Micro-tensile Bond Strength of Composite Resin Bonded to Er:YAG Laser-prepared Dentin

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Purpose

The aims of this study were to evaluate micro-tensile bond strength of composite resin bonded to dentin following high-speed rotary handpiece preparation or Er:YAG laser preparation with two different adhesive systems and to assess the influence of different Er:YAG laser energies on the micro-tensile bond strength.

Materials and Methods

In this study, 40 third morlars were used. Flat dentin specimans were obtained and randomly assigned to eight groups. Dentin surfaces were prepared with one of four cutting types: carbide bur, Er:YAG laser (2 W, 3 W and 4 W) and conditioned with two bonding systems, Scotchbond Multipurpose Plus (SM), Clearfil SE bond (SE) and composite resin-build ups were created. After storage for 24 hours, each specimen was serially sectioned perpendicular to the bonded surface to produce more than thirty slabs in each group. Micro-tensile bond strength test was performed at a crosshead speed of 1.0 mm/min. Micro-tensile bond strengths (μTBS) were expressed as means±SD. Data were submitted to statistical analysis using two-way ANOVA, one-way ANOVA, Student-Newman-Keuls′ multiple comparison test and t-test.

Results and Conclusion

1. Regardless of bonding systems, the μTBS according to cutting types were from highest to lowest : 3 W, 2 W, Bur, and 4 W. In addition, there was no significant difference between Bur and 4 W ($p<0.001$).
2. Regardless of cutting types, SM showed significantly higher μTBS than SE ($p<0.001$).
3. Bonding to dentin conditioned with SM resulted in higher μTBS for 3 W compared to Bur, 2 W, and 4 W. There was no significant difference between 2 W and Bur ($p<0.001$).
4. Bonding to dentin conditioned with SE resulted in higher μTBS for 3 W compared to 2 W, 4 W, and Bur. Bur exhibited significant lower μTBS than all other cutting types. There were no significant differences between 3 W, 2 W and between 4 W and Bur ($p<0.001$).
5. The μTBS of laser cutting groups were shown in order from highest to lowest: 3 W, 2 W and 4 W in two bonding systems. There was no significant difference between 2 W and 3 W in SE ($p<0.001$).

: The μTBS of composite resin bonded dentin was significantly affected by interaction between the cutting type and bonding system.

In the range of 2 W - 3 W, cavity preparation of the Er:YAG laser seems to supply good adhesion of composite resin restoration no less than bur preparation. In particular, if you want to use the self-etching system, including Clearfil SE bond for the purpose of a simplification of the bonding procedures and prevention of adverse effects by excessive etching, an Er:YAG laser may offer better adhesion than a bur.

Key words : Laser, Composite Resin, Bond Strength

I. INTRODUCTION

Since the effect of ruby laser irradiation on dental hard tissue was first reported in 1964, several lasers have been evaluated for their ability to remove hard dental tissue in anticipation of replacing the handpiece dental drill[1)]. However, most lasers are unable to effectively cut biocalcified tissues. CO_2 and Nd:YAG lasers induce surface changes in enamel and dentin, yet tend to cause fissuring, cracking, recrystallization, or crateriform foci of melting. Some of the Eximer lasers are able to ablate carious material, but they cannot effectively cut sound tooth structure and therefore are not amenable to cavity preparation. In addition, laser photon energy is complicated by significant elevations in temperature with a potential for deleterious effects on pulpal tissue[2)].

The Er:YAG laser, originally developed by Zharikov in 1975, was approved by the FDA in 1997 for caries removal, forming cavity preparations, and modifying dentin and enamel prior to etching[1,3)]. Described as a safe and effective tool for the removal of dental hard tissue, Er:YAG laser works at a wavelength of 2.94 μm, which coincides with the absorption peak of water and hydroxyapatite and can ablate the enamel and dentin effectively. Some studies have pointed to the feasibility of using an Er:YAG laser in conjunction with a water spray to remove hard dental tissue without compromising the laser cutting efficiency[1-4)]. With a fine water mist, the temperature can be suppressed and the irradiation can be perfomed with no damage to the pulp[1-4)].

