# Nd:YAG Laser Influence on Dentin Bond Strength of Three Different Adhesive Systems

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

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

**Purpose:** This study examined the effects of Nd:YAG laser irradiation on the shear bond strength of three different adhesive systems.

**Materials and Methods:** Thirty freshly extracted noncarious human molars were ground to expose middle dentin, which was polished down to 600 grit. Specimens were separated into 6 subgroups (n = 5) and received the following treatments: (C1) Prime&Bond NT as indicated by manufacturer; (C2) Xeno III as indicated by manufacturer; (C3) Tyrian SPE One Step Plus as indicated by manufacturer; (L1) Prime&Bond NT + laser; (L2) Xeno III + laser; (L3) Tyrian SPE One Step Plus + laser. Nd:YAG laser was used in noncontact mode at 15 Hz and 40 mJ for 30 s. A standard 5-mm-diameter composite resin cylinder (Synergy, Coltene) was bonded to the dentinal surface, and specimens were then 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 by two-way ANOVA and the Student's t test ($p < 0.05$).

**Results:** The bond strength of the control group was significantly higher than that of the laser group ($p < 0.05$). Xeno III obtained the highest SBS values in the laser group, while Prime&Bond NT showed the highest values in the control group.

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

**Keywords:** Nd:YAG laser, dentin, adhesion, shear bond strength, etching.

*J Oral Laser Applications 2005; 5: 161-167.* *Submitted for publication: 01.04.05; accepted for publication: 15.05.05.*

Possible applications of Nd:YAG laser in adhesive dentistry have been the subject of a large number of studies in recent years.[1-7] Most authors examined preliminary laser treatment of dentin, supposing it could have positive effects on adhesion. This would be very important in the case of laser-made cavities in dental tissue, in which adhesive may be applied without acid etching.[3] Nevertheless, these studies showed that chemical and physical modifications of dentin, induced by Nd:YAG laser before applying adhesives, negatively affected the bond strength, as demonstrated by the results obtained from tensile and shear strength tests.[6-7]

Some authors, however, tried a new approach, using the Nd:YAG laser after applying adhesive instead of the

**Table 1 Composition of adhesive systems tested in this study**

| Adhesive | Composition |
|---|---|
| **Prime&Bond NT** | - di- and trimethacrylate resins<br>- functionalized amorphous silica<br>- PENTA (dipentaerythritol penta acrylate monophosphate)<br>- photoinitiators<br>- stabilizer<br>- cetylamine hydrofluoride<br>- acetone |
| **Xeno III** | **Liquid A**<br>- HEMA (2-hydroxyethyl methacrylate)<br>- purified water<br>- ethanol<br>- BHT (butylated hydroxytoluene)<br>- highly dispersed silicon dioxide<br>**Liquid B**<br>- pyro-EMA (phosphoric acid modified methacrylate)<br>- PEM-F (monofluorophosphate modified methacrylate)<br>- urethane dimethacrylate<br>- BHT (butylated hydroxytoluene)<br>- camphorquinone<br>- ethyl-4-dimethylaminobenzoate |
| **Tyrian SPE** | **Part A**<br>- ethanol<br>**Part B**<br>- 2-acrylamido-2-methyl propane sulfonic acid<br>- bis (2-(methacryloyloxy)ethyl) phosphate<br>- ethanol |

final photopolymerization, melting dentin hydroxyapatite in the presence of resin monomers in order to create a new substrate with more affinity to the adhesion process.[8-11] Very encouraging results have been obtained from these studies, showing performances similar to or better than those obtained from traditional methods.

The purpose of this investigation was, therefore, to determine the effects of Nd:YAG laser on shear bond strength when used after applying three different adhesive systems.

## MATERIALS AND METHODS

### Tooth Preparation

Thirty noncarious human molars were selected according to protocols approved by the institutional review board and with informed consent of the donors.[12] Teeth were stored in 0.5% chloramine and used within 6 months after extraction. Teeth were embedded in acrylic resin blocks and ground mesiodistally to obtain a cut middle-dentin surface that was then smoothed with 600-grit paper.

