

THE EFFECTS OF DIFFERENT DENTIN HYPERSENSITIVITY TREATMENTS ON THE SHEAR BOND STRENGTH BETWEEN ADHESIVE COMPOSITE RESIN AND DENTIN

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ABSTRACT

Background and Aim: The aim of this in vitro study was to evaluate the effects of different hypersensitivity treatments on the shear bond strength of flowable adhesive composite resin to dentin.

Materials and Methods: The whole dentin specimens were etched to remove any smear plugs and to mimic the open dentinal tubules of sensitive dentin using 0.5 M EDTA (pH 7.4) for two minutes. Forty dentin specimens were randomly divided into four groups (n=10) (1) Group C (control); (2) Group N (treated with Nd:YAG laser); (3) Group G (treated with Gluma Desensitizer); (4) Group N+G (treated with Nd:YAG laser following Gluma Desensitizer). Flowable composite resin cement was applied to dentin surface and shear bond strength tests were performed. The mean SBS values were evaluated, failure modes were determined, and data were analyzed by one-way ANOVA test and compared with Tukey HSD test.

Results: There was significant difference among Group G (11.7 ± 4.6 MPa) and Group N (18.5 ± 2.5 MPa) ($p=0.05$). There were no significant differences among the other groups. SEM evaluation revealed that Group N occluded open dentinal tubules in some areas by melting and modifying of dentin tubule periphery. Group G showed prominent narrowing and reduction in the diameter of the affected tubules. Group N+G occluded dentinal tubules to varying degrees.

Conclusion: Nd:YAG laser treatment following Gluma Desensitizer could be an effective treatment for dentin hypersensitivity and does not affect the bond strength of adhesive composite resin to dentin surface detrimentally.

Key words: Bond Strength, Dentin Hypersensitivity Treatment, Dentin Tubule Occlusion, Gluma, Nd:YAG

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ADEZİV KOMPOZİT REZİNİN DENTİNE BAĞLANMASI ÜZERİNE FARKLI DENTİN HASSASİYETİ TEDAVİLERİNİN ETKİLERİ

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ÖZET

Amaç: Bu invitro çalışmanın amacı farklı duyarlılık tedavilerinin, adeziv akışkan kompozit rezinin dentine makaslama bağlanma dayanıklılığı üzerine etkilerini değerlendirmektir.

Gereç ve Yöntem: Tüm dentin örnekleri, smear tabakasını uzaklaştırmak ve hassas dentin yüzeylerini taklit edecek şekilde dentin tübüllerini açmak için 0,5 EDTA (pH 7.4) ile iki dakika pürüzlendirildi: Kırk örnek rastgele dört gruba ayrıldı (n=10) (1) Grup C (kontrol); (2) Grup N (Nd:YAG lazer tedavisi); (3) Grup G (Gluma Hassasiyet giderici tedavisi); (4) Grup N+G (Gluma hassasiyet giderici uygulamasının ardından Nd:YAG lazer tedavisi). Dentin yüzeyine akışkan kompozit rezin uygulandı ve makaslama bağlanma dayanıklılık testi uygulandı. Ortalama MBD değerleri değerlendirildi, kırılma tipleri belirlendi ve veriler tek-yönlü ANOVA ile analiz edilip Tukey HSD testi ile karşılaştırıldı.

Bulgular: Grup G ($11,7 \pm 4,6$ MPa) ve Grup N ($18,5 \pm 2,5$ MPa) arasında anlamlı fark bulundu ($p=0.05$). Diğer gruplar arasında anlamlı fark gözlenmedi. SEM değerlendirmesi, Grup N'nin bazı bölgelerde, dentin tübüllerinin periferini modifiye ederek ve eriterek açık dentin tübüllerini tıkadığını gösterdi. Grup G'de etkilenen tübüllerin çapında azalma ve belirgin daralma gözlemlendi. Grup N+G, dentin tübüllerini değışen derecelerde tıkadı.

Sonuç: Gluma hassasiyet giderici ardından Nd:YAG lazer uygulaması, dentin hassasiyeti için etkili bir tedavi olabilir ve adeziv kompozit rezinin dentin yüzeyine bağlanma dayanıklılığını olumsuz yönde etkilemez.

