UNIVERSIDADE FEDERAL DE PERNAMBUCO
CENTRO DE CIÊNCIAS DA SAÚDE
PROGRAMA DE PÓS-GRADUAÇÃO EM ODONTOLOGIA
MESTRADO EM ODONTOLOGIA

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AVALIAÇÃO DA RESISTÊNCIA DE UNIÃO DE BRACKETS ORTODONTICOS APÓS DIFERENTES TRATAMENTOS DA SUPERFÍCIE DO ESMALTE

RECIFE-PE
2016

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Dissertação apresentada à banca da Pós-Graduação em Clínica Integrada do Centro de Ciências da Saúde da Universidade Federal de Pernambuco, como requisito para obtenção do grau de mestre em Clínica Odontológica Integrada.

Area de Concentração: Clínica Integrada

Orientador: Prof. Dr. Anderson Stevens Leônidas Gomes

RECIFE-PE

2016

Catalogação na Fonte
Bibliotecária: Mônica Uchôa, CRB4-1010

S939a Suassuna, Juliana Carneiro Leão.
Avaliação da resistência de união de brackets ortodonticos após diferentes tratamentos da superfície do esmalte / Juliana Carneiro Leão Suassuna. – 2016.
56 f.: il.; 30 cm.

Orientador: Anderson Stevens Leonidas Gomes.
Dissertação (Mestrado) – Universidade Federal de Pernambuco, CCS. Pós-graduação em Odontologia. Recife, 2016.

Inclui referências, apêndices e anexos.

1. Ortodontia. 2. Lasers. 3. Resistência ao cisalhamento. I. Gomes, Anderson Stevens Leonidas (Orientador). II. Titulo.

617.6 CDD (22.ed.) UFPE (CCS2019-002)

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Aprovada em: 29/02/2016

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Dedico esta conquista aos meus pais e ao meu marido por todo apoio ofertado durante esses anos.

AGRADECIMENTOS

À **Deus**, por estar sempre presente na minha vida, me iluminando e me abençoando.

Aos meu pais, **Edir Jr e Christianne**, pelo apoio incondicional. Por me mostrarem os melhores caminhos a seguir, ajudarem nas decisões mais difícies, chorarem e sorrirem comigo em cada percalço e em cada conquista. Vocês são meu exemplo de vida!

Ao meu amor, **Pedro**, pelo amor e dedicação. Por sempre acreditar em mim e vibrar com cada vitória alcançada. Por sua compreensão nos vários momentos de ausência dedicados ao estudo ou à profissão. Obrigada por ser quem você é!

Ao meu avô **Edir**, por ser um espelho em quem me inspiro todos os dias. Exemplo de vida e de profissional. Sou muito grata a Deus por ter você na minha vida.

Ao meu irmão, **André**, minha cunhada **Augusta** e minha pequena **Maria Letícia,** pelo entusiasmo e apoio constante,

Aos meus tios, **Jair e Antoniêta**, por serem exemplos na profissão. Por me despertarem o amor pela Odontologia científica e clínica respectivamente!

Aos meus **familiares**, por todo amor, carinho e diversão. Estar com vocês renova minha energia! É realmente maravilhoso fazer parte dessa família.

Aos meus **amigos,** pelas palavras de motivações e por vibrarem com todas as minhas conquistas.

Ao meu orientador **Prof. Anderson Gomes**, por ter aceitado ser meu orientador. Sua vontade de fazer ciência é contagiante. Obrigada pela compreensão e cuidado durante esses dois anos.

À **Família Labfoton** pelo apoio e orientação. Por estarem sempre dispostos e prontos a ajudar. Vocês me mostraram o real significado do trabalho em equipe.

Aos colegas de turma pela amizade. Foi muito bom poder conhecer e conviver com vocês.

Aos professores da pós-graduação, por todo ensinamento disponibilizado, cada um contribuiu de forma especial para minha formação.

Aos funcionários do Departamento de Física, em especial ao **Seu João** e da Pós-Graduação em Odontologia, **Ozi, Tamires** e **D. Tânia**, pela paciência e eterna disponibilidade em ajudar.

A todos vocês meu MUITO OBRIGADA!

RESUMO

Os brackets são parte fundamental no tratamento ortodôntico e para isso precisam estar fixados aos dentes durante todos os procedimentos ortodônticos. O objetivo do presente estudo foi avaliar a força de adesão dos braquetes ortodônticos obtida após o tratamento da superfície do esmalte por ácido fosfórico e laser de Er: YAG. Oitenta dentes incisivos bovinos foram divididos aleatoriamente em 4 grupos: Grupo I, o esmalte foi condicionado com ácido fosfórico a 37% e braquetes metálicos de incisivos centrais foram colados com o sistema adesivo Transbond XT, no Grupo II, a superfície dentária foi irradiada com o laser Er:YAG e os braquetes colados também com o adesivo Transbond XT. Já o Grupo III, teve sua superfície dentária condicionada com ácido fosfórico e o braquete colado com o cimento ortodôntico OrthoCem e, por fim, o Grupo IV que foi irradiado com laser Er:YAG e os braquetes colados com a OrthoCem. Foi realizado o teste de cisalhamento e as médias (MPa) com desvio padrão para cada grupo foram calculadas. O índice de remanescente adesivo (ARI) foi determinado. A média do valor de resistência ao cisalhamento foi maior no grupo condicionado com ácido fosfórico do que o grupo irradiado com laser Er:YAG**.** Os resultados sugerem que, embora as amostras irradiadas com o laser Er:YAG tenham obtido resultado de força de resistência inferior aos dentes condicionados com ácido fosfórico, excedem os valores de força de 6 a 8Mpa, que se acreduta seren clinicamente suficientes. Todos os grupos mostraram valores de resistência ao cisalhamento considerados clinicamente aceitáveis e podem, com ponderações, serem indicados para uso clínico.

Palavras-chave: Ortodontia. Lasers. Resistência ao cisalhamento.