According to the method of White et al,[13] radiographs were taken from each specimen using the long cone paralleling technique to standardize the remaining dentin thickness. It was established that the area to be submitted to the test should have a remaining dentin thickness of 2.0 mm (± 0.2 mm).

Two groups – laser and control – were included in this study, and specimens were randomly allocated to one of the 6 subgroups (3 subgroups for each group). On each specimen, the dentin surface to be bonded was limited by means of a self-adhesive vinyl circular mold with a standard 5-mm-diameter central hole.

### Laser Group

*L1 Subgroup (n = 5)*

The dentin area, delimited as described above, was acid etched with a 36% phosphoric acid solution (Conditioner 36, Dentsply DeTrey, Konstanz, Germany) for 15 s according to the manufacturer's instructions, rinsed for 15 s, and gently air dried. One layer of Prime&Bond NT (Dentsply DeTrey) adhesive was applied, left undisturbed for 20 s and then air dried for 5 s. The adhesive was not photocured. In place of the photopolymerization, Nd:YAG laser (Smarty A-10, DEKA Medical Electronics Laser Associated, Calenzano, Firenze, Italy) was used with the parameters described by Gonçalves et al:[10] noncontact mode 1 mm from the dental surface for 30 s at the following parameters: 0.6 W, 15 Hz, 40 mJ/pulse, and an optic fiber of 320 µm.

*L2 Subgroup (n = 5)*

According to the manufacturer's instructions, Xeno III (Dentsply DeTrey) Liquid A and Liquid B were mixed for 5 s, and one layer of adhesive mixture was applied on the dentin area, limited as described above. The adhesive was left undisturbed for 20 s and then gently air dried. The adhesive was not photocured. Instead of photopolymerization, Nd:YAG laser was applied with the parameters described above.

*L3 Subgroup (n = 5)*

As indicated by the manufacturer, two coats of Tyrian SPE One-Step Plus (Bisco, Schaumburg, IL, USA) self-priming etchant liquid were applied on the dentin area, delimited as described above and left undisturbed for 20 s; two coats of adhesive were applied, slightly agitated for 15 s, and gently air dried. The adhesive was not photocured, but instead, Nd:YAG laser was applied with the parameters described above.

The composition of all adhesives used is given in Table 1.

### Control Group

*C1 Subgroup (n = 5)*

Prime&Bond NT was applied following the manufacturer's instructions.

*C2 Subgroup (n = 5)*

Xeno III was applied following the manufacturer's instructions.

*C3 Subgroup (n = 5)*

Tyrian SPE One Step Plus was applied following the 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 (Synergy; Coltene, Altstätten, Switzerland), which was inserted in 1- to 1.5-mm increments and light activated separately for 40 s each by means of an Elipar Trilight (3M ESPE, St Paul, MN, USA) light-curing unit. The total composite thickness was approximately 3 mm.

All specimens were stored in distilled water at 37°C for 24 h after the composite resin placement.[14] The shear bond strength test was conducted by means of a universal testing machine with a crosshead speed of 1 mm/min. The metal ring was maintained in situ during the test in order to distribute the shearing forces.

Results were statistically analyzed by two-way ANOVA and Student's t test ($p < 0.05$).

## RESULTS

### SBS Test

Mean values obtained from each experimental subgroup are shown in Table 2 and Fig 1. L2 obtained the highest mean value of the laser group (13.06 MPa), while C1 showed the highest value of the control group (26.61 MPa). The mean for C1, C2, and C3 (25.56 MPa) was higher than that for L1, L2, and L3 (10.55 MPa).

### Statistical Analysis

Two-way ANOVA revealed that there were statistically significant differences between the laser group and the control group, as shown in Table 3. In particular, the treatment factor (see Table 4) was found to be significant ($p < 0.05$). It means that Nd:YAG laser irradiation, used in place of the adhesive photocuring, significantly influenced the adhesive bonding.