Anahtar Kelimeler: Bağlanma Dayanıklılığı, Dentin Hassasiyeti Tedavisi, Dentin Tübül Tıkama, Gluma, Nd:YAG

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INTRODUCTION

Dentin hypersensitivity is a clinical problem commonly encountered in dental practice. It is characterized by a short, sharp pain when dentinal tubules in the cervical region of a tooth are exposed to thermal, chemical, or tactile stimuli.¹⁻³ To date, several theories have been proposed to explain this phenomenon, but the mechanism responsible remains poorly understood. The most commonly accepted theory is the hydrodynamic theory^{4,5}; this theory proposes that in hypersensitive dentin the tubules are wide, open, and contain a fluid.^{6,7} The thermal, chemical, or tactile stimuli that induce painful symptoms are associated with the movement of this fluid within the pulp-dentin complex.^{4,8,9} Several treatments are available for dentinal hypersensitivity^{6,10,11}, including varnishes, anti-inflammatory agents, tubular obturating procedures, adhesives, and lasers (neodymium-doped: yttrium aluminum garnet (Nd:YAG) and carbon dioxide (CO₂)).¹² Desensitizing agents block the open dentinal tubules and thus reduce fluid infiltration, thereby reducing dentinal hypersensitivity.^{11,12} The desensitizing effects of fluoride-containing solutions are due to the mechanical blocking of exposed dentinal tubules by precipitating fluoride compounds.^{10,13,14} Primers containing glutaraldehyde (GA) and hydroxyethyl methacrylate (HEMA) can reduce hypersensitivity by precipitating plasma proteins in the dentinal fluid and so blocking the exposed dentinal tubules.^{10-12,15} Laser therapy is an alternative means of managing dentinal hypersensitivity.¹ For example, Nd:YAG laser therapy is an effective, U.S. Food and Drug Administration (FDA) approved alternative for managing dentinal hypersensitivity.¹⁶ The frequency, energy, and duration of irradiation influence laser efficiency. If applied correctly, Nd:YAG laser therapy can reduce dentinal hypersensitivity for at least 4 months.^{17,18} Nd:YAG laser could produce a sealing depth of approximately 4 µm within the tubules, usually causing an immediate reduction in dentin hypersensitivity.¹⁹

There are lots of studies about conventional desensitizers on the luting and bonding characteristics of adhesive composite resin to dentin surface in literatures.^{11,20-25} However, little is known about the effect of Nd:YAG laser hypersensitivity treatment and its association with desensitizing agents on the luting and bonding characteristics of composite resin and dentin.²⁶ Lopes et al.²⁷ found that Nd:YAG laser treatment following Gluma Desensitizer treatment is an effective treatment strategy

that has immediate and long-lasting effects. However, desensitizing agent application could reduce the bond strength between dentin and composite resin.²⁸ Huh et al.²⁸ also stated that crystal precipitation on the dentin surface could reduce the bond strength. Thus, the aim of this in vitro study was to evaluate the effects of hypersensitivity treatments on the shear bond strength between flowable adhesive restorative composite resin and dentin, and to observe dentin tubule occlusion using a scanning electron microscope (SEM). The null hypothesis was that different hypersensitivity treatments would not alter the shear bond strength between the flowable adhesive restorative composite resin and dentin.

MATERIALS AND METHODS

Tooth Selection and Specimen Preparation

Forty-three freshly extracted caries-free human first molars were used in this study. Any surrounding soft tissues were removed by immersion in 2.5% NaOCl solution for 10 min. The teeth were then stored in sterile saline (0.9% NaCl) until use. The crowns of the teeth were cut using a diamond disc (Rotary Dental Instruments, Kahla, Germany) to obtain buccal surfaces; they were then immersed in an acrylic mould with the buccal surfaces face-up. Buccal cervical enamel was removed with a water cooling diamond disc (Isomet 11-1180; Buehler Ltd, Evanston, IL) at a thickness of approximately 2 mm, and 40 smooth dentin surfaces were thus obtained for the shear bond strength tests (Figure 1).