ABSTRACT

Brackets are a fundamental part in orthodontic treatment and so it must remain well fixed to the teeth throughout the therapy. The purpose of this study was to evaluate the shear bond strength (SBS) of teeth prepared for orthodontic bracket bonding with 37% phosphoric acid conditioning and Er:YAG laser. Eighty bovine incisors were randomly divided into four groups. In Group I, the teeth were conditioned with 37% phosphoric acid and then upper central incisor stainless steel brackets were bonded with Transbond XT; Group II, the teeth were irradiated with the Er:YAG and bonding with Transbond XT; Group III were conditioned with 37% phosphoric acid and bonded with Orthocem and Group IV were laser irradiated and bonded with Orthocem. Subsequently, the shear bond strength tests were performed and the mean SBS ± sd (MPa) for each group was calculated. The adhesive remnant index (ARI) was determined. Mean SBS for acid-etched enamel was higher than for laser-etched enamel. Adhesion to dental hard tissues after Er:YAG laser etching was inferior to obtained after conventional acid etching, but exceeded the strength of 6 to 8 MPa that is believed to be clinically sufficient. All groups showed shear bond strength values considered clinically acceptable and can, after ponderations, be indicated for clinical use.

Keywords: Orthodontics. Lasers. Shear strenght.

SUMÁRIO

1 INTRODUÇÃO

A prática ortodôntica previne e corrige irregularidades da oclusão para criar uma melhor estética e função do sistema estomatognático. Os brackets são parte fundamental no tratamento ortodôntico e para isso precisam permanecer bem fixados aos dentes durante toda a terapêutica. Inicialmente, esses dispositivos eram presos aos dentes através de bandas ortodônticas, porém tal mecanismo dificultava a higienização oral, induzia a agressão aos tecidos gengivais, levava a um comprometimento estético e uma morosidade de sua execução clínica, além de outras inúmeras desvantagens.[1]

O advento do ataque ácido, introduzido por Buonocore em 1955, trouxe a possibilidade de adesão entre a base do bracket e a superfície dentária, através da criação de retenções mecânicas decorrentes do embricamento da resina nas microporosidades produzidas pelo ácido. Sendo assim, a partir da década de 70, efetivou-se a utilização da resina composta na colagem de brackets ortodônticos. Para suportar os efeitos mecânicos e térmicos do meio oral, a força de adesão entre a superfície do esmalte e o bracket tem que ser suficiente e a resistência ao cisalhamento, observado a nível laboratorial, de um material indicado para colagem deve estar entre 5,9 e 7,8 MPa.[2]

Para a colagem dos brackets ortodônticos, depois de feita a profilaxia dentária, tradicionalmente, o condicionamento ácido é realizado com o objetivo de remover a smear layer e criar uma superfície irregular, preferencialmente dissolvendo os cristais de hidroxiapatita da superfície dentária. Essa nova condição irá facilitar a penetração dos componentes do fluido adesivo nas irregularidades, criando uma retenção microquímica e mecânica que promoverá a união bracket/esmalte.[3] Porém, uma desvantagem potencial do uso do condicionamento ácido é a possibilidade de descalcificação [4,5] uma vez que leva o esmalte a ficar susceptível ao ataque carioso, principalmente embaixo dos acessórios ortodônticos.

Recentemente, métodos alternativos tem sido estudados para auxiliar no preparo das superfícies dentárias, como a irradiação por laser que possui como principal vantagem o efeito inibidor de cárie no esmalte dentário irradiado, já observado em alguns estudos. [6,7,8,9,10]

Dessa forma, sabendo que a falha na adesão dos brackets acaba sendo frustrante para os ortodontistas, afeta a eficiência do aparelho, tem um impacto econômico importante e pode atrasar significativamente o progresso do tratamento,[11,12] o objetivo do estudo foi avaliar o efeito do laser Er:YAG sobre a superfície dentária comparando e mensurando essa força de adesão com a tradicional forma de condicionamento pelo ácido fosfórico. Além disso, no intuito de melhorar a rapidez no processo de colagem dos brackets ortodônticos diminuindo assim o tempo de cadeira do paciente no consultório odontológico foi testado um material que não utiliza a etapa de aplicação do primer, já que alguns estudos tem mostrado que as forças de adesão são similares [13] ou levemente menores [14] quando comparadas com os sistemas convencionais de adesão.

Esta dissertação tem como parte integrante complementar o artigo a ser submetido ao periódico American Journal of Orthodontics & Dentofacial Orthopedics (Qualis Capes A1 Odontologia), contendo metodologia, resultados e discussão acerca do tema, para obtenção do grau de mestre.

2 MATERIAL E MÉTODOS

2.1 Aspectos Éticos e Seleção da Amostra

O estudo foi realizado após aprovação pelo Comitê de Ética em Uso de Animais da UFPE, protocolo n. 23076.015869/2015-65.

Oitenta incisivos inferiores de dentes bovinos, recém extraídos, foram selecionados e armazenados por 48 horas em uma solução de Cloramina T a 1% para desinfecção. Após esse período, tiveram suas raízes seccionadas e a face vestibular foi lixada e polida com lixa d'água (P60, P80, P180 – 3M Unitek) para que as ranhuras mais profundas naturalmente presentes nos dentes bovinos fossem eliminadas e a superfície ficasse mais similar as dos dentes humanos. A coroa foi então incluída em um suporte cilindrico de pvc sob o qual foi vertida resina acrílica de forma que a face vestibular ficasse paralela à borda do cano. Os corpos de prova foram armazenados em água destilada (37±1 ^{o}C) até o momento da colagem.

Os espécimes foram divididos aleatoriamente em 4 grupos (n=20) assim designados:

Grupo I (PA_{XT}): condicionamento com ácido fosfórico 37% (PA) e brackets colados com sistema de resina Transbond XT (XT).

