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Luciana Roggia Friedrich

INFLUÊNCIA DO LASER DE DIODO NA RESISTÊNCIA DE UNIÃO À DENTINA E DA SUPERFÍCIE IRRADIADA NA EVAPORAÇÃO DO SOLVENTE DE SISTEMAS ADESIVOS

Santa Maria, RS
2017

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Tese apresentada ao Curso de Doutorado do Programa de Pós-Graduação em Ciências Odontológicas, Área de Concentração em Odontologia, ênfase em Dentística, da Universidade Federal de Santa Maria (UFSM, RS), como requisito parcial para obtenção do grau de **Doutor em Ciências Odontológicas**.

Orientador: Prof. Dr. Bruno Lopes da Silveira

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Bruno Lopes da Silveira, Dr. (UFSM)
(Presidente da Banca/Orientador)

André Mallmann, Dr. (UFSM)

Carlos Eduardo Agostini Babinot, Dr. (UNIFRA)

Letícia Brandão Durand, Dra. (UFSM)

Marciano de Freitas Borges, Dr. (UNIFRA)

Santa Maria, RS
2017

DEDICATÓRIA

Aos meus pais**, Selso e Geneci...**

Gostaria de tentar expressar em palavras o meu sentimento de gratidão...
A vocês que me deram o dom da vida, e que de todas as formas possíveis me protegeram para que eu pudesse dar meus primeiros passos...
Pelas palavras de apoio e pelo amor incondicional nos momentos certos...
Obrigado pelos valores que me foram passados, por minha formação como pessoa e pelos ensinamentos sobre o certo e o errado...
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Mais ainda por fazerem acreditar em meus sonhos quando eu mesma pensei em desistir...
Essa minha conquista é apenas um reflexo da vitória de vocês que me ensinaram tudo o que eu sou...

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“O dia está na minha frente esperando para ser o que eu quiser.
E aqui estou eu, o escultor que pode dar forma. Tudo depende só de mim."

Charles Chaplin

RESUMO

INFLUÊNCIA DO LASER DE DIODO NA RESISTÊNCIA DE UNIÃO À DENTINA E DA SUPERFÍCIE IRRADIADA NA EVAPORAÇÃO DO SOLVENTE DE SISTEMAS ADESIVOS

AUTORA: Luciana Roggia Friedrich
ORIENTADOR: Bruno Lopes da Silveira

Este estudo teve como objetivo avaliar, *in vitro,* a resistência de união à dentina e a influência da superfície irradiada (vidro e dentina) sobre o grau de evaporação do solvente de sistemas adesivos pelo uso do laser de diodo de alta potência. Foi realizado em duas etapas, que consistiu em: a) avaliar da resistência de união (RU) através do teste de microcisalhamento. Para isso, foram selecionados 48 terceiros molares hígidos, os quais foram seccionados longitudinalmente, obtendo discos de dentina. Os espécimes foram aleatoriamente divididos em 8 grupos (n=6) em função do sistema adesivo (Adper Scotchbond Multi-Purpose, Adper Single Bond 2, Clearfill SE Bond, e Optibond All-in-one) e da irradiação ou não com o laser de diodo de alta potência (técnica experimental x técnica controle). O laser de diodo foi aplicado em modo contínuo, perpendicularmente e a uma distância de 1 cm da superfície irradiada, na potência de 3 W pelo tempo de 25 s. No decorrer, com o uso de uma matriz cilíndrica de amido aderida a dentina, foram confeccionadas restaurações em resina composta, que foram armazenadas por 24 horas a 37°C, e então, submetidas ao teste de microcisalhamento na máquina de ensaios universal, utilizando a velocidade de 1,0 mm/min até ocorrer a falha; b) avaliar a influência da superfície de irradiação no grau de evaporação do solvente (GE) pelo método gravimétrico. Os grupos foram distribuídos em função dos sistemas adesivos (Adper Single Bond 2 e Clearfil SE Bond) e da superfície de irradição (vidro e dentina). Para a superfície dentina, 12 terceiros molares humanos tiveram cavidades classe I confeccionadas. Para ambas as superfícies avaliadas, 10µL de cada um dos produtos testados foram dispensados e a perda de massa foi mensurada. Para cada material, foram realizadas seis séries (n=6) de monitoramento. Os dados do GE e da RU foram submetidos à análise de variância, teste *t-student* e/ou teste de Tukey (α= 5%). Com base nos valores obtidos de RU, o laser promoveu maior valores de RU para os adesivos convencionais quando comparado aos autocondicionantes, sendo superior à técnica controle para o Adper Single Bond 2. Em relação ao GE, o laser de diodo na potência de 3 W a partir de 15 s, provocou maior evaporação dos solventes no sistema adesivo convencional quando comparado ao autocondicionante. Em relação à superfície de irradiação, em quase todos os tempos empregados, o laser provocou maior evaporação dos solventes quando a superfície irradiada foi o vidro. Dessa forma, o laser de diodo surge como um novo método, sendo o resultado dependente das características inerentes a cada sistema adesivo e da superfície irradiada.

Palavras-chave: Evaporação. Laser. Microcisalhamento. Sistema Adesivo.

ABSTRACT

INFLUENCE OF DIODE LASER IN THE MICROSHEAR BOND STRENGTH TO DENTIN AND THE SURFACE IRRADIATED IN THE SOLVENT EVAPORATION OF ADHESIVE SYSTEMS

AUTHOR: Luciana Roggia Friedrich
ADVISOR: Bruno Lopes da Silveira

This study aimed to evaluate, *in vitro,* the bond strength to dentin and the influence of their radiated surface (glass and dentin) on the evaporation degree of solvent of adhesive systems by the use of high power diode laser. It was performed in two stages, which consisted in: a) evaluating the bond strength (*μ*SBS) through the microshear test. For this, 48 healthy third molars were selected, which were sectioned longitudinally, obtaining dentin disks. The specimens were randomly divided into 8 groups (n = 6) as a function of the adhesive system (Adper Scotchbond Multi-Purpose, Adper Single Bond 2, Clearfill SE Bond, and Optibond All-in-one) and no irradiation or irradiation with high power diode laser (experimental technique x control technique). The diode laser was applied continuously, perpendicularly and at a distance of 1 cm from the irradiated surface, at a power of 3 W for a time of 25 seconds. In the course, a cylindrical matrix of starch adhered to dentin, composite resin restora were made, which were stored for 24 hours at 37℃, and then submitted to the microshear test in the universal testing machine, using 1.0 mm/min speed until failure occurs; b) to evaluate the influence of their radiation surface on the evaporation degree of solvent (ED) by the gravimetric method. The groups were distributed according to adhesive systems (Adper Single Bond 2 and Clearfil SE Bond) and their radiation surface (glass and dentin). For the dentin surface, 12 human third molars had class I cavities made. For both evaluated surfaces, 10μL of each of the tested products were dispensed and the weight loss was measured. For each material, six monitoring series (n = 6) were taken. The ED and *μ*SBS data were submitted to variance analysis, t-student test and/or Tukey's test (α = 5%). Based on the values obtained from *μ*SBS , the laser promoted higher *μ*SBS values for the conventional adhesives when compared to the self-etch agents, being superior to the control technique for Adper Single Bond 2. In relation to the ED, the diode laser at a power of 3 W from 15 s, caused greater evaporation of the solvents in the conventional adhesive system when compared to the self-etch. In relation to their radiation surface, in almost all the times used, the laser caused greater evaporation of the solvents when their radiated surface was the glass. In this way, the diode laser appears as a new method, being dependent on the characteristics inherent to each adhesive system and their radiated surface.

Key-Words: Adhesive system. Evaporation. Laser. Microshear.

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1 INTRODUÇÃO

O conhecimento das características e dos mecanismos de união, tanto do sistema adesivo a ser usado como dos substratos a serem unidos, são de extrema importância para que o desempenho do procedimento restaurador seja máximo (DE MUNCK et al., 2005).

Em relação aos materiais biológicos envolvidos nos processos adesivos em Odontologia estão o esmalte e a dentina, sendo nesta o maior desafio para a adesão. Diversos estudos buscam entender a interação deste substrato com os sistemas adesivos (DEEPA et.al., 2014; PASHLEY et al., 1995), bem como discutir e alterar protocolos para uma melhor adesão (FELEMBAN et al., 2017; MOURA et al., 2014; REIS et al., 2010; SHARAFEDDIN, NOURI, KOOHPEIMA, 2015), pois a dentina possui uma complexa estrutura com heterogênea constituição orgânica e mineral, variável porosidade e presença de umidade no interior dos túbulos dentinários (PASHLEY, 1991; PASHLEY, CARVALHO, 1997; PERDIGÃO, 2010).

Ademais, cada substrato apresenta características peculiares e distintas de interação com os sistemas adesivos a partir da sua composição (REIS et al., 2004). Diante da grande variedade de sistemas adesivos existentes no mercado odontológico, eles podem ser classificados em dois grupos, de acordo com a estratégia de adesão à estrutura dentária, em sistemas adesivos de condicionamento ácido prévio ou convencionais (etch-and-rinse) e os autocondicionantes (self-etch) (VAN MEERBEEK et al., 2003) e, dentro destes grupos, eles podem ser classificados de acordo com o número de passos para sua aplicação.

A composição básica de um adesivo é: monômeros resinosos, partículas de carga e solventes, os quais exercem papel fundamental no processo de adesão (VAN LANDUYT et al., 2007). A explicação para tal importância, está no fato de que os solventes tem a capacidade de deslocar a água do interior das fibras colágenas da dentina para que o monômero resinoso possa penetrar nos espaços previamente preenchidos pela água (REIS et al., 2010), além de diminuir a viscosidade do sistema adesivo (CADENARO et al., 2009) proporcionando maior molhamento da estrutura dental (VAN MEERBEEK et al., 2003). Os solventes podem ser orgânicos ou inorgânicos, sendo os mais comuns água, acetona, e etanol (VAN LANDUYT et al., 2007).

