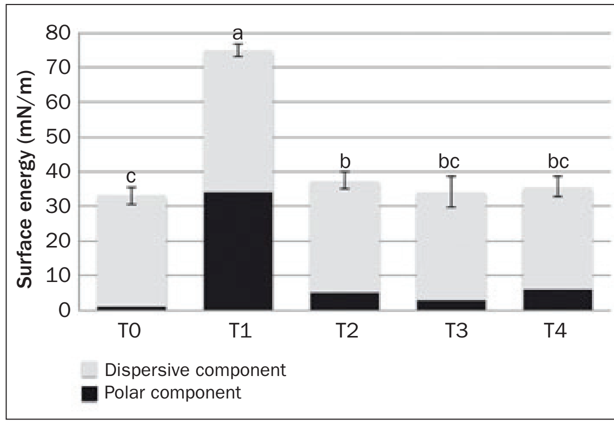

Fig 3 Polar and dispersive components of Y-TZP disks. Different lowercase letters denote statistically significant differences.

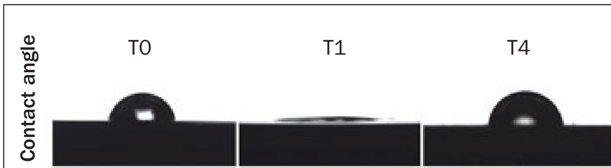

Fig 4 Surface wettability of Y-TZP disks at T0, T1, and T4. The water contact angle with the Y-TZP disks increased dramatically after aging in atmospheric air.

DISCUSSION

The SEM and AFM images showed that the aging periods tested did not alter the morphology of the thin organosilicon film. However, the surface energy increased significantly with aging compared to the period immediately after NTP treatment (T1). Therefore, the null hypotheses tested in the present study were partially accepted.

Regarding zirconia topography, the SEM and AFM images revealed that the NTP treatment produced a thin organosilicon film that was attached to the zirconia surface and maintained its characteristics after 30 days of aging in atmospheric air (Fig 1). The three-dimensional AFM method was performed in the present study to confirm those findings because of its higher accuracy in determining surface roughness parameters,[16,27] whereas the SEM images enabled an excellent analysis of the microstructural characteristics of the thin organosilicon film produced.[5]

The increasing presence of C, Si, and O on the zirconia surface after NTP treatment is consistent with adhesion of the thin film to the surface. The presence of those elements also suggests the presence of silicon oxide (Si-O) associated with methyl (CH_3) groups. EDS analysis can be used to evaluate the surface composition of different materials, but only up to a depth of 1 µm.[4-6] Physical changes on the zirconia disk surface were not apparent from images at 300X magnification, and Zr was not observed on the EDS graphics after NTP treatment. For these reasons, we believe that the thin organosilicon film was not thicker than 1 µm and, thus, clinical mismatches of the tooth finish line with the zirconia coping or framework would not occur.[8,9] The C, Si, and O element levels were preserved and Zr was not observed in any of the tests, suggesting that the thin organosilicon film maintained its integrity and was attached to the zirconia surface. Moreover, the observed alterations suggest that the surface energy of the tested ceramic system was related to the incorporation of organic impurities and/or hydrophilic modifications of the thin organosilicon film. To prevent contamination of the treated surface and to clinically obtain bond strength results that are similar to those obtained experimentally, a clean ceramic surface and maximal intimate contact between the surface and adhesive agents seem to be necessary.[19,22,25]

In the present study, treatment with O_2 plasma was essential to reduce the water contact angle to 0 degrees. This treatment permitted the incorporation of C-O- and C-OH functional groups, which were responsible for the great increase in polar components observed in Fig 3.[23] However, other authors have affirmed that the NTP-produced hydrophilicity of thin films is durable for only a few days or hours.[26] Consistent with this observation, the surface energy analysis revealed that the time factor significantly reduced the hydrophilicity of the zirconia surface. An increase of the water contact angles with aging was also confirmed.

The reduction in hydrophilicity is thought to have been due to two principle factors. The first factor is the incorporation of organic impurities, specifically hydrocarbons. This factor was indicated by the increased presence of new chemical elements (eg, O and C)[26] on the EDS graphics after 30 days of aging. Clinically, the increased presence of O and C might not affect the cementation of zirconia-based restorations in the case of a superhydrophilic material (with water contact angles ≈ 0 degrees). In this case, superhydrophilicity would facilitate intimal contact between the adhesive agent and the zirconia surface; therefore, cementation would still be adequate.[11,15,19,22]

The second factor responsible for the reduced hydrophilicity is related to the environment to which the treated surface is exposed. When the surface was placed in atmospheric air, the polar groups rotated away from the surface and were buried, thereby increasing the surface hydrophobicity.[1,24] Nevertheless, this increased hydrophobicity might provide some benefits to the zirconia material. A hydrophobic surface after cementation might reduce the hydrolysis of the cement/ceramic interface, increasing the bond strength resistance.[7] It might also reduce the inherent and inevitable degradation process of zirconia when in contact with water or low temperatures (subcritical crack growth), preventing the debonding and catastrophic failure of zirconia-based restorations.[2,3,20]

The present study had some limitations, including the lack of microtensile bond strength testing. Although the plasma deposition equipment might be appropriate for use on the industrial scale, the wettability results after aging in atmospheric air suggested that adaptations are needed before this equipment can be used in dental clinics, such that the surface treatment of zirconia-based restorations and their subsequent cementation may be performed. Further studies are also necessary to verify the exact moment when the hydrophilicity of the NTP-treated zirconia surface begins to change. In the present study, the period after 7 days of aging (T2) in atmospheric air was the minimum interval stipulated, with the purpose of simulating the period between treatment in a dental laboratory and the moment of cementation. Nevertheless, the surface at T2 exhibited a significantly higher surface energy compared to the surface at baseline (T0), suggesting that shorter intervals may provide better surface energy results. Thus, additional studies are needed to create methods (eg, vacuum storage) to prevent the contamination of zirconia surfaces that are treated with NTPs by HMDSO monomers.

CONCLUSION

Treatment with HMDSO associated with Ar plasma, followed by treatment with O_2 plasma, showed a high potential to transform the zirconia surface. Aging in atmospheric air preserved the morphology of the thin organosilicon film. However, the superhydrophilic condition was not stable because of the incorporation of organic impurities and changes in the hydrophilic properties.

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Clinical relevance: NTP treatment may be useful for transforming the surface of zirconia ceramic systems and may improve their bond strength to resin cements, but this still needs to be tested. However, atmospheric air aging may play an important role in the durability of zirconia-to-composite chemical bonds.

Effects of Different Surface Treatments on Composite Repairs

Graziela Ribeiro Batista[a] / Maria Beatriz Beber Kamozaki[b] / Natália Cortez Gutierrez[b] / Taciana Marco Ferraz Caneppele[c] / Carlos Rocha Gomes Torres[d]

Purpose: To evaluate the influence of different surface treatments on roughness and bond strength of composite repairs.

Materials and Methods: 120 truncated conical specimens were prepared with composite Grandio SO (VOCO) and submitted to 5000 thermal cycles. Specimens were divided into 12 groups (n = 10) regarding the surface treatments: negative control (NC), without treatment; medium-grit diamond bur (MGD); coarse-grit diamond bur (CGD); conventional carbide bur (ConC); crosscut carbide bur (CutC); chemical vapor deposition diamond bur (CVD); sandblasting with aluminum oxide (AlO); Er:YAG laser 200 mJ/10 Hz (Er200); Er:YAG laser 60 mJ/10 Hz (Er50); Nd:YAG laser 120 mJ/15 Hz (Nd120); Nd:YAG laser 60 mJ/ 15Hz (Nd60); air abrasion with 110-µm silica modified aluminum oxide (Rocatec Plus-3M) (SIL). After the surface treatments, the surface roughness (Ra) was measured using a profilometer, and then the adhesive system Admira Bond (VOCO) was applied. Another truncated conical restoration was built up with the same composite over the bonded area of each specimen. In order to evaluate the cohesive strength, double-cone specimens were made and considered as a control group (CoheC). The specimens were submitted to tensile bond strength testing and the obtained data (MPa) were evaluated by one-way ANOVA, Tukey's and correlation tests.

Results: ANOVA showed significant differences among experimental groups for roughness and adhesive strength ($p < 0.00$). The roughness values (Ra) were: NC (0.21 ± 0.19)[c]; ConC (0.30 ± 0.08)[c]; CutC (0.50 ± 0.22)[cd]; CVD (0.74 ± 0.14)[bd]; MGD (0.89 ± 0.39)[ab]; Er50 (0.89 ± 0.14)[ab]; AlO (0.90 ± 0.07)[ab]; Nd60 (0.94 ± 0.33[ab]; SIL (0.98 ± 0.07)[ab]; Nd120 (1.10 ± 0.19)[a]; CGD (1.10 ± 0.32)[a]; Er200 (1.12 ± 0.21)[a]. The results of the tensile bond strength test in MPa were: CGD (11.58 ± 3.03)[a]; MGD (12.66 ± 3.82)[ab]; NC (13.51 ± 3.95[ab]; Nd120 (14.11 ± 5.95)[ab]; ConC (14.73 ± 6.12)[ab]; Er200 (15.51 ± 1.45)[abc]; CVD (15.61 ± 5.00[abc]; Er50 (16.44 ± 2.75)[abc]; CutC (16.79 ± 2.98)[abc]; Nd60 (17.72 ± 2.45)[abcd]; AlO (18.33 ± 3.19)[bcd]; SIL (21.13 ± 4.48[cd]; CoheC (23.50 ± 5.81)[d]. The groups followed by the same letters were not statistically significantly different (Tukey's test). No correlation was found between bond strength and roughness ($r = 0.007$).

Conclusion: Air abrasion with silica coating (Rocatec) was the only method which resulted in significantly higher bond strength in relation to the negative control group. The increase in laser energy produced a rougher surface, but reduced the bond strength.

Keywords: composite resin, composite repair, roughness, bond strength.

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Today, composite resins are commonly used for restorative treatment in posterior teeth. The increase in the use of the resins is due to their ability to obtain good esthetic results and bonding to tooth structure. In addition, it is a less expensive alternative to indirect restorative treatments. With time, however, composite resin restorations can show wear, discoloration, fractures, or defects which may require their replacement.[6] Total replacement of the restoration can cause significant loss of sound dental tissues and consequently

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Table 1 Experimental groups, materials for surface treatment, and application methods

Groups	Surface treatment employed	Brand name/manufacturer	Application methods
CoheC	Cohesive control group	–	–
NC	Negative control group, no surface treatment	–	–
MGD	Medium-grit rotary diamond bur (91 µm mean particle size)	#1092, KG Sorensen; São Paulo, SP, Brazil	Coupled to low speed dental turbine, under water cooling for 10 s
CGD	Coarse-grit rotary diamond bur (151 µm mean particle size)	#1092G, KG Sorensen	Coupled to low speed dental turbine, under water cooling for 10 s
ConC	Conventional carbide rotary bur	#FG56, KG Sorensen	Coupled to low speed dental turbine, under water cooling for 10 s
CutC	Cross-cut carbide rotary bur	#FG1557, KG Sorensen	Coupled to low speed dental turbine, under water cooling for 10 s
CVD	Chemical Vapor Deposition diamond bur	CVDentus C1, Clorovale Diamantes; São José dos Campos, SP, Brazil	Coupled to an ultrasonic dental unit handpiece (frequency: 30 kHz; power output: 8 W), under water cooling for 10 s
AlO	Air abrasion with aluminum oxide (50 µm particle size)	Microetcher II, Danville Engineering; San Ramon, CA, USA	Applied with an intraoral sandblaster (2.8 bar) for 10 s at a working distance of 5 mm perpendicular to the surface
Er200	Er:YAG laser radiation (200 mJ/10 Hz)	Kavo Key Laser III, Kavo; Biberach Riß, Germany	Laser radiation for 10 s at a working distance 5 mm perpendicular to the surface
Er50	Er:YAG laser radiation (50 mJ/10 Hz)	Kavo Key Laser III	Laser radiation for 10 s at a working distance 5 mm perpendicular to the surface
Nd120	Nd:YAG laser radiation (120 mJ/15 Hz)	Pulse Master 600 IQ, American Dental Technologies; Aston, PA, USA	First medium-grit rotary diamond bur for 10 s, then laser radiation for 10 s at a working distance 5 mm perpendicular to the surface
Nd60	Nd:YAG laser radiation (60 mJ/15 Hz)	Pulse Master 600 IQ	First medium-grit rotary diamond bur for 10 s, then laser radiation at a working distance 5 mm, 90-degree angle to the surface, for 10 s
SIL	Air abrasion with tribochemical silica coating (110 µm particle size)	Rocatec Plus 3M ESPE; St Paul, MN, USA	First medium-grit rotary diamond bur for 10 s, then air abrasion with tribochemical silica coating (2.8 bars) at a working distance 5 mm, 90-degree angle to the surface, for 10 s

weaken dental structure and cause pulpal injuries.[7] To avoid these problems, repair of composite resin restorations has become a frequent procedure, with the advantages of being minimally invasive, protecting dental structures from operative trauma, improving the longevity of the restoration, and requiring less chair time.[24]

When making a new restoration, the adhesion between the layers of composite applied occurs due to the presence of an oxygen-inhibited layer of uncured resin, where unreacted monomers are present and free-radical activity causes the interaction of the composite layers.[8,14] Unreacted C=C bonds are present in this layer,[29] and they enable the adhesion between layers,[22] improving the chemical bond of the materials.[24] It is important to bear in mind that this interaction does not occur between aged and fresh materials, because composite resin restorations are affected by salivary pH, enzymes, and the moist oral environment,[26] so that the amount of unreacted monomers diminishes[30] and there is no free-radical activity.[25] Therefore, the adhesion of a new material to the aged surface is more difficult, impairing repair procedures.[2,9]

High bond strength between old and new materials is mandatory for the success of composite repair, and various surface treatments are employed to this end. Roughening is the most common technique applied; the creation of mechanical interlocking between the materials is a significant factor contributing to improved bond strength between composites.[5,12,27] Further, the probability of exposed, free carbon atoms on the surface is

Table 2 Materials used and their composition

Material	Manufacturer	Composition	Batch number
Grandio SO	VOCO; Cuxhaven, Germany	Resin matrix: bis-GMA, bis-EMA, TEG-DMA, CQ, amine, BHT Inorganic content: Nanoparticles of SiO_2, glass ceramic Filler content: 89 wt%, 73 vol%	1029391
Admira Bond	VOCO	Dimethacrylates, ormocers, silicate fillers, catalyst system, UDMA, bis-GMA, acetone (bond)	1025303
VOCOcid Gel Etch	VOCO	34.9% orthophosphoric acid	1025303

also increased,[19] which could favor chemical bonding as well. Several options for roughening the composite surfaces are available: rotary diamond burs, air abrasion with aluminum oxide, phosphoric or hydrofluoric acid etching, and, more recently, different lasers.[26]

In order to improve the bonding to repair composite, chemical agents can be used in conjunction with mechanical treatment. In tribomechanical silica coating, the silica-modified aluminum oxide particles are applied by air abrasion, so besides roughening the surface, silica particles are deposited on the surface, favoring the chemical interaction.[10] However, in various studies of all these techniques, contradictory results are still observed.[24,26] Good results are directly related to the composition of the composites[15,28] and the application protocol of the different techniques. Time of application, the pressure employed, water cooling, direction of application, different grits and patterns of diamond burs, and the setting of different energy parameters for various types of lasers are some of the factors that can affect the results of the surface treatment and influence the bond strength.

Because there is a large variety of options available for surface treatment – each of which may create a different type or degree of roughening, potentially affecting the bond strength of the composite repair – it is necessary to establish an effective protocol to promote the interaction between the mature composite substrate and the fresh composite. Based on these statements, the null hypotheses of this study were: a) the type of surface treatment does not influence the surface roughness; b) the type of surface treatment does not influence the bond strength of repaired composite resin restorations; c) the surface roughness is not related to the bond strength.

MATERIALS AND METHODS

One hundred twenty truncated conical specimens (4 mm high, 4 mm base and 2 mm top) were prepared with composite resin Grandio SO color A4 (VOCO; Cuxhaven, Germany). Specimens were built up using a sectional Teflon matrix, which was inserted in a metal holder to keep the two halves in place during preparation of the composite specimens. Two increments of 2 mm each were inserted into the Teflon matrix and each one was light cured for 40 s using a curing light (Elipar Free Light 2, 3M ESPE; St Paul, MN, USA) at a power of 1000 mW/cm^2. For the last increment, the surface was covered with a Mylar strip to avoid the formation of an oxygen inhibited layer and to produce a standard initial roughness. In order to measure the cohesive strength of the composite, 10 double-cone specimens (8 mm high, 4-mm-diameter base, and 2 mm interface between apices) were made as the cohesive control group (CoheC), being built up in 4 increments of 2 mm each. After 24 h of deionized water storage (37°C), the specimens were submitted to artificial aging (5000 thermal cycles of 5° to 55°C, 30 s dwell time) and divided into 13 groups according their surface treatment (n = 10). The experimental groups and the surface treatments are described in Table 1.

After each surface treatment the specimens were cleaned in an ultrasonic bath with deionized water for 5 min and dried with blown air. The mean surface roughness (Ra) was evaluated using a profilometer (MaxSurf XT 20, Mahr; Göttingen, Germany). The diamond stylus moved along a distance of 2.5 mm, starting the first measurement 0.2 mm from the lower edge of the specimen. Three profile measurements were performed for each specimen at intervals of 0.25 mm and a final average was used.

For cleaning, 37% phosphoric acid gel was applied to the top surfaces for 15 s, washed with water/air spray, and dried with blown air. After that, the Admira Bond (VOCO) adhesive system was applied to all specimens, followed by gentle air blowing for 5 s and light curing for 10 s. Over each specimen, a sectional truncated conical Teflon matrix was positioned with the smaller area connected to the apex of the composite cone, and using composite Grandio SO shade A1, another cone was built up following the same parameters used to build the first cone, resulting in double-cone specimens connected by their apices (8 mm high, 4 mm base, and 2 mm apical interface). The compositions of the materials are described in Table 2.

The specimens were stored in deionized water at 37°C for 24 h and then submitted to a tensile stress using the universal testing machine (Emic DL-2000; São José dos Pinhais, PR, Brazil) at a crosshead speed of 1 mm/min with a 500 N load cell.

The results obtained for roughness and bond strength were separately submitted to one-way ANOVA and Tukey's test at a significance level of 5%. The correlation between roughness and bond strength was also evaluated.

Table 3 Means ± standard deviation and the results of Tukey's test for roughness (Ra) and bond strength (MPa)

Groups	Mean (± SD) roughness	Mean (± SD) bond strength
NC	0.21 ± 0.19^{A}	13.51 ± 3.95^{ab}
ConC	0.30 ± 0.08^{A}	14.73 ± 6.12^{ab}
CutC	0.50 ± 0.22^{AB}	16.79 ± 2.98^{abc}
CVD	0.74 ± 0.14^{BC}	15.61 ± 5.00^{abc}
MGD	0.89 ± 0.39^{CD}	12.66 ± 3.82^{ab}
Er50	0.89 ± 0.14^{CD}	16.44 ± 2.75^{abc}
AlO	0.90 ± 0.07^{CD}	18.33 ± 3.19^{bcd}
Nd60	0.94 ± 0.33^{CD}	17.72 ± 2.45^{abcd}
SIL	0.98 ± 0.07^{D}	21.13 ± 4.48^{cd}
Nd120	1.10 ± 0.19^{D}	14.11 ± 5.95^{ab}
CGD	1.10 ± 0.32^{D}	11.58 ± 3.03^{a}
Er200	1.12 ± 0.21^{D}	15.51 ± 1.45^{abc}
CoheC	—	23.50 ± 5.81^{d}

Same superscript letters indicate no statistically significant differences (Tukey's test). The results of Tukey's test are independent for each column. Correlation test showed that roughness and bond strength were not correlated ($r = 0.00782$).

RESULTS

The roughness values (Ra) and bond strengths (MPa) are shown as means ± standard deviation in Table 3. The one-way ANOVA for roughness showed statistically significant differences among the groups ($p = 0.000$; $F = 18.925$; $df = 11$). The surfaces treated with carbide burs, conventional or cross-cut, were not statistically different (Tukey's test) from the negative control group (no surface treatment). The treatment with Er:YAG 200 mJ produced rougher surfaces.

One-way ANOVA also showed statistically significant differences in terms of bond strength ($p = 0.000$; $F = 6.391$; $df = 12$). Air-abrasion silica coating (Rocatec) was the only surface treatement that showed a statistically significant difference from the negative control group. Lower bond strengths were obtained for the group treated with coarse grit diamond burs, which also showed second highest values of roughness.

DISCUSSION

According to the results, the first hypothesis – that the type of treatment does not influence the roughness of the surface – was rejected, because some groups differed statistically significantly from others in terms of roughness. The differences between the surface roughness patterns of the applied treatments have been described previously.[7,24,26] In one study, SEM micrographs showed that composite resin treated with aluminum oxide has a substantial roughness.[16] Another study also used SEM micrographs to compare roughness created by diamond burs and Er:YAG laser applied at various radiation intensities, finding that diamond-bur treatment produced surfaces with much lower roughness than those surfaces treated by Er:YAG laser.[26] Examining SEM images, other authors observed that Nd:YAG radiation can create cracks on the composite surface.[13] In the present study, higher roughness values were obtained with the application of high-intensity Er:YAG radiation, supporting previous findings.[26]

The second hypothesis – that the type of surface treatment does not influence the bond strength of repaired composite resin restorations – was also rejected, as there were significant differences in the bond strength between some experimental groups. The third hypothesis, that surface roughness is not related to bond strength, was accepted, because greater roughness did not promote greater bond strength, probably because of the roughness pattern. Despite the higher roughness values, the roughness pattern possibly did not provide adequate mechanical interlocking.

The results of this and a previous study[26] showed that higher intensity Er:YAG laser radiation did not result in higher bond strength values when compared to the negative control group. Er:YAG laser radiation causes ablation of the surfaces; in contrast to the irregular pattern that this ablation produces when radiation is applied to the dental tissues, when applied to composite surfaces, it promotes conical microcavities with well-defined edges,[15,26] creating a surface with a uniform pattern. This is probably due to the homogeneity of the material,[15] and such a regular pattern can be unfavorable for mechanical retention. Other studies also reported that laser radiation applied to composite surfaces produces fissures in the bulk of the composite,[13,26] which could jeopardize the adhesion.

Composite resins behave like soft materials under laser radiation. Laser ablation or melting occurs mostly through the polymer matrix, leaving empty spaces previously occupied by the filler particles of the composite,[15] which could result in weakening of the material. Another factor that could be considered as promoting weakening is the alteration of volume of the cured composite material. This change in volume occurs because of the rapid melting of irradiated composites, and results in expansion forces[15] that are thought to decrease the composite resistance. In indirect composite resins, it was observed that laser radiation promotes the separation of the filler and matrix contents, compromising the bonding properties.[18] This might also be the case for the direct composite resins used in the present study, but further examinations would be necessary to verify this. The results of this study demonstrated that although increasing the laser energy decreased the bond strength, the differences between groups were not statistically significant, nor were the differences vs the negative control group.

The results of the current study corroborate those of previous studies,[7,13,24] which indicate that bond strength may be related to roughness pattern. For example, aluminum oxide (AlO) abrasion and diamond burs can produce similar roughness values, but the patterns are very different. Generally, the peaks and valleys produced by the diamond burs are unidirectional and have similar dimensions, while the roughness pattern produced by AlO abrasion is characterized by peaks of different heights and dimensions, with similar fractal features, creating a three dimensional pattern[7] that could be more favorable to micromechanical retention, since the available area for adhesion is higher than that produced by the burs.