Grupo II (PA_{ORT}): condicionamento com ácido fosfórico 37% (PA) e brackets colados com sistema de resina Orthocem (ORT).

Grupo III (L_{XT}): irradiação com laser Er:YAG (L) e brackets colados com sistema de resina Transbond XT (XT).

Grupo IV (L_{ORT}): irradiação com laser Er:YAG (L) e brackets colados com sistema de resina Orthocem (ORT).

Todas as superfícies foram limpas com pasta de pedra pomes e água e taças de borracha que foram trocadas a cada 20 profilaxias. Depois os dentes foram lavados com spray de água (15s) e secas por mais 15 segundos com spray de água livre de oleo.

Todos os materiais utilizados estão listados:

Material	Manufacturer Batch number #	Composition	Aplication Mode
Primer + Transbond XT adhesive	3M Unitek # 503325	Bisphenol A diglycidyl ether dimethacrylate (10-20 wt%); Bisphenol A bis (2-hydroxyethyl ether) Dimethacrylate (5-10 wt%); Filler: Silane-treated quartz (70-80 wt%)	O primer foi aplicado com microbrush e depois fotopolimerizado por 20s. A resina Transbond XT foi aplicada no bracket que foi então posicionado sobre a superfície dentária e fotoativada por 10segundos em cada face do bracket.
Orthocem	FGM Produtos Odontológicos # 060415	Bisphenol A diglycidyl ether methacrylate (25-35 wt%), Triethylene glicol dimethacrylate (10-15 wt%); Methacrylated phosphate monomer (>2 wt%). Filler: Silane treated silicon dioxide (45-60 wt%)	A resina Orthocem foi aplicada diretamente ao bracket que foi então posicionado sobre a superfície dentária e fotoativado por 10 segundos em cada face do bracket(sem aplicação prévia do primer, conforme orientação do fabricante).

2.2 Condicionamento com ácido fosfórico

O condicionamento foi realizado com gel de ácido fosfórico a 37% (FGM Produtos Odontológicos,) por 15 segundos seguido de lavagem com água por 15 segundos. As espécimes foram secas até que aparecesse a superfície fosca branca demonstrando o condicionamento da área.

2.3 Irradiação com Laser

A irradiação com laser de Er:YAG (Fidelllis Plus III, Fotona, Slovenia), foi feita com 120 mJ a 10 Hz e 1.2 W no modo MSP (Micro Short Pulse = 100 μs). Esses parametros de irradiação foram determinados baseados na literature [15] pesquisada e num estudo piloto realizado previamente.

No intuito de padronizar a irradiação com o laser eliminando variáveis que pudessem interferer no resultado foi utilizado um motor de passo, que movimentava a amostra a uma velocidade constante de 3.8 mm/s e haste fixa como suporte para que a distância entre a ponta da peça-de-mão do laser e a superfície dentária fosse a mesma (12mm) em todos os corpos de prova. Além disso, o motor de passo foi configurado para que as linhas de irradiação não se sobrepusessem promovendo assim uma superfície condicionada homogênea. (**Figura 1 [a]** e **[b]**)

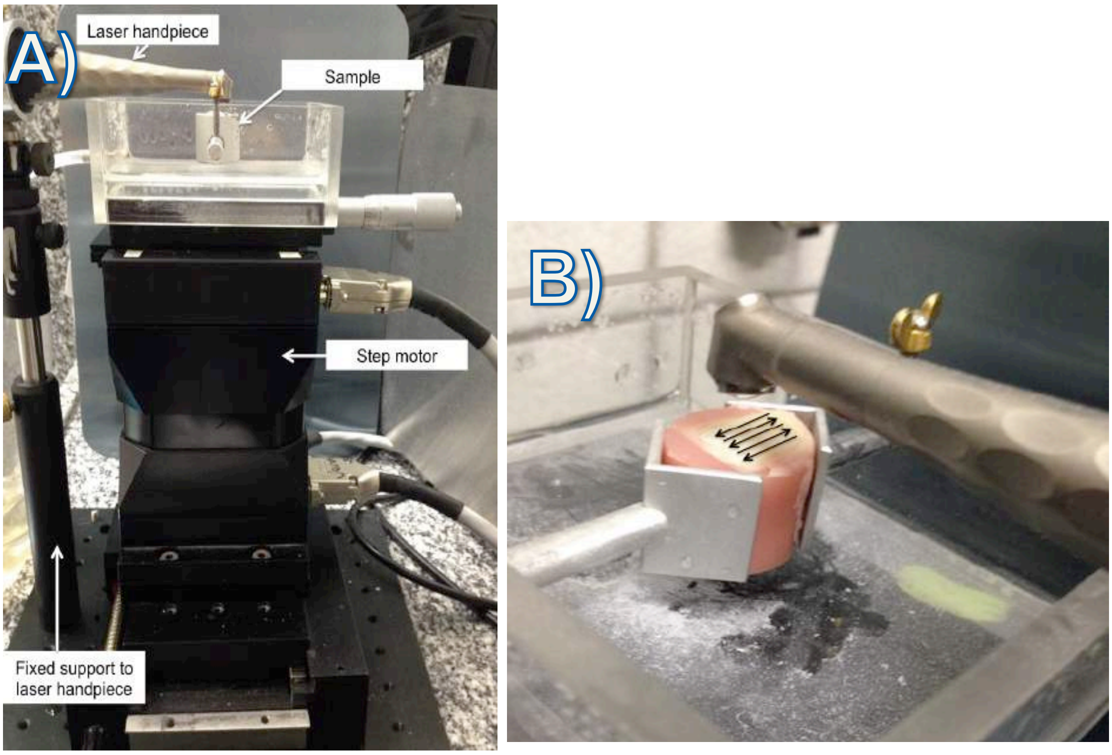

Figura 1. (a) Motor de passo customizado para padronização da aplicação do laser. **(b)** Desenho esquemático mostrando o movimento executado pela amostra durante a irradiação a laser**.**