No entanto, preconiza-se que após o solvente desempenhar sua função, seja totalmente eliminado (CADENARO et al., 2009). Sua presença residual pode gerar redução das propriedades mecânicas (IKEDA et al., 2008) e diminuição da polimerização do adesivo (BAIL et al., 2012; FERREIRA et al., 2011; TAKAHASHI et al., 2011), podendo comprometer a resistência de união à estrutura dental (EL-ASKARY, VAN NOORT, 2011; EMAMIEH et al., 2014).

Assim, muitos são os estudos existentes na literatura científica, com o intuito de investigar e promover um aumento de união entre o sistema adesivo e o substrato dentinário (FELEMBAN, EBRAHIM, 2017; MOURA et al., 2014; SHARAFEDDIN, NOURI, KOOHPEIMA, 2015). Neste sentido, diante do desenvolvimento tecnológico, o laser surge como uma alternativa para melhorar a qualidade de união do sistema adesivo à dentina.

As primeiras pesquisas utilizando o laser foram feitas na década de 1960 por Goldman *et al.* (1965) e Stern (1964) e desde então os efeitos biológicos da irradiação do laser tem sido estudados. Muitos estudos utilizando o laser de Er- Yag diretamente sobre a dentina foram realizados e os resultados foram conflitantes, pois alguns autores concluíram que o laser provocaria uma alteração na mesma, removendo a smear layer, deixando os túbulos dentinários abertos com dentina peritubular proeminente, possivelmente favorável aos procedimentos adesivos (ESTEVES-OLIVEIRA et al., 2007; GUVEN, AKROTEN, 2015; MALKOC et al., 2011). Porém, em outros, a irradiação ocasionou microfendas, desnaturação das fibrilas colágenas na dentina subsuperficial e formação de uma superfície ácido-resistente com estruturas granulares e/ou carbonizadas que provocariam a redução da resistência de união (DE MUNCK et al., 2002; MORETTO et al., 2011).

Além dessas, outras pesquisas foram realizadas e alterações no protocolo de irradiação foram descritas, em que o laser foi aplicado sobre o sistema adesivo previamente à sua fotoativação, bem como outros lasers foram utilizados. Em 1999, Gonçalves, de Araujo, Damião (1999) irradiando o laser de Nd:YFL e, posteriormente, Franke et al. (2006), Marimoto et al. (2013) e Batista et al. (2015), e utilizando o laser de Nd:YAG obtiveram resultados promissores, aumentando a resistência de união à estrutura dental.

Porém, esses lasers são inviáveis para a prática clínica devido ao seu alto custo e ao seu tamanho avantajado. Assim, o laser de Diodo surge como uma alternativa, por ser um equipamento portátil, com grande simplicidade de uso, custo reduzido quando comparado aos outros, possibilitando sua utilização pelos profissionais (MAENOSONO et al., 2015; PICK, 1993). Ademais, o laser de diodo apresenta como meio ativo um sólido semicondutor formado tipicamente de gálio, arseneto e outros elementos como alumínio e índio. Seu comprimento de onda varia de 655 a 980nm, muito próximo ao do Nd-YAG, podendo ser emitido em modo pulsado ou contínuo, na forma de contato ou não com o tecido alvo, dependendo de sua indicação clínica (AOKI, SASAKI, WATANABE, 2004; MAENOSONO et al., 2015; ROMANOS, NENTWIG, 1999).

A produção de calor gerada pelo laser de diodo pode ser influenciada por vários fatores, entre eles, a interação do laser com a superfície irradiada, pois esta é dependente de características inerentes ao próprio tecido, pela sua composição e propriedades ópticas e térmicas (YU et al., 1993; STABHOLZ et al., 2003). Além disso, existem, na literatura científica, estudos em que a evaporação do solvente é realizada sobre a superfície dentinária (MATUDA et al., 2016; MOURA et al., 2014;) e em outros, a evaporação é realizada sobre o vidro (BATISTA et al., 2015; EMAMIEH, SADR, GHASEMI, 2014).

Assim, diante do exposto, o objetivo do presente estudo foi avaliar a resistência de união à dentina e a influência da superfície irradiada (vidro e dentina) sobre o grau de evaporação do solvente de sistemas adesivos pelo uso do laser de diodo em alta potência.

2 ARTIGO 1 – INFLUÊNCIA DO LASER DE DIODO NA RESISTÊNCIA DE UNIÃO DE SISTEMAS ADESIVOS À DENTINA

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Title Page

Influence of diode laser in the microshear bond strength of the adhesive systems to dentin

Luciana Roggia Friedrich 1; Marcela Marquezan 2; Bruno Lopes da Silveira 3.

1. Post-graduate in Dentistry, Federal University of Santa Maria, Santa Maria, Rio Grande do Sul, Brazil.
Rua Floriano Peixoto, 611. Apto 302. Cep 97010310. Santa Maria, Rio Grande do Sul, Brasil.

2. Dentist in pro-rectory of students' affairs, Federal University of Santa Maria, Santa Maria, Rio Grande do Sul, Brazil.
Avenida Roraima, 1000. União Universitária. sala 1. Cep 97105900. Santa Maria, Rio Grande do Sul, Brazil.

3. Professor in Departament of Restorative Dentistry, Federal University of Santa Maria, Santa Maria, Rio Grande do Sul, Brazil.
Rua Floriano Peixoto, 1184. Sala 115. Cep 97015-372. Santa Maria, Rio Grande do Sul, Brazil.

Corresponding Author:

Luciana Roggia Friedrich

Rua Floriano Peixoto, 611. Apto 302. Cep 97010310. Santa Maria, RS, Brasil.

Phone number: 55 55 3026 3418

E-mail address: lucianafriedrich@yahoo.com.br

Abstract

The aim of this study was to evaluate, in vitro, the effects of diode laser irradiation on bond strength of adhesive systems to dentin. The study consists of the evaluation of the bond strength through the microshear test. For this, 48 healthy third molars were selected, which were sectioned longitudinally, obtaining dentin disks. The specimens were randomly divided into 8 groups (n = 6) as a function of the adhesive system (Adper Scotchbond Multi-Purpose, Adper Single Bond, Clearfill SE Bond, and Optibond All-in-one) and no irradiation or irradiation with diode laser of high power (experimental technique x control technique). The diode laser was applied continuously, perpendicularly and at a distance of 1 cm from the irradiated surface, at a power of 3 W for a time of 25 seconds. In the course, a cylindrical matrix of starch adhered to dentin, composite resin restorations were made, which were stored for 24 hours at 37℃, and then submitted to a microshear test in the universal testing machine, using speed of 1.0 mm/min until failure occurs. The results (MPa) were submitted to variance analysis and Tukey's test (α = 5%). To compare the techniques in each adhesive system, t-student test (α = 5%) was used. Based on the values obtained, the laser promoted higher values of bond strength for the conventional adhesives when compared to the self-etching adhesive, being superior to the control technique for Adper Single Bond. Thus, the diode laser appears as a new method and can be used, being the result dependent on the inherent characteristics of each adhesive system.

Keywords: Adhesive System. Bond Strengh. Laser. Microshear.

Introduction

The bond strength between the dental substrate and the adhesive systems is one of the most important factors for the success of the restorative treatment. Therefore, the knowledge of the characteristics and the mechanisms of union, both the system and the use of substrates to be united, are of extreme importance for the performance of the adhesive restoration procedure to be maximum [1].

The bond strength to the dentin depends on the material and its forms of application as well as on the test method used [2]. Thus, there are many studies in the scientific literature which investigate and promote a greater bonding between the adhesive system and the tooth substrate [3-5]. In this sense, because of the technological development, laser appears as an alternative to improve the quality of bonding of the adhesive system to the dentine.

The first research using laser was made in the 1960 by Goldman et al. [6] and Stern [7] and, since then, the biological effects of laser irradiation have been studied. Many studies using the Er-YAG's laser directly on the dentin were performed and the results were conflicting as some authors concluded that the laser beam would cause a change in the same, removing the smear layer, leaving the dentinal tubules open with prominent peritubular dentin favorable to adhesive procedures [8,9]. However, in others, irradiation caused microfractures, denaturation of collagen fibrils in the subsurface dentin, and the formation of an acid-resistant surface with granular and/or carbonized structures that would reduce the bond strength [10-12].

In addition, other investigations were carried out and changes in the irradiation protocol were described, in which the laser was applied on the adhesive system prior to its polymerization, as well as other lasers were used. In 1999, Gonçalves irradiated the Nd:YFL laser [13] and, later, Franke et al. [14], Marimoto et al. [15] and Batista et al. [16] with Nd:YAG laser obtained promising results, increasing the bond strength.

However, these lasers are unviable for clinical practice because of their high cost and large size. Thus, the diode laser appears as an alternative, since it is a portable device, with great simplicity of use, low cost when compared to others, allowing its use by professionals [17,18]. In addition, the diode laser has as active medium a semiconducting solid formed typically of gallium, arsenide and other elements such as aluminum and indium. Its wavelength ranges from 655 to 980nm, very close to that of the Nd-YAG, and can be emitted in pulsed or continuous mode, in the form of contact or not with the target tissue, depending on its clinical indication [19,18].

Thus, in view of the above, the objective of the present study was to evaluate the bond strength and the interaction of dentin adhesive systems by the use of the high power diode laser.

Materials and Methods

Tooth selection

It was 48 third human molars from the Dental Bank of the Dental School with appropriate approval from the Institution's Ethics and Research Committee under the number 66623517.0.0000.5346. The teeth were selected according to the quality criteria of the dental crown, absence of caries lesion, restorations, cracks or opacities, and with a size equal to or greater than 10 mm in the mesiodistal direction and 8.0 mm in the lingual-lingual direction, in order to provide the minimal area for the development of the proposed study.