The cavities prepared with an Er:YAG laser do not present a smooth surface; their surfaces have opened dentinal tubules without smear layer production and microscopically rough surfaces[1-5)]. These dentin characteristics have been expected to favor resin bonding, so that most of these cavities are filled with adhesive materials[4,5)]. Cavity preparations with the Er:YAG laser, followed by adhesive composite resin restoration, were tested[6-13)]. Bond strength studies following Er:YAG preparation report highly variable results. Sakakibara[9)] and Ceballos[10)] reported a decrease in bond strength to laser-irradiated dentin, and Armengol[11)] and Kataumi[12)] found no difference between laser-irradiated and non-irradiated specimens. In contrast, Visuri[13)] reported a significantly higher bond strength of composite to dentin prepared with an Er:YAG laser.

Indeed, the discussion on the real benefits and possible disadvantage of Er:YAG laser on bonding to dentin is not conclusive. In addition, the reliability of the adhesion obtained remains a controversial subject. In literature about the effect of Er:YAG laser for bonding, variable results have been reported. Furthermore, the studies of the optimal laser parameters for good bond strength are scarce.

The aims of this study were to evaluate micro-tensile bond strength of composite resin bonded to dentin following high-speed rotary handpiece preparation or Er:YAG laser preparation with two different adhesive systems and to assess the influence of different Er:YAG laser energies on the micro-tensile bond strength.

II. MATERIALS AND METHODS

1. Specimen preparation

Forty extracted human third molars were immediately cleaned and stored in saline for less than 1 month before the beginning of the experiment. Only caries-free and restorations-free teeth were used. Flat dentin surfaces were obtained by transverse sectioning of the crowns at approximately 1 mm beyond the amelodentinal junction using a low speed saw under water

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Table 1. Eight experimental groups according to dentin treatment

Group	Cutting type*	Bonding system†
1 (n=39)	Bur	SM
2 (n=47)	Bur	SE
3 (n=36)	2 W	SM
4 (n=44)	2 W	SE
5 (n=55)	3 W	SM
6 (n=43)	3 W	SE
7 (n=37)	4 W	SM
8 (n=43)	4 W	SE

*: Bur = high speed handpiece preparation; 2 W, 3 W, 4 W = Er:YAG laser preparation

†: SM = Scotchbond Multipurpose Plus; SE = Clearfil SE bond

cooling. No enamel was visible except at the periphery. Flat dentin surfaces were polished with a 600-1200 grit silicon carbide paper. After that, the forty specimens were randomly assigned to eight groups according to dentin treatment, preparing the surface with one of four cutting types: a carbide bur and Er:YAG laser (2 W, 3 W and 4 W) and conditioning with one of two bonding systems, Scotchbond Multipurpose Plus, and Clearfil SE bond (Table 1).

The mechanical preparations were performed, followed by application of bonding systems on all dentin surfaces. The details of dentin treatments were as follows:

-High speed handpiece

A round carbide bur (1 mm diameter) in a high speed handpiece (200,000 rpm) under air-water spray was used to prepare the dentin surface.

-Er:YAG laser

The Er:YAG laser (SDL-300EN, B&B Systems Co., Korea) emitting photones at a wavelength of 2.94 µm was used to irradiate the dentin surface. The laser beam was delivered with a 90° handpiece equipped with a sapphire tip. The tip end was positioned approximately 0.5 mm from the dentin surface. The irradiation was performed with a constant water-cooled spray. The following three different parameters were used; 2 W (100 mJ/20 Hz), 3 W (150 mJ/20 Hz) and 4 W (200 mJ/20 Hz).

-Cavity preparation

A carbide bur of a high speed handpiece and a sapphire tip of Er:YAG laser were positioned perpendicular to the flat dentin surface and were moved twice in each direction, horizontally and vertically; therefore, the dentin surfaces were cut in a cross-hatched grid pattern. Homogeneous preparations through the entire dentin surface area within 1 mm depth were accomplished.

