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EDITORIAL

79 Congratulations
F. Beer

SCIENCE

83 In Vitro Bonding to Nd:YAG Laser-treated Dentin
D. Re/D. Augusti/S. Salina/A. Cerutti/S. Amatu/C. Maiorana

89 CO_2 Laser Therapy for Intraoral Hemangiomas
J. T. Lambrecht/S. Stübinger/Y. Hodel

97 Periodontal Evaluation of an Nd:YAP Laser Combined with Scaling and Root Planing for Nonsurgical Periodontal Treatment. A Clinical Evaluation
H. E. Yazami/N. Azehoui/M. Ahariz/G. Rey/E. Sauvetre

CASE REPORT

103 Modification of Implant Prosthetic Abutments with Laser Welding and Titanium
M. A. Iglesia-Puig

109 CO_2 Laser Effects on Root Surfaces in Periodontal Treatment: Case Reports
R. Crespi/U. Covani/G. E. Romanos/A. Barone

119 Immediate Implant and Decontamination Using a Nd:YAG Laser Associated with Growth-factor-rich Plasma in Implant Surgery
J. M. de la Fuente Llanos

ABSTRACTS

129 Abstracts Accepted for the International Laser Congress in Abu Dhabi, October 7th-8th, 2004

NATIONAL FORUM

139 Laser Dentistry in the Netherlands

MISCELLANEOUS

141 2nd ESOLA Symposium in Mauritius – March 2004

143 Society News

146 Calendar of Events

In Vitro Bonding to Nd:YAG Laser-treated Dentin

Dino Re[a], Davide Augusti[b], Sergio Salina[c], Antonio Cerutti[d], Silvio Amatu[e], Carlo Maiorana[f]

[a] *Researcher, Department of Prosthodontics, School of Dentistry, University of Milan, Italy.*
[b] *Senior Lecturer, Instructor, Department of Prosthodontics, School of Dentistry, University of Milan, Italy.*
[c] *University Assistant, Department of Implantology, School of Dentistry, University of Milan, Italy.*
[d] *Professor, Department of Restorative Dentistry, School of Dentistry, University of Brescia, Italy.*
[e] *Student, Department of Prosthodontics, School of Dentistry, University of Milan, Italy.*
[f] *Professor, Department of Implantology, School of Dentistry, University of Milan, Italy.*

Purpose: This study examined the shear bond strength of three different adhesive systems to untreated and Nd:YAG laser-treated dentin.

Materials and Methods: Sixty freshly extracted noncarious human molars were ground to expose middle dentin, which was polished down to 600 grit. Half of the samples were prepared with an Nd:YAG laser for 20 s at 10 Hz and 80 mJ (laser group); the other half was maintained as a control (control group). Three dentin adhesive systems were applied according to manufacturer's instructions to the laser-irradiated surfaces and to the control surfaces: Scotchbond Multi-Purpose (SBM), Scotchbond 1 (SB1), and Adper Prompt L-Pop (LP); for SBM and SB1, the dentin surface was etched with 35% phosphoric acid gel for 15 s. A 5-mm-diameter metal ring was used to set the resin composite (Z100), and specimens were stored in water at 37°C for 24 h. Shear bond strength (SBS) was evaluated by means of a universal testing machine with a crosshead speed of 1 mm/min. The results were statistically analyzed with two-way ANOVA and Fisher's PLSD test ($p < 0.05$).

Results: The bond strength of the control group was significantly higher than that of the laser group ($p < 0.05$). SBM obtained the highest SBS values in the control group while LP showed the highest in the laser group.

Conclusion: Nd:YAG laser irradiation adversely affect adhesion to dentin for all three different dentin adhesive systems tested in this investigation.

Key words: Nd:YAG laser, dentin, adhesion, shear bond strength, etching.