After the selection, the teeth were cleaned with Maccall's curettes and Robinson's brushes soaked in a paste of pumice and water. Aiming at disinfection, they were stored for 30 days in 0.5% chloramines aqueous solution at room temperature, with weekly changes of this solution, being removed from this medium one day before the study, cleaned in running water and stored in distilled water for use.

Tooth preparation

The 48 teeth selected elements had their roots cut with double-sided diamond disc (KG Sorensen, Cotia, SP state, Brazil) adapted to the straight part at low- speed, with constant cooling. In order to obtain 3 mm slices of dentin tissue, the occlusal enamel was removed and, at the same time, a new cut, perpendicular to the long axis of the tooth was performed, using a diamond disk in a cutting machine (Labcut

1010, Excet Co., Enfield, CT, USA) at a speed of 250 rpm and under constant irrigation.

Each slice was fixed with cyanoacrylate-based glue to Polyvinyl chloride (PVC) tubes with 20 mm height and 25 mm diameter, previously filled with self-curing acrylic resin (JET Clássico, São Paulo, Brazil). Afterwards, the dentin surfaces were manually abrasive with grit silicon carbide paper number 600 for 60 seconds to carry out the standardization of the smear layer and, therefore, were stored in distilled water until the moment of the adhesive and restorative procedures.

Adhesive and restorative procedures

The adhesive systems used in this study are described in Table 1.

Table 1 - Adhesive System – Manufacturer, classification and chemical composition.

Adhesive Systems Manufacturer Classification	Composition
Adper Scotchbond Multi-Purpose 3M ESPE, St Paul, MN, USA Etch-and-rinse/conventional adhesive	*Primer:* HEMA, Polyalkanoic acid, water. *Adhesive:* Bis-GMA, HEMA, Canphorquinone, EDMAB.
Adper Single Bond 2 3M ESPE, St Paul,MN, USA Etch-and-rinse/conventional adhesive	Bis-GMA, HEMA, silica treated silane, glycerol-1,3-dimethacrylate, copolymer of acrylic acid and itaconic acid, diurethane dimethacrylate, water and ethanol.
Clearfil SE Bond Kuraray, Kurashiki, Okayama, Japan Self-etch adhesive	*Primer:* MDP, HEMA, Hydrophilic dimethacrylate, N-diethanol ptoluidine, camphorquinone, water. *Adhesive:* MDP, Bis-GMA, HEMA, Dimethacrylate hydrophobic, N. N Diethanol ptoluidine, Camphorquinone, silanized colloidal silica.
OptiBond All-in-One Kerr, Orange, CA, USA Self-etch adhesive	GPDM, Methacrylate and dysfunctional monomer, Camphorquinone, Nanosilica, Sodium Hexafluorsilicate, water, acetone and ethanol.

(HEMA: 2-Hydroxyethyl methacrylate; Bis-GMA: Bisphenol diglycidyl dimethacrylate; EDMAB: Ethyl 4-dimethyl aminobenzoate: GPDM: glycerol phosphate dimethacrylate: MDP: 10-Methacrylate dihydrogen phosphate).

The specimens were distributed and randomized (Random Allocation Software, Ispharan, Iran, version 1.0) in 8 groups (n = 6) according to the adhesive system and irradiation (experimental technique) or not (control technique) with diode laser, according to the study design (Chart 1).

In order to delimit the adhesive area to be evaluated, a double-faced adhesive tape was placed on the dentin surface, with perforations of 1 mm diameter, performed as the aid of Ainsworth-style rubber-dam punch (Wilcos; Petropolis, RJ, Brazil) [20,21].

Adhesive System		
	Control Technique	**Experimental Technique**
Adper Scothbond Multi-Purpose	1. Apply etchant for 15s; 2. Rinse; 3. Removal of excess water with absorbent paper; 4. Application of primer; 5. **Air dry for 5s**; 6. Application of a layer of adhesive. 7. Air dry for 5s.	1. Apply etchant for 15s; 2. Rinse; 3. Removal of excess water with absorbent paper; 4. Application of primer; 5. **Laser application for 25s;** 6. Application of a layer of adhesive. 7. Air dry for 5s.
Adper Single Bond 2	1. Apply etchant for 15s; 2. Rinse; 3. Removal of excess water; With absorbent paper; 4. Application of two consecutive layers scrubbing gently for 15s; 5. **Air dry for 5s.**	1. Apply etchant for 15s; 2. Rinse; 3.Removing excess water with absorbent paper; 4. Application of two consecutive layers scrubbing gently for 15s; 5. **Laser application for 25s.**
Clearfill SE Bond	1. Primer application for 20s; **2. Air dry for 5s;** 3. Application of the adhesive for 10 sec; 4. Air dry for 5s.	1. Primer application for 20s; 2. **Laser application for 25s;** 3. Application of the adhesive for 10s; 4. Air dry for 5s.
OptiBond All-in-One	1. Application of two consecutive layers scrubbing gently for 20s; 2. **Air dry for 5s.**	1. Application of two consecutive layers scrubbing gently for 20s; 2. **Laser application for 25s.**

Chart 2 Study design

The application of the air dry was carried out 10 cm away from the analyzed surface with pressure standardized by the same triple syringe. For the Clearfil SE

Bond system, the time of 5 seconds of air dry application was arbitrarily assumed, since the exact time of the procedure is not reported by the manufacturer.

The laser of choice for this study was Thera Lase Surgery (DMC Equipamentos Ltda, São Carlos, São Paulo, Brazil) with a wavelength of 810 nm and fiber diameter of 400 µm, being applied in a continuous way, perpendicularly and at a distance of 1 cm from the irradiated surface, at a power of 3 W for a time of 25 s, generating a maximum density of 60,000 J / cm².

Immediately afterwards, the plastic protective film of the upper face of the double-faced tape was removed and the starch tubes was positioned with a hole of 0.96 mm in diameter and 1 mm in height (Renata, Pastifício Selmi, Londrina, Paraná, Brazil), as advocated by Tedesco et al. (2013) [22], in order to allow restoration with resin composite. The adhesive and starch tubes was light cured with LED (Radii-cal, SDI, São Paulo, São Paulo, Brazil) with light intensity of 800 mW/cm2 measured by radiometer (Power Minter, model FM, number 33-0500, Series - WX65) and thus, the matrix remained fixed on the surface to be restored.

Then, cylindrical restorations were made with resin composite (Fitek Z250 A2, 3M-ESPE St. Paul, MN, USA) in two increments, positioned inside the matrix, and light cured individually for 20s, according to manufacturers' instructions.

All bonding and restorative procedures were carried out by a single trained operator at room temperature (20ºC to 24ºC).

Description of the test - Microshear Bond Strength (µSBS)

After 24 h of water storage at 37℃, the starch tubes were removed using air/water spray, the specimens were adapted to the universal testing machine (EMIC

DL 1000 - Equipamentos e sistemas Ltda. - São José dos Pinhais, Paraná, Brazil) and a 0.2 mm diameter stainless-steel was used to make a loop around the projection of the 0.5 KN load cell and the resin composite cylinder, maintaining contact with the surrounding dentin as close as possible to the adhesive interface. The microshear test was performed at a speed of 1.0 mm/min.

After breaking the union, all the specimens were examined under a stereomicroscope at 40X magnification by a blinded examiner. Failures were classified as mixed/adhesive (failure at the resin/dentin interface or mixed with cohesive failure of the adjacent substrate) or cohesive (resin composite or dentin). [23].

The experimental unit was the tooth and, for each one, an average of 5 specimens were tested. The specimens that failed before the test were considered as premature failures, which were assigned a value of zero.

The bond strength values (μSBS) (MPa) were obtained by the result of the division of the applied force (N) by the area of tooth bond/resin composite (mm^2).

Statistical Analysis

The *μ*SBS values were tabulated in spreadsheets and analyzed using descriptive statistics in the SPSS program (Statistical Package for Social Sciences, version 18.0). For each sample, the normal distribution was verified by the Shapiro-Wilk test, and the homocessability among them, by Levene's test. A two-way variance analysis was used to evaluate the influence of the techniques (control and experimental) and the adhesive systems used on a *μ*SBS. In order to elucidate the isolated effect of these factors, a analysis variance compared the *μ*SBS between adhesive systems in each technique. For the comparison between the techniques, in each adhesive system, t-student test was used. All tests were performed at the significance level of $\alpha = 5\%$.

Results

A two-way variance analysis elucidated that the interaction of adhesive and technical factors significantly influenced μSBS ($p < 0.05$).

The influence of the different techniques and adhesive systems on μSBS is demonstrated in the following table. (Table 2)

Table 2 – Microshear bond Strength (μSBS) - mean (standard deviation) of the adhesive systems for the control (air) and experimental (laser) techniques.

	Control technique	Experimental technique
Adper Single Bond 2	17,35(1,11) Ba	22,43 (1,55) Aa
Scoth Bond Multi-Purpose	16,50 (1,05) Aa	17,15 (2,11) Ab
Clearfill SE Bond	16,69 (0,89) Aa	13,66 (1,36) Bc
Optibond All-in-One	10,58 (0,54) Ab	8,06 (0,56) Bd

Different upper case letters indicate significant difference between the techniques while maintaining the same adhesive system (t-student test).
Different lowercase letters indicate difference between the adhesives for the same technique (ANOVA / Tukey).

For all types of adhesive systems and in all techniques evaluated, adhesive/mixed failures were predominant (94.6%).

Discussion

Since the introduction of Buonocore [24] phosphoric acid conditioning, the mechanism of interaction and adhesion to dental structure of conventional adhesive systems has been widely diffused and scientifically based. However, in order to achieve greater simplicity of the adhesive technique and decrease its sensitivity, self-etching systems are a great option and many researchers have been developed with the aim of improving their understanding of their action and their clinical performance [25-27].

In relation to the Optibond All-in-One adhesive system, the lowest bond strength values found in this study, using the conventional technique, can be explained, since this adhesive is the only one among them which does not present HEMA in its composition. HEMA, due to its hydrophilic characteristics, promotes a better miscibility of the hydrophobic and hydrophilic components of the adhesive systems, thus causing an improvement in the μSBS of adhesives [28].