Three additional 1.5-mm-thick buccal dentin slices were obtained from 3 specimens for SEM analysis. To simulate dentin hypersensitivity, the dentin slices were etched with 0.5 M ethylenediaminetetraacetic acid (EDTA) (pH = 7.4) for 2 min, and then washed with distilled water for 30 s and dried.^{7,29,30} Each dentin slice was divided into 2: one side was not exposed to additional surface treatments and served as a control, the other side was exposed to further surface treatments with Nd:YAG, Gluma, and Nd:YAG+Gluma.

The entire dentin surface of each sample was etched to remove any smear plugs and to mimic the open dentinal tubules of sensitive dentin using 0.5 M EDTA (pH 7.4) for 2 min (applied with a microbrush); the samples were then rinsed with an air-water syringe for 30 s and dried. The specimens were then randomly divided into 4 groups (n = 10) according to the surface treatments performed:



Figure 1. Smooth dentin specimen immersed in acrylic mould

Group C: (control) No additional treatment was performed after the smear layer was removed with EDTA.

Group N (Nd:YAG): Dentin surfaces were manually irradiated by scanning movements performed perpendicular to and approximately 1 mm away from the surface with a Nd:YAG laser (Fotona, AT Fidelis, Ljubljana, Slovenia) under the following conditions: 1 W, 10 Hz, 100 mJ, short pulse (SP) mode (180 μ s) for 60 s, 300 μ m quartz fiber optic delivery system. Therefore, energy density calculated was approximately 130 J/cm².

Group G (Gluma): Gluma desensitizer (Heraeus Kulzer, Dormagen, Germany) was applied with a microbrush on the surface of each specimen and left for 1 min and dried, then rinsed with water.

Group N+G (Nd:YAG+Gluma): The Nd:YAG laser was applied and this was followed by the application of the Gluma desensitizer.

Shear Bond Strength

After the respective pretreatment and adhesive sequences, a round-hole phyllosilicate (mica) mould with an inner diameter of 3 mm and a height of 3 mm was attached to each of the prepared dentin surfaces embedded in the

acrylic moulds. A two-step adhesive procedure (Clearfil® SE Bond, Kuraray Co. Ltd, Osaka, Japan) was used to treat the dentin surface according to the manufacturer's instructions. The primer (Clearfil SE Bond, Kuraray Co. Ltd, Osaka, Japan) was applied to the dentin surfaces for 20s, and the primed dentin surface was then dried with oil-free compressed air. The bonding agent (Clearfil SE Bond, Kuraray Co. Ltd, Osaka, Japan) was applied to dentin surface with a brush tip and polymerized for 10s. Flowable resin composite (Filtek TM Ultimate Flowable, 3M ESPE) was injected into Teflon tubes with a 3-mm internal diameter and height and light cured with a Light Emitting Diode (LED) curing light (Bluephase, Ivoclar Vivadent) for 40 s (Figures 2 and 3). The curing light was in contact with the Teflon tube. Thermal cycling (Thermal Cycler Tester, DentalTechnik, Konya, Turkey) was performed for 5 000 cycles between 5°C and 55°C ($\pm 2^\circ\text{C}$) with a dwell time of 20s to simulate oral conditions and the specimens were stored in distilled water at 37°C for 24h and then loaded onto a universal testing machine (TSTM 02500, Elisa Ltd, Istanbul, Turkey) with a metal rod held parallel and close to the bonding interface at 0.5 mm/min in the shear