Regarding the grits of the diamonds burs, even if the coarse grit promotes more roughness than the medium grit, the pattern is the same,[7] which makes the bond strength results similar for bur treated surfaces, independent of grit size. No reports on carbide vs CVD burs were found in the literature. The results of this study demonstrated that there are no statistically significant differences in bond strength between the groups treated with diamond or carbide burs, nor did these groups differ significantly from the negative control group, where no surface treatment was performed. This suggests that the employment of these surface treatment methods does not promote a significant increase in the bond strength.

Air abrasion has been successfully applied for surface treatments of different materials, such as direct and indirect composite resin, ceramics, and metal alloys,[4,6,7,10,13,18,23] and this success seems to be due to the roughness pattern produced.[3] This treatment cleans the surface, increases the surface area, and decreases surface tension, thus improving its ability to interact with the new material.[10] Even better results can be achieved when air abrasion is performed with silica-modified aluminum oxide.[4,11,20,21,32] This technique consists in the deposition of silica particles on the surface, which increases the surface energy and embeds a silicate ceramic layer.[6] According to the manufacturer, sandblasting with AlO silica-modified particles not only abrades the surface, it also causes silica grains impacting on the composite surface to transfer energy to it, promoting a high increase in the temperature of the surface. This excites atoms and molecules, creating triboplasma forms and impregnating the surface with SiO_2 to a depth of 15 µm, fused to the surface in islands.[1] While microirregularities provide mechanical anchorage of the resin, the silica coating provides chemical anchorage via the interaction of silica coating with the monomers of the new composite.[17]

It is also important to consider that the size of the particles used for air abrasion can influence the mechanical bond.[31] Rocatec particles have an average size of 110 µm, and are larger than aluminum oxide particles (50 µm). Although the results did not show a statistically significant difference between air-abrasion groups, values of bond strength and roughness for the Rocatec group tended to be higher than for the aluminum oxide group.

CONCLUSION

Considering the limitations of the study and the previous literature, is clear that composite repair can be successfully employed, and that it is important to choose a safe, effective protocol to obtain good results.

Air abrasion with silica coating resulted in significantly higher bond strengths when compared to the negative control group. Although higher intensity laser radiation produces a rougher surface, it does not result in improvement of the bond strength.

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Clinical relevance: Composite repair is often performed in the clinical practice. An effective surface treatment of the aged composite is necessary to promote adequate adhesion of the new material.

Bond Strength of a Flowable Bulk-fill Resin Composite in Class II MOD Cavities

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Purpose: To evaluate the microtensile bond strength (μTBS) of a bulk-fill low-stress resin-based composite to dentin from gingival walls of Class II MOD cavities.

Materials and Methods: Class II MOD cavities were prepared in 44 human molars with the distal and mesial proximal boxes 4 and 6 mm deep, respectively. Eight experimental groups (n = 11) were obtained by a factorial design including 1. "composite" in two levels: a bulk-fill low-stress composite (SureFil SDR Flow, Dentsply Caulk) and a conventional composite (Filtek Z350 XT, 3M ESPE); 2. "filling technique" in two levels: bulk-fill (Bf) and incremental (In); and 3. "depth" in two levels: 4 mm and 6 mm in order to create different polymerization conditions. Twenty-four hours after placement of restorations, teeth were sectioned into beams with a cross-sectional bonded area of approximately 1 mm^2. Bonded beams obtained from the gingival walls of the proximal boxes were tested in tension at a crosshead speed of 1 mm/min. Data were submitted to a 3-way ANOVA followed by a post-hoc Tukey's test ($p < 0.05$).

Results: ANOVA failed to identify significant differences for the triple and double interaction between factors. However, significant differences were observed for the factors "composite" and "filling technique" ($p < 0.05$). SDR presented significantly higher μTBS values for bulk and incremental filling techniques ($p < 0.05$), and the incremental filling technique presented significantly higher μTBS values for both composites ($p < 0.05$).

Conclusion: It can be concluded that the bulk-fill flowable composite SDR may improve the bond strength to the gingival walls of Class II MOD cavities.

Keywords: tensile strength, bulk-fill composite, filling technique.

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During photopolymerization, monomers form a polymer network and resin-based composites become solid and shrink.[30,34] Shrinkage manifests itself as stress at the bonded cavity walls, which may develop interfacial defects, enamel fractures, cuspal movements, and microcracks.[9,21,30] In order to reduce polymerization shrinkage stress and obtain optimal outcomes, composites need to be placed in increments of 2 mm.[17,32] The incremental layering technique promotes a smaller ratio of the areas of bonded to unbonded composite resin layer, achieving a lower C-factor during polymerization of each layer.[8,17,21] In addition, an increment thickness ≤ 2 mm provides sufficient light penetration for polymerization, resulting in enhanced physical and mechanical properties, with improved marginal adaptation. A high degree of conversion of the composite resin also contributes to decreased cytotoxicity.[21,23]

However, the incremental technique has disadvantages, including the increased risk of incorporating voids or contamination between composite layers, resulting in possible bond failures between increments. In addition, the clinician can find placement difficult because of limited access in conservative preparations. The increased time required to place and polymerize each layer is longer than in the bulk-filling technique.[1,7,17,26,30] Clinicians still desire easier and quicker composite restorations with less shrinkage.[15]

New materials with modified chemical compositions to reduce polymerization shrinkage stress, marketed for bulk application in direct resin composite restorations, have been recently introduced.[33,36] These bulk-fill composites

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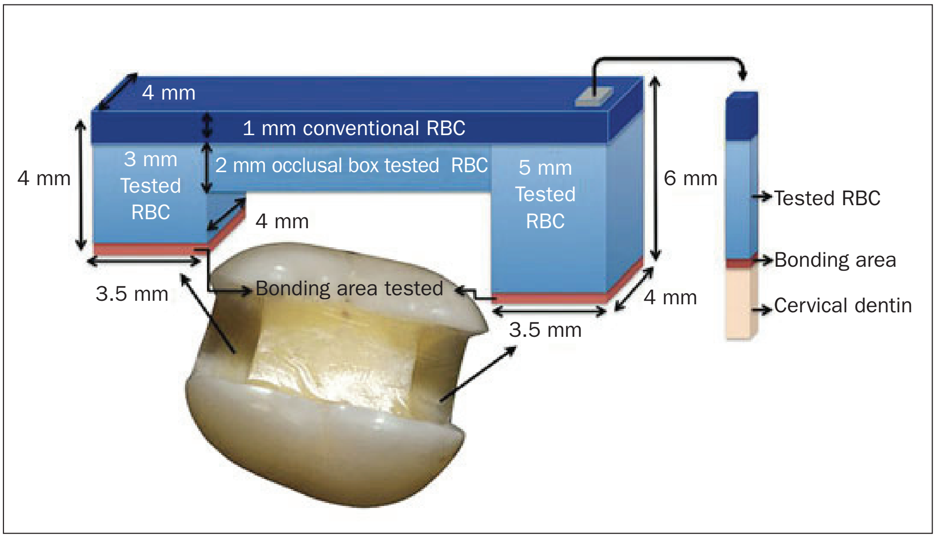

Fig 1 Schematic representation of cavity preparation, resin-based composite (RBC) restoration, and area of the gingival wall in the proximal box of the Class II cavity used for the μTBS evaluation.

are designed to be placed in layers measuring 4 or 5 mm in thickness and to be cured in one single step.[5,13,28] As a further advantage, they can be applied more quickly, thus saving chair time.[23,35]

The first bulk-fill composite was SureFil SDR Flow (SDR), and as a low-viscosity material, it has shown shrinkage stresses lower than conventional flowables, nano- and microhybrid as well as silorane-based composites.[4,6,14,28] In addition to decreased shrinkage stress, adequate polymerization has been reported in 4 mm increments,[15,18] in contrast to conventional composites, that are recommended to be applied in increments of 2 mm.[19] However, few studies have evaluated this bulk-fill low-viscosity composite performance so far.[30,31] A few years ago, concerns about the mechanical stability in stress-bearing areas of restorations made with conventional composites placed in bulk, absence of long-term clinical studies, and the lack of suitable bulk-filling materials discouraged most clinicians from implementing these techniques.[5,7]

Adhesion tests with clinically relevant cavities are important, because the light intensity that reaches the cavity bottom can be reduced in comparison to restorations made on flat dentin surfaces.[29] A decrease in the degree of conversion as well as an increase in increment thickness have both been shown to negatively affect bond strength of composites restorations to dentin.[24,29,35] In addition, the effects of bulk filling of high C-factor posterior cavities on adhesion to cavity-bottom dentin may have a great impact on the adhesion of composite systems.[32]

The aim of this study was to evaluate the microtensile bond strength (μTBS) of a bulk-fill flowable composite to the gingival walls of standardized Class II MOD cavities, as compared to a conventional nanohybrid composite placed incrementally or in bulk. The null hypotheses to be tested were: (1) there is no difference in the bond strength produced by a conventional and a bulk-fill composite; (2) there is no difference in the filling technique, incremental or bulk; and (3) the cavity depth, 4 or 6 mm, does not influence μTBS.

MATERIALS AND METHODS

The study protocol was approved by the Guarulhos University Research Ethics Committee (# 641.271). The present study was designed to evaluate the bond strength to cervical dentin of a bulk-fill flowable composite in a large tooth cavity (Fig 1) where the contraction stress associated with polymerization of resin composite may be high. Forty-four molars received a Class II MOD cavity preparation with 4 or 6 mm of depth in the distal and mesial proximal boxes, respectively. Eight experimental groups with 11 samples each were obtained by a factorial design. The factors under study were (Table 1): "composite" in two levels, bulk-fill flowable (SDR) and conventional nanohybrid composite (Z350); "filling technique" in two levels, bulk-filling and incremental filling; and "cavity depth" in two levels, 4 mm or 6 mm.

Cavity Preparation

Non-carious third molars extracted for therapeutic reasons were stored in thymol solution and debrided of residual plaque and calculus. The roots were removed with double-faced diamond disks (#7020, KG Sorensen; Barueri, SP, Brazil), then the pulp chambers were cleaned and filled with Clearfil SE Bond (Kuraray; Osaka, Japan) adhesive system and Filtek Z350 XT (3M ESPE; St Paul, MN, USA) following manufacturers' recommendations.

Standardized Class II MOD cavities were prepared using a diamond bur (#3101G, KG Sorensen) in a high-speed handpiece with air-water spray. The cavity dimensions were: 4 mm width bucco-lingually, 3 mm depth in the oclusal box, and 4 mm depth in the distal and 6 mm depth in the mesial proximal box (Fig 1). After preparation, the cavities were evaluated using a stereomicroscope at 40X magnification (PanTec, Panambra Ind. e Tecnica; São Paulo, Brazil) to check for any defects. Teeth that presented cavities with pulp exposure or enamel margins in the cervical walls were excluded and replaced by another tooth. Teeth were randomly assigned to the eight experimental groups and restored.

Table 1 Experimental groups obtained by a factorial design

Group	n	Composite type	Product name	Filling technique	Box depth
G1	11	Bulk-fill flowable	SDR	Bulk-fill	4 mm
G2	11	Bulk-fill flowable	SDR	Bulk-fill	6 mm
G3	11	Conventional	Z350	Bulk-fill	4 mm
G4	11	Conventional	Z350	Bulk-fill	6 mm
G5	11	Bulk-fill flowable	SDR	Incremental	4 mm
G6	11	Bulk-fill flowable	SDR	Incremental	6 mm
G7	11	Conventional	Z350	Incremental	4 mm
G8	11	Conventional	Z350	Incremental	6 mm

SDR: SureFil SDR Flow; Z350: Filtek Z350 XT.

Restorative Procedure

A metal matrix band was placed around the tooth using a Tofflemire retainer. All cavities were restored with the same two-step etch-and-rinse adhesive system (XP Bond, Dentsply DeTrey; Konstanz, Germany) applied according to the manufacturer's instructions. All cavity preparations were etched with 36% phosphoric acid (DeTrey Conditioner 36) for 15 s, washed for 15 s, and gently dried with absorption paper. The adhesive XP Bond (Dentsply DeTrey) was dispensed onto a disposable brush and applied to the cavity for 20 s. The solvent was evaporated for at least 5 s and photoactivated for 10 s using an LED device (Radii Plus, SDI; Bayswater, Victoria, Australia) with an average power output of 1850 mW/cm^2, periodically monitored with a curing-light meter (CureRite, Dentsply Caulk; Milford, DE, USA).

The cavities were filled with the tested composites: the bulk-fill flowable composite SDR (SureFil SDR Flow, shade U, Dentsply Caulk) or the conventional composite Z350 (Filtek Z350 XT, shade A3E, 3M ESPE) according to the groups. With the bulk-fill technique, composites were inserted in a 3-mm layer in the 4-mm box, in a 5-mm layer in the 6-mm box, and a 2-mm-thick layer in the occlusal box (Fig 1). Composites were photo-activated for 20 s (LED, Radii Plus, SDI), and because Surefil SDR flow needs conventional composite coverage, a 1-mm final occlusal layer of the conventional composite (Filtek Z350 XT) was applied and polymerized for 20 s for all groups (Fig 1). In the incremental technique groups, both 4-mm and 6-mm boxes were filled in increments of less than 2-mm thickness. The 4-mm box received 2 increments, the 6-mm box 3 increments, and the occlusal box one increment, followed by 1 mm thickness of the conventional composite for all groups. The teeth were stored for 24 h in 100% relative humidity at 37°C.

Microtensile Bond Strength

The proximal boxes of specimens were serially sectioned in the buccal/lingual and mesial/distal directions in order to obtain at least 3 beams with a cross-sectional bonded area of approximately 1 mm^2 at the gingival wall (IsoMet 1000; Buehler; Lake Bluff, IL, USA). Beams were tested in tension in a Universal Testing Machine (EZ Test, Shimadzu; Kyoto, Japan) at a crosshead speed of 1 mm/min until fracture. The cross-sectional area of each specimen was measured using a digital caliper (Mitutoyo; Tokyo, Japan), and the microtensile bond strength was expressed in MPa.

Failure mode was recorded using a light microscope at 50X magnification (PanTec, Panambra Ind e Tecnica). Failure mode at the fractured interface was classified into 1 of 3 types: CD (cohesive failure in dentin), AD (adhesive failure between hybrid layer and dentin), and CC (cohesive failure in composite resin). Instead of classifying failures as mixed, the area percentage of each type of failure in each specimen was recorded.[16]

Statistical Analysis

The Shapiro-Wilk test was applied to test for normality ($p = 0.263$). Since data showed normal distribution, a three-way ANOVA considering the factors "composite", "filling technique", and "depth" followed by a post-hoc Tukey's test at a pre-set α of 5% were applied using statistical software (IBM SPSS version 20.0.0, IBM; Armonk, NY, USA). Pre-test failures were not included in the statistical analysis.[22]

RESULTS

The mean μTBS values are presented in Table 3. Three-way ANOVA revealed significant differences for the factor "composite" ($p < 0.05$) and for the factor "filling technique" ($p < 0.05$). However, no significant difference was detected for the factor "depth" ($p = 0.684$). In addition, 3-way ANOVA failed to identify significant differences for the double interactions ($p > 0.05$) and for the triple interaction "composite x filling technique x depth" ($p = 0.914$).

Table 2 Materials and their components, manufacturers, and batch numbers used in this study

Material (manufacturer), batch number	Components
XP Bond (Dentsply DeTrey; Konstanz, Germany) 1311000750	Carboxylic acid modified dimethacrylate (TCB resin), PENTA, UDMA, TEG-DMA, HEMA, butylated benzenediol (stabilizer), ethyl-4- dimethylaminobenzoate, camphorquinone, functionalized amorphous silica, t-butanol
Filtek Z350 XT, shade AE3 (3M ESPE; St Paul, MN, USA) 902497/984521	Bis-GMA, UDMA, TEG-DMA, bis-EMA, silica filler, zirconia filler, zirconia/silica cluster filler
SureFill SDR, shade U (Dentsply DeTrey; Konstanz, Germany) 785648F	Barium-alumino-fluoro-borosilicate glass, strontium alumino-fluoro-silicate glass, modified urethane dimethacrylate resin, EBPADMA, triethyleneglycol dimethacrylate, camphorquinone, butylated hydroxyl toluene, UV stabilizer, titanium oxide, iron oxide pigments
DeTrey Conditioner 36 (Dentsply DeTrey; Konstanz, Germany) 7523	36% phosphoric acid, silica

Abbreviations: bis-GMA: bisphenol-glycidyl methacrylate; HEMA: 2-hydroxyethyl methacrylate; DMA: dimethacrylate; GPDM: glycerol phosphate dimethacrylate; UDMA: Urethane dimethacrylate; PENTA: phosphonated penta-acrylate ester; EBPADMA, ethoxylated bisphenol-A dimethacrylate; TEG-DMA, triethylene glycol dimethacrylate.

Table 3 Mean bond strength values in MPa for the different composite resins applied with different filling techniques in 4- and 6-mm-deep cavities

Composite		Depth	Filling technique	
			Bulk filling (no. of beams/pre-test failures)	Incremental (no. of beams/pre-test failures)
Bulk-fill flowable	SDR	4 mm	50.8 ± 22.7^{Ab} (33/3)	56.3 ± 11.6^{Aa} (33/6)
		6 mm	49.8 ± 9.8^{Ab} (33/9)	63.9 ± 8.6^{Aa} (33/4)
Conventional	Z350	4 mm	32.5 ± 12.9^{Bb} (33/11)	40.3 ± 14.7^{Ba} (33/7)
		6 mm	27.2 ± 11.5^{Bb} (33/22)	43.6 ± 20.1^{Ba} (33/9)

Means followed by different superscript letters (upper case: column; lower case: row) are significantly different according to Tukey's test at the 95% confidence level.

No significant difference was observed between the 4- and 6-mm-deep proximal boxes, independent of the composite and filling technique used ($p > 0.05$). The bulk-fill flowable composite SDR presented higher bond strength values than did the conventional composite Z350 for both bulk and incremental filling techniques ($p < 0.05$). In addition, independent of the composite resin used, the incremental filling technique produced significantly higher bond strength values than did the bulk-filling technique ($p < 0.05$). Descriptive data of failure mode analysis (Fig 2) showed a higher percentage of adhesive failures between composite and dentin for all groups.

DISCUSSION

The incremental layering technique has been recognized as standard procedure in direct posterior composite restorations to reduce polymerization shrinkage stress and achieve an adequate degree of monomer conversion.[21,31] However, the bulk-fill flowable composite SDR showed higher bond strength values than the conventional composite Z350. Thus, the first null hypothesis was rejected. The second null hypothesis was also rejected, because the incremental filling technique presented significantly higher bond strength values than the bulk-filling technique, for both the conventional and the bulk-fill composites.

The use of a bulk-fill flowable composite in deep, wide dental cavities is faster and easier than traditional incremental restoration, it also saves time and improves material handling and adaptation.[3,5] Cavity depth did not influence bond strength values of either composite independent of the filling technique, which led to acceptance of the third null hypothesis. The bulk-fill flowable SDR showed significantly higher bond strength values than did the conventional composite Z350 in the Class II MOD preparation with deep proximal boxes, even with the 5-mm bulk-filling insertion technique. These results are in agreement with Flury et al,[11] who observed that shear bond strength remained constant for SDR with increasing layer thickness up to 6 mm, while the microhardness and shear bond strength of the conventional resin composite (Filtek Supreme XTE) decreased with increasing layer thickness. SDR hardness values corresponded with those obtained using three distinct increment thicknesses of a conventional composite resin.[11]

The rate of the polymerization reaction has also been shown to modulate stress, since a slower cure would allow viscous flow and/or chain relaxation, accommodating

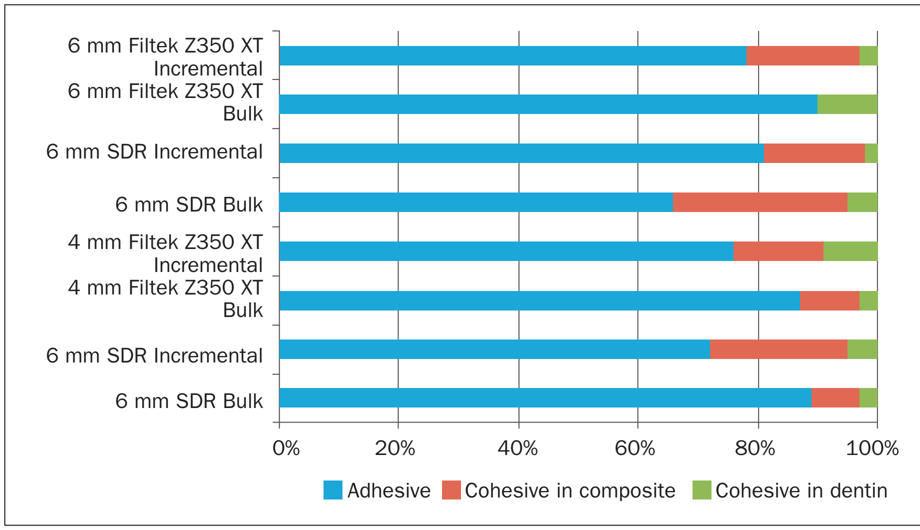

Fig 2 Failure mode distribution in the experimental groups (%).

part of the shrinkage and reducing stress.[6] SDR presents a chromophore-mediated free-radical polymerization for a slower curing process. The extended pre-gel phase allows unconstrained shrinkage while maintaining a low modulus of elasticity, thus resulting in decreased polymerization stress within the developing composite matrix.[27] It is currently accepted that composites with a high modulus of elasticity produce higher shrinkage stresses than do composites with a low modulus of elasticity.[9] There is also a current opinion that composite bulk placement is detrimental to the composite/tooth interface.[1] It seems that SDR counterbalances these two factors. The findings of the present investigation revealed that despite being bulk placed, the bond strength values obtained for SDR, either bulk or incrementally placed, were significantly higher than those obtained for the conventional composite.

SDR is a very translucent composite, and standard light energy densities used to cure conventional composites are able to propagate throughout this material, promoting ideal polymerization in thicker increments.[10,27] These properties were probably improved in the incremental-insertion groups.[10] SDR groups presented significantly higher bond strength values when the incremental technique was used in comparison with the bulk-filling technique. Jang et al[15] showed a favorable degree of conversion at the bottom surface of 4-mm-thick SDR samples, reaching 80% of the mean top surface hardness. Benetti et al[3] observed that the depth of cure is generally improved for the bulk-fill material when compared with conventional resin composites. It has also been demonstrated that with increasing increment thickness, microhardness and bond strength decrease for the conventional composite, but generally remains constant for the bulk-fill resin composites.[11]

Conventional composites are not intended for placement in one bulk increment in deep cavities. The conventional composite used here was an enamel shade (AE3) of Z350 XT – which is more translucent – to improve the light propagation throughout conventional control groups. This increased the chance of light to reach the bottom surface of 6- and 4-mm-deep fillings. If a body or dentin shade had been used, the light would probably not have been able to reach the bottom surface and bond strength would likely be severely compromised. The theory that placing direct restorations in multiple layers for conventional composites is beneficial was confirmed in the present study.