The use of the diode laser was proposed, because the application of air dry can cause the incorporation of oxygen, compromising the polymerization and could lead to adhesive failure [29]. In addition, the excessive use of the air can lead to the adhesion of the adhesive at the internal angles of the preparation, as well as to the contamination of the adhesive layer with water and/or oil and to the extravasation of adhesive beyond the cavity limits [30].

Another factor of great clinical investigation is the adhesion to the dentin, due to its highly organic composition and the presence of high concentration of water. Also, many protocols are used to increase the bond strength to this substrate, among them, the use of the laser [14-16]. In this context, the diode laser was used to evaluate its influence on the bond strength, because this device, due to the photothermal effect, causes the elevation of temperature on the target tissues during the irradiation [13]. In this study, the use of high power (3 W) and a complementary time of application of the irradiation (25 s) were necessary in this study, as higher power and/or longer times increased the interaction between laser and adhesive.

The laser irradiation protocol used in this study demonstrated higher bond strength values for Adper Single Bond 2 and Adper Scotchbond Multi-Purpose adhesives, and, for Adper Single Bond 2, there was a statistically significant difference in relation to the control method. This result was in agreement with the study of Maenosono et al. [18], that the same adhesive also obtained results with significant statistical difference.

Regarding the results found for the self-etching adhesives, these showed lower bond strength values when irradiated with diode laser. These values may have been due to self-etching adhesives, according to Yiu et al. [31], they present more complex formulations in which the resinous monomers are generally more acidic and hydrophilic and that the higher the hydrophilicity of the system, the greater the solvent retention and the lower its evaporation even with the use of the laser.

However, there is a need for caution in comparing the results obtained in this study, with the results presented by other researchers in relation to the bond strength, since there are many lasers and irradiation parameters used in each study and different experimental designs used, which can interfere in the results found as: factors inherent to the laser device, such as power, wavelength, fiber diameter and radiation time [32]; relation to target tissue such as fiber distance and angulation [33], and the tissue itself by its composition and optical and thermal properties [6,34].

It is important to emphasize that the application of laser, in the different parameters of time and power, did not cause the polymerization of the adhesive system. This can be explained because the light cured of the adhesive systems, which contains camphorquinone as a photoinitiator, is initiated by the blue light, with a wavelength of 480 nm [35], and as the diode laser emits infrared light beam, with length of specific wavelength of 810 nm, but it is not able to photoinitiate the polymerization reaction of adhesive systems.

Regarding the types of flaws, which in this study revealed a greater amount of adhesive/mixed failures in all groups analyzed, it showed results similar to other microshear tests [36,23,27]. According to some authors [37,36], this fact happens because the area evaluated is very small, resulting in a greater uniformity in the stress distribution through the adhesive interface during the mechanical test and the fractures end up being in the adhesive interface.

Thus, the diode laser can be used as a substitute for the air dry in conventional adhesive systems. Additional studies should be performed to evaluate the influence of diode laser on the degree of conversion of adhesive systems, as well as to complement the understanding of the laser and adhesive interaction on the dental surface.

Conclusion

Based on the values obtained in the present study, it can be concluded that the diode laser was able to promote higher and\or similar *μ*SBS values than the conventional technique, mainly in relation to conventional adhesive systems. In this way, the diode laser appears as a new method and can be used, being the result dependent on the inherent characteristics of each adhesive system.

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3 ARTIGO 2 – INFLUÊNCIA DA SUPERFÍCIE IRRADIADA COM LASER DE DIODO NA EVAPORAÇÃO DO SOLVENTE DE SISTEMAS ADESIVOS

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Title Page

Influence of irradiated surface with diode laser in the solvent evaporation of the adhesive systems

Luciana Roggia Friedrich 1; Marcela Marquezan 2; Bruno Lopes da Silveira 3.

1. Post-graduate in Dentistry, Federal University of Santa Maria, Santa Maria, Rio Grande do Sul, Brazil.
Rua Floriano Peixoto, 611. Apto 302. Cep 97010310. Santa Maria, Rio Grande do Sul, Brasil.

2. Dentist in Pro-rectory of students' affairs, Federal University of Santa Maria, Santa Maria, Rio Grande do Sul, Brazil.
Avenida Roraima, 1000. União Universitária. sala 1. Cep 97105900. Santa Maria, Rio Grande do Sul, Brazil.

3. Professor in Departament of Restorative Dentistry, Federal University of Santa Maria, Santa Maria, Rio Grande do Sul, Brazil.
Rua Floriano Peixoto, 1184. Sala 115. Cep 97015-372. Santa Maria, Rio Grande do Sul, Brazil.

Corresponding Author:

Luciana Roggia Friedrich

Rua Floriano Peixoto, 611. Apto 302. Cep 97010310. Santa Maria, RS, Brasil.

Phone number: 55 55 3026 3418

E-mail address: lucianafriedrich@yahoo.com.br

Abstract

The aim of this study was to evaluate, *in vitro*, the effects of the irradiation surface of the diode laser in the solvent evaporation of adhesive systems. The groups were distributed according to the adhesive systems (Adper Single Bond 2 and Clearfil SE Bond) and laser irradiation surface (glass and dentin). For the dentin surface, 12 human third molars had class I cavities made. In both evaluated surfaces, 10μL of each of the tested products were dispensed and the mass loss was measured. For the solvent evaporation , the diode laser was applied continuously, perpendicularly and at a distance of 1 cm from the irradiated surface, at power 3 W for the times of 5, 10, 15, 20 and 25 seconds. For each material, six monitoring series (n = 6) were performed. The evaporation degree (ED) was determined by measuring the loss of mass by the gravimetric method in a digital analytical balance. The results were submitted to variance analysis and t-student test (α = 5%). Based on the values obtained from the ED, the diode laser at power of 3 W from 15 seconds, caused greater solvent evaporation in the conventional adhesive system when compared to the self-etching. In relation to the irradiation surface, in almost all the times used, the laser caused greater solvent evaporation when the irradiated surface was the glass. Diode laser is a new method for solvent evaporation of adhesive systems, the outcome being dependent on the inherent characteristics of each adhesive system, the irradiated surface and the laser interaction with both of them.

Keywords: Adhesive System. Evaporation Degree. Laser. Solvent evaporation.

Introduction

Adhesive Dentistry is a constant development of contributions to conservative treatments, because the contemporary adhesive systems make it possible to perform a minimally invasive dentistry [1,2].

The contemporany dentin bonding agents are a combination of resin monomers and charge particles diluted in organic or inorganic solvents, the most common ones being water, acetone, and ethanol [3,4].

The solvents play an essential role in the adhesion process, as they have the ability to displace water inside the collagen fibers of the dentin and concomitantly promote the penetration of resin monomers in the interfibrillar spaces [5], besides reducing the viscosity of the adhesive system [6], providing greater wettability of the tooth structure [7].

However, it is recommended that, after the solvent performs its function, it is totally eliminated [6]. Its residual presence may lead to a reduction of the mechanical properties [8] and a decrease in the adhesive polymerization [9-11], which may compromise the bond strength to the dental structure [12,13].

When heat is supplied to a substance, there is an increase in the kinetic energy of its molecules, leading to a change of state [5]. As a result, heated air dry surveys were carried out, resulting in higher evaporation rates of solvents of adhesive systems [14,11].

The use of the diode laser appears in this context because it causes elevation of temperature on the target and adjacent tissues during the irradiation caused by the photothermal effect. This effect consists of the absorption of the laser by the tissue and its transformation into thermal energy, heating the tissue [15], which can promote the evaporation of solvents from the adhesive and an increase in bond strength [16]. In addition, it is suggested the use of this laser because it is a semiconductor device, portable that, due to its simplicity and practicality, can be used routinely in the dental clinic [17,16].

There are, in the scientific literature, studies in which solvent evaporation is carried out on the dentin surface [18,19] and in others, the evaporation is carried out on the glass [14,20]. The production of heat generated by the diode laser can be influenced by several factors, among them, the interaction of the laser with the irradiated surface, since this is dependent on characteristics inherent to the fabric itself, its composition and optical and thermal properties [21, 22]. Therefore, the objective of the present study was to investigate the influence of the irradiated surface (glass x dentin) with the diode Laser in high power on the degree of the solvent evaporation of adhesive systems.

Materials and Methods

The experimental design of the present in vitro study was 2 x 2 factorial considering the variation factors: adhesive systems in 2 levels (Table 1) and irradiation surface in 2 levels (glass and dentin).

Table 1 Adhesive System - Manufacturer, Classification and Chemical Composition

Adhesive system Manufacturer	Classification	Composition (highlight to the solvent)
Adper Single Bond 2 3M ESPE, St Paul, MN, EUA	Etch-and-rinse /conventional adhesive	Bis-GMA, HEMA, silica treated silane, glycerol-1,3-dimethacrylate, copolymer of acrylic acid and itaconic acid, diurethane dimethacrylate, **water and etanol**.
Clearfil SE Bond Primer Kuraray, ToKoyama, Japan	Self-etch adhesive	Primer - MDP, HEMA, hydrophilic dimethacrylate, N.N. diethanol ptoluidine, camphorquinone, **water**

(HEMA: 2-Hydroxyethyl methacrylate; Bis-GMA: Bisphenol diglycidyl dimethacrylate; GPDM: glycerol phosphate dimethacrylate; MDP: 10-methacrylate dihydrogen phosphate)

Irradiated Surface: Glass

The container used to dispense the adhesive system was a concave glass container, called watch glass (Uniglas, Porto Alegre, RS state, Brazil) with dimensions 60 mm x 10 mm.

Irradiated Surface: Dentin

The research was approved by the Ethics and Research Committee of the Federal University of Santa Maria, under the number 67787617.9.0000.5346.