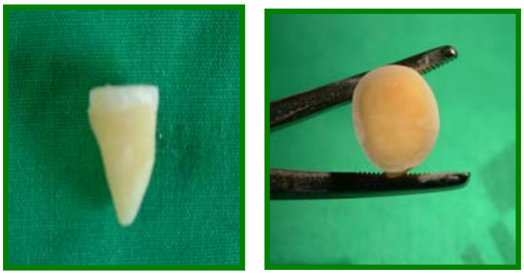
-Bonding system application

After the surface preparation, the specimens were submitted to the bonding procedures. The compositions and procedures of two bonding systems, Scotchbond Multipurpose Plus (3M Dental Product, St. Paul, USA) and Clearfil SE bond (Kuraray, Osaka, Japan) are shown in Table 2.

Composite resin (Filtek Z250, 3M Dental Product, St. Paul, USA) build-ups were created on the teeth in 2 mm increments to a height of 4-5 mm. The resin bonded specimens were stored in saline for 24 hours (Fig. 1).

2. Micro-tensile bond strength (µTBS)

After 24 hours storage, each specimen was serially sectioned perpendicular to the bonded surface (mesiodistally and buccolingually) to produce several slabs using a low speed precision cut-off machine, under water cooling. Each slab was a resin-dentin stick of about 1x1x10 mm^3(Fig. 2). More than thirty slabs were made in each group. Each slab was fixed to a specialized metal test bed using cyanoacrylate adhesive, Zapit (DVA Inc., Corona, USA) and was divided in tension using a micro-tensile tester (Bisco Inc., Shaumburg, USA) at a crosshead speed of 1 mm/min (Fig. 3). The microtensile bond strength of each slab was



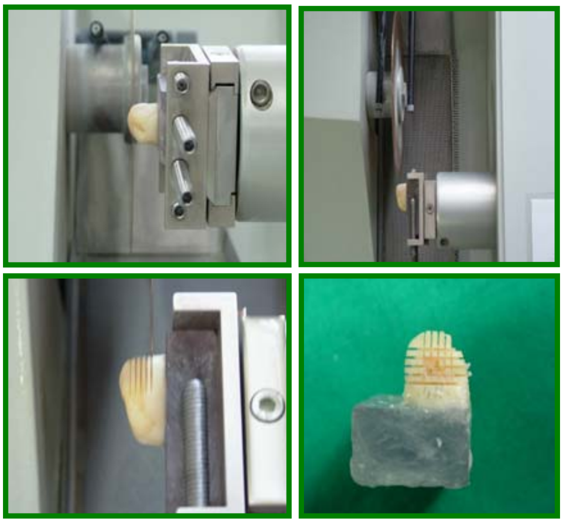
Flat dentin surfaces were obtained by transverse sectioning of the crowns at approximately 1 mm beyond the amelodentinal junction using a low speed saw under water cooling(Fig. 1. a).

A carbide bur of a high speed handpiece and a sapphire tip of Er:YAG laser were positioned perpendicular to the flat dentin surface and were moved twice in each direction, horizontally and vertically(Fig. 1.b).

Composite resin build-ups were created on the teeth in 2 mm increments to a height of 4-5 mm(Fig. 1.c).

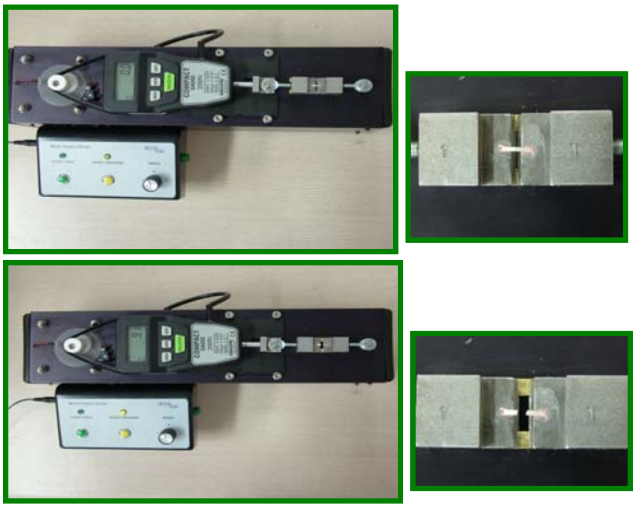
Table 2. Composition and procedure of bonding systems