The lower bond strength values observed in groups restored with the conventional composite Z350 applied in one bulk-fill increment are a result of the interaction of factors, such as limited light penetration throughout the composite resin as function of depth, restricted by 20 s of light curing and the configuration of the cavity walls. This might have affected the degree of conversion and thus adhesion. However, a lower degree of conversion is likely to generate less contraction stress around the cavity walls. The conventional composite Z350 presented significantly lower bond strength values and a high number of pre-test failures when the bulk placement technique was used. Thus, for Z350 conventional composite, the bulk-filling technique, which is not recommended by the manufacturer, should not be encouraged.

Nevertheless, if the light is only partially able to reach the bottom surface, the conversion of monomers is incomplete while the polymerization shrinkage is building up in the restoration. Notwithstanding, the low bond strength results observed for Z350 in the present study may be due to the combination of a lower degree of conversion and less strain in the bonding area. This may explain lower bond strength for the bulk-filling technique than for multiple increments. Several studies have found SDR to achieve an acceptable degree of conversion,[2,3,11,15] and the mechanism of shrinkage stress reduction is related to chemically modified polymer chains, which are very flexible in the pregelation phase.[26] The lower flexural modulus combined with the slower contraction rate allowed the material to partially counteract the effect of polymerization contraction.[14]

Optical coherence tomography studies showed that SDR performed better than the conventional composites, with 20% less volumetric polymerization contraction than a conventional composite in a micro computed-tomography analysis in Class I cavities.[12,20] Jang et al[15] observed that

SDR showed lower linear polymerization shrinkage and lower shrinkage stress than did a conventional flowable composite. In addition, under fatigue testing, similar marginal integrity was observed in MOD cavities restored with a 4-mm bulk increment of SDR and incremental layering of a conventional composite.[25,35] A long-term clinical study demonstrated that the 4-mm bulk-filling technique with the flowable resin composite SDR showed good clinical performance, comparable at the 3-year follow-up with the 2-mm resin composite incremental layering technique.[30]

Especially due to regional variability in the dentin substrate, the microtensile bond strength test can sometimes result in high standard deviation values. However, it is still the most commonly used test for measuring the performance of materials applied on human teeth in a clinically relevant setup.[22] Our results support previous findings that the flowable bulk-fill SDR seems to be acceptable for bulk application in increments thicker than 4 mm. However, further laboratory and long-term clinical investigations with bulk-fill composites remain necessary.

CONCLUSION

Compared to a conventional nanohybrid composite, the bulk-fill flowable composite SDR improves the bond strength at gingival walls of large Class II cavities.

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Clinical relevance: The bulk-fill flowable composite may improve the bond strength in MOD cavities.

Ten-year Clinical Performance of Posterior Resin Composite Restorations

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Purpose: To investigate the clinical behavior of two different resin-based restorative systems in Class II cavities in a controlled prospective split-mouth study over 10 years.

Materials and Methods: Thirty patients received 68 resin composite restorations (Solobond M + Grandio: n = 36; Syntac + Tetric Ceram: n = 32) by one dentist in a private practice. 35% of cavities revealed no enamel at the bottom of the proximal box, 48% of cavities provided < 0.5 mm of remaining proximal enamel. Restorations were examined according to modified USPHS criteria at baseline, after 6 months, and 1, 2, 4, 6, 8, and 10 years.

Results: Twenty-nine out of 30 patients attended the 10-year recall. The overall success rate of all restorations was 96.9%. One Grandio restoration suffered marginal fracture with exposed dentin and one Tetric Ceram restoration failed due to cusp fracture. After 10 years, Grandio showed higher surface roughness ($p = 0.03$) and less color match ($p = 0.024$; Mann-Whitney U-test). Molar restorations performed worse than premolar fillings regarding marginal integrity (4 and 10 years), filling integrity (4, 8, and 10 years), and tooth integrity (4, 8, and 10 years). The main reasons for degradation of resin composites were chipping and cracks in molar restorations after 8 years. Beyond the 4-year recall, marginal staining increased (43% bravo for stained margins at four years, 52% at 8 years, and 71% at 10 years). Tooth integrity deteriorated significantly due to more enamel cracks and chipping over time (9% at baseline and 89% after 10 years ($p<0.05$).

Conclusions: Direct resin composite restorations performed satisfactorily over 10 years of clinical service.

Keywords: resin composites, nanofillers, clinical trial, marginal integrity, etch and rinse.

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After the ban of dental amalgam in many countries, resin-based composites (RBC) are today the biomaterials of choice for the restoration of cavitated carious lesions.[10,20] Despite some innovative enhancements regarding in vitro performance, RBC still suffer polymerization contraction, which makes durable adhesion to tooth hard tissues a fundamental prerequisite for clinical success.[2,3,7,14,20,21] Loss of adhesion leads to gap formation, and secondary caries may affect clinical outcome.[11,16,18,20,23,25] While bonding to enamel has long been regarded as reliable,[3,4,36,37] dentin adhesion, especially in deep proximal boxes, is more challenging in terms of long-term stability.[8,15,21] Nevertheless, clinically proven sealing and acceptable rates of postoperative hypersensitivity demonstrate its success.[18,19,31,32,34,39] RBC were repeatedly reported to durably seal dentin; however, long-term sealing in Class II cavities with proximal margins ending in dentin is still dubious.[25,28,37,38]

Aside from the biomechanical issues concerning shrinkage, failing adhesion, and gap formation, recent studies increasingly suggest that in addition to the tremendeous influence of the operator,[6] patient factors seem to greatly determine clinical outcome.[9,15,21,23-25,34] It has been proven that probably most clinically investigated RBC restorations show leakage to a greater or lesser degree, but while this may cause secondary caries in many patients, in some it does not.[30]

Randomized long-term trials remain the ultimate instrument to elucidate restorative questions in operative dentistry. Nevertheless, in vitro studies are still important for short-term lab screenings,[1,8,12,16,29] especially when they are combined with in vivo investigations. The main disadvan-

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Table 1 Evaluated clinical codes and criteria

Modified criteria	Description	Analogous USPHS criteria
Excellent	Perfect	Alpha
Good	Slight deviations from ideal performance, correction possible without damage to tooth or restoration.	
Sufficient	Few defects, correction impossible without damage to tooth or restoration. No negative effects expected.	Bravo
Insufficient	Severe defects, prophylactic removal for prevention of severe failures.	Charlie
Poor	Immediate replacement necessary.	Delta

tage of time-consuming clinical studies is that after years of clinical observation, the materials in question are usually no longer on the market.[5] Compared to RBC, amalgam was reported to be more successful over the long term, at least for extended defects or in patients with high caries risk.[23-25]

In recent years, material developments in the RBC sector, such as hybrid composites, fine hybrid composites, nanohybrid composites, nanofilled resin composites, silorane-based composites, and bulk-fill composites, have led to some changes in material perception, but clinical problems remained exactly the same.[12,14,34,35] Furthermore, clinical studies did not show significantly better clinical outcomes when more innovative materials were used.[26,34,35] Similarly, the assumption that nanofilled resin composites may reveal more enamel-like abrasion characteristics has also not been clinically proven.[26]

The aim of this clinical trial was to examine two different restorative material systems (adhesive and resin composite) in Class II cavities over 10 years in order to observe differences between conventional (Tetric Ceram) and partially nanofilled (Grandio) resin composites. The null hypothesis tested was that there would be no difference between the different resin composite systems examined.

MATERIALS AND METHODS

Patients selected for this study met the following criteria: 1) absence of pain from the tooth to be restored; 2) application of rubber-dam during luting of restoration was possible; 3) no further restorations planned in other posterior teeth; 4) good level of oral hygiene; 5) absence of any active periodontal and pulpal disease; 6) restorations required in two different quadrants (split-mouth design); 7) age 18 to 65; 8) no pregnancy.

The study was approved by the Ethics Committee of the University Clinic Erlangen, Germany. All patients were required to give written informed consent before starting the study and agreed to participate in a recall program. Thirty patients (23 female, 7 male, mean age 32.9 [range: 24 to 59] years) with a minimum of two restorations to be replaced in different quadrants received at least two different restorations in a random decision according to recommendations of the CONSORT statement.[22] Sample size calculation was performed according to previous clinical studies.[5,6] Occluding teeth were not excluded.[5]

Thirty-six Grandio fillings were bonded using an etch-and-rinse technique using Solobond M (Voco; Cuxhaven, Germany), and 32 Tetric Ceram restorations were bonded with Syntac (Ivoclar Vivadent; Schaan, Liechtenstein). All fillings (only Class II, 52 MO/OD, 16 MOD or more surfaces, no cusp replacements) were re-restorations made by one dentist in a private practice (31 maxillary premolars, 12 maxillary molars, 14 mandibular premolars, 11 mandibular molars). Reasons for replacement were caries (n = 19), insufficient esthetics (n = 2), and secondary caries beneath amalgam restorations (n = 47). For all teeth receiving restorations, recent radiographs (within 6 months of the procedure) were present. After evaluating the radiographs, 53 cavities (78%) were treated as caries profunda. Twenty-four cavities (35%) revealed no enamel on the floor of the proximal box, while 33 cavities (49%) exhibited a proximal enamel width of < 0.5 mm.

All fillings were inserted in permanent vital teeth without pain symptoms. Extension for prevention was disregarded for maximal substance protection; however, the majority of restorations had been previously prepared with undercuts for amalgam retention. The cavities were cut using coarse diamond burs under profuse water cooling (80-µm diamond, Komet; Lemgo, Germany), and finished with a 25-µm finishing diamond. Inner angles of the cavities were rounded and the margins were not bevelled. After cleaning and drying under rubber-dam isolation (Coltene/Whaledent; Altstätten, Switzerland), adhesive procedures were performed with Solobond M (two-step etch-and-rinse adhesive) and Syntac (four-step etch-and-rinse adhesive). The resin composite materials were applied into the cavity in layers approximately 2 mm thick and adapted to the cavity walls with a plugger. Each layer was light cured for 40 s (Elipar Trilight 3M ESPE; Seefeld, Germany). The occlusal region was modelled as exactly as possible under intraoral conditions, avoiding visible overhangs. The light-emission window was placed as close as possible to the cavity margins. The intensity of the light was checked periodically with a radiometer (Demetron Research; Danburg, CT, USA) and was found to be constantly above 650 mW/cm^2.

As soon as polymerization was completed, the surface of the restoration was controlled for defects and corrected when necessary. Visible overhangs were removed with a scaler and the rubber-dam was removed. Contacts in centric and eccentric occlusion were controlled with foils (Roeko; Langenau, Germany) and adjusted with finishing diamonds (Komet Dental; Lemgo, Germany), then shaped with flexible disks (3M Dental; St Paul, MN, USA), superfine disks (3M Dental) and polishing brushes (Hawe-Neos; Bioggio, Switzerland).

At the initial recall (baseline, ie, within 2 weeks), after 6 months, and 1, 2, 4, 6, 8, and 10 years, all restorations

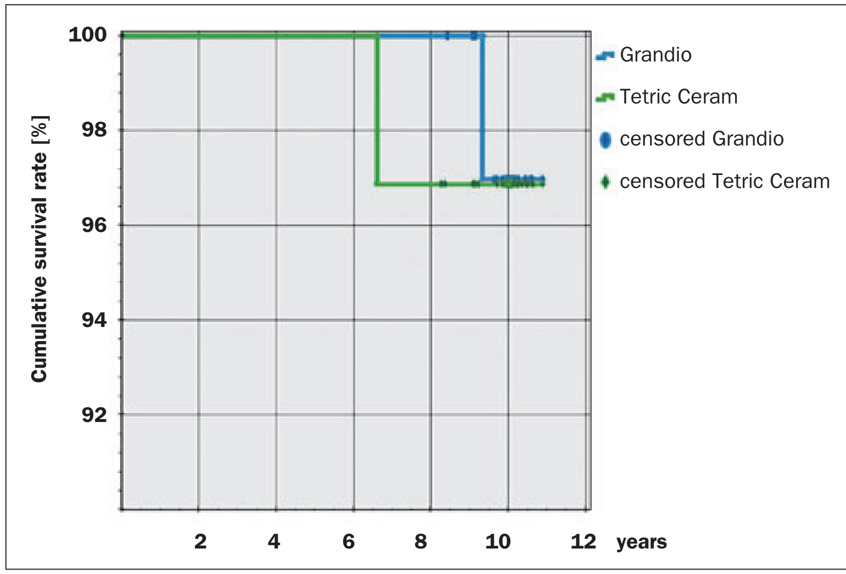

Fig 1 Kaplan-Meier survival analysis over 10 years of clinical service.

Fig 2 Clinical examples of restorations after 10 years.

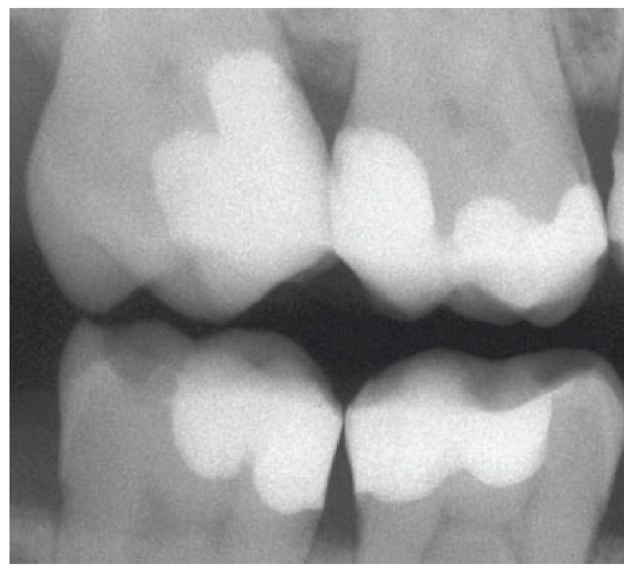

Fig 3 Example of typical proximal restoration extension below the cementoenamel junction after 8 years.

were assessed according to the modified United States Public Health Service (USPHS) criteria (Table 1) by two independent examiners (dentists, both professors) using loupes with 3.5X magnification, mirrors, probes, bitewing radiographs, and intraoral photographs. The examiners were blinded, trained, and calibrated through eight previous clinical studies and additional calibration sessions. Recall assessments were not performed by the clinician who initially placed the restorations.

Statistical analysis was performed with SPSS for Windows XP 15.0 (SPSS; Chicago, IL, USA). The statistical unit was one tooth. Differences between groups were evaluated using the Mann-Whitney U-test, and changes over time were calculated with the Friedman test ($p = 0.05$).

RESULTS

Twenty-nine out of 30 patients attended the 10-year recall. Sixty-five out of 68 restorations were examined after 10 years. One patient with two restorations was not available. One restoration failed due to cusp fracture after 6.6 years of clinical service. The overall success rate of all restorations was 96.9% (Kaplan-Meier survival algorithm, Fig 1). Figures 2 and 3 show representative samples of restoration size and depth. One Grandio restoration was lost due to marginal fracture with exposed dentin (Fig 4), and one Tetric Ceram restoration failed due to cusp fracture.

The results of the clinical examinations are displayed in Tables 2 to 6. The localization of the restoration in the max-

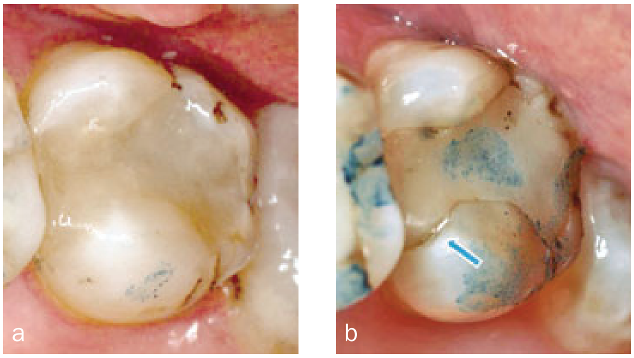

Fig 4 (a) Clinical view of a Grandio restoration at baseline (tooth #17; patient No. 23). Already directly after placement, color mach was not perfect. (b) Clinical view of the Grandio restoration shown in 4a after 10 years of clinical service. Mesiopalatally, a marginal fracture with exposed dentin is evident (arrow), so the filling had to be replaced. Wear lead to a distinct negative step with partially discolored margins.

illa or mandible did not reveal any significant differences ($p > 0.05$; Mann-Whitney U-test), with two exceptions: surface roughness was significantly better in the maxilla after 10 years ($p = 0.48$) and wear was significantly less in the mandible after 8 years ($p = 0.013$; Mann-Whitney U-test). After 10 years, only two criteria showed significant differences between the type of resin composite used: Grandio showed higher surface roughness ($p = 0.03$) and reduced color match ($p = 0.024$; Mann-Whitney U-test; Tables 2 and 3). Molar restorations performed worse than premolar restorations regarding marginal integrity (4 and 10 years; Table 6a), filling integrity (4, 8, and 10 years), and tooth integrity (4, 8, and 10 years; Tables 6a and 6b). The main reasons for degradation of restorative materials were chipping and cracks in molar restorations after 8 years (Table 6b; Fig 4).

Irrespective of the resin composite used, significant changes over time were found for all criteria evaluated in clinical examinations (Friedman test; $p < 0.05$). Marginal integrity started with a large percentage of overhangs in all marginal areas until the 1-year recall and dropped dramatically afterwards (overhangs at baseline 44%; 6 months: 65%; 1 year: 47%; 2 years: 6%; 4 years: 4%; 6 years: 3%; 8 years. 3%; 0%). Beyond the 1-year recall, negative step formation with or without staining was found due to wear of the resin composite (86% after 10 years; Figs 4 and 5). After the 4-year recall, marginal staining significantly increased ($p < 0.05$). Both phenomena were found earlier in molars (43% bravo due to stained margins after four years, 52% after 8 years, and 71% after 10 years; Fig 4). Tooth integrity significantly deteriorated because of more enamel cracks and chipping over time (9% at baseline and 89% after ten years; $p < 0.05$). Enamel chipping or cracks were significantly more often observed in molars (35% vs 10% bravo ratings after 10 years). The main reasons for decreasing restoration integrity were distinct wear traces (80% after 10 years, Tables 5a and 5b, Fig 5), cracks and chipping of the restoration (11% after 10 years, Tables 5a and 5b), as well as voids having been exposed by resin composite wear (5% after 10 years). Significantly more cracks were detected in molar restorations (26% bravo

Table 2 Descriptive statistics for all Grandio restorations

	Baseline (n = 36)			2 years (n = 36)			4 years (n = 36)			8 years (n = 36)				10 years (n = 35)			
	Alpha 1	Alpha 2	Bravo	Alpha 1	Alpha 2	Bravo	Alpha 1	Alpha 2	Bravo	Alpha 1	Alpha 2	Bravo	Charlie	Alpha 1	Alpha 2	Bravo	Charlie
Criterion	%			%			%			%				%			
Surface roughness	100			97	3		92	8		69	31			74	26		
Color match	92	8		92	8		81	14	5	58	42			69	31		
Marginal integrity	50	47	3		53	47		36	64		19	81			9	88	3
Integrity Tooth	86	14		47	42	11	31	58	11	17	67	16		9	77	14	
Integrity Filling	100			11	45	44	3	28	69		17	80	3		20	77	3
Proximal contact	94	3	3	89	11		94	6			81	19		89	11		
Change of sensitivity	100			100			100				100			100			
Hyper-sensitivity	97	3		100			100				100			100			
Radiographic assessment*	89	3	8				97	3						100			

*At 10-year recall, 11 restorations were evaluated due to medical indications.

Table 3 Descriptive statistics for all Tetric Ceram restorations

	Baseline (n = 32)			2 years (n = 32)			4 years (n = 32)			8 years (n = 31)				10 years (n = 30)			
	Alpha 1	Alpha 2	Bravo	Alpha 1	Alpha 2	Bravo	Alpha 1	Alpha 2	Bravo	Alpha 1	Alpha 2	Bravo	Charlie	Alpha 1	Alpha 2	Bravo	Charlie
Criterion	%			%			%			%				%			
Surface roughness	100			100			94	6		87	13			100			
Color match	97	3		94	6		88	13		84	16			90	10		
Marginal integrity	37	63			69	31		31	69		16	84			17	83	
Integrity Tooth	97	3		31	53	16	28	53	19	7	61	32		13	63	24	
Integrity Filling	85	9	6	6	38	56		22	78		13	87			17	83	
Proximal contact	94	3	3	75	22	3	88	9	3	77	19			80	20		
Change of sensitivity	94		6	100			100			100				100			
Hyper-sensitivity	84	13	3	100			100			100				100			
Radiographic assessment*	94	6					94	3	3					90	10		

*At 10-year recall, 11 restorations were evaluated due to medical indications.

Table 4a Descriptive statistics regarding "marginal integrity" (Grandio restorations)

	Criterion	Baseline (n = 36)	24 months (n = 36)	48 months (n = 36)	72 months (n = 36)	96 months (n = 36)	120 months (n = 35)
Alpha I Excellent		50%	0.0%	0.0%	0.0%	0.0%	0.0%
Alpha II Slight defects, easily correctable	Negative step	5.6%	38.9%	27.8%	33.3%	16.7%	8.6%
	Overhang	38.9%	2.8%	8.3%	2.8%	2.8%	0.0%
	Stained overhang	2.8%	11.1%	0.0%	2.8%	0.0%	0.0%
Bravo Slight defects, not correctable without damage	Gap/negative step	2.8%	19.4%	25.0%	8.3%	30.6%	20.0%
	Staining	0.0%	27.8%	38.9%	52.8%	50.0%	68.6%
Charlie Severe defects, prophylactic removal for prevention of severe failures	Gap (dentin exposure)	0.0%	0.0%	0.0%	0.0%	0.0%	2.9%
	Secondary caries (dentin exposure)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

for premolar vs 69% bravo and charlie for molars; Mann-Whitney U-test, p < 0.01, Table 6b).

DISCUSSION

Today, one of the greatest challenges posed by clinical long-term studies is to keep dropout rates low; otherwise, the impact of the clinical trial will decrease steadily over time.[32-35] The observed recall rate in the present clinical study of almost 100% over a 10-year period is outstanding. This is clearly related to the clinical operator, who succeeded in both acquiring and keeping reliable patients. The reported dropout of one Tetric Ceram restoration was attributed to a cusp fracture, which was not counted as restoration failure because all palatal cusps in the same quadrant fractured and the restoration was relatively small.