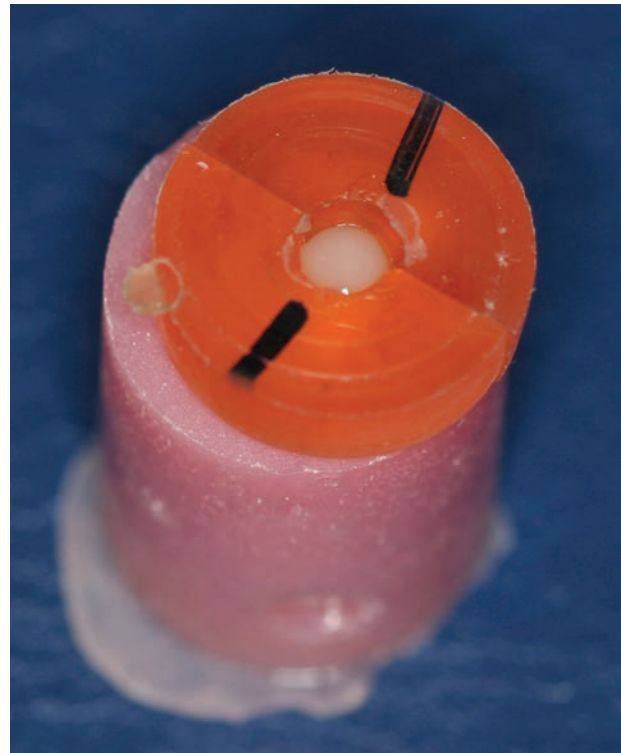


Figure 2. Flowable composite resin bonded dentin specimen among teflon tubes



Figure 3. Light curing of flowable composite resin

mode until fracture occurred. Shear bond strength values were calculated as the ratio of the fracture load relative to the bonding area and were expressed in megapascals.

The fractured surface of each specimen was examined with a stereomicroscope (Olympus SZ 40, SZ-PT, Japan) at $\times 40$ magnification to determine the mode of failure. The failure mode was classified as either adhesive, cohesive, or mixed (a combination of adhesive and cohesive failures). The data obtained from the shear bond strength testing were then subjected to statistical analyses to test for any differences between and within groups.

SEM Analysis

The specimens were dried with a critical point dryer and mounted on SEM stubs then sputter-coated with gold palladium (Cressington 108 Auto Sputter Coater, Cressington MTM-20, Elektronen Optic Service, Dortmund, Germany) and analyzed with a SEM (Evo LS10, Carl Zeiss,

Oberkochen, Germany) at $\times 2000$ magnification.

Statistical Analysis

Levene test was performed to evaluate homogeneity of variances. The shear bond strength data were normally distributed, and so a one-way analysis of variance (ANOVA) was used for data comparison. Tukey's HSD test was used to determine whether there were any statistically significant differences among groups. Significance was determined at a probability value of $p < 0.05$. All the statistical analyses were performed using Statistical Package for Social Sciences (SPSS 17.0, Chicago, IL).

RESULTS

One-way ANOVA revealed a significant difference among groups ($p = 0.02$). The mean shear bond strengths and the differences between groups are shown in Table 1. According to Tukey's HSD pair-wise multiple comparison test there was only a significant difference between Group G (11.7 ± 4.6 MPa) and Group N (18.5 ± 2.5 MPa) ($p = 0.01$). There were no significant differences among the other groups.

SEM evaluation revealed that the Nd:YAG laser (Group N) occluded the open dentinal tubules in some areas by melting and modifying the dentin tubule periphery (Figure 4). Dentin specimens treated with Gluma desensitizer showed prominent narrowing and a reduction in the diameter of the affected tubules (Figure 5). The samples treated with the Nd:YAG laser followed by the Gluma desensitizer occluded dentinal tubules, but to varying degrees (Figure 6).

The fracture types and failure mode distributions are shown in Figure 7. The fracture types in Group C were generally mixed (90%) whereas adhesive fractures were less common in Group N (10%), Group G (20%), and Group N+G (10%). Cohesive fractures also occurred in all treatment groups.

DISCUSSION

Dentinal hypersensitivity is a common problem that is specifically associated with periodontal diseases.³¹ Various treatments have been applied for dentin hypersensitivity.³² A number of different sealant agents are usually effective in rapidly reducing sensitivity, but their effectiveness is rapidly diminished.³³ Recently, an increasing number of studies relating to laser therapy for dentin hypersensitivity have been published.^{2,34,35} Laser therapy is an effective and reliable method that provides rapid pain relief without any detrimental pulpal effects.³⁶ However, although the application of a Nd:YAG laser and desensitizing agents

Table 1. Mean and SD values for shear bond strength (MPa)