For the development of this stage of the study, 12 third human molars were used, from the Teeth Bank of the Dentistry Course of the Federal University of Santa Maria. The inclusion criteria of the teeth took into account the absence of carious lesions, restorations and cracks in the dental element.

After selection, the teeth were cleaned with McCall's curettes and Robinson's brushes, soaked in a paste of pumice and water. Aiming at disinfection, they were stored for 30 days in 0.5% chloramines aqueous solution at room temperature, with weekly changes of this solution. One day prior to the study, the specimens were cleaned in tap water and stored in distilled water.

The selected teeth were included in Polyvinyl chloride (PVC) tubes, through their root portions, with self-curing acrylic resin (JET Clássico, São Paulo, SP state, Brazil). After the polymerization of the acrylic resin, the dental enamel had its occlusal surface totally removed through the use grit silicon carbide paper number 100. Then, with the aid of a vertical device, cavidades classe I standardized wells with a depth of 1 mm and 5 mm diameter on dentinal occlusal surfaces were made with the use of a high rotation diamond tip 4054 (KG Sorensen, Cotia, SP state, Brazil) under constant irrigation. Dimensions were verified by means of a periodontal probe, millimeter (PCP-UNC 15, Hu-Friedy, Chicago, Illinois, USA).

In order to facilitate the adaptation of the teeth in the digital balance, the roots were cut about 2mm apical to the cement-enamel junction, in order to obtain a flat base with the use of double-sided diamond disc 7020 (KG Sorensen, Cotia, São Paulo, Brazil) adapted to the straight part at low speed, with constant cooling.

After this procedure, the specimens were stored in distilled water until the moment of gravimetric analysis.

Gravimetric Method

The solvents evaporation was verified by the gravimetric method, where the weight change of each sample was measured on a digital balance (Bosh SAE 200, Bosh, Jungingen, BW, Germany) with an accuracy of 0.0001 g, previously calibrated at the beginning of step with constant calibration monitoring throughout the test. For each measurement, the specimen was placed in the center of the balance and, after weighting, the scale was tared.

For Adper Single Bond 2 adhesive system, when applied on the dentin surface, it was done conditioning with 37 % phosphoric acid for 15 s, wash and remove excess water with absorbent paper (according to manufacturers' instructions use in dentin) .

Along with the use of high precision micropipette (Kacil Indústria e Comércio Ltda, Recife, Pernambuco, Brazil) and disposable tip (Cral, Cotia, São Paulo, Brazil), 10 μL of each adhesive system was dispensed.

Immediately after placing the tested material on the specimen, the initial weight value (IW) was recorded.

After the previous procedure, the solvent was evaporated with high power diode laser (Thera Lase Surgery DMC Equipamentos Ltda, São Carlos, São Paulo, Brazil) with a wavelength of 810 nm and fiber diameter of 400 μm applied in Continuous mode, perpendicularly and at a distance of 1cm from the surface with power of 3 W for the times of 5, 10, 15, 20 and 25 seconds, generating energy density maximum of 71,656 J / cm².

The variation between initial (IW) and final (FW) weight of the samples, respectively before and after application, was transformed into Evaporation Degree (ED) by applying the following equation: (IW-FW / IW) x100.

The entire experiment was performed by a single operator in a laboratory environment with a controlled temperature between 20 ºC and 24 ºC and the relative humidity of approximately 50% was monitored by means of thermohygrometer.

Statistical Analysis

The ED values were tabulated in spreadsheets and analyzed using descriptive statistics in the SPSS program (Statistical Package for Social Sciences, version 18.0). For each sample, the normality of distribution was verified by Shapiro-Wilk test, and the homocessability among them, by the Levene's test. A two-way variance analysis was used to evaluate the effect of adhesive systems and irradiation surfaces on the evaporation degree. In order to elucidate the isolated effect of these factors the t-student test was used to compare the ED between the adhesive systems in each irradiation surface at each of the times analyzed. The t-student test was also used to compare the irradiated surfaces in each adhesive system. All tests were realized at the significance level of $\alpha = 5\%$.

Results

The two-way variance analyses elucidated that, at all times from 15 s, the adhesive factors, irradiated surface and the interaction between these affects ED.

The influence of the diode laser on the different irradiated surfaces and the adhesive systems tested on ED is shown in the following table (Table 2).

Table 2 Evaporation Degree (ED) - mean (standard deviation) of the adhesives tested in relation to the irradiated surfaces and times of application.

		5s	10s	15s	20s	25s
Adper Single Bond 2	Glass	1,06 ^{aA} (0,39)	2,25 ^{aA} (0,87)	4,14 ^{aA} (0,77)	5,08 ^{aA} (0,63)	7,19 ^{aA} (0,77)
	Dentin	0,00 ^{bA} (0,00)	0,43 ^{bA} (0,67)	1,42 ^{bA} (0,50)	2,19 ^{bA} (0,56)	3,39 ^{bA} (0,80)
Clearfill SE Bond	Glass	0,62 ^{aA} (0,43)	1,53 ^{aA} (0,40)	2,23 ^{aB} (0,41)	2,83 ^{aB} (0,52)	3,93 ^{aB} (0,43)
	Dentin	0,39 ^{aA} (0,70)	0,39 ^{bA} (0,70)	0,60 ^{bB} (0,63)	1,21 ^{bB} (0,50)	1,83 ^{bB} (0,55)

Different lowercase letters indicate a significant difference between the irradiated surfaces when compared to the same adhesive system at each ED time (t-student test).
Different upper case letters indicate significant difference between adhesives when the same irradiated surface is maintained in each ED (t-student test).

Discussion

The results found in the present research for Adper Single Bond 2 adhesive system in relation to Clearfil SE Bond, in almost all irradiated times, are in agreement with those obtained by Abate et al. [23] and in which systems containing ethanol and water had a higher rate of evaporation when compared to water-based products only. This fact can also be explained, since the volatilization capacity of the solvents is directly linked to parameters such as solvent molecular weight, vapor pressure, temperature and relative humidity [24]. The higher the vapor pressure of a substance, the higher its evaporation rate, so ethanol has a higher vapor pressure (43.9 mmHg) when compared to water (17.5 mmHg), resulting in higher evaporation rates [23]. In addition, according Yiu et al. [25], the adhesive system, when simplified, presents more complex formulations in which the resinous monomers are generally more acidic and hydrophilic and that the higher the hydrophilicity of the system, the greater the permeability of the solvent and the lower its evaporation .

According to Batista et al. [20], the Nd-YAG laser when used for the removal of the solvent, resulted in higher evaporation rates when compared to those provided by the application of the air dry at room temperature. In this context, the diode laser was used to evaluate its influence in relation to solvent evaporation, because the diode laser, due to the photothermal effect, causes the temperature rise on the target tissues during the irradiation [15].

However, for the adhesives tested, the laser, when used for 5 seconds and 10 seconds, resulted in small evaporation rates. This is possibly due to the fact that, until a significant temperature change occurs that can lead to a reduction of mass loss, it takes a while for the laser to interact with the adhesive system and produce heat.

The loss of mass of the solvent, represented in this study by ED, has often been reported as an important variable in the performance of an adhesive [26-28]. The tests used to verify the loss of solvent mass can be performed by different analytical techniques such as the gravimetric analysis used in this research, this technique being a simple and effective method to evaluate the solvent evaporation of adhesive systems [29-31].

The different values found for the irradiated surface may have been due to the fact that, when the laser light reaches a tissue, it can be reflected, spread, absorbed or transmitted, and this interaction is dependent on the composition and properties of the tissue to be irradiated [32].

Another relevant result found in this study was that the evaporation rate was significantly higher almost in its entirety when the irradiated surface was the glass, except in the time of 5 seconds, for the Clearfill SE Bond adhesive. This can be explained by the fact that some types of LASER, when irradiated in the dentin, may promote a micro-retentive surface, open dentinal tubules and the absence of smear layer [33,34]. Also, according with Marimoto et al. [35] the laser irradiation promotes a high penetration of the adhesive in the dentin structure or promotes the formation of a substrate in which dentine and adhesive fuse by the activation of the laser. However, caution should be exercised in the evaluation of the results, since there is no study in the current literature that evaluates micromorphologically the interaction of diode laser with dentin.

It is important to point out that the application of laser, in the different parameters of time and power, did not cause the polymerization of the adhesive system. This can be explained because the polymerization of the adhesive systems, which contains camphorquinone as a photoinitiator, is initiated by the blue light, with a wavelength of 480 nm [36], and as the diode laser emits infrared light beam, with specific wavelength of 810 nm, is not able to photoinitiate the polymerization reaction of the adhesive systems.

Thus, in view of the above, the diode laser can be used for solvent evaporation of adhesive systems, however, longer periods, need to be used. Further, the solvents evaporation is superior to the conventional adhesive and when the irradiated surface is glass. In addition, the finding that there is less solvent evaporation when the substrate is dentin leads us to a closer approximation of the dental clinical situation leading to the understanding that the most adequate surface to perform solvent evaporation tests is the dentin structure. In addition, more research should be conducted to understand the laser and the adhesive interaction on the dental surface and on the conversion degree of the different adhesive systems.

Conclusion

Based on the values obtained from ED, verified in the present study, it can be concluded that the diode laser at 3 W power, starting 15 seconds, caused greater evaporation of the solvents in the conventional adhesive system when compared to the self-etch. In relation to the irradiation surface, in almost all analyzed times, the laser caused greater solvents evaporation when the surface irradiated was glass. Diode laser is a new method for solvent evaporation of adhesive systems, the outcome being dependent on the inherent characteristics of each adhesive system, the irradiated surface and the laser interaction with both of them.

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4. DISCUSSÃO

A utilização dos lasers vem sendo amplamente difundida dentro da Odontologia Moderna. O laser de diodo aparece nesse contexto, e em relação com os resultados obtidos neste estudo, surge como uma nova opção e pode ser empregado no intuito de promover a evaporação do solvente e aumentar a resistência de união de sistemas adesivos à dentina.