Without adequate bonding to dental hard tissues, clinical success with shrinking RBC biomaterial is impossible.[3,10,20,25] Nonetheless, several recent studies indicated that it is no longer acceptable to equate the pres-

Table 4b Descriptive statistics regarding "marginal integrity" (Tetric Ceram restorations)

	Criterion	Baseline (n = 32)	24 months (n = 32)	48 months (n = 32)	72 months (n = 32)	96 months (n = 31)	120 months (n = 30)
Alpha I Excellent		37.5%	0.0%	0.0%	0.0%	0.0%	0.0%
Alpha II Slight defects, easily correctable	Negative step	12.5%	50.0%	31.3%	43.8%	12.9%	10.0%
	Overhang	50.0%	9.4%	0.0%	0.0%	3.2%	0.0%
	Stained overhang		9.4%	0.0%	0.0%	0.0%	6.7%
Bravo Slight defects, not correctable without damage	Gap/negative step	0.0%	12.5%	21.9%	15.6%	29.0%	10.0%
	Staining	0.0%	18.8%	46.9%	40.6%	54.8%	73.3%

Table 5a Descriptive statistics regarding "integrity filling" (Grandio restorations)

	Criterion	Baseline (n = 36)	24 months (n = 36)	48 months (n = 36)	72 months (n = 36)	96 months (n = 36)	120 months (n = 35)
Alpha I Excellent		100.0%	11.1%	2.8%	2.8%	0.0%	0.0%
Alpha II Slight defects, easily correctable	Chipping	0.0%	0.0%	0.0%	0.0%	2.8%	2.9%
	Crack	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Abrasion	0.0%	44.4%	27.8%	38.9%	13.9%	17.1%
	Roughness	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bravo Slight defects, not correctable without damage	Chipping	0.0%	5.6%	8.3%	2.8%	2.8%	2.9%
	Crack probing	0.0%	0.0%	2.8%	0.0%	8.3%	2.9%
	Abrasion	0.0%	16.7%	50.0%	55.6%	66.7%	57.1%
	Roughness	0.0%	5.6%	8.3%	0.0%	0.0%	5.7%
	Void	0.0%	16.7%	0.0%	0.0%	2.8%	8.6%
Charlie Prophylactic removal for prevention of severe failures	Chipping	0.0%	0.0%	0.0%	0.0%	2.8%	2.9%
	Crack probing	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Abrasion	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Roughness	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
	Void	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table 5b Descriptive statistics regarding "integrity filling" (Tetric Ceram restorations)

	Criterion	Baseline (n = 32)	24 months (n = 32)	48 months (n = 32)	72 months (n = 32)	96 months (n = 31)	120 months (n = 30)
Alpha I Excellent		84.4%	6.3%	0.0%	3.1%	0.0%	0.0%
Alpha II Slight defects, easily correctable	Chipping	6.3%	0.0%	0.0%	3.1%	0.0%	3.3%
	Crack	0.0%	3.1%	0.0%	0.0%	0.0%	0.0%
	Abrasion	0.0%	34.4%	21.9%	25.0%	12.9%	12.5%
	Roughness	3.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Bravo Slight defects, not correctable without damage	Chipping	0.0%	0.0%	6.3%	3.1%	12.9%	6.7%
	Crack probing	6.3%	0.0%	6.3%	3.1%	6.5%	0.0%
	Abrasion	0.0%	46.9%	53.1%	62.5%	67.7%	73.3%
	Roughness	0.0%	3.1%	6.3%	0.0%	0.0%	3.3%
	Void	0.0%	6.3%	6.3%	0.0%	0.0%	0.0%

Table 6a Descriptive statistics of premolars vs molars regarding "marginal integrity"

Criterion	Crack/Chipping premolars (n=42)	Crack/Chipping molars (n=23)	Abrasion premolars (n=42)	Abrasion molars (n=23)	Voids premolars (n=42)	Voids molars (n=23)
Alpha I Excellent	59.5%	30.4%	0.0%	0.0%	73.8%	69.6%
Alpha II Slight defects, easily correctable	14.3%	0.0%	38.1%	13.0%	4.8%	4.3%
Bravo Slight defects, not correctable without damage	26.2%	65.2%	61.9%	87.0%	21.4%	26.1%
Charlie Prophylactic removal for prevention of severe failures	0.0%	4.3%	0.0%	0.0%	0.0%	0.0%

The data are listed concerning the subcriteria "cracks and chipping", "abrasion" and "voids", due to possible multiple ratings per criterion. Significant differences were calculated for the criterion "cracks and chippings" after 96 months ($p = 0.028$) and 120 months ($p = 0.003$). For the criterion "abrasion", the difference was significant after 48 months ($p = 0.02$) and 120 months ($p = 0.035$; Mann-Whitney U-test).

Table 6b Descriptive statistics of premolars vs molars regarding "integrity filling"after 120 months

Criterion		48 months premolars (n=45)	48 months molars (n=23)	96 months premolars (n=44)	96 months molars (n=23)	120 months premolars (n=42)	120 months molars (n=23)
Alpha I Excellent		2.2%	4.3%	0.0%	0.0%	0.0%	0.0%
Alpha II Slight defects, easily correctable	Negative step	40.0%	8.7%	18.2%	8.7%	14.3%	0.0%
	Overhang	6.7%	0.0%	2.3%	4.3%	0.0%	0.0%
	Stained overhang	0.0%	0.0%	0.0%	0.0%	4.8%	0.0%
Bravo Slight defects, not correctable without damage	Gap/ negative step	20.0%	26.1%	38.6%	13.0%	14.3%	17.4%
	Staining	31.1%	60.9%	40.9%	73.9%	66.7%	78.3%
Charlie Prophylactic removal for prevention of severe failures	Gap (dentin exposure)	0.0%	0.0%	0.0%	0.0%	0.0%	4.3%
	Secondary caries (dentin exposure)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Significant differences between premolars and molars were calculated after 48 months ($p = 0.007$) and 120 months ($p = 0.013$; Mann-Whitney U-test). In contrast, after 96 months, no significant difference was detected ($p = 0.456$).

ence of a gap with secondary caries; many patients with restorations showing considerable leakage do not develop secondary caries even over long periods of time.[5,15,16,30] On the other hand, this observation may also be attributed to the exact location of the gap, eg, when the gap occurred between adhesive and RBC or within the adhesive layer, there may be no substrate or space for the development of secondary caries.[14,16,29] In the present study, it is possible that the oral hygiene of the patients was above average, which would limit the validity of the overall outcome. However, neither the clinical examples nor the extension below the cementoenamel junction (CEJ) support this idea.

It is long established that RBC are well suited for small-volume, minimally invasive cavities of primary lesions without pre-existing restoration;[20] in contrast, the limits of proximal extension below the dentin-enamel junction are still not fully understood.[15,18,19,21,25] It was previously assumed that RBC materials may be inferior in proximally extended cavities and therefore different materials and techniques such as amalgam or indirect approaches should be used. Reports of extensive secondary caries and heavy wear rates after some years of clinical service are serious arguments against bonded RBC in these distinct clinical cases.[17] If proximal margins are located in dentin/cementum in Class II cavities, the risk of secondary caries is certainly higher due to inferior sealing compared to etched enamel margins.[15] On the other hand, several in vitro and in vivo studies demonstrated that margins extending beyond the CEJ can be safely restored.[5,15,23,31,34,37-39] This is also true for Class V restorations, in which 50% of the margin length is always located in dentin.[28] Finally, clinical reports of proximal marginal seal in dentin-bordered cavities restored with direct RBC restorations are clearly under-represented in the literature. Recent results by Kuper et al[15] are promising, having detected no significant effect of proximal cavity extension below the CEJ on secondary caries formation; however, the overall risk for failure was higher in these groups but not dependent on materials (RBC vs amalgam).

The setup of the present clinical trial was characterized by a significant number of amalgam replacements, so that 35% of cavities lacked proximal-cervical enamel and 49% had a proximal enamel width of < 0.5 mm, making treatment preconditions very difficult. Finally, even after 10 years of clinical service in heavy stress-bearing cavities (Fig 2), these restorations showed neither significantly worse clinical outcomes nor recurrent caries or severe marginal staining. Nevertheless, considerable marginal deterioration was clinically detected beyond the 6-year recall (Tables 2 and 3). After re-evaluation of the cavity images from the treatment session 10 years ago, it was obvious that larger cavities – especially in molars – suffered significantly more marginal discoloration, especially when flexible dentin support was weak after extensive caries excavation (Figs 2 and 3).

RBC for the present clinical trial were pre-selected after thorough in vitro testing with previous encouraging results for both materials in terms of marginal quality and long-term occlusal stability.[4,7] This safety issue was considered due to the catastrophic outcome of other studies with materials that did not undergo thorough preclinical screening.[13] The adhesives examined here required special bonding protocols, eg, wet bonding with the acetone-based Solobond M, however, without significant clinical problems such as postoperative hypersensitivities or pulpal irritation. At baseline, Syntac produced an even higher rate of hypersensitivity compared to the simplified Solobond M (baseline vs 6 months / 3% vs 0% bravo scores), but without further clinical impact beyond one year of observation. Therefore, both the internal and external sealing of dentin margins were possible with the different adhesive approaches used here, ie, two-step etch-and-rinse vs four-step etch-and-rinse.

The chosen clinical setup – using complete restorative systems (ie, adhesive plus resin composite of the same manufacturer) – may be viewed critically. Such an approach is more complex than evaluating two different adhesives with one resin composite, which would thus involve fewer variables. However, the present trial was not designed to thoroughly elucidate this question, but instead, the overall outcome over the 10-year period confirms that both restorative systems showed an excellent clinical outcome.

Nanofillers have been widely incorporated into RBC formulations during the last decade. Despite convenient aspects such as easier achievable translucency effects for incisal esthetics or increased polish retention,[12,34] clinical studies failed to prove a better clinical outcome or increased longevity.[26,27] In our study, Tetric Ceram was used as a classical control fine-hybrid resin composite (ie, without nanofillers),[34] whereas Grandio was used as one of the first resin composites with nanofiller addition to hybrid-type fillers, a so-called nanohybrid resin composite.[8] Finally, these 10-year findings were also not able to demonstrate superior clinical performance of nanofillers vs conventional hybrid RBCs.

Due to the fact that the present paper covers a long-term trial, the most recent recommendations for clinical trials with restorative materials[11] could not be addressed in the present study, because these recommendations were published a considerable period after its start. Therefore, it was not possible to include other evaluation aspects beside well-suited protocols such as the CONSORT statement.[22] Nevertheless, during the 10 years of this clinical trial, both the clinical procedures and the randomized prospective approach demonstrated that this is a valid, scientifically sound way of conducting clinical trials.

CONCLUSION

Altogether, the null hypothesis of the present investigation was accepted because there was no significant difference in the clinical behavior between Grandio and Tetric Ceram used for extended Class II posterior restorations after ten years of clinical service.

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Clinical relevance: The adhesive restorative systems under investigation exhibited excellent clinical outcomes.

01. Student Researcher

Nanolayering in Resin-Dentin Interfaces Created by Commercialized 10-MDP-containing Self-etching/Universal Primers

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Purpose: 10-MDP produces nanolayering by self-assembly of the resin monomer, calcium ions, and partially-dissolved apatite into nano-arrays of electron-dense 10-MDP+Ca salt. Because of its hydrolytic stability, 10-MDP+Ca nanolayering has been claimed to render the dentin/adhesive interface more resistant to degradation. Such a notion, however, is founded upon the ubiquity of nanolayered deposits along the resin/dentin interface. The objective of the present study was to determine the extent of nanolayering in resin/dentin interfaces after application of commercialized self-etching adhesives containing 10-MDP, and universal adhesives in the self-etching mode, to human dentin.

Materials and Methods: Seven commercialized adhesives were examined: Clearfil SE Bond 2, Clearfil S3 Bond, Clearfil Universal Bond (all from Kuraray Noritake Dental), Scotchbond Universal (3M ESPE), All-Bond Universal (Bisco), AdheSe Universal (Ivoclar Vivadent), and G-Premio Bond (GC). Each adhesive was applied in the self-etching mode on midcoronal dentin according to the respective manufacturer's instructions. Thin-film x-ray diffraction (XRD) was used to detect the characteristic peaks exhibited by nanolayering (N = 2). Additional bonded dentin specimens (N = 3) were covered with flowable resin composite and processed for transmission electron microscopy without further staining. The control consisted of an experimental self-etching adhesive prepared from 10-MDP (Designer Molecules), ethanol, and water (15:45:40 wt% ratio, with photoinitiators to render it light curable) applied to dentin for 20 s and examined in the same manner.

Results: Profuse nanolayering with highly ordered periodicity (~4 nm wide) was observed adjacent to partially-dissolved apatite crystallites in dentin bonded with the control adhesive. Three peaks in the range of 2.50 degrees (3.53 nm), 4.93 degrees (1.79 nm), and 7.37 degrees (1.20 m) were identified from thin-film XRD. These features were rarely observed in specimens prepared from the commercialized adhesives.

Conclusion: The sparsity of nanolayering in resin/dentin interfaces created by commercialized adhesives challenges its usefulness as a mechanism for improving bond longevity in dentin bonding.

Keywords: methacryloyloxydecyl dihydrogen phosphate, transmission electron microscopy.

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02. Junior Researcher

10-MDP or Its Analog as Self-etching Primers for Dentin Bonding

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Purpose: To test the hypothesis that two phosphate-containing monomethacrylate resin monomers, methacryloyloxidecyl dihydrogen phosphate (10-MDP; Mw: 326 Da) or methacryloyloxipentapropyleneglycol dihydrogen phosphate (analog of 10-MDP; Mw: 456 Da), are equally effective as the sole resin component for formulating self-etching primers for bonding to dentin.

Materials and Methods: Experimental adhesives were formulated by mixing 10-MDP or its analog (both from Designer Molecules), ethanol, and water at a 15:45:40 wt% ratio with photoinitiators added to render the adhesives light curable. Each primer was applied to human midcoronal dentin for 20 s, air dried, and light cured. Contact angles of water on the primed dentin were measured (EasyDrop DSA30). After coupling the primed dentin with a bonding resin and

resin composite, the microtensile bond strength of the bonded dentin was measured and compared with Clearfil SE Bond (Kuraray Noritake Dental). Transmission electron microscopy was used to examine the resin/dentin interface for the presence of nanolayering. Photoinitiator-free primers were dissolved in Tris buffer for size exclusion chromatography, using demineralized bovine dentin powder as the stationary phase, to examine their potential to access the intrafibrillar milieu of collagen.

Results: Static contact angles for smear layer-covered dentin, 10-MDP-, and MDP-analog-primed dentin were 25.1 ± 6.1 degrees, 47.7 ± 7.7 degrees, and 36.4 ± 7.7 degrees, respectively ($p < 0.05$; one-way ANOVA). Microtensile bond strength (in MPa) for 10-MDP-, MDP-analog-, and SE Bond-bonded dentin were $67.7 \pm 12.a$ / 59.9 ± 14.4, and 57.2 ± 10.9, respectively ($p > 0.05$, one-way ANOVA). Nanolayering of resin-Ca salts was only identified in the resin/dentin interface of the 10-MDP-containing adhesive. Both 10-MDP and its analog were capable of accessing intrafibrillar water compartments to infiltrate spaces lost by intrafibrillar apatite demineralization.

Conclusion: When used as sole resin components in self-etching primers, 10-MDP and its analog produce equally strong initial bonds to dentin after forming cross-linked polymer networks with dimethacrylates derived from bonding resin. Absence of nanolayering in resin/dentin interfaces produced by the MDP analog provides a good model for evaluating the contribution of nanolayering to bond degradation.

Keywords: dentin bonding agents, self-etching primer, 10-MDP, chromatography.

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03. Student Researcher

Analysis of Experimental Adhesive System Containing $ZnCl_2$ as MMP Inhibitor

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Purpose: To evaluate the degree of conversion (DC%), water sorption (WS), solubility (SO), and microtensile bond strength (µTBS) stability to the dentin of experimental etch-and-rinse adhesive systems containing 0% (Z0), 2% (Z2), 3.5% (Z3.5) and 5% (Z5) $ZnCl_2$.

Materials and Methods: DC% was measured by FT-IR spectroscopy and WS and SO were calculated based on ISO4049. Fifty human molars were wet ground until occlusal dentin was exposed. The adhesive systems were applied and resin composite buildups were incrementally constructed. After 24 h in distilled water at 37°C, bonded teeth were cut into resin-dentin beams with a cross-sectional area of 1 mm^2. The µTBS was evaluated after 24 h and 12 months of water storage at 37°C. The data were analyzed using ANOVA and Tukey's HSD test.

Results: Z5 and Z3.5 presented the lowest DC% and µTBS ($p < 0.05$) and the highest WS and SO ($p < 0.05$). Z2 and ZO presented similar WS, SO, DC, and µTBS ($p > 0.05$).

Conclusions: None of the groups maintained µTBS stability after 12 months of water storage. The experimental adhesive systems with higher percentages of $ZnCl_2$ presented the lowest physicochemical properties.

Keywords: adhesive systems, dentin.

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04. Student Researcher

Bond Strength of an Experimental One-Bottle 4-META Adhesive System

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Purpose: To develop an experimental one-bottle total etching adhesive system containing 4-META in different concentrations (12%, 20%, 30%. and 40%) and evaluate bond strength (µTBS) to dentin immediately and after storage for 6 months. The influence of acetone and ethanol as solvents was also evaluated.

Materials and Methods: The Single Bond 2 system was used as the control. The basic composition of the experimental adhesive was: ethanol or acetone (20%), HEMA (30%), TEG-DMA (25%), UDMA (20%), water (4%), camphorquinone

(0.5%), and tertiary amine (0.5%). Different concentrations of 4-META were added to this composition. To evaluate the bond strength to dentin, 63 extracted human molars were used, from which the enamel had been removed to expose the dentin. Restorations with adhesive systems under study and composites were made. The tooth/restoration unit was sliced to obtain sticks, which were stored in distilled water for periods of 24 h and 6 months. After the immersion period, the microtensile test was performed. The pattern of failure was also evaluated. The data were submitted to ANOVA and Tukey's test ($\alpha = 0.05$). In the immediate evaluation and in the evaluation after 6 months of storage was no significant difference between groups (different concentrations and different solvents). All adhesives were able to maintain µTBS after 6 months of storage.

Results: The µTBS (22.55 MPa) of the 12% 4-META/ethanol-solvent group stored for 6 months was significantly lower than the 40% 4-META/acetone-solvent group tested immediately (38.80 MPa) and the 20%-4-META/ethanol-solvent group tested immediately (37.06 MPa). The pattern of failure was predominantly adhesive in all groups.

Keywords: adhesion, microtensile bond strength, 4-META, experimental adhesives.

05. Junior Researcher

Shear Bond Strengths to Dentin of a New Universal Bonding Agent in Multiple Modes

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Purpose: A new universal adhesive (Scotchbond Universal, 3M ESPE; St Paul, MN, USA) was recently introduced to the market accompanied by claims that it can be used with the self-etching, selective-etching, or etch-and-rinse modes. The purpose of this study was to evaluate the dentin shear bond strengths of the new universal adhesive system used in each of the 3 modes.

Materials and Methods: The labial surfaces of 80 bovine teeth were ground up to 600 grit to create flat dentin surfaces. Resin composite (Filtek Z250, A2, 3M ESPE) was bonded to dentin using the new universal self-etching system with three etching techniques: self-etching, selective etching, and etch-and-rinse. The etchant was a 35% phosphoric acid gel. When used in the etch-and-rinse mode, it was applied for 15 s. For selective etching, it was applied to dentin only for 2 s. An etch-and-rinse, two-step adhesive (Adper Single Bond Plus, 3M ESPE) served as control. Following storage in water for 24 h, shear bond strengths were determined using an Instron universal testing machine. The data were subjected to a one-way ANOVA and Duncan's test for multiple comparisons.

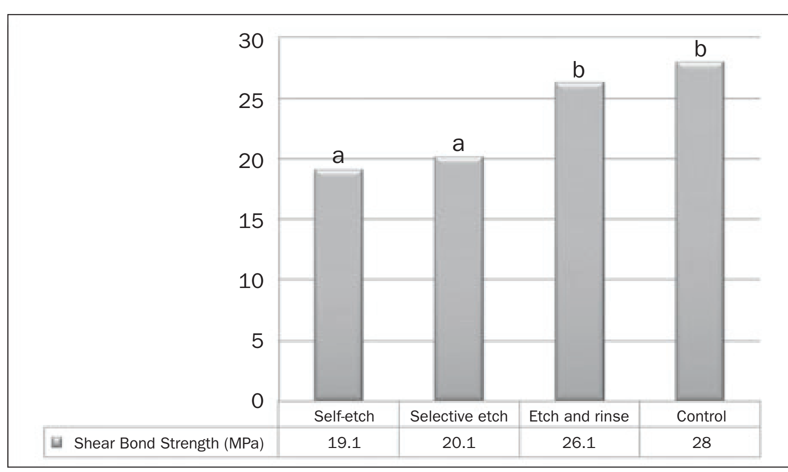

Fig 1 Shear bond strength by technique. Different letters indicate statistically significant differences.

Conclusions: The new universal adhesive had higher dentin bond strengths when used with the etch-and-rinse technique compared to the selective-etching and self-etching modes. The clinical relevance of the slightly lower bond strengths in the self-etching and selective-etching modes is not known.

Keywords: adhesive, resin composite, self-etching, selective etching, etch-and-rinse.

06. Junior Researcher

Influence of Atmospheric Plasma on the Durability of Dentin Adhesion

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Purpose: To investigate the effect of nonthermal atmospheric pressure plasma on dentin bond strength after 24 h and 12 months of water storage.

Materials and Methods: The occlusal enamel was removed from 48 human third molars to fully expose the dentin surface. Dentin was abraded with 600-grit SiC paper under water cooling to standardize the smear layer. Scotchbond Universal (SBU, 3M ESPE) adhesive was used in self-etching (SE) and etch-and-rinse (ER) approaches. Teeth were divided into six groups (n = 8) according to the plasma application for 10 or 30 s, and two control groups, which corresponded the use of SBU according to the manufacturers' recommendations (without plasma): 1. SE control group; 2. plasma 10 s + SE; 3. plasma 30 s + SE; 4. ER control group; 5. ER + plasma 10 s; 6. ER + plasma 30 s. Composite resin blocks were incrementally built up with Filtek Z350 XT (3M ESPE) on bonded dentin surfaces. After 24 h, teeth were vertically and serially sectioned to obtain specimens for microtensile BS, and ten bonded beams were obtained per tooth. Five beams were randomly selected per tooth and tested after 24 h, while the remaining five beams were tested in tension after 12 months of distilled water storage (37°C). Bond strength data were analyzed by two-way ANOVA and Tukey's test (5%).

Results: Bond strength was not improved by plasma application. Control groups and the use of plasma for 10 s kept the bond strength stable for one year. However, bond strength was reduced when the dentin was treated with plasma for 30 s.

Table 1 Mean (SD) microtensile bond strength in MPa to plasma-treated dentin after water storage for 24 h and 12 months

Treatment	24 h	12 months
SE Control	69.6 (7.2)^{Aa}	61.2 (11.4)^{Aa}
SE Plasma 10 s	73.1 (3.4)^{Aa}	70.3 (12.0)^{Aa}
SE Plasma 30 s	78.1 (6.5)^{Aa}	66.4 (4.0)^{Ba}
ER Control	71.2 (5.2)^{Aa}	73.6 (8.4)^{Aa}
ER Plasma 10 s	71.9 (3.4)^{Aa}	67.9(7.9)^{Aa}
ER Plasma 30 s	76.7 (6.2)^{Aa}	69.4 (6.8)^{Ba}

Means followed by different superscript letters (upper case: row, comparing storage times; lower case: column, comparing treatments) indicate significant differences among the groups (Tukey's test, $p \leq 0.05$).

Conclusion: The results suggested that the bond strength of SBU used according to the manufacturer's instructions (for SE and ER approaches) or combined with 10 s of plasma did not alter after 12 months of water storage. Conversely, the bond strength of plasma-treated dentin for 30 s decreased after one year.

Keywords: plasma gases, dentin, adhesives, tensile strength.

07. Senior Researcher

Effect of Biosilicate® on Adhesion to Carious Dentin

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Purpose: To evaluate the effect of a bioglass (Biosilicate) on microtensile bond strength (μTBS) of different adhesive systems to sound and carious dentin (natural and artificial caries).

Materials and Methods: Forty molars presenting natural caries and 80 sound molars (40 left sound, 40 with artificial caries) were divided into 4 groups (n = 10) according to the adhesive system: G1: acid etching + Biosilicate + adhesive system; G2: acid etching + adhesive system; G3: self-etching adhesive system + Biosilicate; G4: self-etching adhesive system. Teeth were restored with composite, sectioned into beams (±0.9 mm^2) and submitted to microtensile testing (crosshead speed: 0.5 mm/min). Failures were analyzed by scanning eletronic microscopy. Bond strength data were analyzed statistically by two-way ANOVA and the Bonferroni test ($\alpha = 5\%$).