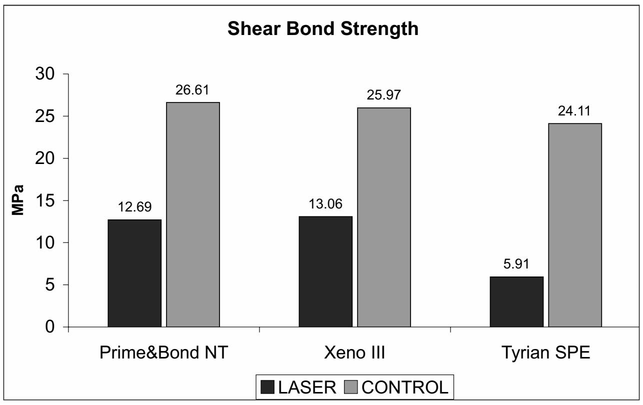


**Fig 1** The bar graph illustrates the mean SBS values (MPa) obtained after testing.

**Table 2 SBS results (MPa) after the different treatments (means ± SD)**

| Group | Subgroup (n=5) | Adhesive system | SBS ± SD |
|---|---|---|---|
| Laser | L1 | Prime&Bond NT | 12.69 ± 4.92 |
| | L2 | Xeno III | 13.06 ± 2.21 |
| | L3 | Tyrian SPE | 5.91 ± 1.67 |
| Control | C1 | Prime&Bond NT | 26.61 ± 7.83 |
| | C2 | Xeno III | 25.97 ± 5.46 |
| | C3 | Tyrian SPE | 24.11 ± 2.13 |

**Table 3 Two-way ANOVA: grey values are statistically significant ($p < 0.05$)**

| Source | SS | df | MS | F | p (< 0.05) | F crit |
|---|---|---|---|---|---|---|
| Adhesive (A) | 139.320 | 2 | 69.660 | 3.279 | 0.055 | 3.403 |
| Treatment (T) | 1689.451 | 1 | 1689.451 | 79.524 | $0.042 \cdot 10^{-7}$ | 4.260 |
| (A) x (T) | 39.435 | 2 | 19.717 | 0.928 | 0.409 | 3.403 |
| Residual | 509.866 | 24 | 21.244 | | | |
| Total | 2378.071 | 29 | | | | |

Table 4 shows one-way ANOVA among control subgroup results, and Table 5 shows one-way ANOVA among laser subgroup results.

One-way ANOVA (Table 4) for the control groups revealed no statistically significant differences between C1, C2, and C3 results. Conversely, laser one-way ANOVA (Table 5) revealed a statistically significant difference between L1, L2, and L3 results. This suggested that, under the same conditions, results were influenced by the type of adhesive system used. In particular, L3 (Tyrian SPE) obtained the lowest value. A statistically significant difference between laser group results was also confirmed by comparison of means using the Student's t test (Table 6).

## DISCUSSION

Effects of Nd:YAG laser on dentin mineral content and surface morphology have been widely described in the literature. The dentin surface irradiated with Nd:YAG laser shows structural, morphological, compositional, and phase changes. When the melting temperature is reached, vaporization occurs, steam forms, and micro-

**Table 4 One-way ANOVA for control group: grey values are statistically significant (p < 0.05)**

| Source | DF | SS | MS | F ratio | p (< 0.05) |
|---|---|---|---|---|---|
| Adhesive | 2 | 16.83628 | 8.4181 | 0.2640 | 0.7723 |
| Error | 12 | 382.60936 | 31.8841 | | |
| C. Total | 14 | 399.44564 | | | |

**Table 5 One-way ANOVA for laser group: grey values are statistically significant (p < 0.05)**

| Source | DF | SS | MS | F ratio | p (< 0.05) |
|---|---|---|---|---|---|
| Adhesive | 2 | 162.08764 | 81.0438 | 7.6398 | 0.0072 |
| Error | 12 | 127.29688 | 10.6081 | | |
| C. Total | 14 | 289.38452 | | | |

**Table 6 Comparison of laser group means (Student's t test)**

Dif=Mean[i]- Mean[j]

| | NT | Xeno | Tyrian |
|---|---|---|---|
| NT | 0.0000 | -0.3771 | 6.7771 |
| Xeno | 0.3771 | 0.0000 | 7.1541 |
| Tyrian | -6.7771 | -7.1541 | 0.0000 |