2.4 Procedimentos adesivos

Para todas as colagens foram utilizados brackets Roth Max Morelli® (Dental Morelli, Sorocaba, São Paulo, Brasil) de Incisivos superiores com área da base de aproximadamente 14mm^2. Estes brackets foram escolhidos devido à semelhança de anatomia dos incisivos inferiores bovinos com os incisivos centrais superiores humanos

Os brackets foram colados de acordo com as intruções do fabricante (Tabela 1) no centro da superfície vestibular do dente. No intuito de controlar a força exercida na colagem (350g) e assim a espessura da película de resina, foi utilizado o disositivo de Gillmore. (**Figura 2**) Com o dispositivo em posição, os excessos de resina foram removidos e então realizou-se a fotopolimerização com LED na potência de 1200 mW/cm^2 (Radii cal LED, SDI, Bayswater, Australia) por 10s em cada face do bracket (mesial, distal, cervical e incisal).

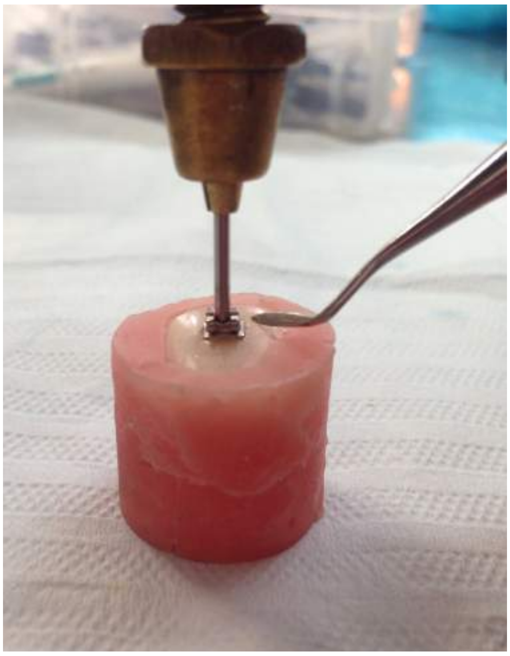

Figura 2. Dispositivo de Gillmore em posição para remoção do excesso de resina durante a colagem do bracket.

Após a colagem, os corpos de prova foram armazenados em água destilada em estufa biológica a 37°C por 24 horas, para simular a temperatura bucal.

Todas as amostras foram então submetidas a termociclagens utilizando máquina Nova Ética (modelo 521-E, Ética Equipamentos Científicos S/A, São Paulo, SP, Brasil) num total de 500 ciclos alternados (5-55 ± 2°C), por 30s em cada banheira e tempo de transferência de 4 segundos para simular as diferenças de temperatura na boca.

2.5 Avaliação da força de adesão

Os corpos de provas foram preparados para o teste de cisalhamento, que foi realizado utilizando-se a Máquina de Ensaios Universal (Kratos Equipamentos Industriais Ltda, Modelo K2000MP, Taboão da Serra, São Paulo, Brasil) com cinzel a uma velocidade de 0,5mm/s e célula de carga de 200kgf.

Quando se avalia a resistência de cisalhamento de um corpo, o tamanho da base do braquete tem uma importância significativa, visto que quanto maior a base do braquete maior é a sua retenção, então os valores foram medidos levando em consideração a força de ruptura e o tamanho da base do bracket.[16,17,18] Os valores obtidos em Newtons foram convertidos para megapascal. Esta conversão foi feita usando a seguinte fórmula Mpa=F/A ou seja (Mpa) é a força em megapascal, (F) é a força de descolagem em Newtons e (A) é a área da base do braquete em mm^2.

2.6 Avaliação do Índice de Adesivo Remanescente

Após a descolagem, os dentes foram examinados com o auxílio de uma lupa estereomicroscópica com aumento de 20 vezes (Stemi 2000-C Stereomicroscope, Zeiss, Oberkochen, Germany) e classificados de acordo com o Índice de Adesivo Remanescente (IAR), proposto por Artun e Bergland[19]:

•Escore 0 = nenhum remanescente de adesivo foi deixado no dente.

•Escore 1 = menos que 50% do adesivo foi deixado no dente.

•Escore 2 = mais que 50% do adesivo foi deixado no dente.

•Escore 3 = todo o adesivo foi deixado no dente.

2.7 Análise Estatística

A análise estatística foi feita utilizando-se a estatística descritiva com os valores mínimos e máximos e desvio padrão calculados para cada grupo. Comparações múltiplas entre as forças de cisalhamento obtidas foram feitas entre os grupos e testados com o teste ANOVA. Foram utilizados os testes T-Student entre os pares de comparações de interesse.As comparações duas-a-duas foram feitas atrvés do teste T-Student adotando-se nível de significância de 5%.

Para a avaliação do Índice de Adesivo Remanescente, foi utilizado o teste exato de Fisher para as variáveis não categóricas. Todos os testes estatísticos foram feitos com o software SPSS, versão 21.

3 RESULTADOS

Os resultados desta pesquisa encontram-se relacionados em forma de artigo científico que é apresentado no Apêndice desta dissertação.

4 CONCLUSÃO

Os espécimes condicionados com Laser mostraram valores mais baixos de resistência ao cisalhamento quando comparados aos condicionados com ácido fosfórico. Quando considerada a mesma superfície de tratamento, a resina Orthocem apresentou resultados similares aos apresentados pela resina considerada “padrão ouro” para a colagem de brackets ortodônticos.

Por fim, todos os grupos apresentaram valores considerados clínicamente aceitáveis de resistência ao cisalhamento demonstrando assim que o Laser Er:YAG pode ser uma alternativa para o condicionamento prévio à colagem de brackets ortodônticos. No entanto, outros estudos clínicos precisam ser realizados a fim de corroborar com os resultados obtidos.

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APÊNDICE A – Artigo a ser submetido na American Journal of Orthodontics & Dentofacial Orthopedics

Shear Bond Strength of orthodontic brackets after different enamel pre-treatment.