Results: Biosilicate application increased ($p < 0.05$) bond strength values for all types of dentin. In the groups without Biosilicate, G4 (sound dentin + self-etching adhesive system) exhibited higher μTBS values ($p < 0.05$). For sound dentin, G1 exhibited the highest values of μTBS ($p < 0.05$), followed by G3 and G2. Groups with artificial caries showed higher values ($p < 0.05$) than natural caries. Adhesive failures were predominant in all groups.

Conclusion: The association of an etch-and-rinse adhesive system and Biosilicate provided a positive effect on bond strength to sound and carious dentin.

Keywords: bioglasses, adhesion, dentin.

Acknowledgment: Funded through FAPESP (2013/12215-1), Brazil.

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08. Senior Researcher

Biosilicate as Dentin Pretreatment for Etch-and-Rinse and Self-Etching Adhesives

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Purpose: To evaluate the effect of using Biosilicate microparticles prior to the application of etch-and-rinse and self-etching adhesives on dentin microtensile bond strength.

Materials and Methods: The enamel of 40 bovine central incisors was removed using 600-grit SiC disks to expose flat dentin surfaces. Teeth were randomly assigned into 4 groups (n=10), according to the Biosilicate pretreatment and adhesive system: Group 1: 10% Biosilicate suspension prior to etching with 35% phosphoric acid + adhesive Adper Single Bond 2; Group 2: 10% Biosilicate suspension after etching with 35% phosphoric acid + adhesive Adper Single Bond 2; Group 3: 10% Biosilicate suspension prior to self-etching adhesive Adper Easy One; Group 4: 10% Biosilicate suspension after self-etching adhesive Adper Easy One. Composite buildups were made incrementally with Filtek Z350. The specimens were stored in humidity for 24 h at 37°C and sectioned into sticks cross-sectional areas of 1.0 mm^2. Each stick was tested in a universal testing machine (crosshead speed: 0.5 mm/min), and mean microtensile bond strength data (MPa) were analyzed by 2-way ANOVA and Bonferroni's multiple comparisons test ($\alpha = 0.05$).

Results: Group 2 (10% Biosilicate suspension after acid etching with 35% phosphoric acid + adhesive Adper Single Bond 2) showed the highest bond strength values ($p < 0.05$) compared to Groups 1 and 4. Regarding self-etching adhesive, there was no difference ($p > 0.05$) between Groups 3 and 4.

Conclusion: The application of biosilicate microparticle suspension after acid etching positively influenced the bond strength of an etch-and-rinse adhesive to dentin, but it has no significant effect on the bond strength of self-etching adhesive to dentin.

Keywords: bioglasses, biosilicate, microtensile bond strength, dentin.

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09. Senior Researcher

Microtensile Bond Strength of Adhesive Systems in Different Regions of Dentin in a Class II Preparation

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Purpose: To evaluate the microtensile bond strength (μTBS) of self-etching and etch-and-rinse adhesives compared on different dentin regions (central or proximal) in a class II preparation.

Materials and Methods: A class II (MOD) preparation measuring 4 mm in width and approximately 3 mm in depth was simulated on 20 extracted human third molars until middle dentin was exposed. Etch-and-rinse adhesives (Scotchbond Multi Purpose [SMP], 3M ESPE, St Paul, MN, USA; Optibond FL [OP], Kerr; Orange, CA, USA) and self-etching adhesives (Clearfil SE Bond [CSE], Kuraray, Osaka, Japan; Optibond XTR [OPX], Kerr) were used according to manufacturer's instructions. Class II restorations were placed using the incremental technique (Filtek Z250, 3M ESPE). Photoactivation was performed on each layer for 20 s using an LED light-curing unit (BluePhase G2, Ivoclar Vivadent, Schaan, Liechtenstein). Samples were sectioned in a beam shape with a maximum 1-mm^2 cross section and dichotomized into central and proximal locations, placed on Geraldeli's device, and submitted to μTBS testing at 0.5 mm/min crosshead speed (OMT-100, Odeme Dental Research; Joacaba, SC, Brazil). Fracture patterns were analyzed with a stereomicroscope (Leica Mz 9.5, Meyer Instruments; Houston, TX, USA) and extra samples were obtained for scanning electron microscope observation (LEO 435 VP, LEO Electron Microscopy; Cambridge, UK). Data were submitted to two-way ANOVA and Tukey's test at a 5% significance level.

Results: There were no statistically significant differences among SMP (30.5 MPa), OP (29.3 MPa), CSE (29.1 MPa), and OPX (29.6 MPa) in central dentin regions ($p > 0.05$). However, in proximal dentin regions, the μTBS values of SMP (23.2 MPa) and OP (22.0 MPa) were lower compared to CSE (27.1 MPa) and OPX (28.1 MPa) ($p < 0.05$). In all groups, mixed failure was the most frequent mode.

Conclusion: Etch-and-rinse and self-etching adhesives did not differ statistically significantly in terms of μTBS on central dentin, while on proximal dentin, etch-and-rinse adhesives produced statistically significantly lower μTBS values than did etch-and-rinse adhesives.

Keywords: adhesive systems, dentin, bond strength.

10. Senior Researcher

Arginine Incorporated into an Etch-and-Rinse Adhesive System

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Purpose: Arginine metabolism by oral bacteria generates ammonia, which can neutralize glycolytic acids and reduce the risk of secondary caries at the tooth/composite interface. This preliminary study aimed to develop and compare an etch-and-rinse adhesive system containing four different concentrations of arginine for sustainable release without affecting the mechanical properties.

Materials and Methods: The experimental etch-and-rinse two-bottle adhesive was formulated without arginine (control: C) and with different effectively incorporated concentrations of arginine: G2.5%, G5%, G7%, and G10%. A three-point bending flexural strength test (FS) and flexural modulus analysis (FM) were conducted on a total of 40 bar-shaped specimens 10 x 2 x 2 mm (n = 8 for each group) according to ISO 4049. A universal testing machine (Instron, Norwood, MA, USA) with a span between supports and a crosshead speed of 0.5 mm/min was used to conduct the tests. FM was calculated using Bluehill 3 software. Data were analyzed by ANOVA and post-hoc Tukey's test. Statistical significance was established at $\alpha = 0.05$.

Results: FS results for each group were as follows: C (10.70 MPa), G2.5% (9.53 MPa), G5% (9.56 MPa), G7% (9.77 MPa), G10% (9.45 MPa). There were no statistically significant differences for FS values between C and G7% ($p > 0.05$) or among G2.5%, G5%, G7%, and G10% ($p > 0.05$). Group C had statistically significantly higher FS values when compared to G2.5%, G5%, and G10% ($p > 0.05$). The FM results were as follows: C (1.24 GPa), G2.5% (1.18 GPa), G5% (1.13 GPa), G7% (1.26 GPa), G10% (1.29 GPa), and no statistically significant difference was found among any of the groups ($p > 0.05$).

Conclusions: The incorporation of arginine at all concentrations tested did not alter the flexural modulus and the incorporation of 7% arginine did not alter the flexural strength of the experimental adhesive as compared to the control. Future study should include testing of other physical and mechanical properties as well as the anti-caries efficacy of this novel arginine-based adhesive.

Keywords: adhesion, microtensile bond strength, nanoleakage, degradation, dentin treatment.

11. Student Researcher

New Strategy in Dentin Treatment Prior to Etch-and-Rinse Adhesive Application

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Purpose: To evaluate the effect of dentin treatment with HEMA-P on the microtensile bond strength (μTBS) and nanoleakage of an etch-and-rinse adhesive system.

Materials and Methods: The occlusal surfaces of human molars were wet ground to expose superficial dentin and assigned to two groups according to the dentin treatment: PA: 37% H_3PO_4 for 15 s; HP: HEMA-P for 15 s. Adper Single Bond 2 was applied to treated dentin surfaces, and resin composite buildups were incrementally constructed over them. After 24 h in artificial saliva at 37°C, bonded teeth were cut into resin-dentin sticks with a cross-sectional area of 1 mm^2 that were submitted to μTBS testing (immediately or after 3 months of storage in artificial saliva at 37°C). The nanoleakage was investigated by SEM/EDS and the interaction between dentin and H_3PO_4 or HEMA-P was analyzed by combining micro-Raman and FT-IR spectroscopy. The data were analyzed by two-way ANOVA and Tukey's HSD post-hoc test ($\alpha = 0.05$).

Results: The HP group presented significantly higher μTBS than did the PA group at both observation times ($p < 0.05$). Both treatments maintained the μTBS stability after 3 months of artificial saliva storage ($p > 0.005$). At both times, the PA group presented higher nanoleakage than did the HP ($p < 0.05$).

Conclusions: HEMA-P maintained the μTBS stability after 3 months of artificial saliva storage. This dentin treatment performs better than the traditional phosphoric-acid etching in terms of nanoleakage.

Keywords: adhesion, microtensile bond strength, nanoleakage, degradation, dentin treatment.

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12. Junior Researcher

Effect of Radiotherapy on the Dentin/Composite Interface

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Purpose: The purpose of this in vitro study was to evaluate the effect of radiotherapy on the dentin/composite interface in human teeth through the microtensile bond strength test (μTBS) with and without doxycycline application.

Materials and Methods: Sixty human third molars were sectioned to expose mid-dentin surfaces and distributed into 3 groups (n = 20) according to the adhesive system (Adper Scotchbond MP and Clearfil SE Bond) applied, doxycycline application (with/without), and exposure or not to 60 Gy total radiation (2 Gy daily doses, 5 days/week, total of 6 weeks). No radiotherapy was performed in the control group (n = 20). Group RtRes (n = 20) was submitted to radiotherapy before the restoration procedure, and group ResRt (n = 20) was submitted to radiotherapy after restoration. Specimens underwent μTBS testing in a universal testing machine (EZ-Test, Shimadzu; Tokyo, Japan). Failure modes were determined with optical microscopy (Leica Mz 9.5; Heerbrugg, Switzerland) and extra samples were analyzed using SEM (LEO 435 VP, Carl Zeiss; Jena, Germany). Data were submitted to two-way ANOVA and Tukey's test ($p < 0.05$).

Results: μTBS values (MPa) for Adper Scotchbond MP (25.5 ± 4.8) and Clearfil SE (27.6 ± 4.2) were not statistically different. The control (30.5 ± 4.9) and ResRt (29.2 ± 4.4) groups presented μTBS values significantly higher than RtRes (23.1 ± 3.2). Doxycycline application (21.7 ± 3.6) significantly reduced μTBS values compared to groups without doxycycline application (33.6 ± 4.2). Dentin cohesive failure mode was predominant for RtRes and mixed failure mode for ResRt. Mixed and adhesive failures were more often observed in control group.

Conclusion: Specimens submitted to radiotherapy before restoration presented significantly lower μTBS values. Specimens submitted to radiotherapy after restoration presented μTBS values similar to those of the control group. The use of doxycycline significantly reduced μTBS values regardless of other test conditions.

Keywords: adhesive, radiation, bond strength, doxycycline.

13. Junior Researcher

Effect of Deproteinization on Dentin Bond Strength in Amelogenesis Imperfecta

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Purpose: To evaluate the effect of different dentin deproteinization procedures on the microtensile bond strength (µTBS) of composite resin to primary dentin affected by hypocalcified amelogenesis imperfecta (AI).

Materials and Methods: Flat dentin surfaces were obtained from extracted hypocalcified AI-affected and noncarious primary molars. The specimens were randomly distributed into 3 groups according to surface conditioning procedures: control, sodium hypochlorite (NaOCl), and chlorine dioxide (ClO_2) groups. A universal testing machine was used to measure µTBS, and data were analyzed using one-way ANOVA and Tukey's test.

Results: µTBS values for all groups in the sound primary teeth were significantly higher than for comparable groups in the hypocalcified-AI primary teeth ($p < 0.05$). For both sound and hypocalcified-AI primary teeth, no significant differences were found between the µTBS values of the control and NaOCl groups ($p > 0.05$); however, µTBS values for the ClO_2 group were significantly higher than for both control and NaOCl groups ($p < 0.05$).

Conclusion: Deproteinization with ClO_2 could be considered effective in enhancing dentin bonding in hypocalcified-AI primary teeth.

Keywords: microtensile bond strength, chlorine dioxide, deproteinization, hypocalcified amelogenesis imperfecta, sodium hypochlorite.

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14. Junior Researcher

Different Adhesives for Immediate Dentin Sealing: Effects on µTBS Durability

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Purpose: To evaluate the effects of using different adhesive systems for immediate dentin sealing (IDS) and three months of water storage on bond strength (µTBS).

Materials and Methods: Dentin/resin/resin interfaces were produced by a self-adhesive cement (RelyX U100, 3M ESPE) and IDS surfaces. For IDS, four adhesives were used: two etch-and-rinse adhesives – a 3-step system [OptiBond FL (OB, Kerr)] and a 2-step system [XP Bond (XP, Dentsply)] – and two self-etching adhesives – a 2-step self-etching adhesive [Clearfil SE Bond (SE, Kuraray)] and a single-step adhesive [Xeno V (XV, Dentsply)]. IDS was not performed in the control group, which did not receive any dentin pretreatment. Sixty molars were divided into 5 groups according to adhesive procedures, then subdivided into 2 subgroups according to water-storage time ($n = 6$). Pre-polymerized composite blocks were air abraded, silanized, and cemented according to manufacturer's recommendations. After 7 days of water storage, specimens were sectioned to produce beams of approximately 1 mm^2 cross-sectional area. Half of the beams were tested immediately and the remaining beams were stored in water (37°C) for 3 months prior to testing in tension (1 mm/min). Fracture pattern was determined using an SEM. µTBS data were analyzed by two-way ANOVA and Tukey's test.

Results: No pre-test failures were observed. Results are presented in Table 1. After 7 days, IDS groups presented higher µTBS values than those of the control group, although XP and SE did not differ significantly. However, after 3 months, no significant differences were observed between IDS groups and the control group. XV and OB presented a significant reduction in µTBS values compared to baseline. The majority of failures occurred between cement and dentin, with or without IDS.

Conclusions: IDS was not able to prevent a decrease in µTBS for some materials after 3-month water-storage. The control group did not differ from IDS groups after storage in water.

Table 1 Mean (SD) bond strength values in MPa for the different materials used for immediate dentin sealing after 7 days or 3 months of storage in water

Materials used for IDS		7 days	3 months
1-step self-etching	Xeno V	48.0 (14.1)^{Aa}	18.6 (9.8)^{Ab}
2-step self-etching	Clearfil SE Bond	33.0 (8.4)^{ABa}	25.4 (3.9)^{Aa}
2-step etch-and-rinse	XP Bond	30.8 (14.0)^{ABa}	21.9 (2.5)^{Aa}
3-step etch-and-rinse	OptiBond FL	45.1 (6.0)^{Aa}	28.3 (9.2)^{Ab}
Self-adhesive cement	U100 (control/no IDS)	22.8 (7.7)^{Ba}	23.3 (17.3)^{Aa}

Means followed by different superscript letters (upper case – column; lower case – row) differ at the 95% confidence level (Tukey's test).

Keywords: immediate dentin sealing, self-adhesive resin cement, durability, SEM.

15. Senior Researcher

Immediate Dentin Sealing: A Narrative Review

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Purpose: Preparation of teeth for indirect bonded restorations involves cutting dentin and thus exposure of dentinal tubules. Many approaches have been used to seal exposed dentin tubules. Immediate dentin sealing (IDS) with dentin bonding agents is a new strategy. The aim of this study was to review published studies that evaluated the effectiveness of IDS in restorative dentistry.

Materials and Methods: This report was conducted in accordance with the PRISMA Statement. A literature search was carried out using PubMed Plus, Ovid Medline, Cochrane Library, Web of Science, and Scopus databases in English and without time restrictions. Studies evaluating the effect of IDS were deemed eligible. Case reports or case series, abstracts, short communication, observational studies, review articles/letters, and studies in which the effect of immediate dentin sealing was not determined were excluded. Two reviewers independently selected the studies, extracted the data, and assessed the risk of bias. From 205 potentially eligible studies, 41 were selected for full-text analysis, and 15 were included for review.

Results: The review of the full-text articles confirmed that 8 studies determined bond strength, 2 studies identified interactions between impression materials and dentin bonding agents, 2 articles evaluated the thickness of IDS materials. Cuspal deflection with the fracture resistance of teeth, fluid permeability, postcementation hypersensitivity, and microleakage were investigated in another study. One study examined both microleakage and bond strength. The studies demonstrated that IDS improved bond strength of luting cements to dentin. No change was observed in microleakage values of cemented crowns. Polyether impression materials are not recommended to be used in combination with IDS due to their interaction with dentin bonding agents.

Conclusion: The IDS technique seems to be effective in improving bond strengths and reducing postoperative sensitivity. However, cuspal deflection, fracture resistance, fluid permeability, and microleakage of the restorations are not secured with this strategy.

Keywords: immediate dentin sealing, review.

16. Student Researcher

Shear Bond Strength of Three Adhesive Luting Agents to Bovine Dentin

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Purpose: To compare the shear bond strength (SBS) to dentin of a resin-modified glass-ionomer cement (group A), a self-adhesive resin cement (group B), and an etch-and-rinse adhesive resin cement (group C).

Materials and Methods: A total of 60 bovine teeth were prepared by grinding the buccal surface flat with a carbide disk on a low-speed trimmer and 600-grit carbide paper under continuous water flow. Teeth were randomly assigned to 3 groups of 20 specimens each. All specimens were placed in a thermostatically controlled water bath at constant temperature of 37°C for 24 h. All groups were prepared according to the manufacturer's (all 3M) instructions. 10 specimens per group were thermocycled 1000 times (5°C-55°C) and the other 10 specimens per group spent another 24 h in the 37°C water bath. Shear bond strength values were determined by a Chantillon testing machine. One-way ANOVA and Bonferroni tests were used to determine significant differences ($p < 0.05$) between the material groups.

Results: Pre-test failures were observed. The mean SBS in group A was 4.24 ± 0.87 MPa, in group B 6.59 ± 1.46 MPa, and in group C 9.68 ± 0.76 MPa. Groups A and B ($p = 0.035$), groups A and C ($p = 0.000$), and groups B and C ($p = 0.001$) were found to be statistically significantly different (Bonferroni test).

Conclusions: Statistically significant differences were found between groups A (3M RelyX Luting Plus), B (3M RelyX Unicem 2) and C (3M RelyX Ultimate). The etch-and-rinse system had better retentive properties.

Keywords: resin-modified glass-ionomer cement, self-adhesive resin cement, adhesive resin cement, shear bond strength.

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17. Senior Researcher

Bond Strength of a Newly Developed Luting Resin Composite Cement

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Purpose: To evaluate shear bond strength of a newly developed luting resin composite cement to bovine dentin.

Materials and Methods: Four luting resin cements were tested: Panavia V5 with a self-etching primer (Kuraray Noritake Dental; Tokyo, Japan), RelyX Ultimate with Scotchbond Universal Adhesive (3M ESPE; St Paul, MN, USA), NX3 with OptiBond All-In-One (Kerr; Orange, CA, USA) and Panavia F2.0 with ED Primer II (Kuraray Noritake Dental). Bovine mandibular incisors were embedded in a self-curing resin and the labial surfaces were ground with 600-grit SiC paper under running water to obtain flat dentinal surfaces. The surface was then treated with the primer or adhesive, and a resin composite cylinder (2.3 mm diameter, 2.2 mm height, Clearfil AP-X, Kuraray Noritake Dental) was bonded to the surface using the corresponding cement under a pressure of 5 N. Following removal of excess cement, the cement was irradiated according to the manufacturers' instructions. The bonded samples were stored in distilled water at 37°C for 24 h. Shear bond strengths were measured using a universal testing machine (Instron 4443; Canton, MA, USA) at a crosshead speed of 1.0 mm/min ($n = 10$). Data were statistically analyzed using one-way ANOVA and Tukey's test at $\alpha = 0.05$.

Results: Means and standard deviations of the shear bond strength were 42.3 ± 7.3 MPa for Panavia V5, 14.3 ± 7.2 for RelyX Ultimate, 6.0 ± 1.5 MPa for NX3 and 13.0 ± 6.0 for Panavia F2.0. The bond strength of Panavia V5 was approximately three times greater than that of Panavia F2.0, and was the statistically significantly highest among the four cements.

Conclusion: The newly developed luting composite resin cement (Panavia V5) demonstrated significantly higher bond strength to dentin than the three reference products tested.

Keywords: resin cement, dentin, adhesive.

Acknowledgment: This study was funded by Kuraray Noritake Dental.

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18. Junior Researcher

Influence of Aging Protocol on the Adhesive Interface Using Different Adhesive Systems

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Purpose: To evaluate the influence of different aging protocols on the microtensile bond strength (μTBS) and nanoleakage between bovine dentin and a composite resin using three adhesive systems.

Materials and Methods: The enamel of the vestibular surface of 120 bovine incisors was ground away to expose the dentin. Teeth were randomly distributed into groups according to the adhesive systems (Adper Scotchbond Multipurpose, Clearfil SE bond, Scotchbond Universal Adhesive) and the aging protocols (storage for 24 h, storage for 6 months, mechanical cycling, thermocycling) used in this study, totaling 12 experimental groups ($n = 10$). After construction of composite blocks, beams were obtained and used for the microtensile and the nanoleakage tests. The percentage of silver nitrate was recorded under energy dispersive spectroscopy. Data were submitted to the Kruskal-Wallis and Mann-Whitney U-tests for post-hoc comparisons (5%).

Results: Thermocycling resulted in lower µTBS values ($p < 0.05$) for Clearfil. The aging protocols had no detrimental effect on the other adhesives. Generally, Scotchbond Multipurpose adhesive showed the highest µTBS values. Clearfil and Universal adhesives yielded more adhesive failures than did Scotchbond Multipurpose, which had more cohesive failures. Storage for 6 months and mechanical cycling resulted in higher nanoleakage ($p < 0.05$) for all adhesives. After mechanical cycling, some significant differences were found (Universal < Scotchbond = Clearfil, $p < 0.05$).

Conclusion: Only thermocycling together with the two-step self-etching adhesive influenced the µTBS. The etch-and-rinse adhesive presented the highest µTBS values. As for nanoleakage, storage for 6 months and mechanical cycling damaged the adhesive interface for all adhesives.

Keywords: aging, self-etching adhesives, bond strength, nanoleakage.

19. Junior Researcher

Effect of Combination of Different Core Buildup Composites/Dual-curing Adhesives on Microtensile Bond Strength to Dentin after Long-term Storage

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Purpose: To evaluate the microtensile bond strength (µTBS) of two core buildup composites (Core.X Flow, Dentsply de Trey and Rebilda, VOCO) combined with two dual-curing adhesive systems (XP Bond+Self Cure Activator, Dentsply and Futurabond DC, VOCO).

Materials and Methods: Twenty sound, freshly extracted human molars were randomly divided into four groups: G1: Futurabond DC/Rebilda (FB+RB); G2: XP Bond+SCA/Rebilda (XP/RB); G3: XP Bond+SCA/Core.X Flow (XP+CF); G4: Futurabond DC/Core.X Flow (FB+CF). Teeth were flattened and dentin was polished down to 600-grit SiC paper. Adhesive systems were applied on dentin surfaces according to manufacturers' recommendations. A metal matrix band was used for constructing a 3-mm high composite buildup, which was then photo-activated (Radii Plus; SDI, output 1411 mW/cm^2) for 40 s. Samples were stored for 24 h or 6 months at 37°C and 100% humidity. The µTBS test was carried out in a universal testing machine operated at a crosshead speed of 1 mm/min. Failure mode was observed under a stereomicroscope. The main factors "combination" and "time" as well as their interactions were tested by 2-way ANOVA ($\alpha = 0.05$).