Bonding system	Composition	Procedure
Scotchbond Multipurpose Plus	conditioner; 35% phosphoric acid primer; HEMA, polyalkenoic acid, copolymer, water adhesive; HEMA, Bis-GMA	1. apply etchant for 15 sec 2. rinse for 15 sec 3. dry 4. apply primer 5. dry for 5 sec 6. apply adhesive 7. dry 8. light cure for 10 sec
Clearfil SE bond	primer; MDP, HEMA, water, CQ hydrophilic dimethacrylate, N,N-diethanol-p-toluidine adhesive; MDP, Bis-GMA, CQ, hydrophobic dimethacrylate, N,N-diethanol-p-toluidine, silanized colloidal silica	1. apply primer 20 sec 2. dry 3. apply adhesive 4. dry 5. light cure 10 sec



Each specimen was serially sectioned perpendicular to the bonded surface (mesiodistally and buccolingually) to produce several slabs using a low speed precision cut-off machine, under water cooling(Fig. 2.a).

More than thirty slabs were made in each group. Each slab was resin-dentin stick of about 1x1x10 mm^3(Fig. 2.b).



The slab was fixed to a specialized metal test bed using cyanoacrylate adhesives, Zapit and was divided in tension using a micro-tensile tester at a crosshead speed of 1 mm/min. The microtensile bond strength of each slab was expressed in MPa.

expressed in MPa.

3. Statistical analysis

Statistical analysis was performed using SPSS version 11.0. For µTBS analysis, data of each group were expressed as means±SD. The differences of µTBS between cutting type and bonding system were analysed by two-way ANOVA. The differences of µTBS among eight groups were analysed by one-way ANOVA. A Student-Newman-Keuls' multiple comparison test was used

Table 3. The effect of cutting type and bonding system on μTBS by two-way ANOVA

Source	Type III sum of squares	df	mean square	F	p
corrected model	3127.01[a]	7	446.72	15.82	<0.001
intercept	98458.51	1	98458.51	3485.84	<0.001
cutting type and bonding system	391.04	3	130.35	4.62	.004
cutting type	1114.44	3	371.48	13.15	<0.001
bonding system	1297.44	1	1297.44	45.94	<0.001
error	9490.41	336	28.25		
total	113613.85	344			
corrected total	12617.42	343			

[a] R squared = .248 (Adjusted R squared = .232)

Table 4. The effect of cutting type on μTBS (MPa) regardless of bonding system

Cutting type	μTBS
4 W (n=80)	14.73 ± 4.19^{a}
Bur (n=86)	15.72 ± 6.32^{a}
2 W (n=80)	17.82 ± 5.70^{b}
3 W (n=98)	19.78 ± 6.35^{c}

^{a,b,c}Same letter indicates non-significant difference among groups based on Student-Newman-Keuls' multiple comparison test

for individual comparisons among four cutting types and among eight experimental groups. The t-test was used for comparison between two bonding systems.

Ⅲ. RESULTS

The results of the two-way ANOVA are summarized in Table 3. The μTBS was significantly affected by cutting types and bonding systems regardless of another factor (p<0.001), and there was statistically significant interaction between 2 factors (p=0.004).

Regardless of bonding systems, the μTBS according to cutting type were from highest to lowest : 3 W, 2 W, Bur, and 4 W. Also, there was no significant difference between Bur and 4 W (Table 4).

Table 5. The effect of bonding system on μTBS (MPa) regardless of cutting type

Bonding system	μTBS	p*
SM (n=167)	19.34 ± 6.05	p<0.001
SE (n=177)	15.05 ± 5.30	

* by t-test

Table 6. The comparison of μTBS (MPa) among eight groups

Group	Treatment	μTBS
2 (n=47)	Bur + SE	12.57 ± 4.98 ^{a}
8 (n=43)	4 W + SE	13.90 ± 4.12 ^{a,b}
7 (n=37)	4 W + SM	15.68 ± 4.12 ^{b,c}
4 (n=44)	2 W + SE	16.94 ± 4.86 ^{c,d}
6 (n=43)	3 W + SE	16.99 ± 5.81 ^{c,d}
3 (n=36)	2 W + SM	18.89 ± 6.50 ^{d}
1 (n=39)	Bur + SM	19.53 ± 5.67 ^{d}
5 (n=55)	3 W + SM	21.96 ± 5.92 ^{e}

^{a,b,c,d,e}same letter indicates non-significant difference among groups based on Student-Newman-Keuls' multiple comparison test

For bonding systems, regardless of cutting types, SM showed significantly higher μTBS than SE (Table 5).