A aplicação de jato de ar é o método proposto pelos fabricantes com o objetivo de potencializar a evaporação dos solventes (GARCIA et al., 2010). Porém, o seu uso para tal fim, pode provocar a incorporação de oxigênio, comprometendo a polimerização e podendo levar a falha adesiva (MIYAZAKI et al., 1996). Ademais, o uso excessivo do ar pode levar ao empoçamento do adesivo nos ângulos internos do preparo, contaminação da camada adesiva com água e extravasamento de adesivo para além dos limites cavitários (LUQUE-MARTINEZ et al., 2014).

Conforme Batista et al. (2015), o laser de Nd:YAG quando utilizado para a eliminação do solvente, resultou em maiores taxas de evaporação quando comparada às proporcionadas pela aplicação do jato de ar à temperatura ambiente. Nesse contexto, utilizou-se o laser de diodo para avaliar a sua influência em relação à evaporação dos solventes, pois o laser de diodo, devido ao efeito fototérmico, causa a elevação de temperatura sobre os tecidos alvos durante a irradiação (GONCALVES, DE ARAUJO,DAMIAO, 1999).

Porém, para os adesivos testados, o laser, quando utilizado durante 5 s e 10 s, resultou em pequenas taxas de evaporação. Isso possivelmente se deve ao fato de que, até ocorrer uma alteração significativa de temperatura que possa levar a uma redução de perda de massa, leva-se um tempo até o laser interagir com o sistema adesivo e produzir calor.

Os diferentes valores encontrados, quanto à superfície irradiada, pode ter sido ocasionada devido ao fato de que, quando a luz laser atinge um tecido, esta poderá ser refletida, espalhada, absorvida ou transmitida, e esta interação é dependente da composição e propriedades do tecido a ser irradiado (SEKA et al., 1995).

Outro resultado relevante encontrado, neste estudo, foi de que a taxa de evaporação foi significativamente superior quase em sua totalidade, quando a superfície irradiada foi o vidro, exceto no tempo de 5s para o adesivo Clearfill SE Bond. Esta maior interação do laser com a dentina, produzindo menor taxa de evaporação, pode ser explicado, pois alguns tipos de laser, quando irradiados em dentina, podem promover uma superfície micro-retentiva, túbulos dentinários abertos e ausência de *smear layer* (BERTRAND et al., 2004; FREITAS et al., 2007) ou também, de acordo com Marimoto et al. (2013) a irradiação laser promove uma alta penetração do adesivo na estrutura dentinária ou promove a formação de uma substrato em que dentina e adesivo se fusionam pela ativação do laser. Contudo, deve-se ter cautela na avaliação dos resultados, pois não tem nenhum estudo, na literatura vigente, que avalia micromorfologicamente a interação do laser de diodo com a dentina.

Em relação à resistência de união, Gonçalves, de Araujo, Damião (1999) irradiando o laser de Nd:YFL e, posteriormente, Batista et al. (2015), Franke et al. (2006) e Marimoto et al. (2013) com o laser de Nd:YAG obtiveram resultados promissores, aumentando a resistência de união. E, em outros utilizando o laser de Er:YAG diretamente sobre a dentina, também tiveram valores aumentado de resistência de união (ESTEVES-OLIVEIRA et al., 2007; GUVEN, AKROTEN, 2015; MALKOC et al., 2011). Porém, esses lasers são inviáveis para a prática clínica devido ao seu alto custo e ao seu tamanho avantajado. Assim, o laser de Diodo surge como uma alternativa, por ser um equipamento portátil, com grande simplicidade de uso, custo reduzido quando comparado aos outros, possibilitando sua utilização pelos profissionais (MAENOSONO et al., 2015; PICK, 1993).

Nesse contexto, utilizou-se o laser de diodo para avaliar a sua influência na resistência de união. E diante disso, como potências maiores e/ou tempos maiores aumentam a interação entre laser e adesivo (FRIEDRICH et al., 2013) fez-se necessário, neste estudo, o uso de uma potência alta (3 W) e um tempo prolongado de aplicação da irradiação (25 s).

O protocolo de irradiação do laser, 3 W por 25 s, demonstrou maiores valores de resistência de união para os adesivos Adper Single Bond 2 e Adper Scotchbond Multi Purpose , sendo que para o Adper Single Bond 2 houve diferença estatística significativa em relação ao método controle. Este resultado foi ao encontro do estudo de Maenosono et al. (2015), que o mesmo adesivo também obteve resultados com diferença estatística significativa.

Em relação aos resultados encontrados para os adesivos autocondionantes, estes demostraram valores de resistência de união inferiores quando irradiados com laser de diodo. Esse valores podem ter sido ocasionados, pois os adesivos autocondicionantes, segundo Yiu et al. (2005), apresentam formulações mais complexas, em que os monômeros resinosos são geralmente mais ácidos e hidrofílicos e que, quanto maior a hidrofilia do sistema, maior a retenção de solvente, menor a sua evaporação e assim, menor a resistência de união obtida.

Por conseguinte, a temperatura que se desenvolve na polpa é um fator muito importante quando se procura avaliar a indicação do laser no tratamento do dente vitalizado (DE ALENCAR MOLLO et al., 2011). Conforme Zach e Cohen (1995), um aumento de temperatura de 5,6 °C na polpa dental, resultou em necrose em 15% das amostras avaliadas, 60% para uma elevação de temperatura de 11 °C e 100% para uma temperatura de 16,6 °C. Conforme Friedrich et al. (2013), o laser de diodo na potência de 3 W por 25 s provocou uma variação média de temperatura de 3,27 °C, e portanto, o laser de diodo não causaria danos ao tecido pulpar, sendo considerado seguro nos parâmetros utilizados.

É importante salientar que a aplicação do laser, no diferentes parâmetros de tempo e potência, não acarretou a polimerização do sistema adesivo. Isso pode ser explicado, pois a polimerização dos sistemas adesivos, que contém canforoquinona como agente fotoiniciador, é iniciada pela luz azul, com comprimento de onda de 480 nm (CASSONI, RODRIGUES, 2007) e como o laser de diodo emite feixe de luz inframervelha, com comprimento de onda específico de 810 nm, não é capaz de fotoiniciar a reação de polimerização dos sistemas adesivos.

Assim, diante do exposto,o laser de diodo pode ser utilizado em sistemas adesivos convencionais, obtendo maior resistência de união para o Adper Single Bond 2, e similar resistência de união para o Adper Scotchbond Multi Purpose , quando comparado ao jato de ar. E, ademais, o laser de diodo pode ser utilizado para a evaporação do solvente de sistemas adesivos, entretanto, altas potências, por períodos mais longos, necessitam ser utilizadas. Além disso, a evaporação dos solventes é superior para os adesivos convencionais e quando a superfície irradiada é o vidro. Portanto, pesquisas adicionais devem ser conduzidas para entender a interação laser e adesivo sobre a superfície dentária e sobre o grau de conversão dos diferentes sistemas adesivos.

5 CONCLUSÃO

De acordo com a metodologia proposta e com base nos resultados obtidos, pode-se concluir que:

- A aplicação do laser de diodo, em modo contínuo, na potência de 3 W por 25 s, promoveu maiores valores de resistência de união para os adesivos convencionais quando comparado aos autocondicionantes.
- A evaporação do solvente foi maior quando o laser foi irradiado sobre o vidro em relação à dentina.
- A interação laser/adesivo é dependente dos parâmetros de irradiação e das carecterísticas inerentes a cada sistema.

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ANEXO A - PARECER DO COMITÊ DE ÉTICA EM PESQUISA – UFSM EM RELAÇÃO AO ARTIGO 1

UNIVERSIDADE FEDERAL DE SANTA MARIA/ PRÓ-REITORIA DE PÓS-GRADUAÇÃO E

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: INFLUÊNCIA DO LASER DE DIODO NA RESISTÊNCIA DE UNIÃO DE SISTEMAS ADESIVOS À DENTINA.

Pesquisador: Bruno Lopes da Silveira

Área Temática:

Versão: 1

CAAE: 66623517.0.0000.5346

Instituição Proponente: Universidade Federal de Santa Maria/ Pró-Reitoria de Pós-Graduação e

Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 2.014.967

Apresentação do Projeto:

O projeto tem o título: "INFLUÊNCIA DO LASER DE DIODO NA RESISTÊNCIA DE UNIÃO DE SISTEMAS ADESIVOS À DENTINA" e se trata de um projeto de pesquisa do "PROGRAMA DE PÓS-GRADUAÇÃO EM CIÊNCIAS ODONTOLÓGICAS" da UFSM.

Consta que "O objetivo deste estudo será avaliar in vitro os efeitos da irradiação do laser de diodo na resistência de união de sistemas adesivos à dentina. O estudo será realizado em duas etapas, em que a primeira consiste na avaliação da resistência de união através do teste de microcisalhamento. Para isso, serão selecionados 48 terceiros molares hígidos. Os espécimes serão aleatoriamente divididos em 8 grupos (n=6) em função do sistema adesivo (Adper Scotchbond Multipurpose, Adper Single Bond, Clearfil SE Bond, e Optibond All-in-one) e da irradiação ou não com o laser de diodo de alta potência (técnica experimental x técnica controle). O laser de diodo será aplicado em modo contínuo, perpendicularmente e a uma distância de 1 cm da superfície irradiada, na potência de 3 W pelo tempo de 25 s. No decorrer, com o uso de uma matriz cilíndrica de amido aderida a dentina, serão confeccionadas restaurações em resina composta, que serão armazenadas por 24 horas a 37°C, e então, submetidas ao teste de microcisalhamento na máquina de ensaios universal, utilizando a velocidade de 1,0 mm/min até

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ocorrer a falha. Os resultados (MPa) serão submetidos à análise estatística descritiva e testes de comparações. A segunda etapa baseia-se na análise estrutural da superfície dentinária pelo microscópico eletrônico de varredura –
MEV."