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A range of lasers is now available for use in dentistry. Used in conjunction with or as a replacement for traditional methods, it is expected that specific laser technologies will become an essential component of contemporary dental practice over the next decade.[1] Lasers in dentistry constitute a promising tool, but some dentists are still sceptical due to a lack of knowledge and high costs.[2]

Nd:YAG laser was developed in 1964 by Geusic et al[3] and was applied to dentistry for the first time in 1984 by Myers.[4] Due to its characteristics, Nd:YAG laser is mainly used in intraoral soft tissue treatment (frenulectomy, vestibuloplasty, gingivectomy, gingivoplasty, removal of benign tumors and other lesions, periodontology, etc), but it can also be applied as an adjunct to hard tissue treatment (pulpal analgesia, dentinal desensitization, enamel etching, caries removal and prevention, etc).[5,6]

The Nd:YAG laser's effect on dentin consists in the fusion and consequent occlusion of dentinal tubules;

dentinal fusion is several microns deep and gives dentin the appearance of a lava flow called "melting".[7] For this reason, Nd:YAG laser has been recently proposed for use on the prepared cavity dentin just before adhesively cementing inlays in order to reduce risk of postoperative sensitivity.[7] Furthermore, Nd:YAG laser has a dentin decontaminating effect because of its bactericidal action.[2,4,8-11]

The increasing importance of adhesion in dentistry and the continuous improvement in lasers are the impetus for many investigations[12-23] to evaluate laser effects on adhesion with the final aim of verifying the claims made by the dental laser manufacturers, clarifying whether the laser really increases the bond strength of the adhesive systems now in use and if the laser can be used as a valid substitute for the well-established dentin acid etching.

In the absence of comparative clinical trials, much emphasis has been placed on laboratory assessment of bond strength. While bond strengths cannot predict exact clinical behavior, they may be useful for batch quality control.[24] The quality control should be well standardized and easy to perform. It can consist of tensile, shear, torsion, cleavage, pull or extrusion, or 4-point bending tests.[25]

The purpose of this investigation is therefore to determine if irradiating the dentin with Nd:YAG laser affects the shear bond strength (SBS) between dentin and three different resin bonding systems.

MATERIALS AND METHODS

For this study, 60 freshly extracted noncarious human molars were selected. Teeth were selected, stored, and handled according to the ISO 11405:2003 technical specification:[24] they were washed in running water immediately after extraction and all blood and adherent tissues were removed; teeth were then placed in distilled water, and, after a week, were embedded in acrylic resin blocks. Thus prepared, teeth were ground mesiodistally to obtain a cut middle dentin surface that was then smoothed with 600-grit paper.

Six groups (n = 10 each) were included in this study and specimens were randomly allocated to one of the six groups.

Laser Group

The samples were irradiated for 20 s at 10 Hz and 80 mJ in contact mode using the Nd:YAG laser (DEKA, Medical Electronics Laser Associated, Smarty A-10, Calenzano, IT), producing a wavelength of 1064 µm with a pulse length of 150 µs delivered by means of an optical fiber of 300 µm diameter.

Three dentin adhesive systems were then applied, according to manufacturer's instructions, to laser-irradiated surfaces:

- Subgroup L1 (n = 10) Scotchbond Multi-Purpose (SBM) (3M ESPE, St Paul, MN, USA): etched with 35% phosphoric acid gel (Scotchbond etchant, 3M ESPE) for 15 s and rinsed for 10 s; then primer and adhesive were applied.
- Subgroup L2 (n = 10) Scotchbond 1 (SB1) (3M ESPE): etched with 35% phosphoric acid gel (Scotchbond etchant) for 15 s and rinsed for 10 s; then self-priming adhesive was applied.
- Subgroup L3 (n = 10) Adper Prompt L-Pop (LP) (3M ESPE): applied according to manufacturer's instructions.