Groups	Mean±SD	
Group C (Control)	16.83±6.15	
Group N (Nd:YAG)	18.56±2.56	*
Group G (Gluma)	11.76±4.65	*
Group N+G (Nd:YAG+Gluma)	15.61±5.25	

*, shows statistical significance, (p<0.05)

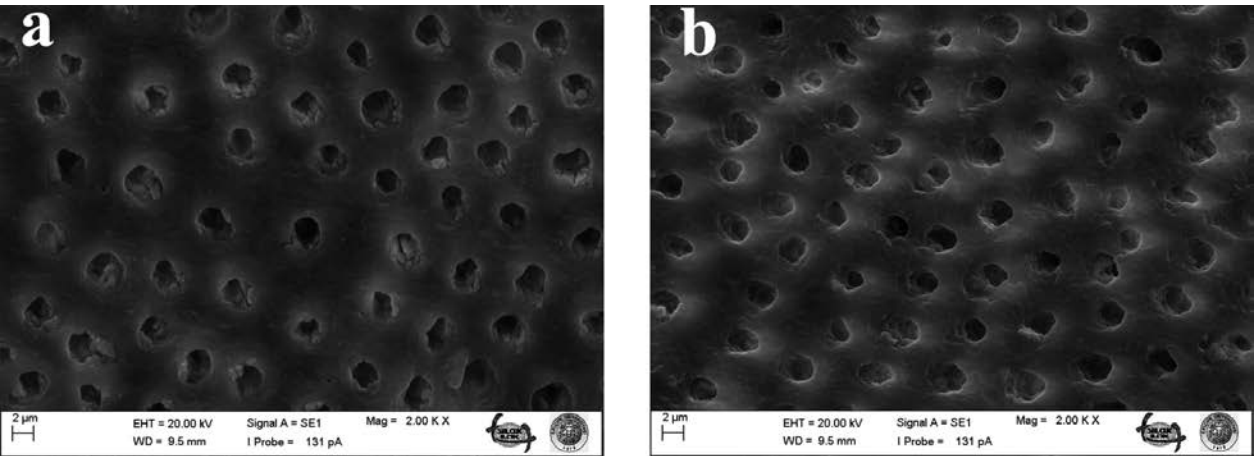


Figure 4. a. SEM views of dentin surface treated with 0.5 M EDTA (control group) b. SEM views of dentin surface treated with Nd:YAG laser (Group N)

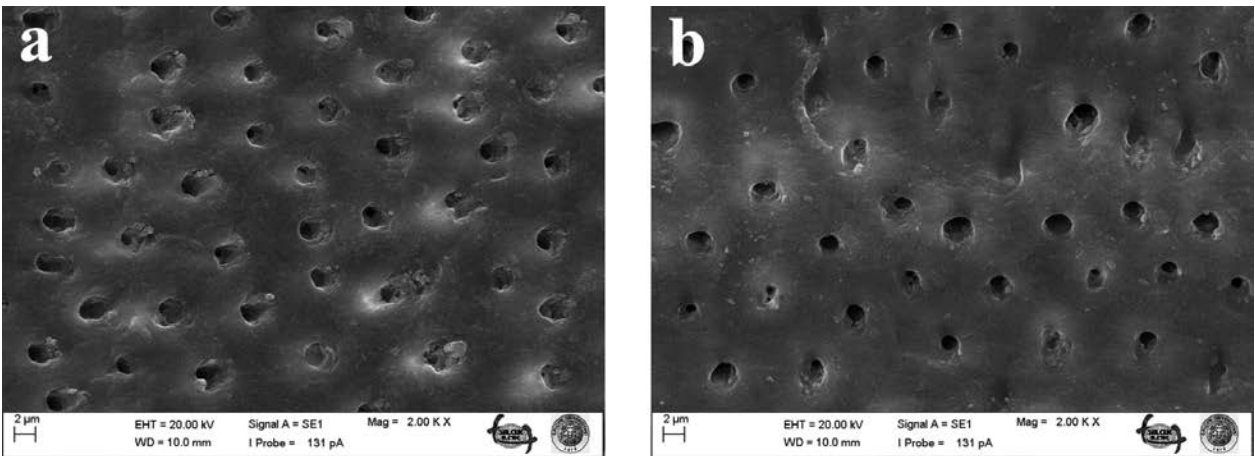


Figure 5. a. SEM views of dentin surface treated with 0.5 M EDTA (control group) b. SEM views of dentin surface treated with Gluma Desensitizer (Group G)