There were statistically significant differences in μTBS among the eight experimental groups ($p<0.001$). The μTBS of eight groups are presented in order from lowest to highest in Table 6.

Bonding to dentin conditioned with SM resulted in higher μTBS for 3 W compared to Bur, 2 W, and 4 W. There was no significant difference between 2 W and Bur, and 4 W showed the lowest μTBS. Bonding to dentin conditioned with SE resulted in higher μTBS for 3 W compared to 2 W, 4 W, and Bur. Bur exhibited significant lower μTBS than all other cutting types. There were no significant differences between 3 W and 2 W and between 4 W and Bur. Under the same cutting type, SM exhibited higher μTBS than SE. However, for 2 W and 4 W, there were no significant differences between SM and SE. According to applied laser energies, different results of μTBS were shown. The μTBS of laser cutting groups were shown in order from highest to lowest: 3 W, 2 W and 4 W in two bonding systems. However, there was no significant difference between 2 W and 3 W in SE.

Ⅳ. DISCUSSION

The present study compared the in vitro μTBS of composite resin to human dentin that were prepared with the carbide bur or the Er:YAG laser applied with three different energies and conditioned with two different adhesive systems. It is known that the hydrophobic nature of restorative composite renders bonding to hard dental tissue difficult. Therefore, to achieve bonding of these resins, it is neccessary to alter the tooth surface topography and use hydrophilic resins[14)]. This study was performed attempting to modify the surface morphology by cutting the tooth surface with a bur or an Er:YAG laser applied with different energies (2 W, 3 W and 4 W) and by conditioning the surface with SM or SE.

The Er:YAG laser applies the thermal effect of light energy, which is completely different from conventional mechanical cutting. The Er:YAG laser emits a 2.94 μm wavelength that coincides with the absorption peak of water and is also well- absorbed by OH-group in hydroxyapatites. Due to the great water content in its composition, dentin substrate is a target tissue with a strong interaction with Er:YAG laser beams. During irradiation, the incident energy is readily and highly absorbed by water molecules present in dentin crystalline structures and organic components (mainly the intratubular fluid and collagen network), thus causing sudden heating and water vaporization. The resulting high-stream pressure within the irradiated tissue leads to the occurrence of multiple microexplosions, which constitute the major principle of Er:YAG laser ablation and produce a non-uniform destruction of tooth structure and the ejection of both organic and inorganic tissue particles. Therefore, Er:YAG prepared-surfaces have opened dentinal tubules without smear layer production. They also show morphological micro-irregularities and a cuff-like appearance due to more ablation of intertubular dentin, including higher water contents than peritubular dentin[15,16,17)].

However, in spite of favorable morphology of Er:YAG laser prepared-dentin, still bond strengths in dentin improved with acid etching such as bur treated-dentin[1,5,14)]. Although some studies reported that laser etching was available as an alternative to acid etching of enamel and dentin[18)], most studies have reported that laser alone does not demineralize dentin or widen the tubule entrance, and does not expose the dentin organic portion[5,15,19)]. Cyntia p. et al.[14)] reported that the subsequent use of acidic conditioning after laser irratiation produced higher bond strength than when a laser was used alone.