Não há justificativa ou cálculo para o tamanho da amostra a ser utilizada.

Objetivo da Pesquisa:

Objetivo primário: avaliar o efeito da irradiação do laser de diodo sobre a resistência de união de diferentes sistemas adesivos aplicados sobre a dentina humana.

Objetivo secundário: - Comparar os valores de resistência de união de um mesmo adesivo submetido a irradiação ou não com laser de diodo; - Avaliar qualitativamente a interação do laser de diodo na interface adesiva através do MEV.

Avaliação dos Riscos e Benefícios:

Riscos: Em relação aos aspectos éticos, a realização da presente pesquisa não implicará riscos e irá respeitar a integridade física e moral do sujeito da pesquisa dentro dos padrões éticos conforme a Resolução do Conselho Nacional de Saúde 196/96 , pois será realizada com dentes doados.

Benefícios: Em relação aos benefícios, os pesquisadores, bem como todos os profissionais de Odontologia, irão ampliar os seus conhecimentos em relação as aplicações e os parâmetros seguros de irradiação do laser de diodo.

Comentários e Considerações sobre a Pesquisa:

.

Considerações sobre os Termos de apresentação obrigatória:

Foram apresentados o termo de confidencialidade, a autorização institucional e uma declaração do Banco de Dentes.

Recomendações:

Num projeto razoável convém justificar de forma empírica ou apresentar cálculo para a definição do tamanho da amostra a ser utilizada.

Veja no site do CEP - http://w3.ufsm.br/nucleodecomites/index.php/cep - na aba "orientações gerais", modelos e orientações para apresentação dos documentos. ACOMPANHE AS ORIENTAÇÕES DISPONÍVEIS, EVITE PENDÊNCIAS E AGILIZE A TRAMITAÇÃO DO SEU PROJETO.

Conclusões ou Pendências e Lista de Inadequações:

.

Considerações Finais a critério do CEP:

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_893097.pdf	03/04/2017 23:35:09		Aceito
Outros	confidencialidaderesistencia.pdf	03/04/2017 23:34:20	Bruno Lopes da Silveira	Aceito
Outros	bancoresistencia.pdf	03/04/2017 23:33:43	Bruno Lopes da Silveira	Aceito
Outros	registrogapresistencia2.pdf	03/04/2017 23:05:17	Bruno Lopes da Silveira	Aceito
Outros	registrogapresistencia.pdf	03/04/2017 23:02:19	Bruno Lopes da Silveira	Aceito
Declaração de Instituição e Infraestrutura	autorizacaoinstitucionalresistencia.pdf	03/04/2017 22:59:52	Bruno Lopes da Silveira	Aceito

Projeto Detalhado / Brochura Investigador	projetoresistencia.pdf	03/04/2017 22:53:11	Bruno Lopes da Silveira	Aceito
Folha de Rosto	folhaderostoresistencia.pdf	03/04/2017 22:50:43	Bruno Lopes da Silveira	Aceito

Situação do Parecer:
Aprovado

Necessita Apreciação da CONEP:
Não

SANTA MARIA, 13 de Abril de 2017

Assinado por:
CLAUDEMIR DE QUADROS
(Coordenador)

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ANEXO B - PARECER DO COMITÊ DE ÉTICA EM PESQUISA – UFSM EM RELAÇÃO AO ARTIGO 2

UNIVERSIDADE FEDERAL DE SANTA MARIA/ PRÓ-REITORIA DE PÓS-GRADUAÇÃO E

Plataforma Brasil

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: INFLUÊNCIA DA SUPERFÍCIE IRRADIADA COM LASER DE DIODO NA EVAPORAÇÃO DO SOLVENTE DE SISTEMAS ADESIVOS

Pesquisador: Bruno Lopes da Silveira

Área Temática:

Versão: 2

CAAE: 67787617.9.0000.5346

Instituição Proponente: Universidade Federal de Santa Maria/ Pró-Reitoria de Pós-Graduação e

Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 2.062.849

Apresentação do Projeto:

O projeto tem o título "INFLUÊNCIA DA SUPERFÍCIE IRRADIADA COM LASER DE DIODO NA EVAPORAÇÃO DO SOLVENTE DE SISTEMAS ADESIVOS" e se vincula ao Programa de Pós-Graduação em Ciências Odontológicas.

No resumo do projeto consta que "O objetivo deste estudo será avaliar in vitro os efeitos da superfície de irradiação do laser de diodo na evaporação do solvente de sistemas adesivos. Os grupos serão distribuídos em função dos sistemas adesivos (Adper Single Bond 2 e Clearfil SE Bond) e da superfície de irradição do laser. (lâmina de vidro e dentina). Para a superfície dentina, 12 terceiros molares humanos terão cavidades classe I confeccionadas, de forma padronizada, com ponta diamantada de alta rotação. Para ambas as superfícies avaliadas, 10µL de cada um dos produtos testados serão dispensados e a perda de massa será mensurada. Para cada material, serão realizadas seis séries (n=6) de monitoramento. O grau de evaporação (GE) será determinado através da mensuração da perda de massa pelo método gravimétrico em uma balança analítica digital. Os resultados serão submetidos à análise estatística descritiva e testes de comparações."

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A referência à res. 196/96 foi atualizada no projeto, mas não do formulário gerado pela PB.

Objetivo da Pesquisa:

Na p. 6 do projeto consta que o objetivo geral é "avaliar o efeito da superfície irradiada no grau de evaporação de diferentes sistemas adesivos".

Os objetivos específicos são:

"- Comparar os valores de evaporação do solvente conforme diferentes tempos de irradiação.

- Comparar o grau de evaporação utilizando adesivos total-etching e self-etching."

Avaliação dos Riscos e Benefícios:

No projeto consta: "Em relação aos aspectos éticos, a realização da presente pesquisa não implicará riscos e irá respeitar a integridade física e moral do sujeito da pesquisa dentro dos padrões éticos conforme a Resolução do Conselho Nacional de Saúde 466/2012 , pois será realizada com dentes doados. Em relação aos benefícios, os pesquisadores, bem como todos os profissionais de Odontologia, irão ampliar os seus conhecimentos em relação as aplicações e os parâmetros seguros de irradiação do laser de diodo."

Comentários e Considerações sobre a Pesquisa:

.

Considerações sobre os Termos de apresentação obrigatória:

Foram apresentados de modo suficiente.

Recomendações:

Veja no site do CEP - http://w3.ufsm.br/nucleodecomites/index.php/cep - na aba "orientações gerais", modelos e orientações para apresentação dos documentos. ACOMPANHE AS ORIENTAÇÕES DISPONÍVEIS, EVITE PENDÊNCIAS E AGILIZE A TRAMITAÇÃO DO SEU PROJETO.

Conclusões ou Pendências e Lista de Inadequações:

A referência à res. 196/96 foi atualizada no projeto, mas não do formulário gerado pela PB.

UNIVERSIDADE FEDERAL DE SANTA MARIA/ PRÓ-REITORIA DE PÓS-GRADUAÇÃO E

Continuação do Parecer: 2.062.849

Considerações Finais a critério do CEP:

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_315316.pdf	12/05/2017 19:04:01		Aceito
Projeto Detalhado / Brochura Investigador	ultimaversaoprojetolaminaedente.pdf	12/05/2017 19:03:34	Bruno Lopes da Silveira	Aceito
Outros	confidencialidadetecnicasfinal.pdf	27/04/2017 22:57:28	Bruno Lopes da Silveira	Aceito
Outros	instituicaotecnicas.pdf	09/04/2017 23:18:19	Bruno Lopes da Silveira	Aceito
Folha de Rosto	folhaderostotecnicas.pdf	09/04/2017 23:07:27	Bruno Lopes da Silveira	Aceito
Outros	registrotecnicas2.pdf	03/04/2017 23:48:58	Bruno Lopes da Silveira	Aceito
Outros	registrotecnicas.pdf	03/04/2017 23:48:26	Bruno Lopes da Silveira	Aceito
Outros	declaracaocomitelamina.pdf	03/04/2017 23:47:13	Bruno Lopes da Silveira	Aceito
Declaração de Instituição e Infraestrutura	autorizacaodisciplinatecnicas.pdf	03/04/2017 23:43:37	Bruno Lopes da Silveira	Aceito

Situação do Parecer:
Aprovado

Necessita Apreciação da CONEP:
Não

SANTA MARIA, 15 de Maio de 2017

Assinado por:
CLAUDEMIR DE QUADROS
(Coordenador)

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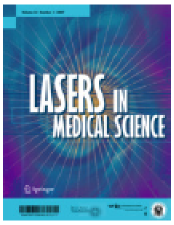
ANEXO C - NORMAS PARA PUBLICAÇÃO NO PERIÓDICO *LASERS IN MEDICAL SCIENCE*



Lasers in Medical Science

Editor-in-Chief: Keyvan Nouri

ISSN: 0268-8921 (print version)

ISSN: 1435-604X (electronic version)

Journal no. 10103

Instructions for Authors

Instructions for Authors

TYPES OF PAPERS

- Original Article – limited to 4000 words, 45 references, no more than 5 figures
- Review Article – limited to 5000 words, 50 references, no more than 5 figures
- Brief Report - limited to 2000 words, 25 references, no more than 4 figures - Case Reports will not be accepted!
- Letter to the Editor – up to 600 words

MANUSCRIPT SUBMISSION

Manuscript Submission

Submission of a manuscript implies: that the work described has not been published before; that it is not under consideration for publication anywhere else; that its publication has been approved by all co-authors, if any, as well as by the responsible authorities – tacitly or explicitly – at the institute where the work has been carried out. The publisher will not be held legally responsible should there be any claims for compensation.

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Authors should submit their manuscripts online. Electronic submission substantially reduces the editorial processing and reviewing times and shortens overall publication times. Please follow the hyperlink "Submit online" on the right and upload all of your manuscript files following the instructions given on the screen.