Control Group

The same three dentin adhesive systems described above were applied according to manufacturer's instructions to nonlasered surfaces:

- Subgroup C1 (n = 10) Scotchbond Multi-Purpose (SBM) (3M ESPE, St Paul, MN, USA): etched with 35% phosphoric acid gel (Scotchbond etchant, 3M ESPE) for 15 s and rinsed for 10 s; then primer and adhesive were applied.
- Subgroup C2 (n = 10) Scotchbond 1 (SB1) (3M ESPE): etched with 35% phosphoric acid gel (Scotchbond etchant) for 15 s and rinsed for 10 s; then self-priming adhesive was applied.
- Subgroup C3 (n = 10) Adper Prompt L-Pop (LP) (3M ESPE): applied according to manufacturer's instructions.

Specimen Preparation for SBS Test

One metal ring of 5 mm internal diameter was used per specimen to set the resin composite (Z100, 3M ESPE), inserted in 1- to 1.5-mm increments and light activated separately for 40 s each; the total composite thickness was approximately 3 mm.

All specimens were stored in water at 37°C for 24 h. The shear bond strength test was conducted by means of a universal testing machine with a crosshead

Table 1 SBS results (MPa) after the different treatments; values are shown as means ± SD

Group	Subgroup n = 10	Adhesive System	SBS ± SD
Laser	L1	SBM	7.3 ± 2.8
	L2	SB1	12.4 ± 7.1
	L3	LP	13.3 ± 4.2
Control	C1	SBM	35.7 ± 14.4
	C2	SB1	23.4 ± 8.5
	C3	LP	27.3 ± 7.3

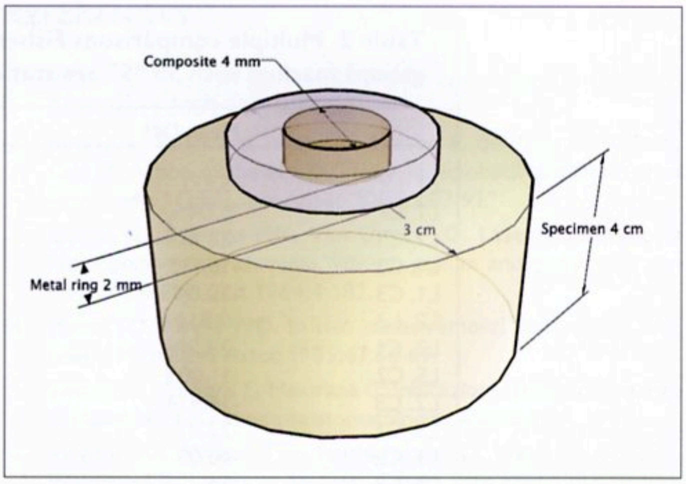

Fig 1 Schematic drawing of specimens prepared for the SBS test.

speed of 1 mm/min. The metal ring was maintained in situ during the test in order to distribute the shearing forces (Fig 1).

The results were statistically analyzed with two-way ANOVA and Fisher's PLSD test ($p < 0.05$).

RESULTS

SBS Test

The mean values obtained in each experimental group are shown in Table 1 and in Fig 2. C1 obtained the highest mean value of the control groups (35.7 MPa), while L3 showed the highest of the laser groups (13.3 MPa). The mean of C1, C2, and C3 (28.8 MPa) was higher than mean of L1, L2, and L3 (11 MPa).

Figure 3 (box plot) shows the range (min and max value) and the median value for each group.

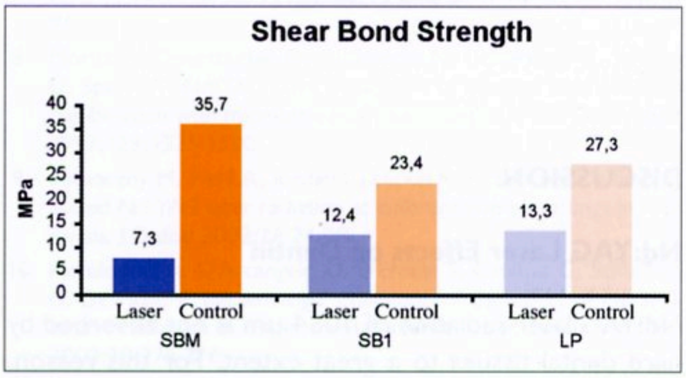

Fig 2 The bar plot illustrates the SBS mean values (MPa) obtained after the test.