Results: Significant differences were observed for the factors 'combination' and 'time' ($p < 0.05$). However, no significant difference was observed for the interaction between factors. Storage increased the µTBS values after 6 months. The mean µTBS (SD) values in MPa were: G1: 24.3 (5.2)^{B}; G2: 40.2 (14.1)^{A}; G3: 35.9 (8.0)^{A}; G4: 31.2 (7.8)^{AB}. The mean µTBS (SD) values after 24 h and 6 months in MPa were 27.8 (6.4)^{b} and 37.9 (12.0)^{a}, respectively. Different capital superscript letters indicate significant differences between combinations; different small superscript letters indicate significant differences between storage periods. The lowest bond strength values were found in G1. The µTBS values increased after 6 months storage.

Conclusions: The different dual-curing adhesive/core buildup composite combinations did not reduce the µTBS values in comparison with the original, manufacturer-recommended combination.

Keywords: cements, adhesive system, bond strength.

20. Senior Researcher

Effects of In Vivo and In Vitro Aging Protocols on Resin-Dentin Bond Strength

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Purpose: To evaluate the bond strength of in vivo and in vitro restorations under different aging protocols and simulated pulpal pressure.

Materials and Methods: Fifty teeth were divided into five groups (n = 10): G1: in vivo restoration 24 h prior to extraction; G2: in vitro restoration and 24-h storage in deionized water; G3: in vitro restoration and aging with 28 thermal cycles and 666 mechanical cycles; G4: in vitro restoration under simulated pulpal pressure; G5: in vitro restoration under combined simulated pulpal pressure and aging protocols. Standardized cavity preparations were 4 mm long, 5 mm wide, and 2 mm deep in relation to the marginal ridge. The restorative procedure was performed with Single Bond 2 (3M ESPE, Brazil) and resin composite – Grandio (VOCO, Germany) using an incremental technique. A single calibrated operator performed all procedures, including finishing and polishing of the restoratons. Beams with cross sections of approximately 1 mm^2 were obtained and tested for microtensile bond strength using a universal testing machine using 10 kg load and a crosshead speed of 1 mm/min. Fractures were evaluated with stereomicroscopy; only data from adhesive and mixed fractures were evaluated. Data were analyzed with ANOVA and Tukey's test with $\alpha = 0.05$.

Results: Bond strength means and standard deviations in MPa were: G1: 23.2 ± 3.9^A; G2: 25.0 ± 3.0^A; G3: 24.0 ± 1.8^A; G4: 17.4 ± 1.8^B ; G5:19.5 ± 1.6^B. Significant differences between groups were detected ($p < 0.05$). Tukey's test idenitifed a significant reduction in G4 and G5 compared with the other groups.

Conclusion: Restoration under simulated pulpal pressure resulted in significant bond strength reduction compared to the in vivo control group (G1).

Keywords: microtensile bond strength, aging, simulated pulpal pressure, in vivo, in vitro.

Acknowledgment: Research funded by FAPESP 2014/07047-5.

21. Senior Researcher

Effect of Fluoride Varnishes on Bond Strength to Enamel

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Purpose: To evaluate the effect of three varnishes containing casein phosphopeptide-amorphous calcium phosphate, tricalcium phosphate, and fluoride on shear bond strength (SBS) of two adhesive systems to enamel.

Materials and Methods: Forty-eight permanent molars were hemi-sectioned buccolingually and embedded in acrylic resin. The outer surfaces of specimens were ground with 600-grit SiC paper to create flat enamel surfaces and randomly distributed into four groups according to the enamel pretreatment agents; control (no treatment, CNT), MI Varnish (MIV), Clinpro White varnish (CWV), and Duraphat varnish (DV). Each group was further divided into two adhesive subgroups (n = 12) as follows: etch-and-rinse (Adper Single Bond, ASB) or self-etching (Clearfil SE Bond, CSE). Enamel surfaces were pretreated with the varnishes and stored in distilled water at 37°C for 24 h. The pretreatment agent residues were then removed with acetone solution (1:1) and a plastic scaler. Cylindrical composite samples (2.3 mm in diameter, 3 mm in height) were bonded to the enamel surfaces with one of the study adhesives. The specimens were stored in distilled water at 37°C for 24 h and then subjected to a SBS test. The data were analyzed by one-way ANOVA and Tukey's test.

Results: For both CSE and ASB, SBS values of the CNT groups were significantly higher than those of other groups ($p < 0.05$). Among the enamel pretreatment groups, SBS values of both adhesive systems were lowest in group MIV, followed by the groups CWV and DV.

Conclusion: Pretreatment of enamel surfaces with fluoride-containing varnishes reduced the bonding performance of adhesive systems to enamel. It seems that MIV application caused greater enamel surface alterations and precipitation, which interfered with the bonding mechanism of the adhesives.

Keywords: casein phosphopeptide-amorphous calcium phosphate, enamel, fluoride, shear strength, varnish.

Mean (MPa) and standard deviations		
Groups	ASB	CSE
CNT	30.49 ± 2.08[1,A]	29.05 ± 1.66[1,A]
MIV	18.33 ± 1.87[1,D]	19.20 ± 2.66[1,C]
CWV	22.10 ± 2.40[1,C]	23.70 ± 2.37[1,B]
DV	24.19 ± 1.96[1,B]	25.60 ± 1.89[1,B]

*Different superscript letters and numbers indicate significance within columns and rows ($p < 0.05$).

22. Junior Researcher

Temporal Development of Dentin-Composite Bond Strength During Curing

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Purpose: To determine the time-dependent formation of the dentin-composite bond during light curing and to investigate the effect of composite thickness on its rate of formation.

Materials and Methods: A 0.2-mm-thick layer of uncured composite (Z250, 3M ESPE) was placed between a cured block of the same composite (1.0 or 3.0 mm thick) and a bovine dentin slab with a layer of adhesive (Single Bond, 3M ESPE; output 1200 mW/cm^2) pre-cured on its surface. The assembly was cured through the composite block using a 3M ESPE S-10 curing light modified with a power supply and a digital trigger. The dentin-composite bond strength at 0.5, 1.0, 2.5, 5.0, 7.0, 10, 15, and 20 s was measured by the uniaxial tensile test. Forty specimens were prepared for each thickness, providing 5 measurements per time point. The failure surfaces were examined by SEM to determine the proportions of cohesive and adhesive failure.

Results: Bond strength (S) increased with time (t) according to the equation $S = S_0\ (1–e^{–kt})$, where S_0 is the final bond strength and k the rate of formation (Fig 1). The values of S_0 and k were 11.26 MPa, 0.513 s^{-1} and 10.06 MPa, 0.236 s^{-1} for the 1.2-mm-and 3.2-mm-thick specimens, respectively. Initially, only composite and adhesive could be seen on the failure surfaces (Fig 2). With time, an increasing proportion of dentin surfaces could also be seen, which appeared earlier in the thin specimens than in the thick ones.

Conclusion: The time-dependent dentin-composite bond strength follows the equation $S = S_0\ (1–e^{–kt})$, with the rate of development being reduced by composite thickness. The predominant mode of failure changed from cohesive in the composite and adhesive at the composite/adhesive interface to adhesive at the adhesive/dentin interface.

Keywords: composite resins, dentin, bond strength.

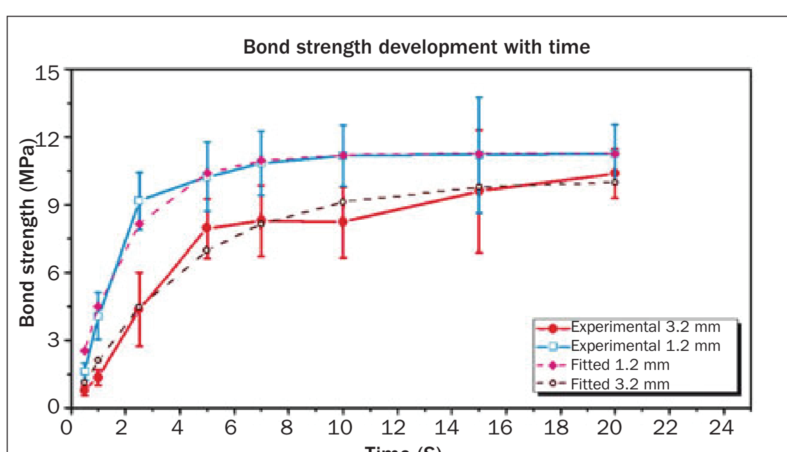

Fig 1 Bond strength development with time.

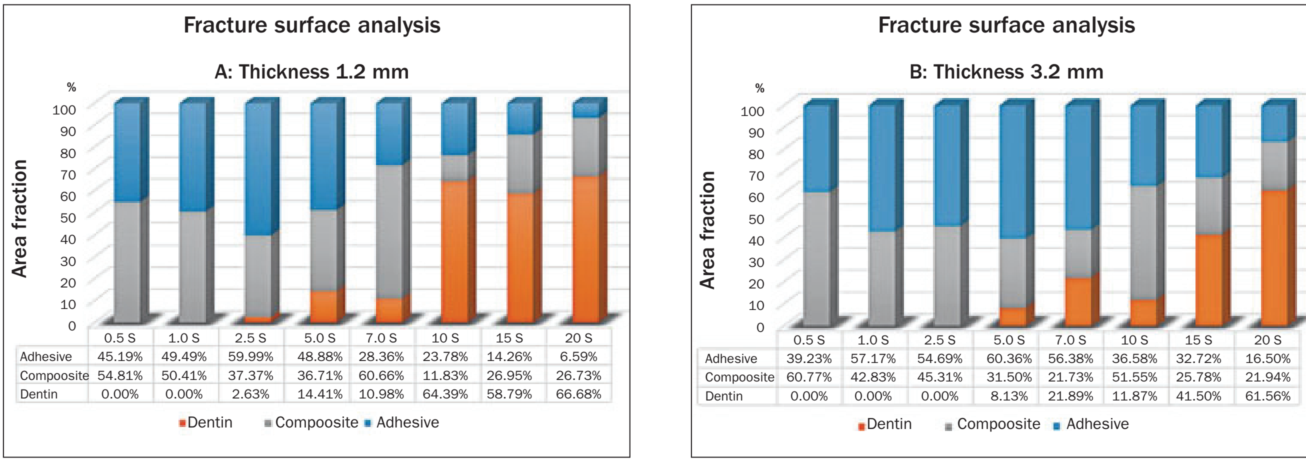

Fig 2 Fracture surface analysis.

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23. Junior Researcher

Evaluation of Dentin Bond Strength by a Thin-film Scratch Test

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Purpose: To evaluate 1) thin-film bond strength between a bonding agent and human dentin using a scratch test, and 2) the characteristics and accuracy of measurement.

Materials and Methods: Four one-step bonding agents (BeautiBond; Bond Force; Adper Easy Bond; Clearfil tri-S Bond) and two two-step bonding agents (Cleafil SE Bond; FL-Bond II) were investigated in this study. Flat dentin surfaces were prepared on extracted human molars. The dentin surfaces were ground and bonding agents were applied and light cured. The thin-film bond strength test of the specimens was evaluated by the critical load at which the coated bonding agent failed and dentin appeared. The scratch-mark sections were then observed under a scanning electron microscope. Indentation hardness was evaluated by the variation in depth under an applied load of 10 gf. Data were compared using one-way ANOVA with the Scheffé's post-hoc multiple comparison test ($p < 0.05$). In addition, thin-film bond strength and indentation hardness were analyzed using analysis of correlation and covariance.

Results: The thin-film bond strength of two-step bonding agents were found to be significantly higher than that of one-step bonding agents with small standard deviations (Table 1). Scratch marks consistently showed adhesive failure in the vicinity of the bonding agent/dentin interface. The indentation hardness showed a trend that two-step bonding agents have greater hardness than one-step bonding agents (Table 2). A moderately significant correlation ($r^2 = 0.31$) was found between thin-film bond strength and indentation hardness.

Conclusion: The thin-film bond strength test is a valid and reliable means of evaluating bond strength in the vicinity of the adhesive interface and is more accurate than other methods currently in use. Further, the thin-film bond strength is influenced by the hardness of the bonding agent.

Keywords: thin-film bond strength, indentation hardness, scratch test, bonding agent.

Table 1 Thin-film bond strength values (in N) for bonding agents to human dentin

Steps	Adhesive	Mean (N)	SD	Group differences*
One	Beauti Bond	5.64	0.94	c
One	Bond Force	7.19	0.92	b
One	Adper Easy Bond	5.81	0.85	c
One	Clearfil Tri S Bond	5.63	0.85	c
Two	Clearfil SE Bond	8.90	0.68	a
Two	FL-Bond II	8.30	0.53	ab

*Groups with different letters are significantly different from each other.

Table 2 Indentation hardness values for bonding agents

Steps	Adhesive	Mean	SD	Group differences*
One	Beauti Bond	14.55	1.75	b
One	Bond Force	7.95	1.35	cd
One	Adper Easy Bond	9.09	1.17	c
One	Clearfil Tri S Bond	6.74	1.44	d
Two	Clearfil SE Bond	13.17	0.63	b
Two	FL-Bond II	20.79	1.09	a

*Groups with different letters are significantly different from each other.
Load: 10 gf for 15 s. Hardness values were calculated as 37.838 x load (gf)/indentation depth(μm)^2

24. Student Researcher

Adhesion of Resin Cement to Zirconia Using Plasma and Primer

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Purpose: To evaluate the effectiveness of nonthermal atmospheric plasma (NTAP) and priming on the shear bond strength of a resin cement to two zirconia ceramics.

Materials and Methods: Sixty Katana zirconia (Kuraray Noritake) and 60 ZirCAD (Ivoclar Vivadent) plates (9 mm x 7 mm x 1 mm) were prepared and randomly divided into 12 groups (n = 10). The zirconia plates were embedded in resin blocks and the exposed surface was submitted to the following treatments: 1) untreated (control); 2) treated with Z-Prime Plus (Bisco) primer; 3) NTAP (model SAP, surface) application for 10 s; 4) NTAP for 30 s; 5) NTAP for 10 s followed by priming; 6) NTAP for 30 s followed by priming. The resin cement (Panavia F2.0, Kuraray Noritake) was manipulated and inserted into two prefabricated matrices (2.37 mm diameter x 1 mm height) positioned on the zirconia surfaces. Specimens were tested after 24 h and 1 year of water storage. A shear load was applied to the base of the resin cement cylinders with a loop wire (0.20 mm diameter) at 0.5 mm/min until failure. Data were analyzed by three-way ANOVA and Tukey's test at $\alpha = 5\%$.

Results: At 24 h, bond strength was higher for ZirCAD in all treatments, except for 30 s of NTAP + primer. For Katana, increasing of NTAP application time followed by priming yielded higher bond strength. After 1 year of storage, there was no significant difference in the bond strength among treatments and zirconias. Bond strength decreased after 1 year of storage, independent of treatment and zirconia ceramic.

Table 1 Mean (SD) bond strength of resin cement to zirconia (in MPa)

Time	Treatment	Zirconia	
		ZirCAD	Katana
24 h	No treatment	*6.9 (1.18) Ad	*3.5 (1.35) Bd
	Primer	*7.6 (2.50) Acd	*4.8 (2.92) Bd
	NTAP 10s	*11.4 (2.21) Aa	*6.9 (2.35) Bc
	NTAP 30s	*8.7 (1.13) Abc	*7.2 (1.56) Bc
	NTAP 10s + Primer	*12.8 (2.74) Aa	*9.5 (3.33) Bb
	NTAP 30s + Primer	*9.6 (3.32) Ab	*11.4 (2.06) Ba
1 year	No treatment	0.0 (0.00) Aa	0.7 (0.55) Aa
	Primer	0.1 (0.20) Aa	0.9 (0.72) Aa
	NTAP 10s	0.0 (0.00) Aa	0.4 (0.44) Aa
	NTAP 30s	0.0 (0.00) Aa	1.0 (0.66) Aa
	NTAP 10s + Primer	0.2 (0.20) Aa	1.3 (0.52) Aa
	NTAP 30s + Primer	0.2 (0.70) Aa	1.2 (0.54) Aa

Means followed by different letters (capital letters compare different zirconia ceramics and lower case letters compare treatments) differ significantly ($p \leq 0.05$). Asterisks show differerences under the same treatment conditions and zirconias after 1 year of storage ($p \leq 0.05$).

Conclusions: NTAP application increases the bond strength of resin cement to zirconia. When followed by priming, it only increased bond strength for Katana zirconia. After 1 year of storage, bond strength decreased dramatically for all groups in both zirconias.

Keywords: zirconia, argon plasma, primer, resin cement, bond strength.

25. Junior Researcher

Effect of Surface Treatment on Bond Strength to Hybrid Ceramic

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Purpose: This study investigated the effect of different surface treatments on the bond strength of two different luting agents to a hybrid ceramic material.

Materials and Methods: A total of 160 specimens (10 x 10 x 2 mm) of a CAD/CAM hybrid ceramic (VITA ENAMIC, Vita Zahnfabrik) were randomly divided into 8 groups ($n = 20$) based on the respective surface treatment: as-milled with Cerec MXCL (Cerec surface, C), Cerec surface + Silane (CS), hydrofluoric acid (HF), HF + silane (HFS), airborne-particle abrasion (AA), AA + silane (AAS), machined (M), and polished (P). Two subgroups of $n = 10$ per group were created by bonding resin composite cylinders (Tetric EvoCeram, shade A2, Ivoclar Vivadent) to the ceramic with two different luting agents: Variolink II (VL, Ivoclar Vivadent) and Rely X Unicem2 (RU, 3M ESPE). Specimens were stored in distilled water at 37°C for 24 h and then subjected to 10,000 thermocycles at 5°C and 55°C. Shear bond strength was tested in a universal testing machine at a crosshead speed of 1 mm/min. Failure modes were investigated with a light microscope at 30X. Data were analyzed with Student's t-test and the Tukey-Kramer test at $\alpha = 0.05$.

Results: As shown in Table 1, pretreatment methods had significant effects on bond strength ($p < 0.001$). Treatments with application of a silane coupling agent revealed significantly higher bond strength values than the ones without ($p < 0.05$). Different adhesive cements had no effect on bond strength ($p > 0.05$). Failure modes were predominantly mixed (adhesive and cohesive combined) for all groups.

Conclusion: Hydrofluoric acid etching and silane application provided the highest bond strength values. Different cements did not affect bond strength.

Table 1 Mean (SD) shear bond strength values in MPa

Cement \ Group	C	CS	HF	HFS	AA	AAS	M	P
VL	9.32[a] (5.99)	22.00[b] (8.00)	16.44[b] (2.89)	22.71[b] (5.44)	17.46[b] (4.11)	18.95[b] (2.76)	7.41[a] (4.56)	4.48[a] (2.79)
RU	10.72[df] (4.33)	20.92[c] (3.33)	16.88[cd] (6.62)	16.63[cd] (5.62)	15.94[cde] (4.66)	13.88[def] (5.08)	8.90[f] (3.38)	9.39[ef] (4.28)

Different superscript lower-case letters indicate significant differences within rows. Different cements had no effect on bond strength (columns).

Keywords: resin cements, CAD/CAM, hybrid materials, adhesive luting.

Acknowledgment: All materials used in this study were sponsored by VITA Zahnfabrik, Bad Säckingen, Germany.

26. Senior Researcher

Bond Strength of Different Luting Cements to Metal Alloy Surfaces

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Purpose: To compare shear bond strengths of seven different luting cements to different metal alloy surfaces.

Materials and Methods: Three water-based cements were examined (Durelon carboxylate [DC, 3M ESPE], glass ionomer [GI, Ketac-CEM 3M ESPE], zinc phosphate cement [ZP, Hoffmann's Harmonic Shades]), 2 resin-based cements (RelyX U200 [RX, 3M ESPE], C&B Cement [CB,Bisco]), and 2 temporary cements (RelyX Temp NE [RXT, 3M ESPE], Telio CS Cem Implant [TCS, Ivoclar]). Sixteen square blocks (5 x 5 x 3 mm) were prepared from titanium (T), gold (G) and chrome cobalt (CC) metal alloys for each cement group. The top surfaces of metal blocks were polished with #600 SiC papers. Cylindrical composite samples (2.1 mm in diameter, 3 mm in height) were prepared and bonded to the polished metal surfaces with one of the study cements in a special alignment apparatus, where a load of 10 N was applied for 10 min. The specimens were irradiated for 40 s from three sides for a total of 120 s. The specimens were then stored in deionized water at 37°C for 24 h. Shear bond strengths were determined at a crosshead speed of 0.5 mm/min. Data were analyzed with ANOVA and Tukey's HSD test.

Results: RX showed the highest bond strengths for titanium alloy surfaces. However, GI did not bond to titanium. Bonding performance of temporary cements to metal alloy surfaces was not reliable.

Groups	Means ± SD in MPa		
	T	G	CC
DC	3.75 ± 0.9[d]	4.08 ± 0.4[d]	3.69 ± 0.9[d]
GI	0[a]	1.28 ± 0.1[b]	2.45 ± 0.8[c]
ZP	2.26 ± 0.7[bc]	0.43 ± 0.1[a]	1.84 ± 0.6[bc]
RX	5.71 ± 2.2[e]	2.32 ± 0.6[c]	2.62 ± 0.8[cd]
CB	1.44 ± 0.5[bc]	2.96 ± 0.4[cd]	1.51 ± 0.4[bc]
RXT	0.47 ± 0.1[a]	0.50 ± 0.1[a]	0.50 ± 0.3[a]
TCS	0.75 ± 0.2[ab]	0.44 ± 0.1[a]	0.24 ± 0.1[a]

Same letters indicate statistically similar groups ($p > 0.05$).

Conclusion: The water-based carboxylate cement provided reliable bonding performance to metal alloy surfaces.

27. Senior Researcher

Bond Strength of Multi-Mode Adhesives to Indirect Restorative Materials

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Purpose: To investigate the bond strength performance of two multi-mode adhesives (MMA) to indirect resin composite and lithium disilicate glass ceramic substrates after 24 h or 1 year water storage.

Materials and Methods: Sixty flat, polished plates of indirect resin composite (Epricord, n = 30) and lithium disilicate glass ceramic (IPS e.max Press, n = 30) were prepared. The surfaces were pre-treated using sandblasting for the indirect resin composite or hydrofluoric acid for the glass-based ceramic plates. The specimens were bonded with two MMAs: Scotchbond Universal (SBU), All-Bond Universal (ABU), or ceramic primer and hydrophobic bonding resin (RelyX Ceramic Primer and Adper Scotchbond Multi-Purpose Bond) as a control group. Small resin cement cylinders were also bonded to both substrate surfaces using the respective adhesive manufacturer's instructions. After 24 h or 1 year water storage at 37°C, their bonding performance was measured using the microshear bond strength test. The results were statistically analyzed using two-way ANOVA with Tukey's post-hoc test at a significance level of 0.05.

Results: For the indirect resin composite, there was a significant difference between ABU and SBU, which did not differ from the control after 24 h (ABU > SBU = control). However, no significant difference between groups was observed after 1 year ($p > 0.05$). For the glass-based ceramic, no significant differences in bond strength were observed between SBU and ABU adhesives after 24 h (control = ABU ≥ SBU). After 1-year storage, bond strength for ABU decreased significantly (control > SBU = ABU) ($p < 0.05$).

Conclusions: After aging, the MMAs showed good bonding performance to indirect resin composite, but the use of separate bottles of silane and resin bonding is still recommended for etched-glass-based ceramic substrates.