affects the strength of the bond between the composite resin materials and dentin, few studies have investigated these effects. In this in vitro study, a Nd:YAG laser, a desensitizing agent (Gluma), and both combined were tested to evaluate their effects on the bond strength between flowable resin cements and dentin surface. All of

the dentin surfaces tested were etched with 0.5 M EDTA prior to treatment to remove the smear layer or plugs to simulate the open tubules characteristic of sensitive teeth, and prepared for bonding.^{7,37} Gluma consists of an aqueous solution of 35% HEMA and 5% GA and occludes dentinal tubules by coagulating

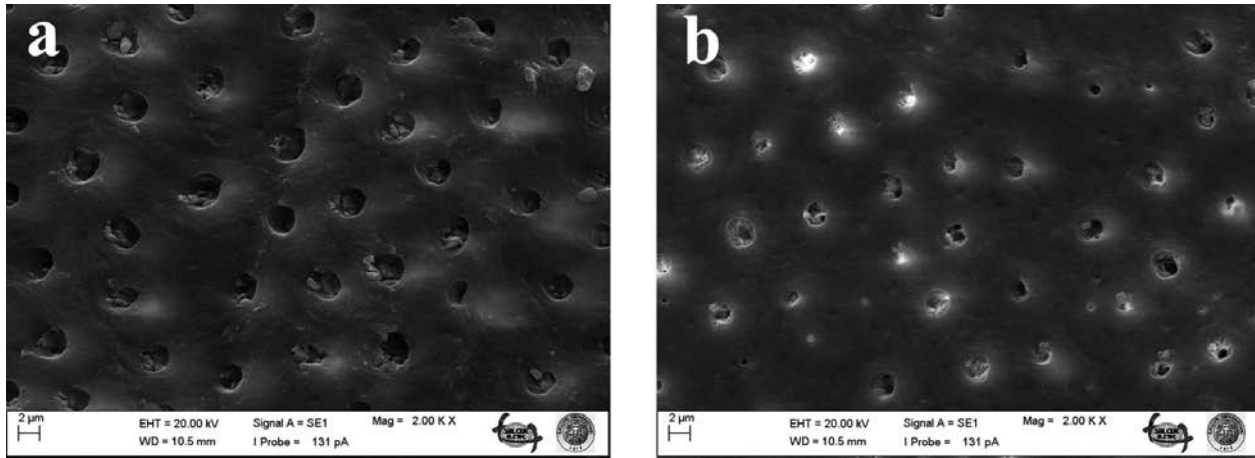


Figure 6. a. SEM views of dentin surface treated with 0.5 M EDTA (control group) b. SEM views of dentin surface treated with Nd:YAG laser following Gluma Desensitizer (Group N+G)

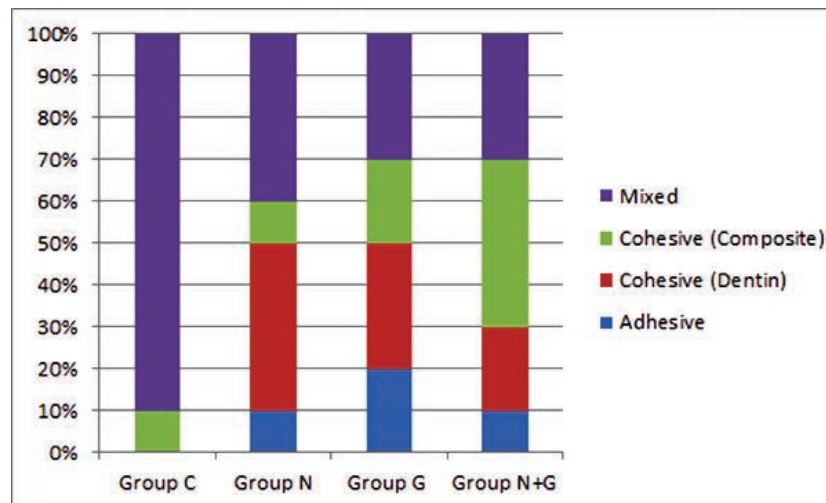


Figure 7. Fracture types and failure mode distributions (%) of dentin specimens.