Alpha=0.05

Comparison for each pair using Student's t test

| T | Alpha |
|---|---|
| 2.17881 | 0.05 |

Abs(Dif)-LSD

| | NT | Xeno | Tyrian |
|---|---|---|---|
| NT | -4.4882 | -4.1111 | 2.2889 |
| Xeno | -4.1111 | -4.4882 | 2.6660 |
| Tyrian | 2.2889 | 2.6660 | -4.4882 |

Positive values show pairs of means that are significantly different.

| Level | Mean | |
|---|---|---|
| NT | 12.687898 | A |
| Xeno | 13.064968 | A |
| Tyrian | 5.910828 | B |

Levels not connected by the same letter are significantly different.

explosion results in ejection of the molten mineral phase that resolidifies at the surface[15] producing a sponge-like appearance[16] and an increase in surface roughness. Dentin irradiation with Nd:YAG results both in occlusion of dentinal tubules at a depth of several microns[17,18] and in recrystallization of the apatite with the formation of additional calcium phosphate phases[19] that could alter the solubility of the irradiated dentin, making it less susceptible to both acid dissolution and the caries process.[20]

This rough, melted, glazed, acid-resistant dentin surface resulting from Nd:YAG laser irradiation, seemed to be a favorable substrate for adhesion processes. Nevertheless, many studies showed that dentin chemical and physical modifications, induced by the Nd:YAG laser before applying adhesives, negatively affected the bond strength.[6,7,9-11] Most studies investigating the Nd:YAG laser effects on dentin adhesion used the laser before applying the adhesive; however, other authors have tried a new approach, using the Nd:YAG laser after the application of the adhesive in place of the final photopolymerization.[8-11] According to Gonçalves et al,[10] Nd:YAG laser application after the use of nonphotocured adhesives should generate a new substrate, composed of recrystallized hydroxyapatite melted in the presence of adhesive resin monomers, with more chemically affinity to the adhesion process.

This study therefore analyzed Gonçalves' hypothesis that the use of Nd:YAG laser after the application of the adhesive in place of the final photopolymerization would promote better bond strength than the conventional method. Our results led to the rejection of this hypothesis. The laser group, in fact, obtained the lowest SBS values, and the ANOVA revealed that shear bond strength depended on the different treatments used (Nd:YAG laser vs photopolymerization).

Lower values may be explained by the fact that high temperature and high pressure, induced by laser irradiation, affected the hybrid layer, probably vaporizing collagen fibers[21] and chemically altering a large part of the resin monomers, making them unable to create a viable bond. Furthermore, the Nd:YAG laser wavelength of 1064 µm was not able to promote the reaction of monomer polymerization. Consequently, it can be supposed that, under the above conditions, adhesion was mainly provided by mechanical retention and, to a minor extent, residual intact monomers, which had been reached by the curing light during photopolymerization of the first layer of the composite resin, resulting in a lower bond strength.

As suggested by the one-way ANOVA (see Table 6) of laser group results, the low L3 compared to L1 and L2 values could depend on the different adhesive compositions, maybe because of the different susceptibility of resin monomers to Nd:YAG laser effects.

## CONCLUSION

In conclusion, the new substrate developed by lasing the nonphotocured adhesive after its application on dentin seemed to be unable to ensure a strong, durable bond. Obviously, further research in this field is required.

Nd:YAG laser, used after the application of adhesives in place of photocuring, adversely affected adhesion to dentin for all three dentin adhesive systems tested in this investigation.