Keywords: multi-mode adhesives, indirect resin composite, lithium disilicate glass ceramic, bond strength, storage time.

Table 1 Microshear bond strength values in MPa (mean ± standard deviation) of the adhesives tested on an indirect resin composite substrate, after 24-h or 1-year storage

Material	24 h	1 year
Scotchbond Universal	26.6 ± 5.6^{Aa}	20.2 ± 3.1^{Ba}
All-Bond Universal	32.7 ± 3.3^{Ab}	25.1 ± 2.0^{Ba}
RelyX Ceramic Primer and Adper Scotchbond Multi-Purpose Bond	25.5 ± 7.9^{Aa}	22.7 ± 2.7^{Aa}

Two-way ANOVA with post-hoc Tukey's test ($p < 0.05$). Similar capital letters in rows and lower case letters in columns indicate statistical similarity.

Table 2 Microshear bond strength values in MPa (mean ± standard deviation) of the different adhesives tested on lithium disilicate glass ceramic substrate, after 24-h or 1-year storage

Material	24 h	1 year
Scotchbond Universal	23.9 ± 6.1^{Aa}	21.3 ± 5.6^{Aa}
All-Bond Universal	31.5 ± 7.0^{Aab}	16.9 ± 4.4^{Ba}
RelyX Ceramic Primer and Adper Scotchbond Multi-Purpose Bond	35.3 ± 8.5^{Ab}	31.2 ± 5.9^{Ab}

Two-way ANOVA with post-hoc Tukey's test ($p < 0.05$). Similar capital letters in rows and lower case letters in columns indicate statistical similarity.

28. Student Researcher

Acoustic Properties of Interfacial Debonding of Resin Composite Restoration During Curing

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Purpose: To investigate the properties and their correlations of acoustic emissions (AE) of interfacial debonding of composite restoration during curing.

Materials and Methods: An AE sensor (Physical Acoustics, USA) was attached to the surface of intact human molars with a Class I composite restoration of 4 x 3 x 2 mm^3 to monitor the interfacial debonding during curing. Background signals were analyzed before curing to determine the threshold amplitude for noise filtering. Three groups of composites were tested: (1) Z100 Restorative, (2) Filtek Z250, and (3) Filtek LS (all 3M ESPE, USA). The restorations in groups (1) and (2) were bonded with Adper Single Bond Plus and those in group (3) with LS System Adhesive from the same manufacturer. All restorations were cured with an LED blue light (3M S-10, output 1200 mW/cm^2) for 40 s. AE signals were recorded continuously for 10 min, and their frequency, amplitude, and duration were analyzed.

Results: 30 dB was chosen as the threshold with the background signals mainly around 25 dB. The cumulative number of AE events was 28, 19, and 5, for Z100, Z250, and LS, respectively (Fig 1), which corresponded to the shrinkage stress. The amplitude of all events lay mainly within the range of 30 to 50 dB, whereas the peak frequency had two main values: 100 to 200 kHz and 700 to 800 kHz. The duration range of 0 to about 200 µs increased with increasing amplitude (Fig 2), but no correlation was found between frequency and the other two parameters.

Conclusion: 30 dB should be used as the amplitude threshold for AE analysis of interfacial debonding. The amount of interfacial debonding increased with the shrinkage stress of a composite. The duration of an AE event increased with its amplitude, but there was no correlation between its frequency and the other two parameters.

Keywords: resin composite restoration, interfacial debonding, acoustic emission.

Acknowledgment: The authors would like to acknowledge 3M ESPE for providing the restorative materials, and the Minnesota Dental Research Center for Biomaterials and Biomechanics (MDRCBB) for providing the testing devices.

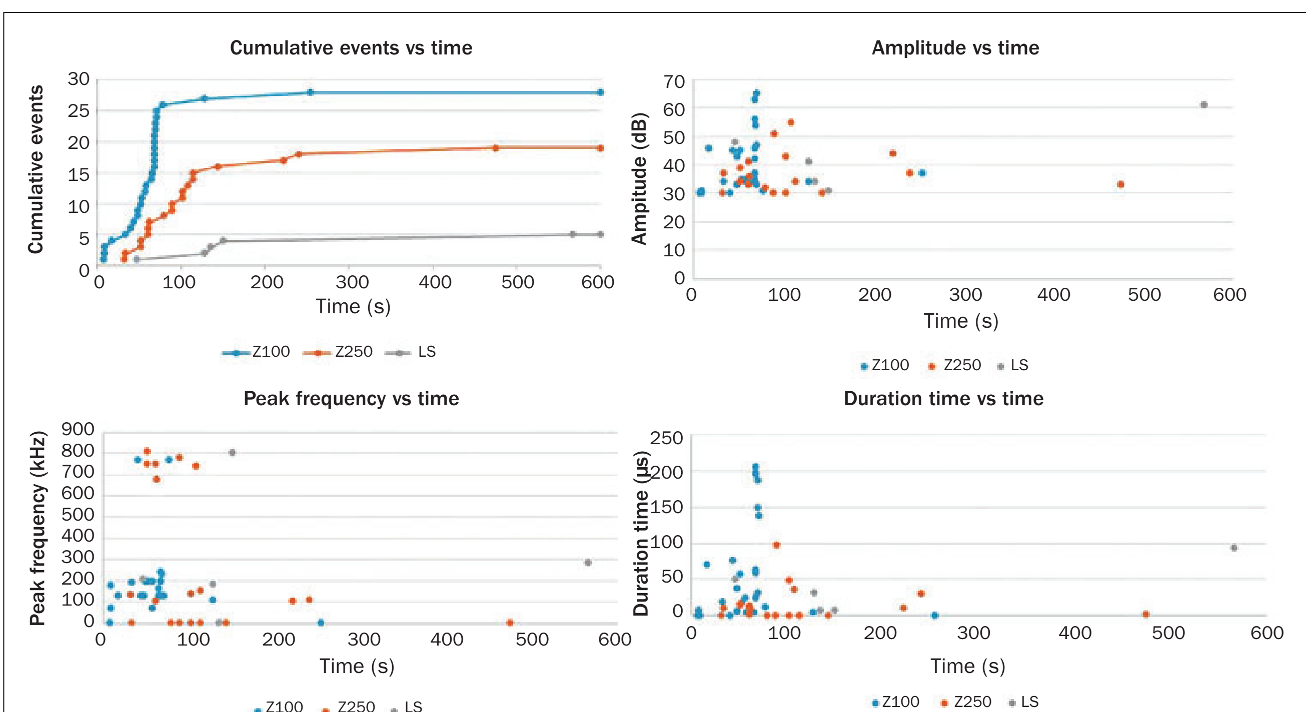

Fig 1 Cumulative events, amplitude, peak frequency, and duration with time.

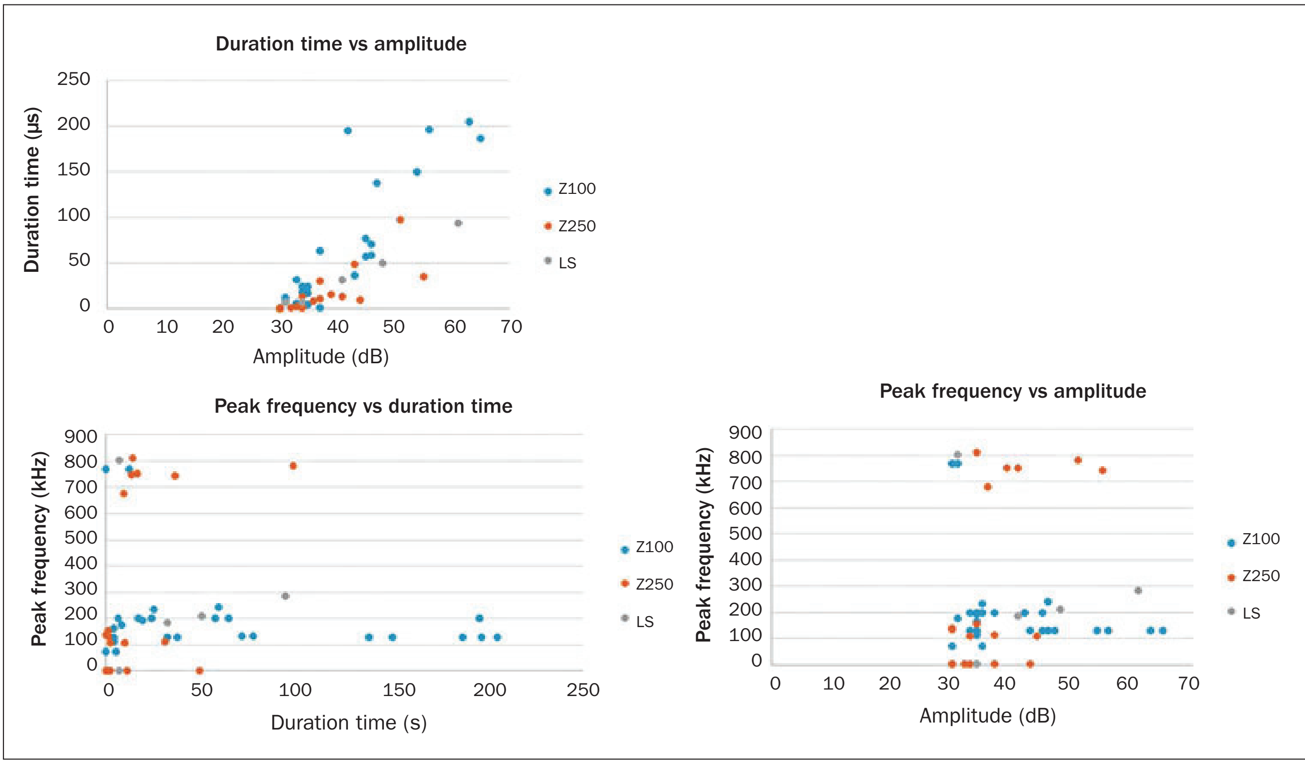

Fig 2 Correlations of AE event properties.

29. Junior Researcher

Internal Adaptation Depending on Resin Polymerization Stress

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[c]*Tokyo Medical and Dental University, Tokyo, Japan.*

[d]*Yonsei University, Seoul, Korea.*

Purpose: The first purpose of this study was to compare internal adaptations of different composite resins in cavities of two different depths. The second purpose of this study was to find out the relationship between internal adaptation and polymerization shrinkage stress.

Materials and Methods: One hundred teeth were divided into “deep” and “shallow” groups. The deep group had a cylindrical cavity with a diameter of 3 mm and a depth of 4 mm, whereas the shallow group had a cylindrical cavity with a diameter of 3 mm and a depth of 1 mm. The deep and shallow groups were each divided into 5 subgroups depending on the material used: Filtek supreme (3M), Charisma Diamond (Heraeus Kulzer), Amelogen Plus (Ultradent), Tetric Evoceram Bulk Fill (Ivoclar Vivadent), and Venus Bulk Fill (Heraeus Kulzer). After application of dentin adhesive, composite resin was filled or built up in the same dimension (3 mm diameter, 4 mm height). Thermomechanical cycling was applied, and SS-OCT images were taken to measure internal adaptations. Internal adaptations were compared in two ways: among the different materials and between the two cavity configurations. The polymerization shrinkage stress of resin composite was measured in two ways: the stress under zero-compliance condition and that under compliance-allowed condition. The relationships between internal adaptations and polymerization stress were investigated.

Results: A significant difference was found between internal adaptations of deep and shallow cavities. Statistically significant differences were found among some subgroups of different materials. In shallow cavities, the relationship between the leakage and polymerization stress under the zero-compliance condition ($R^2 = 0.498$) was found to be lower than that under compliance-allowed condition ($R^2 = 0.649$).

Conclusion: Internal adaptation was inferior in the deep cavity group. SS-OCT images showed different internal adaptations depending on the material used. In the shallow cavity group, the relationship between internal adaptation and polymerization stress under zero-compliance conditions were different from that of polymerization stress under compliance-allowed condition.

Keywords: internal adaptation, C-factor, composite resin, polymerization stress, compliance.

30. Student Researcher

Influence of Organic Acids from Oral Biofilm on Resin Composite Properties

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Purpose: To evaluate the repair bond strength after storage in water, lactic and propionic acid for 7 days and 6 months as well as the sorption and solubility of resin composites used.

Materials and Methods: Five cylinders of each resin composite (microhybrid, nanofilled, and silorane-based) were prepared. Specimens were aged by thermocycling (5°C and 55°C) 5000 times. A repair procedure was performed using intraoral sandblasting with 50-µm aluminum oxide, application of an adhesive system, and a cylinder of composite. Specimens were sectioned into beams and stored in three immersion media: water, propionic acid, and lactic acid. The microtensile bond strength was measured after periods of 7 days and 6 months. Sorption and solubility were evaluated using fifteen specimens (Ø = 6 mm; height = 1 mm) of each resin composite, which were prepared and assigned into three groups (n = 5) according to the immersion media. Data were analyzed using one-way/two-way/three-way ANOVA and Tukey's test ($\alpha = 0.05$).

Results: The resin composites, immersion media, and time of immersion did not affect the repair bond strength (microhybrid 38.3 to 40.9 MPa; nanofilled 38.7 to 42.2 MPa; silorane 41.2 to 51.1 MPa). Additionally, the immersion media did not affect the sorption and solubility. The silorane-based composite presented the lowest sorption (10.5 to 12.1 µg/mm^3) and solubility (-2.4 to -2.7 µg/mm^3), while the nanofilled methacrylate-based composite showed the highest sorption (32.1 to 33.6 µg/mm^3). Regarding solubility, the nanofilled and microhybrid methacrylate-based composites did not present statistically significant differences.

Keywords: resin composite, bond strength, sorption, solubility, biofilm.

31. Student Researcher

Influence of PVM/MA Copolymer on Surface Adherence of Streptococcus Mutans

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Purpose: The study investigated 1. the surface roughness of a one-bottle adhesive bonding agent by incorporating a polyvinyl methylether/maleic acid (PVM/MA) copolymer, and 2. its antibacterial activity in preventing colonization of composite surfaces by cariogenic Streptococcus mutans biofilms.

Materials and Methods: Eighteen composite-resin (Estelite Omega, Tokuyama Dental) disks (diameter 8 mm, thickness 2 mm) were made. The adhesive bonding agent Prelude One (PO; Danville Materials) was applied to composite surfaces with or without incorporation of PVM/MA. Composite samples without bonding application were used as controls. The surface roughness of the samples was determined through a stylus profilometer. Bacterial adherence to surfaces was assessed by determining colony-forming units (CFU) and viewed with scanning electron microscopy (SEM). The specimens were sterilized by UV irradiation before incubation with bacteria and immersed in sterilized whole saliva for 2 h, then placed in individual wells containing 1 x 10^8 cells/ml of S. mutans in PBS. Immersed specimens were incubated at 37°C for 4 h and washed with PBS to remove unattached bacteria. Specimens were then placed into tubes containing 1 ml of PBS. Attached bacteria were dispersed by sonication and CFU counts were determined. For SEM analysis, three specimens prepared in the same manner as for counting CFU were immersed in Karnovsky's fixative for 24 h, then coated with gold-palladium. Data were analyzed with ANOVA and Tukey's test.

Results: Integration of PVM/MA into PO increased the surface roughness of the composite surfaces 4.6 fold; however, it decreased colonization of S. mutans biofilms 2.1 fold. SEM images also confirmed these results.

	Control	PO	PVM/MA+PO
Surface roughness (µm)	0.027 ± 0.005^{A}	0.543 ± 0.113^{A}	2.492 ± 0.763^{B}
CFU (10^3 cfu/mm^2)	4.84 ± 1.12^{a}	15.02 ± 2.04^{b}	7.32 ± 1.92^{a}
Means with the same superscript letter are not statistically different from each other ($p > 0.05$).			

Conclusions: Integration of PVM/MA into the dentin bonding agent showed an antibacterial effect, which helps to reduce the initial adhesion of bacteria onto the composite surfaces.

Keywords: PVM/MA, antibacterial, bonding.

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32. Student Researcher

Push-Out Bond Strength of an Experimental Post in Bovine Root Dentin

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Purpose: To evaluate the bond strength of bovine dentin (experimental) and glass-fiber (control) posts to root canal walls in bovine dentin.

Materials and Methods: Twenty bovine incisor roots were selected to receive experimental (bovine dentin) posts and glass fiber posts (n = 10 for each group). After canals were prepared and irrigated (2.5% NaOCl), dentin canal walls and experimental posts were conditioned under the same adhesive protocol (H_3PO_4 37%/15 s + conventional one bottled adhesive). The glass fiber post surfaces were conditioned (24% H_2O_2/5 min), air dried, and silanized. Posts were cemented with a dual-curing resin cement (1200 mW/cm^2 /40 s). In order to evaluate bond strength in different regions (coronal, middle, and apical), the root-post set was sectioned into 1.5-mm-thick disks and submitted to the push-out test in a universal testing machine (1.0 mm/min). After subjecting bond strength data to Levene's test and the sample homoscedasticity was confirmed, data were subjected to two-way ANOVA ($\alpha = 0.05$).

Results: While there was no statistically significant difference ($p > 0.05$) for the "root region" factor or for the interaction, the experimental posts showed statistically significantly higher bond strength values (9.52 ± 1.93 MPa) when compared to glass fiber posts (6.74 ± 3.35 MPa).

Conclusion: Within the limitations of this study, it can be inferred that the experimental post of bovine dentin led to higher bond strength values than did a conventional glass-fiber post.

Keywords: bond strength, bovine dentin, experimental posts, fiber post.

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33. Student Researcher

Properties of a Novel Resin-based Pulp Capping Material

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Purpose: To evaluate the physicochemical properties, cytotoxicity, and bioactivity of a novel light-curing pulp capping material composed of resin with antibacterial monomer (MAE-DB) and Portland cement (PC).

Materials and Methods: The experimental material was prepared by mixing PC with a resin containing MAE-DB. Cured pure resin containing MAE-DB served as resin control. ProRoot MTA and Dycal served as commercial controls. The depth of cure, degree of monomer conversion, water absorption, solubility, calcium release, alkalinizing activity, cytotoxicity, and bioactivity were evaluated.

Results: The experimental material had a curing depth of 1.19 mm and a high degree of monomer conversion. Its water absorption was between that of MTA and Dycal, and its solubility was significantly less than that of Dycal. The experimental material exhibited continuous calcium release and an alkalinizing power between those of MTA and Dycal throughout the test period. None of the tested materials showed cytotoxicity. The experimental material, MTA, and Dycal all exhibited the formation of apatite precipitates after immersing in PBS.

Conclusion: The novel material possessed adequate physicochemical properties, low cytotoxicity, and good bioactivity. These properties provide major advantages for a pulp capping material and make it an attractive alternative to conventional pulp capping materials.

Keywords: pulp capping material, quaternary ammonium salt, Portland cement, physicochemical properties, cytotoxicity, bioactivity.

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34. Junior Researcher

N-acetyl Cysteine (NAC)-directed Detoxification of Methacryloxylethyl Cetyl Ammonium Chloride (DMAE-CB)

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Purpose: Methacryloxylethyl cetyl ammonium chloride (DMAE-CB) is a polymerizable antibacterial monomer with reliable bacterial inhibitory effects. The cytotoxicity of DMAE-CB has been attributed to the induction of reactive oxygen species (ROS) with reduced glutathione (GSH). The aim of this study was to investigate the role of adduct formation in N-acetyl cysteine (NAC)-directed detoxification.

Materials and Methods: To this end, the possible formation of NAC-DMAE-CB adduct was investigated by high performance liquid chromatography (HPLC) and liquid chromatography-mass spectrometry (LC-MS). Human dental pulp cells (hDPCs) were exposed to different concentrations of DMAE-CB (0.001 to 0.1 mM), and the cytotoxicity was assessed

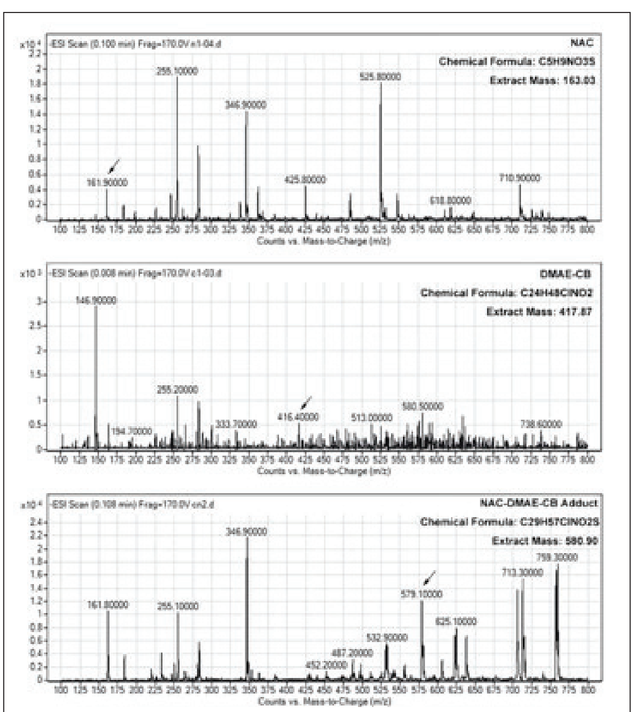

Fig 1 Results of LC-MS.

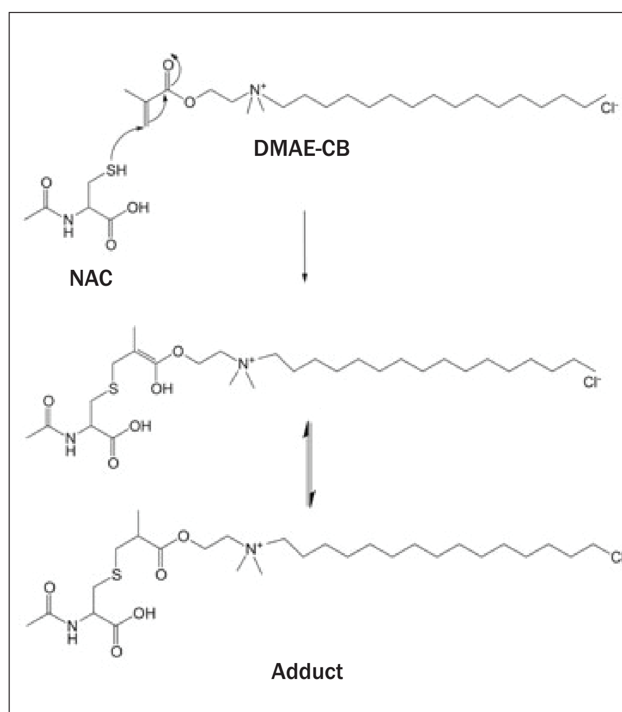

Fig 2 Postulated chemical reaction between NAC and DMAE-CB.

by CCK-8 assay. To investigate the oxidative stress, the contents of ROS and GSH were determined by flow cytometry and microplate reader, respectively. To examine apoptosis, hDPCs treated with the DMAE-CB and the mixtures of NAC and DMAE-CB with 48 h of pre-incubation were analyzed by flow cytometry using Annexin V and propidium iodide staining. Hoechst 33342 staining was also performed to observe the morphological changes of the apoptotic cells. Mitochondrial membrane potential (MMP) and caspase-3 activity were also performed by flow cytometry and microplate reader.