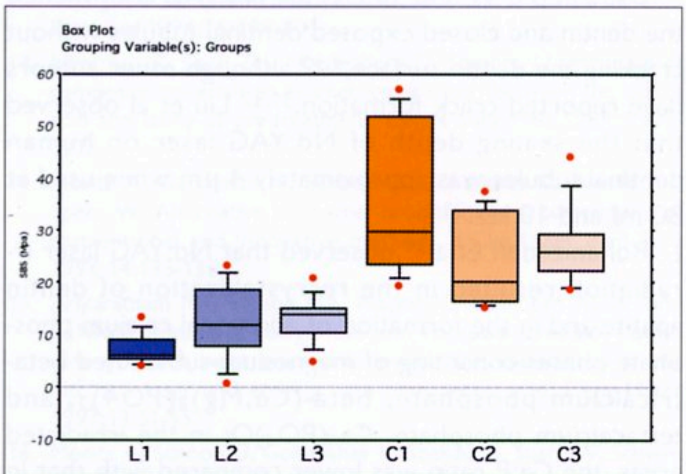

Fig 3 The box plot summarizes the results of this investigation.

Statistical Analysis

Two-way ANOVA revealed that there were statistically significant differences between laser groups and control groups ($p < 0.0001$). On this basis, it seems that the Nd:YAG laser irradiation significantly influenced the adhesive bonding. Fisher's PLSD test for multiple comparisons revealed that there were statistically significant differences ($p < 0.05$) between the pairs of groups marked with an "S" in Table 2.

In particular, both in the control and in the laser group, no statistically significant differences were observed among SB1 and LP results. Statistically significant differences were instead observed both in the control and in laser group among SBM and SB1 and among SBM and LP. On the basis of the Fisher's PLSD test, it seems that the results were statistically significantly influenced by the kind of adhesive system used.

Table 2 Multiple comparisons Fisher's PLSD test p-values: the pairs of groups marked with an "S" are statistically significantly different ($p < 0.05$).

	Mean Diff	Critcal Diff	P-Value	
L1. L2	*-5.131*	*7.416*	*0.1711*	
L1. L3	*-6.045*	*7.416*	*0.108*	
L1. C1	-28.415	7.416	<0.0001	S
L1. C2	-16.135	7.416	<0.0001	S
L1. C3	-20.045	7.416	<0.0001	S
L2. L3	*-0.914*	*7.416*	*0.8058*	
L2. C1	-23.284	7.416	<0.0001	S
LS. C2	-11.004	7.416	0.0044	S
L2. C3	-14.914	7.416	0.0002	S
L3. C1	-22.37	7.416	<0.0001	S
L3. C2	-10.09	7.416	0.0086	S
L3. C3	-14	7.416	0.0004	S
C1. C2	12.28	7.416	0.0016	S
C1. C3	8.37	7.416	0.0277	S
C2. C3	*-3.91*	*7.416*	*0.2952*	

DISCUSSION

Nd:YAG Laser Effects on Dentin

Nd:YAG laser radiation of 1064 µm is not absorbed by hard dental tissues to a great extent. For this reason, the Nd:YAG laser in this study was used in contact mode, which has been corroborated by other studies as well.[6,26-29]

Used at 0.8 W and 10 Hz, the Nd:YAG laser melted the dentin and closed exposed dentinal tubules without cracking the dentin surface,[4,30] although other authors have reported crack formation.[31,32] Liu et al observed that the sealing depth of Nd:YAG laser on human dentinal tubules was approximately 4 µm when used at 30 mJ and 10 Hz.[33]