Thus, in this study, laser alone without acid conditioning was excluded. To achieve higher bond strength, both mechanical preparation followed by application of two bonding systems with different etching mechanism. Scotchbond Multipurpose Plus is a total-etching system that uses a separate acidic conditioner (35% phosphoric acid gel). Phosphoric acid etching removes the smear layer, increases the micro-porosity and results in the highest bond strength on bur prepared-dentin. On the other hand, Clearfil SE bond is a self-etching system in which acidic conditioner and primer have been combined into one solution[20]. Although the self-etching system has shown high bond strength on bur prepared-dentin, its limitations compared to the total-etching system have been reported. First, the acidic primer partially dissolves smear layer, instead of removing it completely. In addition, their relative high pH has less etching ability[20,21,22]. On laser treated-dentin, the effect of acid etching is still unclear[14]. There have been data reporting an increased resistance to acid dissolution showed by dental substrates following laser treatment. Consequently, the collagen matrix may not be totally exposed, and adhesion to resin can be disturbed by the lack of resin infiltration into demineralized dentin[4]. However, Marie et al.[15] reported that regardless of the kind of dentin preparation (carbide bur or Er:YAG laser), when acid etching and bonding were performed, a homogenous hybrid layer and funnel-shaped resin tags were visible. On the contrary, when an Er:YAG laser was used alone, no hybrid layer could be detected and the resin tags appeared thinner, in a cylindrical shape without any enlarged funnel-shape. Besides, Elisangela M. et al.[16] reported that when a lased dentin surface was acid-etched, a less irregular, scaly surface was observed, with the widening of dentinal tubules's entrances by peritubular dentin etching. In this study, laser prepared-dentin applied with 2 W and 3 W exhibited high bond strength using a two etching system no less than with bur prepared-dentin. In particular, when using Clearfil SE bond, an Er:YAG laser seemed to offer more effective bond strength compared to conventional handpiece. This result could be explained as follows: when bur prepared-substrates were conditioned with a self-etching system, a smear layer partially remained and micro-irregularities were relatively rare. Nonetheless, laser treated-substrates exhibit readily favorable morphological change; that is, they have a micro-retentive pattern and no smear layer prior to dentin conditioning. Thus, laser preparation seems to supply a self-etching system with reduced etching abilities.

Different parameters of laser irradiation such as energy, pulse frequency, focus mode, exposure time and wavelength can affect the adhesion. The energy parameter seems to provide a decisive influence on composite bond strength values to dentin[16,23]. Considering the lack of studies about the influence of energy of Er:YAG laser on the bond strength of composites to dentin, this study evaluated in vitro the effects of energy on the tensile bond strength of a compostie to dentin.

Elisangela M. et al.[16] reported that shear bond strengths of groups of 60 mJ/2 Hz, 80 mJ/2 Hz, and 100 mJ/2 Hz were showed no significant differences, but increases in laser energy resulted in increasingly cratered surfaces. Likewise, Armengol V. et al.[11] observed the presence of fissures and cracks that increased in size with a rise in energy. On the other hand, Hossain M. et al.[24] reported a gradual removal of the smear layer with an increase in laser energy. In this study, three different energies of 100 mJ (2 W), 150 mJ (3 W) and 200 mJ (4 W) were applied under the same pulse frequency of 20 Hz. For all bonding systems, 3 W and 2 W laser groups showed significantly higher bond strength than 4 W laser groups. Contrary to our expectation that higher laser energy causes lower bond strength, μTBSs were in order from highest to lowest: 3 W, 2 W, and 4 W. This result suggests that laser energy decisively affects bond strength; namely, while the optimal laser energy contributes to effective ablation and good bonding, excessively low or high energies give rise to poor bonding. This supports the findings of Kim. et al.[25] that the high energy irradiated-substrates showed severe irregularities; in addition, in low energy irradiaton, rapid ejection of ablated substrates did not occur. Thus, adequate adhesion could be disturbed.

In addition to the possibility of ablating dental hard tissue and increasing the adhesion of composite resin to dentin without damage to the pulpal tissue, another important characteristic of laser treatment is its antimicrobial property. Even if there is no difference between the irradiated and non-irradiated dentin with respect to its bond strength, cavities prepared with the laser device are expected to undergo microbial reduction in the infected dentin[4)].

With regard to resin-dentin bond strength, according to laser parameters and adhesive systems, highly variable results ensue. In view of the widespread appeal for adhesive dentistry and the increased interest in application of Er:YAG laser on dental hard tissue, future studies should include testing other ablative parameters, as well as different restorative materials for good bond strength.

V. CONCLUSIONS

1. Regardless of bonding systems, the μTBS according to cutting types were from highest to lowest : 3 W, 2 W, Bur, and 4 W. Also, there was no significant difference between Bur and 4 W ($p<0.001$).
2. Regardless of cutting types, SM showed significantly higher μTBS than SE ($p<0.001$).
3. Bonding to dentin conditioned with SM resulted in higher μTBS for 3 W compared to Bur, 2 W, and 4 W. There was no significant difference between 2 W and Bur ($p<0.001$).
4. Bonding to dentin conditioned with SE resulted in higher μTBS for 3 W compared to 2 W, 4 W, and Bur. Bur exhibited significant lower μTBS than all other cutting types. There were no significant differences between 3 W and 2 W, or between 4 W and Bur ($p<0.001$).
5. The μTBS of laser cutting groups were shown in order from highest to lowest: 3 W, 2 W and 4 W in two bonding systems. There was no significant difference between 2 W and 3 W in SE ($p<0.001$).