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INTRODUCTION

The brackets are a fundamental part in orthodontic treatment and it must remain well fixed to the teeth throughout the therapy. The adhesion between the enamel surface and the bracket must be enough to support the mechanical and thermal effects present in the oral environment. Bracket adhesive failure is quite frustrating for the orthodontists as it affects the efficiency of the braces causing treatment delay with an important economic impact.[1,2] Therefore, the shear bond strength at the tooth-bracket interface should ideally range between 5.9 and 7.8 MPa.[3]

Enamel acid etching removes the smear layer and creates an irregular surface, by the dissolution of the hydroxyapatite crystals. This topography facilitates the penetration of the bonding agents into the irregularities, creating a micro mechanical and/or chemical retention that will promote the bracket/enamel union.[4] However, a potential disadvantage of this procedure is the possibility of excessive decalcification,[5,6] making the enamel susceptible to carious attacks, especially under the orthodontic components. Another important fact in the long-term management of the patient is the erosive tooth wear. Dental erosion involves both the surface and the subsurface region and may permanently compromise the patient's dentition.[7]

Laser irradiation of dental hard tissues has been proposed as an alternative to prevent enamel demineralization due to it´s capacity to modify the calcium-to-phosphorus ratio to carbonate-to-phosphate ratio. This leads to the formation of more stable and less acid-soluble compounds that reduces susceptibility to acid attack and caries.[6,8] Laser irradiation can also be used prior to bonding, instead of acid etching. Therefore, considering the need of enamel etching for the achievement of micromechanical retention and surface alterations obtained by laser irradiation, [9,10,11,12,13] it seems that laser radiation can act as an alternative to acid etching pre-treatment in orthodontics.

The most common method to determine the efficiency of bonding systems in Orthodontics is the shear bond strength (SBS) test. However, the great variability of results suggests the hypothesis of deficiency in technical standardization, which makes it difficult to interpret and compare to other studies. Among the variables that may influence the results, it is mentioned the storage of the teeth made before the inclusion in the specimens, the time and the type of surface conditioning, the type of bracket used, the speed of the load cell of the test machine and how it is applied and the storage time after bonding, among others.[14]

The objective of this study was to evaluate the effect of Er:YAG laser irradiation compared to conventional acid etching on the SBS of orthodontics brackets. Additionally, in an attempt to save chair time during bonding, a self-adhesive cement was tested compared to a well stablished conventional bonding system. The hypothesis tested is that laser irradiation promotes similar SBS values for both resin cements, with no differences between them.

MATERIAL AND METHODS

This study was conducted after approval by the Ethics Committee on Animal Use of the University Federal of Pernambuco, under protocol number 23076.015869/2015-65.

Eighty freshly extracted bovine lower incisors were selected and stored in 1% Chloramine-T solution during 48 hours for disinfection. The roots were sectioned and the buccal surfaces were manually polished with sandpaper (P60, P80, P180 – 3M Unitek). The specimens were included in a polyvinyl chloride (PVC) cylindrical support with acrylic resin, keeping the buccal surface parallel to the mold base. Specimens were stored in distilled water (37±1 ^{o}C) until bonding procedures were performed.

The materials tested are listed in Table I.

Table I – Materials tested.

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Material	Manufacturer Batch number #	Composition	Aplication Mode
Primer + Transbond XT adhesive	3M Unitek # 503325	Bisphenol A diglycidyl ether dimethacrylate (10-20 wt%); Bisphenol A bis (2-hydroxyethyl ether) Dimethacrylate (5-10 wt%); Filler: Silane-treated quartz (70-80 wt%)	The primer was applied with microbrush and then light cured for 20 seconds. Transbond XT adhesive paste should be applied on the bracket, positioned over the tooth surface and photoactivated for 10 seconds in each side of the bracket.
Orthocem	FGM Produtos Odontológicos # 060415	Bisphenol A diglycidyl ether methacrylate (25-35 wt%), Triethylene glicol dimethacrylate (10-15 wt%); Methacrylated phosphate monomer (>2 wt%). Filler: Silane treated silicon dioxide (45-60 wt%)	Orthocem should be applied on the bracket, positioned over the tooth surface and photoactivated for 10 seconds in each side of the bracket.

*Table adapted from Scribante *et al.,*2013. [16] 3M Unitek, Monrovia, CA, USA; FGM Produtos Odontológicos, Joinville, Santa Catarina, Brazil.

Specimens were divided into 4 groups (n=20) as follows:

- Group I (PA_{XT}): etching with 37% phosphoric acid (PA) and brackets bonding with Transbond XT Primer and Adhesive Paste (XT).
- Group II (PA_{ORT}): etching with 37% phosphoric acid (PA) and brackets bonding with Orthocem (ORT).
- Group III (L_{XT}): Er:YAG laser irradiation (L) and brackets bonding with Transbond XT Primer and Adhesive Paste (XT).
- Group IV (L_{ORT}): Er:YAG laser irradiation (L) and brackets bonding with Orthocem (ORT).

All surfaces were cleaned with pumice paste and rubber cup, replaced after twenty uses. Teeth were then washed with water spray (15s) and dried for another 15 seconds with oil-free air.

Acid Etching Procedure

Etching was performed with a 37% phosphoric acid gel (FGM Produtos Odontológicos,) for 15s followed by a 15s water rinse. Specimens were air dried until a frosty white appearance was achieved.

Laser Etching Procedure

Er:YAG laser irradiation (Fidelllis Plus III, Fotona, Slovenia), was applied with 120 mJ at 10 Hz and 1.2 W in a MSP (Micro Short Pulse = 100 μs) mode. These irradiation parameters were determined based on the literature[17] and a previous pilot study.