dentin fluid proteins.³⁸ Araha and colleagues²⁰ evaluated the effects of different desensitizing agents (Gluma and Oxa-gel; Art Dent, Araraquara, SP, Brazil) and a low-intensity laser (MM Optics; Sao Carlos, SP, Brazil) on the bond strength between total-etch adhesive resin cement and dentin. They found that the Gluma desensitizer did not have any detrimental effects on bond strength. Huh and colleagues²⁸ examined the effects of previously applied desensitizers (SuperSeal, Phoenix Dental, Inc., USA; MS-Coat, Sun Medical Co. Ltd, Japan; Gluma and Copalite Varnish, Cooley & Cooley Ltd, USA) on the bond strength of resin cements using a self-etching primer. They reported that the group treated with the Gluma desensitizer (5.2 MPa) had lower shear bond strength than the control group (14.7 MPa). Our findings are consistent with theirs as our Group G (11.7 MPa) had a lower bond strength than Group C (control) (16.8 MPa).

Nd:YAG laser therapy has long been used to treat dentin hypersensitivity.^{36,39,40} Thermal energy absorption leads to laser-induced occlusion and narrowing of dental tubules and melting of the hydroxyapatite structure.^{7,18,34,41} However, the effects of previously applied laser sensitivity treatments on the bond strength of resin cement when a self-etching primer is used have yet to be clarified. While some researchers²⁶ have investigated the bond strength of agents applied after dentin Nd:YAG laser irradiation, others⁴² have investigated the effect of Nd:YAG laser irradiation of the hybrid layer or Nd:YAG laser irradiation performed after an adhesive has been applied but prior to polymerization.⁴³ Ferraira et al.⁴² evaluated the bond strength and hybrid layer morphology of different adhesive systems after Nd:YAG laser irradiation (0.8 W, 10 Hz; 1, 2 W, 20 Hz). They found that Nd:YAG laser irradiation of

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the hybrid layer promoted morphological changes in dentin and negatively influenced bond strength. By contrast, Yazici et al.²⁶ evaluated the shear bond strength of two-step self-etch adhesives applied to coronal dentin exposed to Nd:YAG laser therapy (1 W, 15 Hz) for dentin hypersensitivity. They found that Nd:YAG laser irradiation of dentin reduced the bond strength compared with the control group, but there were no statistically significant differences among the groups.

In our study there were no significant difference between Group N and the control group ($p=0.102$), but Nd:YAG laser therapy increased the shear bond strength compared to the control group. Consistent with our study findings, Rolla et al.⁴⁴ found that Nd:YAG laser irradiation of dentin increased bond strength for different adhesive systems (Tyrion SPE/One Step Plus and Adper Prompt L-Pop) and favored greater micromechanical retention of self-etch adhesives compared with non-irradiated dentin, but did not influence the bond strength of the single bond adhesive system. The adhesive system that is generally used by most clinicians was used in our study, and so different adhesive systems should be compared to evaluate the effects of different hypersensitivity treatments. The limitation of this study was the use of one adhesive system for luting composite resin and non vital teeth which probably caused some loss of dentin fluid protein.

CONCLUSION

Different hypersensitivity treatments significantly altered the strength of the bond between flowable resin composites and dentin. The bond strength of the composites applied to dentin samples irradiated with the Nd:YAG laser was significantly higher than that of those applied to the samples treated with the Gluma desensitizer. Nd:YAG laser irradiation following the application of the Gluma desensitizer could be an effective treatment for dentin hypersensitivity, and this combination did not have a detrimental effect on the strength of the bond between the resin cement and the dentin surface. Further, in vivo studies could be helpful for determining the effects of different dentin hypersensitivity treatments on the bond strength of adhesive materials.

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