## REFERENCES

1. Moritz A, Gutknecht N, Schoop U, Goharkhay K, Wernisch J, Sperr W. Alternative in enamel conditioning: a comparison of conventional and innovative methods. J Clin Laser Med Surg 1996;14:133-136.
2. Ariyaratnam MT, Wilson MA, Mackie IC, Blinkhorn AS. A comparison of surface roughness and composite/enamel bond strength of human enamel following the application of the Nd:YAG laser and etching with phosphoric acid. Dent Mater 1997;13:51-55.
3. Moritz A, Schoop U, Goharkhay K, Szakacs S, Sperr W, Schweidler E, Wernisch J, Gutknecth N. Procedures for enamel and dentin conditioning: a comparison of conventional and innovative methods. J Esthet Dent 1998;10:84-93.
4. Ariyaratnam MT, Wilson MA, Blinkhorn AS. An analysis of surface roughness, surface morphology and composite/dentin bond strength of human dentin following the application of the Nd: YAG laser. Dent Mater 1999;15:223-228.
6. Rappelli G, Massaccesi C, Putignano A, Procaccini M. Influence of Nd:YAG laser pretreatment on hybrid layer formation in luting ceramic inlays: an SEM evaluation. J Oral Laser Applic 2003;3:93-96.
7. Re D, Augusti D, Salina S, Cerutti A, Amatu S, Maiorana C. In vitro bonding to Nd:YAG laser-treated dentin. J Oral Laser Applic 2004;4:83-88.
8. Araujo RM, Eduardo CP, Duarte Junior SL, Araujo MA, Loffredo LC. Microleakage and nanoleakage: influence of laser in cavity preparation and dentin pretreatment. J Clin Laser Med Surg 2001;19:325-332.
9. Matos AB, Oliveira DC, Navarro RS, de Eduardo CP, Matson E. Nd:YAG laser influence on tensile bond strength of self-etching adhesive systems. J Clin Laser Med Surg 2000;18:253-257.
10. Gonçalves SE, Araujo MA, Damiao AJ. Dentin bond strength: influence of laser irradiation, acid etching, and hypermineralization. J Clin Laser Med Surg 1999;17:77-85.
11. Matos AB, Oliveira DC, Kuramoto M, Edurado CP, Matson E. Nd:YAG laser influence on sound dentin bond strength. J Clin Laser Med Surg 1999;17:165-169.
12. ISO/TS 11405:2003. Dental materials - Testing of adhesion to tooth structures. Second edition, 2003.

13. White JM, Fagan MC, Goodies HE. Intrapulpal temperatures during pulsed Nd:YAG laser treatment of dentin, in vitro. J Periodontol 1994;65:255-259.
14. Reis A, Carrilho MR, Schroeder M, Tancredo LL, Loguercio AD. The influence of storage time and cutting speed on microtensile bond strength. J Adhes Dent 2004;6:7-11.
15. Ariyaratnam MT, Wilson MA, Blinkhorn AS. An analysis of surface roughness, surface morphology and composite/dentin bond strength of human dentin following the application of the Nd:YAG laser. Dent Mater 1999;15:223-228.
16. Sazak H, Türkmen C, Günday M. Effects of Nd:YAG laser, air-abrasion and acid-etching on human enamel and dentin. Oper Dent 2001 Sept-Oct;26:476-481.
17. Liu HC, Lin CP, Lan WH. Sealing depth of Nd:YAG laser on human dentinal tubules. J Endod 1997;23:691-693.
18. Lan WH, Liu HC. Treatment of dentin hypersensitivity by Nd:YAG laser. J Clin Laser Med Surg 1996:14:89-92
19. Kinney JH, Haupt DL, Balooch M, White JM, Bell WL, Marshall SJ, Marshall GW Jr. The threshold effects of Nd and Ho:YAG laser-induced surface modification on demineralization of dentin surfaces. J Dent Res 1996:75:1388-1395.
20. Rohanizadeh R, LeGeros RZ, Fan D, Jean A, Daculsi G. Ultrastructural properties of laser-irradiated and heat-treated dentin. J Dent Res 1999;78:1829-1835.
21. Ceballos L, Toledano M, Osorio R, Tay FR, Marshall GW. Bonding to Er-YAG-laser-treated dentin. J Dent Res 2002;81:119-122.

**Contact address:** Dr. Dino Re, University of Milan, P.zza S.Agostino, 24, 20123 Milan, Italy. Tel: +39-024-9825-36, Fax: +39-024-9825-95. e-mail: dino.re@unimi.it