In order to eliminate variables that could interfere in our results, irradiation was standardized using a custom-made device. A fixed support held the laser handpiece, maintaining the same focal distance (12 mm) to the dental surface (Figure 1a). A step motor was attached to enable the sample to move at a constant speed of 3.8 mm/s. The step motor translated 6000 μm laterally and 800 μm down vertically after each line scan, so the irradiation lines did not overlap themselves (Figure 1b), promoting a homogeneous etching throughout the enamel surface.

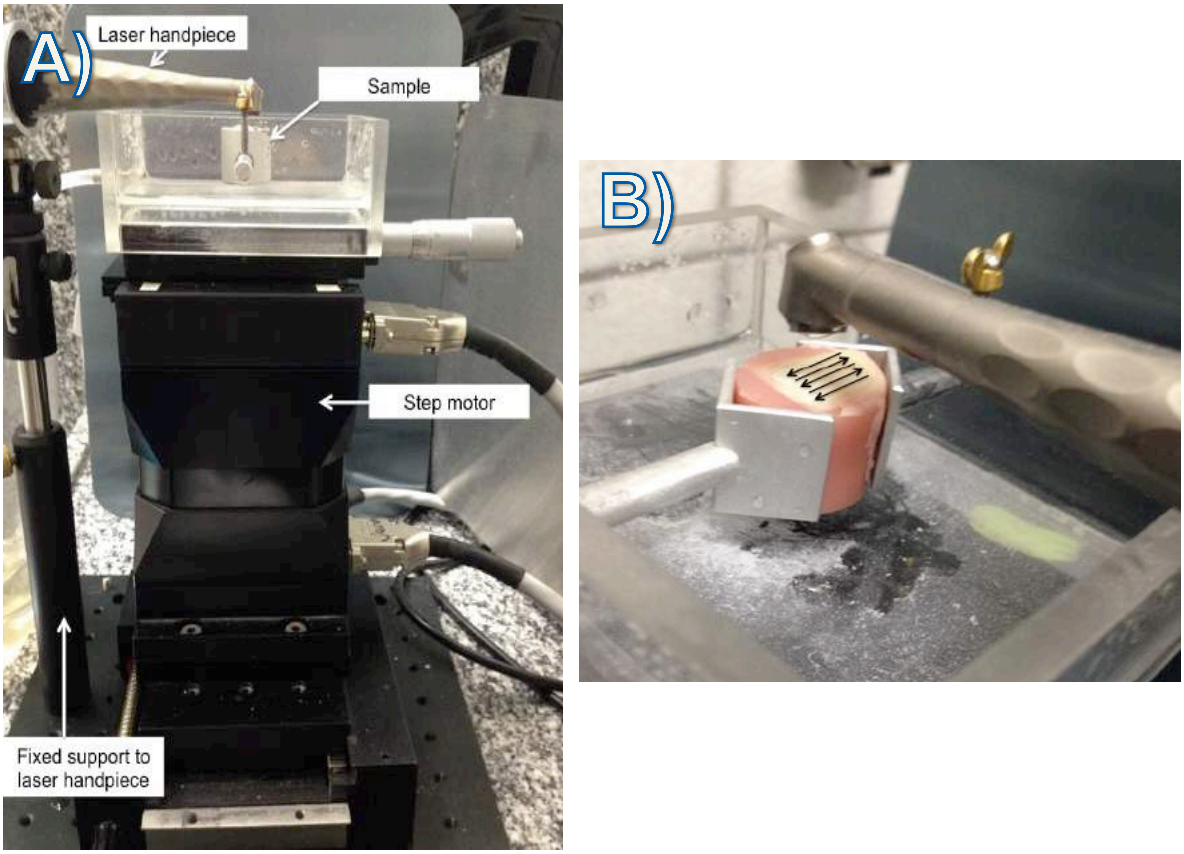

Figure 1. (a) Custom-made device for the standardization of laser application. **(b)** Schematic drawing of the sample movement by the step motor during laser irradiation.

Bonding Procedures

Brackets for upper incisors with a 14 mm^2 base area were used (Roth Max Morelli®, Dental Morelli, Sorocaba, São Paulo, Brazil). These brackets were chosen due to the similarities between bovine lower incisors and human upper central incisors.

Brackets were fixed according to the manufacturers instructions (Table I) at the center of the buccal surface. In an attempt to control the thickness of the adhesive film a static load of 350 g was applied using a Gillmore needle. Excesses of the orthodontic cement were carefully removed and then photoactivated. All photoactivation procedures were performed using a LED curing unit at 1200 mW/cm^2 (Radii cal LED, SDI, Bayswater, Australia) for 10 seconds in each side of the bracket. (mesial, distal, cervical and incisal).

After 24h storage in distilled water at 37±1 ^oC, all the specimens were thermocycled (Nova Ética, model 521-E, Ética Equipamentos Científicos S/A, São Paulo, SP, Brazil). A total of 500 cycles of alternate baths (5-55 ± 2^{o}C), 30 s in each bath and a 4 s transfer time was performed.

Evaluation of shear bond strength

The specimens were prepared for the SBS test, under a Universal Testing Machine (Kratos Equipamentos Industriais Ltda, Modelo K2000MP, Taboão da Serra, São Paulo, Brasil) with a chisel at 0.5 mm/s speed and 200 kgf load cell.

To evaluate the SBS, the size of the bracket base has a meaningful importance, since the bigger the base, the greater sustaining. Therefore the values were measured taking into account the rupture strength and the size of the bracket base.[18,19,20] The values were obtained in Newtons (N) and converted into Megapascal (MPa) using the formula: MPa=F/A, where, (MPa) is the strength in Megapascal, (F) is the debonding force in Newtons and (A) is the bracket base area in mm².

Adhesive Remnant

After debonding, teeth were examined under a stereomicroscope at 20x (Stemi 2000-C Stereomicroscope, Zeiss, Oberkochen, Germany) and classified according to the Adhesive Remnant Index (ARI), proposed by Artun and Bergland[21]:

- Score 0 - no adhesive remnant left on the tooth;
- Score 1 - less than 50% adhesive remnant left on the tooth;
- Score 2 - more than 50% adhesive remnant left on the tooth;
- Score 3 - 100% adhesive remnant left on the tooth.