TITLE PAGE

Title Page

The title page should include:

- The name(s) of the author(s)
- A concise and informative title
- The affiliation(s) and address(es) of the author(s)
- The e-mail address, telephone and fax numbers of the corresponding author

Abstract

Please provide an abstract of 150 to 250 words. The abstract should not contain any undefined abbreviations or unspecified references.

Keywords

Please provide 4 to 6 keywords which can be used for indexing purposes.

TEXT

Text Formatting

Manuscripts should be submitted in Word.

- Use a normal, plain font (e.g., 10-point Times Roman) for text.
- Use italics for emphasis.
- Use the automatic page numbering function to number the pages.
- Do not use field functions.
- Use tab stops or other commands for indents, not the space bar.
- Use the table function, not spreadsheets, to make tables.
- Use the equation editor or MathType for equations.
- Save your file in docx format (Word 2007 or higher) or doc format (older Word versions).

Manuscripts with mathematical content can also be submitted in LaTeX.

LaTeX macro package (zip, 182 kB)

Headings

Please use no more than three levels of displayed headings.

Abbreviations

Abbreviations should be defined at first mention and used consistently thereafter.

Footnotes

Footnotes can be used to give additional information, which may include the citation of a reference included in the reference list. They should not consist solely of a reference citation, and they should never include the bibliographic details of a reference. They should also not contain any figures or tables.

Footnotes to the text are numbered consecutively; those to tables should be indicated by superscript lower-case letters (or asterisks for significance values and other statistical data). Footnotes to the title or the authors of the article are not given reference symbols.

Always use footnotes instead of endnotes.

Acknowledgments

Acknowledgments of people, grants, funds, etc. should be placed in a separate section before the reference list. The names of funding organizations should be written in full.

SCIENTIFIC STYLE

Generic names of drugs and pesticides are preferred; if trade names are used, the generic name should be given at first mention.

Units and abbreviations

- Please adhere to internationally agreed standards such as those adopted by the commission of the International Union of Pure and Applied Physics (IUPAP) or defined by the International Organization of Standardization (ISO). Metric SI units should be used throughout except where non-SI units are more common [e.g. litre (l) for volume].
- Abbreviations (not standardized) should be defined at first mention in the abstract and again in the main body of the text and used consistently thereafter.

Drugs

- When drugs are mentioned, the international (generic) name should be used. The proprietary name, chemical compositon, and manufacturer should be stated in full in

REFERENCES

Citation

Reference citations in the text should be identified by numbers in square brackets. Some examples:

1. Negotiation research spans many disciplines [3].

2. This result was later contradicted by Becker and Seligman [5].

3. This effect has been widely studied [1-3, 7].

Reference list

The list of references should only include works that are cited in the text and that have been published or accepted for publication. Personal communications and unpublished works should only be mentioned in the text. Do not use footnotes or endnotes as a substitute for a reference list.

The entries in the list should be numbered consecutively.

- Journal article

  Gamelin FX, Baquet G, Berthoin S, Thevenet D, Nourry C, Nottin S, Bosquet L (2009) Effect of high intensity intermittent training on heart rate variability in prepubescent children. Eur J Appl Physiol 105:731-738. doi: 10.1007/s00421-008-0955-8

  Ideally, the names of all authors should be provided, but the usage of "et al" in long author lists will also be accepted:

  Smith J, Jones M Jr, Houghton L et al (1999) Future of health insurance. N Engl J Med 965:325–329
- Article by DOI

  Slifka MK, Whitton JL (2000) Clinical implications of dysregulated cytokine production. J Mol Med. doi:10.1007/s001090000086
- Book

  South J, Blass B (2001) The future of modern genomics. Blackwell, London
- Book chapter

  Brown B, Aaron M (2001) The politics of nature. In: Smith J (ed) The rise of modern genomics, 3rd edn. Wiley, New York, pp 230-257
- Online document

  Cartwright J (2007) Big stars have weather too. IOP Publishing PhysicsWeb. http://physicsweb.org/articles/news/11/6/16/1. Accessed 26 June 2007
- Dissertation

  Trent JW (1975) Experimental acute renal failure. Dissertation, University of California

Always use the standard abbreviation of a journal's name according to the ISSN List of Title Word Abbreviations, see

www.issn.org/2-22661-LTWA-online.php

For authors using EndNote, Springer provides an output style that supports the formatting of in-text citations and reference list.

EndNote style (zip, 2 kB)

Authors preparing their manuscript in LaTeX can use the bibtex file spbasic.bst which is included in Springer's LaTeX macro package.

TABLES

- All tables are to be numbered using Arabic numerals.

- Tables should always be cited in text in consecutive numerical order.
- For each table, please supply a table caption (title) explaining the components of the table.
- Identify any previously published material by giving the original source in the form of a reference at the end of the table caption.
- Footnotes to tables should be indicated by superscript lower-case letters (or asterisks for significance values and other statistical data) and included beneath the table body.

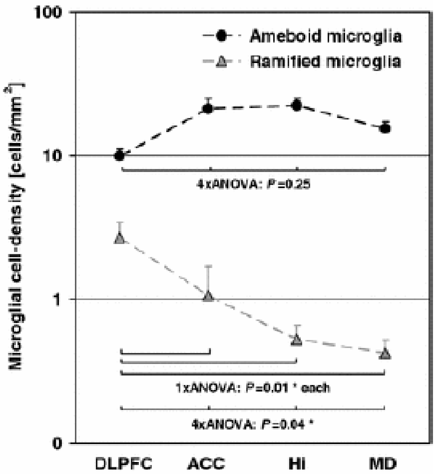
ARTWORK AND ILLUSTRATIONS GUIDELINES

For the best quality final product, it is highly recommended that you submit all of your artwork – photographs, line drawings, etc. – in an electronic format. Your art will then be produced to the highest standards with the greatest accuracy to detail. The published work will directly reflect the quality of the artwork provided.

Electronic Figure Submission

- Supply all figures electronically.
- Indicate what graphics program was used to create the artwork.
- For vector graphics, the preferred format is EPS; for halftones, please use TIFF format. MS Office files are also acceptable.
- Vector graphics containing fonts must have the fonts embedded in the files.
- Name your figure files with "Fig" and the figure number, e.g., Fig1.eps.

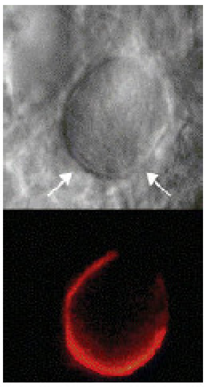
Line Art



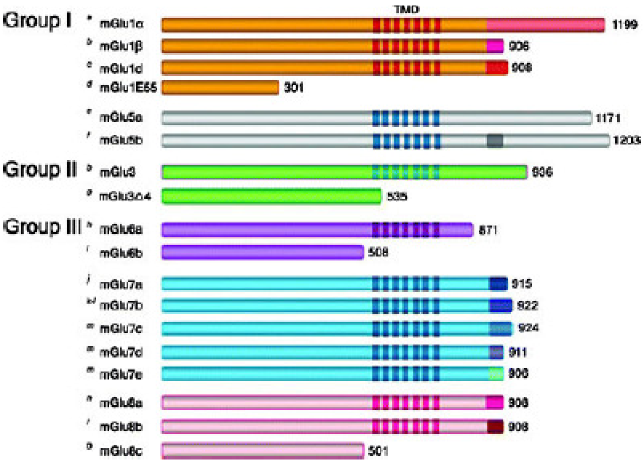
- Definition: Black and white graphic with no shading.
- Do not use faint lines and/or lettering and check that all lines and lettering within the figures are legible at final size.
- All lines should be at least 0.1 mm (0.3 pt) wide.
- Scanned line drawings and line drawings in bitmap format should have a minimum resolution of 1200 dpi.
- Vector graphics containing fonts must have the fonts embedded in the files.

Halftone Art

- Definition: Photographs, drawings, or paintings with fine shading, etc.
- If any magnification is used in the photographs, indicate this by using scale bars within the figures themselves.
- Halftones should have a minimum resolution of 300 dpi.



Combination Art



- Definition: a combination of halftone and line art, e.g., halftones containing line drawing, extensive lettering, color diagrams, etc.
- Combination artwork should have a minimum resolution of 600 dpi.

Color Art

- Color art is free of charge for online publication.
- If black and white will be shown in the print version, make sure that the main information will still be visible. Many colors are not distinguishable from one another when converted to black and white. A simple way to check this is to make a xerographic copy to see if the necessary distinctions between the different colors are still apparent.
- If the figures will be printed in black and white, do not refer to color in the captions.
- Color illustrations should be submitted as RGB (8 bits per channel).

Figure Lettering

- To add lettering, it is best to use Helvetica or Arial (sans serif fonts).
- Keep lettering consistently sized throughout your final-sized artwork, usually about 2–3 mm (8–12 pt).
- Variance of type size within an illustration should be minimal, e.g., do not use 8-pt type on an axis and 20-pt type for the axis label.
- Avoid effects such as shading, outline letters, etc.
- Do not include titles or captions within your illustrations.

Figure Numbering

- All figures are to be numbered using Arabic numerals.
- Figures should always be cited in text in consecutive numerical order.
- Figure parts should be denoted by lowercase letters (a, b, c, etc.).
- If an appendix appears in your article and it contains one or more figures, continue the consecutive numbering of the main text. Do not number the appendix figures, "A1, A2, A3, etc." Figures in online appendices (Electronic Supplementary Material) should, however, be numbered separately.

Figure Captions

- Each figure should have a concise caption describing accurately what the figure depicts. Include the captions in the text file of the manuscript, not in the figure file.
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- Identify all elements found in the figure in the figure caption; and use boxes, circles, etc., as coordinate points in graphs.
- Identify previously published material by giving the original source in the form of a reference citation at the end of the figure caption.

Figure Placement and Size

- When preparing your figures, size figures to fit in the column width.
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- For books and book-sized journals, the figures should be 80 mm or 122 mm wide and not higher than 198 mm.

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