Rohanizadeh et al[34] observed that Nd:YAG laser irradiation resulted in the recrystallization of dentin apatite and in the formation of additional calcium phosphate phases consisting of magnesium-substituted beta-tricalcium phosphate, beta-$(Ca,Mg)_3(PO4)_2$, and tetracalcium phosphate, $Ca_4(PO_4)O$; in the irradiated areas, the Ca:P ratio was lower compared with that in the nonirradiated dentin; the ultrastructural and compositional changes observed in laser-irradiated dentin may be attributed to high temperature and high pressure induced by microplasma during laser irradiation. These changes may alter the solubility of the irradiated dentin, making it less susceptible to acid dissolution or to the caries process.[34]

SBS Test Results

The mean SBS values obtained in the control group are similar to those cited by the manufacturer. The differences could be attributed to variables involved in dentin substrate and in specimen handling.[25]

In terms of Nd:YAG laser influence on adhesion observed in the laser group, two points stand out:

1. The shear bond strength obtained in this group is significantly lower than the SBS obtained in the control group;
2. L3 achieved the highest values.

As suggested by the two-way ANOVA, the first point probably depends on the Nd:YAG laser irradiation: as seen before, the laser treatment appeared to alter the chemical structure and surface morphology of the dentin:[32] the reduced dentinal surface susceptibility to acid dissolution[34] and the depth of these morphological changes[33] could reduce the efficacy of the etchant in opening dentinal tubules and exposing the collagen network. Adhesion to laser-treated dentin may be explained by the mechanical retention provided by short conical resin structures (pseudotags), probably corresponding to the entrance of the dentinal tubules. This may be explained by the fact that, although dentinal tubules are sealed by laser irradiation, acid etching demineralized dentin to a depth of a few microns. Thus, only the tubule entrances are penetrated by adhesive: upon reaching the entrance, the adhesive meets a barrier of melted dentin.[7] Nd:YAG laser also affects hybrid layer formation.[7] We can suppose that Nd:YAG laser, similar to Er:YAG laser, completely melts and vaporizes collagen fibrils.[20] Dentinal collagen has an important role when adhesive resins are used for bonding composite restoration. As widely described in the literature, acid-etched dentinal collagen is penetrated by adhesive resin and forms the hybrid layer, which creates a micromechanical bond between resin and dentin.[35] Although some authors maintain that the hybrid layer may not be crucially important for the mechanism of adhesion between bonding material and dentin,[36,37] the presence of a laser-fused layer in which interfibrillar spaces were lacking probably restricted resin diffusion into the subsurface intertubular dentin, resulting in lower shear bond strength.[20]

The Fisher's PLSD test results suggest that the second point probably depends on the different adhesion mechanism characterizing LP: self-etching acidic components demineralize through the smear layer and diffuse a short distance into the underlying dentin, resulting in the creation of a thin hybrid layer with strong bonds to dentin.[38] Therefore, LP does not require open dentinal tubules to unfold its action.

In short, the low L3 values compared to C3 values may depend on Nd:YAG laser effects on dentin's chemical structure and morphology (melted, glazed, and acid-resistant surface); the high L3 values compared to L1 and L2 values could instead depend on the different L3 adhesion mechanism. The lased acid-proof surface seems to be similar to that of sclerotic dentin: demineralization is more difficult in both the peritubular and intertubular regions as dentinal tubules are occluded by a mineral substance.[39,40] This similarity could make sclerotic dentin an indication for the use of self-etching adhesives.

Finally, some authors have reported that lasing after adhesive application did not affect bond strength.[18,21-23] Nevertheless, further research in this field is necessary.

CONCLUSION

Nd:YAG laser adversely affected adhesion to dentin for all three different dentin adhesive systems tested in this investigation; self-etching adhesive systems, due to their adhesion mechanism, seem to be less influenced by laser irradiation.

Sclerotic dentin, morphologically similar to Nd:YAG lased dentin, could be an indication for the use of self-etching adhesives.

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Contact address: Dino Re, P.zza S. Agostino, 24, 20123 Milan, Italy. Tel: +39-0249-82536, Fax: +39-0249-82595. e-mail: dino.re@unimi.it