Statistical analysis

Descriptive statistics, means and standard deviations were calculated for each group. Statistical analysis were performed using SPSS version 21 (SPSS for Windows version 21.0, SPSS, Chicago Ill). Multiple comparisons between SBS were done using ANOVA and two-by-two comparisons, with T-Student test, were performed. For the ARI evaluation, Fishers exact test was used. A 5% significance level was adopted.

RESULTS

The results for SBS are shown in Table II. ANOVA test showed statistically significant differences between groups ($p \leq 0.005$). Two by two comparisons, using T-Student, detected significant differences between PA_{XT} and L_{XT} ($p=0.030$). The maximum coefficient of variation obtained in all groups was 46.80%.

Table II. Mean shear bond strength (MPa) for all groups (n=20).

Group	Mean (MPa)	p-value
PA_{XT}	10.32 ± 4.38^{A}	$p^{(a)} \leq 0.005$*
PA_{ORT}	8.60 ± 3.77^{AB}	$p^{(2)} = 0.242$
L_{XT}	7.25 ± 2.96^{B}	$p^{(3)} = 0.030$*
L_{ORT}	6.79 ± 2.79^{B}	$p^{(4)} = 0.110$ $p^{(5)} = 0.638$

(*): Significant difference at 5.0%
(a): Through the F test (ANOVA) among all groups.
(2): Through the t-Student test with equal variances for the comparison between groups PAXT and PAORT.
(3): Through the t-Student test with unequal variances for the comparison between groups PAXT and LXT.
(4): Through the t-Student test with equal variances for the comparison between groups PAORT and LORT.
(5): Through the t-Student test with equal variances for the comparison between groups LXT and LORT.

For the evaluation of the ARI, samples were observed in a stereoscopic microscope and classified by the scores according to Figure 2.

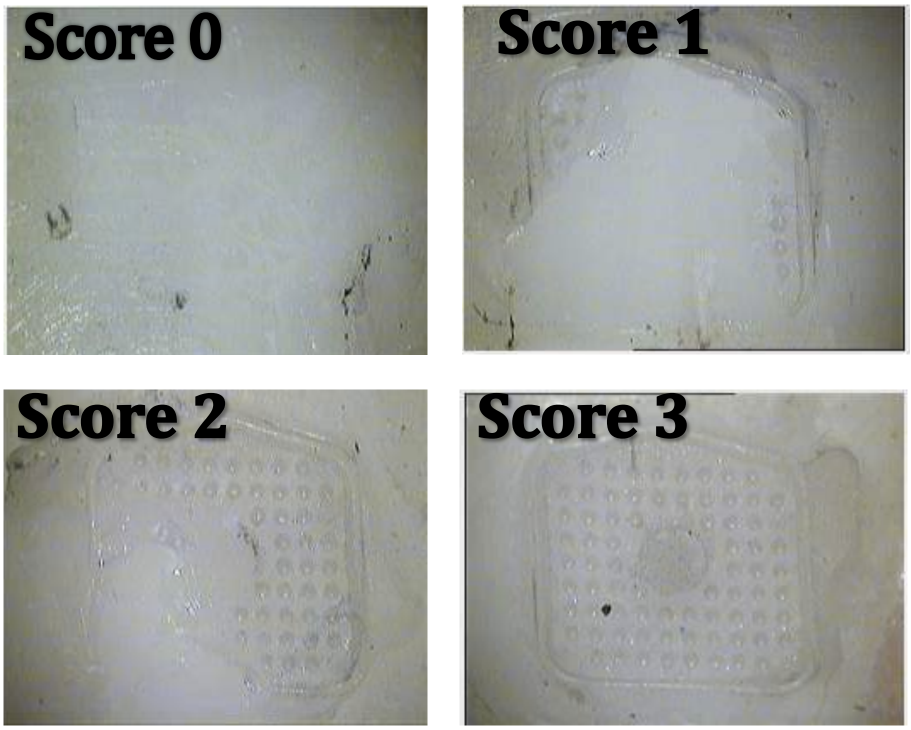

Figure 2. Illustrative images of the ARI obtained of PA_{XT} group.

The results for the ARI are demonstrated in Figure 3. Fisher's Exact Test, showed significantly statistically difference between groups ($p \leq 0.01$).