: The μTBS of composite resin bonded dentin was significantly affected by interaction between the cutting type and bonding system.

In the range of 2 W - 3 W, cavity preparation of Er:YAG laser seems to supply good adhesion of composite resin restoration no less than bur preparation. In particular, if you want to use the self-etching system, including Clearfil SE bond for the purpose of a simplification of the bonding procedures and prevention of adverse effects by excessive etching, an Er:YAG laser may offer better adhesion than a bur.

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국문요약

Er:YAG 레이저로 삭제된 상아질에 대한 컴포지트 레진의 미세인장결합강도에 관한 연구

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목적

전통적 고속 회전식 절삭기구 또는 Er:YAG 레이저로 삭제된 상아질에, 두가지 다른 접착 시스템을 적용한 후, 축조한 컴포지트 레진의 미세인장결합강도를 비교하고, 다양한 Er:YAG 레이저 에너지가 미세인장결합강도에 미치는 영향을 평가한다.

재료 및 방법

40개의 제3대구치를 사용하여, 평평한 상아질면을 만든 후 8개의 군으로 나누어, 4가지 절삭방법 (고속 회전식 절삭기구, 2 W, 3 W, 4 W 출력의 Er:YAG 레이저) 중 한 가지로 삭제하고, 2가지 접착 시스템 (Scotchbond Multipurpose Plus, Clearfil SE bond) 중 한 가지로 처리하여 컴포지트 레진을 축조하였다. 24시간의 저장 후, 각 시편을 결합면에 수직으로 자르고, 미세인장결합강도를 측정하였다. 각 군의 미세인장결합강도는 평균±표준편차로 표현하였고, 통계분석을 위해 two-way ANOVA, one-way ANOVA, student-Newman-Keuls′ multiple comparison test, 그리고 t-test가 사용되었다.

결과 및 결론

1. 접착시스템과 관계없이, 절삭방법에 따른 미세인장결합강도의 유의한 차이가 있었고, 높은 순서대로 나열하면 다음과 같다: 3 W, 2 W, Bur, 4 W ($p<0.001$).
2. 절삭방법과 관계없이, Scotchbond Multipurpose Plus로 처리한 군이 Clearfil SE bond로 처리한 군보다 유의하게 높은 미세인장결합강도를 나타냈다 ($p<0.001$).
3. Scotchbond Multipurpose Plus로 처리한 군 중에서, 3 W 레이저 절삭군이 가장 높은 미세인장결합강도를 나타냈고, 다음이 Bur, 2 W, 4 W 절삭군 순이었다 ($p<0.001$).
4. Clearfil SE bond로 처리한 군 중에서 3 W 레이저 절삭군이 가장 높은 미세인장결합강도를 나타냈고, 다음이 2 W, 4 W, Bur 절삭군 순이었다 ($p<0.001$).
5. 두 가지 접착 시스템 모두에서, 레이저로 절삭한 군의 미세인장결합강도의 차이가 있었고, 높은 순서대로 나열하면 3 W, 2 W, 4 W 순이었다 ($p<0.001$).

:상아질에 접착된 컴포지트 레진의 미세인장결합강도는 절삭방법과 접착시스템의 상호작용에 의해 유의한 영향을 받았다.

임상에서 레진 수복시, 2 W - 3 W 범위내로 Er:YAG laser를 사용한다면 전통적 핸드피스 못지않게 수복물의 우수한 결합강도를 얻을 수 있다. 특히 시술시간의 단축, 과도한 산부식에 따른 부작용의 예방을 위해 Clearfil SE bond를 포함한 self etching system을 사용하고자 한다면 bur보다 Er:YAG laser를 이용한 삭제방법이 더 유용한 결합력을 제공할 것이다.

주제어 : 레이저, 복합레진, 결합력