Results: HPLC and LC-MS analysis revealed that chemical binding of NAC and DMAE-CB occurred under neutral conditions after pre-incubation in a time-dependent manner. The amounts of the NAC-DMAE-CB adduct increased with incubation time. DMAE-CB reduced hDPC viability by increasing ROS and reducing the cellular GSH. Flow cytometry indicated that DMAE-CB induced hDPC apoptosis with reduced MMP and increased caspase-3 activity. Typical morphologies of apoptotic cells and morphological hallmarks of chromatin condensation were observed under fluorescence microscopy. However, remarkable protection against DMAE-CB-induced cell death was detected when the mixture was tested after 48 h of pre-incubation.

Conclusion: Our results suggest that the in vitro detoxification ability of NAC against DMAE-CB-induced cell damage might occur through NAC-DMAE-CB adduct formation.

Keywords: DMAE-CB, NAC, ROS, adduct, detoxification.

Acknowledgements: This study was financially supported by grant 81130078 (principal investigator Jihua Chen) and grant 81300927 (principal investigator Sai Ma) from the National Nature Science Foundation of China, and Program No. IRT13051 from the Program for Changjiang Scholars and Innovative Research Team at University (PCSIRT). There is no conflict of interest.

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35. Senior Researcher

Canal Irrigants and Coronal Fracture Resistance of Endodontically Treated, Bleached Teeth

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Purpose: Irrigation plays a pivotal role in the success of endodontic treatment. Various single and combined irrigants and irrigation protocols are used during endodontic treatment. The aim of this study was to evaluate the effect of different irrigation regimens on coronal fracture resistance of endodontically treated teeth undergoing bleaching treatment.

Materials and Methods: Access cavities were prepared in 216 maxillary premolars which were divided into 2 groups ($n = 108$). Group A: non-bleached (NB); group B: bleached (B). Each group was subdivided into 9 subgroups based on irrigation protocol ($n = 12$). During endodontic treatment, the teeth were irrigated as follows: G1: normal saline (NS); G2: 2.5% NaOCl; G3: 10% citric acid (CA); G4: 2% chlorhexidine (CHX); G5: 17% EDTA; G6: NaOCl plus CHX; G7: NaOCl plus EDTA; G8: NaOCl plus CA, G9: NaOCl plus EDTA plus CHX. In group B, after cervical sealing with light-cured glass ionomer, the teeth were bleached using 38% hydrogen peroxide and 20% carbamide peroxide gels as in-office and at-home bleaching techniques for 3 weeks. All the teeth (NB & B) were restored with composite resin, thermocycled, and incubated for 24 h. The specimens underwent fracture resistance tests. Data were analyzed with ANOVA, Tukey's HSD test, and the t-test ($\alpha = 0.05$).

Results: The t-test showed significant differences between each two corresponding subgroups ($p < 0.0001$). In group A, NS demonstrated significantly higher fracture resistance compared to others, with the least fracture resistance recorded in G2. In group B, the highest fracture resistance was recorded in G1, with the lowest being recorded in G7. Samples irrigated with NaOCl, NaOCl plus CA, and NaOCl plus EDTA exhibited significantly lower fracture resistance compared to NS group ($p < 0.05$).

Conclusion: Within the limitations of this study, it can be concluded that the irrigation regimen used during endodontic treatment with/without bleaching can affect the coronal fracture resistance.

Keywords: bleaching, canal irrigants, coronal fracture resistance, endodontically treated teeth.

36. Junior Researcher

Composite Restorations in Dental Traumatology – From Feasible to (almost) Untreatable

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Background and Purpose: Dental trauma occurs rather frequently in the age group below 35 years. In the permanent dentition, fractures are the most common injuries, and often the maxillary central incisors are affected. The presented clinical cases show how traumatic injuries of the maxillary incisors can be treated with composite restorations in order to preserve healthy tooth structure.

Case Reports: The four clinical cases presented differ in the severity of dental injury. Case 1 shows an enamel-dentin fracture, which was easily treated with composite restorations. In case 2, an enamel-dentin-pulp fracture occurred. Because the tooth fragment was preserved, it was possible to re-attach it by means of standard bonding procedures followed by root canal treatment. The 3rd case was an enamel-dentin-pulp fracture as well, with a subgingival fracture line of the maxillary left lateral incisor and no preserved tooth fragments. Although the defect of this tooth was very deep, it was possible to place a composite restoration with the use of teflon band and a special matrix technique. The 4th case illustrates the application of composite after avulsion of both maxillary central incisors. Because both teeth were missing and therefore not available for replantation, premolars from the maxilla were transplanted to the anterior region. In order to achieve an esthetic appearance, both premolars were reshaped by means of direct partial composite veneers.

Results: After up to 4.5 years of observation, teeth which were treated with composite restorations after experiencing a dental trauma showed excellent esthetic results and a healthy gingival environment.

Conclusion: Depending on the severity of the dental injury after a trauma, composite restorations are the treatment of choice. Even difficult cases which push the limits of current bonding strategies can be treated with composite, if the appropriate techniques for creating sufficiently dry conditions are used.

Keywords: composite resins, tooth fractures, dental bonding, dental esthetics.

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37. Student Researcher

Maxillary Arch Rehabilitation Using Telescopic Copings and Adhesive Technology

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[b]*Hospital Center Commons, Hilton Head Island, SC, USA.*

Purpose: To rehabilitate a maxillary arch using adhesion and telescopic gold copings and show how five abutment teeth can be restored with adhesion technology, composite core buildups, and metal ceramic FDPs.

Case Report:

- Records appointment: Face bow, CR, CO, protrusive, diagnostic images, radiographs, comprehensive perio exam (Fig 1).
- Diagnostic wax up.
- Removed existing provisional bis-GMA restoration (abutments: 17, 13, 23, 24, 27 [FDI]); fabrication of new PMMA provisional with Ribbond reinforcement to refine margins, OHI.
- Adhesively bonded core buildups on teeth 17, 13, 23, 24, 27 (FDI) using Renamel Posterior Composite (Cosmedent), Renamel De-Mark Flowable Composite (Cosmedent) and Clearfil SE Bond (Kuraray Dental) (Fig 2).
- New PMMA provisional fabricated with Ribbond reinforcement; occlusion adjusted (patient with new provisional for approximately 4 months).
- Scan of all prepared teeth and opposing mandibular arch using iTero Intraoral Digital Scanner (Align Technology).
- Fabrication of cast gold telescopic copings with Paul Westbrook, CDT (Westbrook Dental Lab).
- Adhesive bonding of cast gold telescopic copings with RelyX Unicem self-adhesive universal resin cement (3M ESPE).
- Scan of cast gold telescopic copings using iTero Intraoral Digital Scanner.
- Custom gingival shade selection (Paul Westbrook, CDT) and tooth shade using Vita 3D Master Shade Guide.

Fig 1 (left) Diagnostic view of existing maxillary abutment teeth.

Fig 2 (right) Adhesively bonded abutment teeth with provisional crowns on teeth 17 and 27 (FDI) to maintain occlusal vertical dimension.

- Framework try in.
- Bisque bake try in and adjustment of occlusion.
- Delivery of maxillary FDP.
- Bonding of maxillary FDP using RelyX luting cement (3M ESPE).

Results: The maxillary arch was rehabilitated using adhesion technology, cast gold telescopic copings, and metal ceramic FDP.

Discussion: An alternative approach has been presented for rehabilitating a partially edentulous arch without the use of endosseous dental implants. Conventional prosthodontics and occlusion principles were followed and confirmed with provisional prostheses.

Conclusion: Within the limits of this clinical report, it is possible to rehabilitate a patient with adhesive technology and telescopic copings.

Keywords: adhesion, telescopic copings, maxillary arch rehabilitation.

38. Junior Researcher

Interdisciplinary Approach to Improve Esthetics in the Anterior Maxilla

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Purpose: To improve the esthetics of the anterior maxilla of a patient with peg-shaped maxillary lateral incisors.

Case Report: A 26-year-old female patient with peg-shaped maxillary lateral incisors was evaluated at the School of Dentistry of the University of North Carolina, and treated with an interdisciplinary (orthodontic, periodontic, and restorative) approach to improve esthetics.

Results: The orthodontic treatment helped to obtain space between anterior maxillary teeth. Enough space was obtained for the placement of porcelain veneers. Crown lengthening for the maxillary anterior teeth was performed to obtain esthetic harmony of gingival margins. Four porcelain veneers were fabricated and placed on central and lateral maxillary incisors.

Conclusion: This clinical report shows the importance of an interdisciplinary approach to improve the esthetics of the anterior maxilla.

Fig 1 Before.

Fig 2 After.

39. Junior Researcher

A Novel Solution for Anterior Implant Restoration

Yen Jung Lai

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Purpose: To present a novel solution for both optimal esthetics and long-term maintenance in anterior implant restorations.

Case Report: A patient with two implants at positions 12 and 21 was planned to be restored as a 12X21 bridge. The screw access of each implant was palatal to the incisal edge by about 0.7 to 1 mm. According to the diagnostic wax-up, customized zirconia abutments were made by CAD/CAM and cemented to titanium bases. The framework design of a 12X21 bridge is a monolithic block with cut-backs at 12 and 21 for bonded veneers and at 11 for veneering porcelain. The bridge and the veneers were made of lithium disilicate (Fig 1). The bridge and veneers were bonded by resin cement after surface treatment using HF and silane (Fig 2). After cementation, part of the veneer near the screw access was removed for retrievability. After extra-oral polishing and finishing, the bridge was placed and the screw access was sealed by teflon tape and composite resin.

Results: The definitive restoration displayed optimal function and esthetics. The restoration has been in place for 20 months without complications.

Conclusion: Screw retention is recommended for implant-supported prostheses because they offer more reliable retrievability, and no cement cleanup is necessary, resulting in healthier soft tissues. However, the oro-facial implant axis may not be ideal for screw-retained restorations, due to the bone volume and ridge alignment in some cases. With the high-strength lithium disilicate veneer and the adhesive combination with a framework, it is possible to obtain more screw-access freedom for screw-retained restorations.

Keywords: implant-supported prosthesis, adhesion, lithium disilicate, zirconia ceramic, retrievability.

Fig 1 Bridge and veneers made of lithium disilicate.

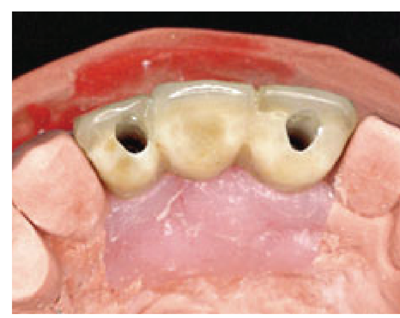

Fig 2 Bridge and veneers bonded in place.

40. Student Researcher

The Natural Restoration: Adhesive Reattachment of a Tooth Fragment Retrieved From Lip

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Purpose: To describe a case of traumatic crown fracture of a maxillary incisor, with successful adhesive reattachment of the tooth fragment after retrieving it from the upper lip.

Case Report: A 24-year-old male, who fell from a skateboard and sustained a complicated crown fracture in his maxillary right central incisor (tooth 11, FDI), associated with a laceration wound in the upper lip showing local edema, reported to our department in the post-graduate operative dentistry clinic (Fig 1a). After comprehensive evaluation followed by periapical radiographs of the fractured tooth and injured upper lip, we found the remaining tooth fragment in the upper lip. The lip was opened with a small incision and the tooth fragment was found; the laceration was closed with chromic gut sutures. A triage provisional filling (FUJI II resin-modified glass ionomer) was placed on the fracture site. The remaining tooth fragment was placed in distilled water for 2 weeks. Two weeks later, a new periapical radiograph was taken and evaluated apically within normal limit. Cold tests were positive. Endodontic examination showed the the tooth was vital; however, it is possible that root canal treatment might be necessary at some point, and there may be risk of an abscess in the future.

Treatment was performed under rubber-dam isolation (Fig 2). The existing composite restoration in tooth 11 was removed, and the outer enamel surface was roughened with a diamond bur at slow speed, avoiding contact with the dentin. The tooth fragment was tried in and adjusted as needed until fully seated. The preparation was cleaned with Consepsis (2.0% chlorhexidine gluconate solution), rinsed, and gently air dried. Tooth fragment preparation: the fragment was washed and cleaned, then etched with 35% phosphoric acid for 15 s and rinsed (Fig 3). Optibond FL (primer and bond 4th generation) were applied and dried.

Washing, cleaning, and Consepsis (2.0% chlorhexidine gluconate solution) application, then rinsing and gentle air drying (Fig 1c). The adjacent teeth were protected with a teflon tab. Etching was performed with 35% phosphoric acid for 15 s, then rinsed. Optibond FL (primer and 4th generation bond) were applied and cured for 10 s. Flowable composite shade A2 was applied, the fragment was attached, and excess composite was removed. Light curing was performed for 40 s while air cooling. Occlusion and contacts were checked and adjusted as needed. After two weeks, the previously chipped incisor was restored with composite, and the restoration was finished and polished using diamond finishing burs and Diacomp composite polishing kit.

Results: At the follow-up 9 months later, the vitality test (including periapical radiograph) showed the teeth to be vital and neither of the two traumatized teeth showed any sign of discoloration; esthetics and function were satisfactory (Fig 1b).

Keywords: tooth fragment, reattachment, adhesion, adhesive dentistry.

Fig 1 a) Patient before treatment; b) patient after treatment; c) prepared tooth; d) fragment bonded to tooth.

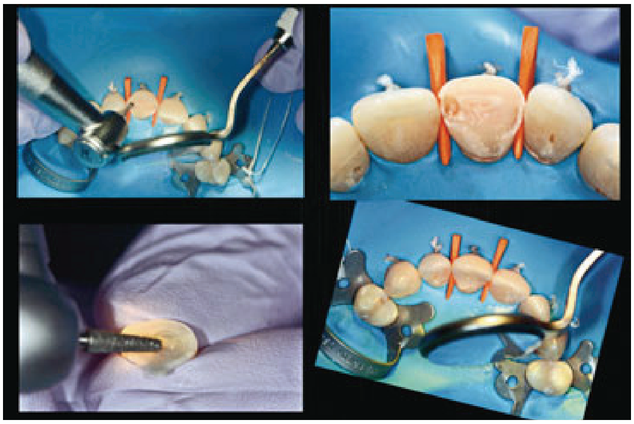

Fig 2 Treatment performed under rubber-dam isolation.

Fig 3 Tooth fragment.

41. Student Researcher

Diastema Closure Using Prefabricated Composite Veneers

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Purpose: The concept of one-visit prefabricated resin-based veneers was introduced in the early 1980s. Taking advantage of a modern technology that enables the production of a resistant, inorganic glossy surface, prefabricated composite veneers recently revitalized this concept. This poster presents the use of prefabricated composite veneers to enhance the anterior esthetics of a patient with several diastemas and poor tooth anatomy. This technique is considered a more affordable, alternative esthetic solution than traditional porcelain veneers.

Case Report: A young male patient presented to the post-graduate operative clinic after completion of orthodontic treatment. Several diastemas between the anterior teeth, peg-shaped lateral incisors, and poor anatomy and contour of the anterior teeth were present. Facial and smile analysis were an integral part of treatment planning, assisted by the use of the DSD (Digital Smile Design) concept. Teeth 13, 12, 11, 21, 22, 23 (FDI) were successfully restored using the layering technique and microhybrid direct composite Vita-l-escence (Ultradent, South Jordan, UT, USA) in association with the Edeweiss system (Ultradent), which contains thin prepolymerized hybrid composite shells. Finishing and polishing were accomplished with silicone tips, brushes, and disks.

Conclusion: Conservative treatment, natural-looking restorations in the esthetic zone with control of color, morphology, and high patient satisfaction were achieved. This technique can be used to restore function and esthetics in one office visit. However, it does not replace conventional custom-made ceramic veneers, but offers the clinician a one-visit, cost-effective alternative.

Keywords: veneers, composite, esthetic.

42. Student Researcher

Reproducing Anatomy and Esthetics in Direct Composite Restorations

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Purpose: One of the clinician's main concerns when using composites is the difficulty of obtaining good anatomy, proper proximal contact, and the time spent on finishing and polishing. The fabrication of a clear custom index prior to tooth preparation has been suggested as a promising technique to be used in many clinical situations. This technique permits the final composite restoration to reproduce the original anatomy and occlusion, requires minimal finishing and polishing, and reduces the incidence of voids at the occlusal surface. This poster presents a technique that uses a clear custom index to restore Class I and Class V cavities and re-establishes the original anatomy with minimal finishing and polishing time. For the Class I restoration, a clinical case was selected.

Case Report: Tooth 46 (FDI) had advanced hidden caries and intact occlusal anatomy. For the Class V restoration, a clinical case of a patient with multiple noncarious cervical lesions was selected and a diagnostic wax-up was used to restore form and function of the cervical area. For both cases, the technique consisted of fabricating an index using a clear silicone bite registration (Blu-Bite clear, Henry Schein; Melville, NY, USA). The silicone was applied onto the occlusal surface of the tooth prior to preparation. After the material was set, the bite registration was trimmed to include at least one tooth anterior and posterior to the working area. The layering technique using composite resin Vit-l-escence (Ultradent; South Jordan, UT, US). After the last increment, the clear index was applied under finger pressure and light curing. The same steps were followed for the restoration of the Class V preparations, except the silicone was applied onto the facial surface of the waxed model. Often, if the index is placed properly, the restoration needs only minimal finishing and polishing and minimal occlusal facial adjustments.

Keywords: esthetic, composites.

International Academy for Adhesive Dentistry (IAAD)

Fig 1 The First Biennial Meeting of the IAAD in Orlando, Florida, September 11-12, 2015.

Fig 2 The overall theme of the Meeting: "Science meets Practice".

Fig 3 Members of the IAAD Executive Committee enjoying the opening reception (from left to right: Bart Van Meerbeek, Petra Gierthmuehlen, Mutlu Özcan, Markus Blatz, Junji Tagami, Uwe Blunck, Roland Frankenberger).

Fig 4 Jean-François Roulet bequeaths the IAAD presidency and president's medal to Markus B. Blatz.

Dear Members,

Just to make sure that I wasn't dreaming, I had to pinch myself a few times. What had started as a vague idea just a few years ago had ultimately become reality: the First Biennial Meeting of the International Academy for Adhesive Dentistry (Figs 1 and 2). And what a great success it was! Big thanks and congratulations are due to Quintessence Publishing for superb organization at a perfect location and to the Program Co-Chairs Sillas Duarte and Jin-Ho Phark for an outstanding scientific program and poster sessions.

It is thrilling and rewarding to see our young Academy thriving, interacting at the highest scientific and clinical level while setting the standards for the future of dentistry. Much of the success is owed to the unshakable determination and tireless work of our first President. Thank you, Jean-François Roulet, for your incredible leadership!

During the General Assembly, a new Executive Committee was elected and confirmed: Jean-François Roulet (Past President), Lorenzo Breschi (President Elect), Milos Tomic (Treasurer), Uwe Blunck (Secretary General) (Fig 3) as well as the Officers: Alireza Sadr, Jin-Ho Phark, Petra Gierthmuehlen, Marcelo Giannini, Mutlu Özcan, Junji Tagami, Sillas Duarte, Bart Van Meerbeek, and Roland Frankenberger.

It was also decided that annual membership dues should be paid exclusively through our website (Paypal) to simplify processing and tracking. Jean-François Roulet and Uwe Blunck (Fig 4) will initiate an interactive "Glossary of Adhesive Terms" on the website – members' input is greatly encouraged. Alireza Sadr will continue to manage the website. Minutes of the Executive Committee Meeting and General Assembly as well as numerous photos from the meeting are available in the member's area of our website (www.adhesivedentistry.org).

The wonderful memories of this great meeting will surely be with us for a long time. However, we are still just at the beginning and your engagement and participation is required now more than ever to bring our Academy to the next level! Thank you for all your support!

Prof. Dr. Markus B. Blatz
President IAAD

Protocol for Removal of Clinically Relevant Contaminants from Glass Ceramic-based Restorations

Thorsten Bock[a] / Mutlu Özcan[b]

IAAD WORKING INSTRUCTIONS

Question: What is the best cleaning method to remove saliva, blood, and silicone disclosing medium contaminants from etched and silanized bonding surfaces of glass ceramic restorations?

Answer: During intraoral try-in of ceramic restorations, the bonding surfaces may come in contact with saliva or occasionally blood.[1,5] The resulting persistent protein contamination from saliva in particular was shown to hinder adhesion of resin cements to glass ceramics.[1,5-7,9] Similarly, the use of silicone-based materials during checking the fit of indirect glass ceramic restorations contaminates the bonding surfaces with silicone residues, also impeding adhesion of resin cements.[5,10,11] Water spray, alcohol, and acetone do not seem effective in removing saliva residues from glass ceramics,[1,5,7] but 35% to 37% phosphoric acid gel application presented effective cleaning.[1,3-5] Several studies also demonstrated that cleaning pastes with particles (eg, Ivoclean) could also remove saliva contaminants from both glass and oxide-based ceramic surfaces.[2-4] Since durable adhesion of glass-ceramic restorations is crucial, especially in minimally invasive restorations, the following surface cleaning sequence can be recommended to eliminate contaminants from ceramic surfaces, based on the available scientific reports.

Do	Why?
Place rubber-dam before try-in, where possible.	This prevents contamination of the restoration with saliva and blood as much as possible.
After try-in, rinse the restoration copiously with water spray.	This will partially remove the adhering layer of saliva and blood.
Determine the type of ceramic material used for the indirect restoration to be bonded.	The cleaning protocol must be compatible with the ceramic material type. Glass ceramics should be initially cleaned with phosphoric acid gel,[1,3,5] particulate cleaning paste (eg, Ivoclean),[2-4] or conditioned with hydrofluoric acid and silane coupling agent.[5]
Determine the types of contaminants (saliva, blood, or silicone disclosing medium).	The cleaning protocol must be effective for the corresponding contaminant.
In case of saliva or blood contamination, clean the surface with 35% to 37% phosphoric acid without agitation for 30 s to 60 s[1,3-5] or clean the surface with a particulate cleaning paste (eg, Ivoclean) for 20 s.[2-4] Then, rinse at least for 30 s and dry with oil-free air.	Adsorbed proteins are detached by coagulation (phosphoric acid) or desorption from the ceramic surface onto the cleaning particles (eg, Ivoclean). Subsequent water rinsing can then remove the coagulated or desorbed proteins.
In case of contamination with saliva/blood and/or silicone or silicone only, re-etch the contaminated surface using hydrofluoric acid etching gel according to the instructions for the ceramic used (depending on the ceramic, for 20 s to 60 s using 5% or 9.5% hydrofluoric acid etching gel).[5,8,11] Rinse for at least 30 s and dry.	Silicone residues are highly persistent on glass ceramics[5] and can only be removed by hydrofluoric acid etching.
Apply a thin coat of silane coupling agent with a clean microbrush on the whole surface to be bonded without agitation and allow it to react for 60 s. Then, dry with a strong stream of oil-free air.	Re-application of silane after cleaning with phosphoric acid increases adhesion of resin cements;[1,7] the manufacturer also recommends it after the use of particulate cleaning paste (eg, Ivoclean). Etching with hydrofluoric acid removes the previously applied silane layer, making re-application of silane mandatory.
Keep the restoration out of direct sunlight and free from dust and aerosol until placement. Do not touch the surfaces to be bonded with instruments or latex gloves.	The cementation surfaces are highly susceptible to further contamination and should not be brought into contact with dust, aerosols, or glove powder.
Continue with the cementation according to the instructions of the adhesive resin and resin cement.	The cementation surface is now properly conditioned for copolymerization with the methacrylate-based luting cement.

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CAVE: When re-etching glass ceramics with hydrofluoric acid, the recommended etching duration for the corresponding ceramic must be followed in order to avoid over-etching.[8]

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