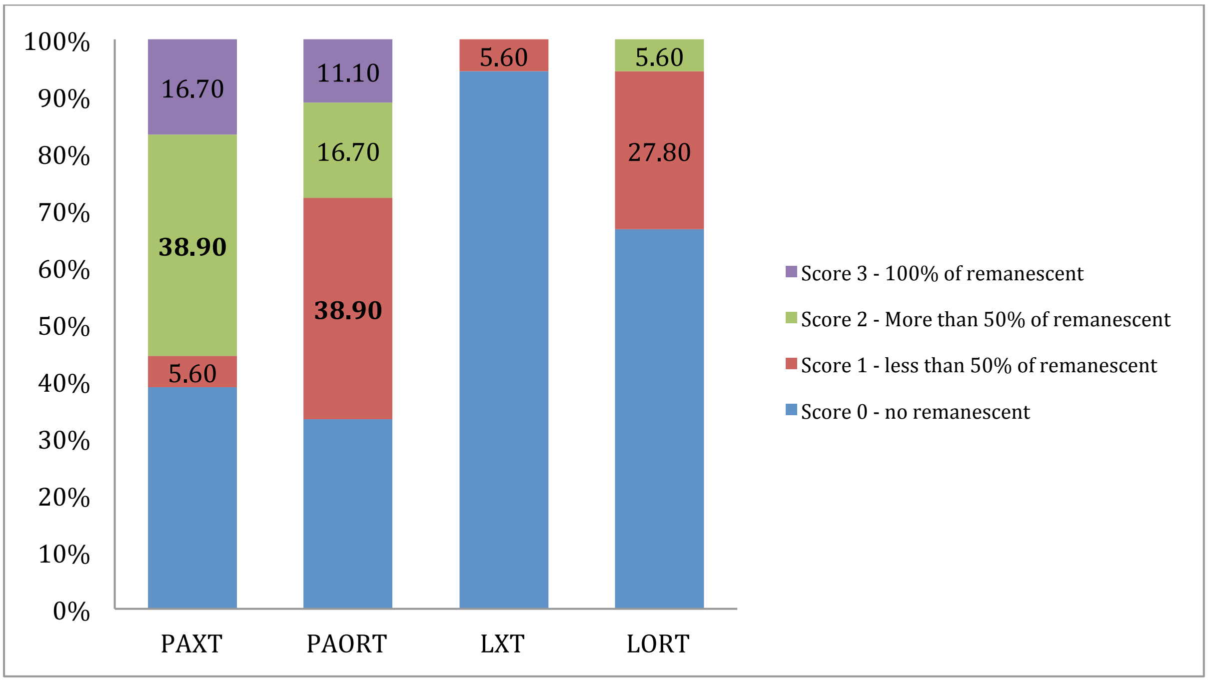

Figure 3. Distribution of Adhesive Remnant Index (%) between studied groups (n =20).

DISCUSSION

The hypothesis tested was partially rejected. Laser irradiation promoted lower SBS values when compared to phosphoric acid. However, no differences were observed between cements within the same surface treatment.

The use of laser as a surface conditioning method has been previously discussed with controversial results. [23,24,25,26,27] This is due to the differences in the laser parameters used such as, focal distance, irradiation time, air/water cooling, fluence and pulse repetition rate. All of these factors will affect in some way the bond strength on tooth structure. [28,29,30] In our study, the groups irradiated with Er:YAG laser yielded lower SBS with significant statistical differences. However, the achieved values are still between the acceptable range for clinical bonding resistance (5.9 - 7.8 MPa).

It is also important to highlight in this study, the use of the standardization for laser application. The constant displacement and beam/sample distance favored the elimination of bias regarding uneven etching patterns which could lead to higher standard deviations of SBS. Although there is no similar device clinically available, the development of a suitable laser hand piece might overcome these variability.

The success of the bonding strength at the tooth/bracket interface involves a combination of three basic factors: mechanical and/or chemical retention to the surface, correct selection and manipulation of the bonding materials, and the retentive potential of the accessories or brackets used.[22]

Regarding the bonding systems, the Transbond XT is the most cited and thus seems to be considered as “gold standard”. In this study we also tested a self-adhesive orthodontic bonding agent (Orthocem). The main advantage of these systems is the technique simplification, this can achieve an additional 10-second reduction in the bonding time for each tooth. During routine orthodontic bonding procedures involving 20 teeth, for example, it could lead to 200 seconds time reduction (more than three minutes) of chair time per patient. Our results did not show any statistical significant difference between cements. The SBS values of the self-adhesive cement were similar to the ones obtained by the conventional cement.

Another study[31] suggested the use of a stainless steel tape, to create the best conditions for the establishment of the true shear loading test but producing smaller

SBS. However, the majority of studies consulted to base[15,16,17,27,32,33] this investigation did not mention or use the chisel in SBS as our study.

The ARI most prevalent scores were 0 and 1, demonstrating that the fractures happened mainly between the dental surface and the adhesive system. The laser treated groups, in particular group $L_{TX,}$ presented the largest number of specimens classified as score 0 when compared to the other groups. It is believed that the adhesive failure between the enamel and the bonding system is advantageous[34] because there will be less adhesive remnant and, consequently, less time will be spent to remove it, besides a reduced chance of excessive wear. However, most of the authors [35,36,37] seem to accept that the safest place to debonding is between the adhesive system and the bracket, which warrant the risk reduction of cracks and fractures of the enamel.

CONCLUSION

Laser treated specimens showed lower SBS. However, it seems to be material related as the Transbond XT demonstrated higher decrease. Within the same surface treatment, the self-adhesive resin cement Orthocem produced similar results as to conventional orthodontic resin cement.

Notwithstanding, considering that all groups showed clinically acceptable SBS values, Er:YAG laser can also be used for enamel pretreatment prior to orthodontics brackets bonding. However, further clinical studies are needed to confirm the results obtained.

ACKNOWLEDGMENTS

The authors are thankful to the Brazilian agency CAPES (Coordination for the Improvement of Higher Education Personnel) for scholarship for JCLS. This study was carried out under the PRONEX FACEPE/CNPq (Center of Excellence on Biphotonics and Nanophotonics – Foundation for Science and Technology of Pernambuco State and National Council of Technological and Scientific Development) program and INCT (National Institutes of Science and Technology) of Photonics program, sponsored by CNPq/MCT (National Council of Technological and

Scientific Development and Ministry of Science and Technology). The authors report no conflicts of interest related to this study.

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APÊNDICE B - Artigo aceito para apresentação em pôster na Conferência Photonics West 2016, BIOS, Paper 9692-26 (Publicado no Proceedings da Conferência)

A comparative study of shear bond strength of orthodontic bracket after acid-etched and Er:YAG treatment on enamel surface

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ABSTRACT

This study aimed to evaluate the shear bond strength (SBS) of teeth prepared for orthodontic bracket bonding with 37% phosphoric acid and Er:YAG laser. Forty bovine incisors were divided into two groups. In Group I, the teeth were conditioned with 37% phosphoric acid and brackets were bonded with Transbond XT; in Group II, the teeth were irradiated with Er:YAG and bonding with Transbond XT. After SBS test, the adhesive remnant index was determined. Adhesion to dental hard tissues after Er:YAG laser etching was inferior to that obtained after acid etching but exceeded what is believed to be clinically sufficient strength, and therefore can be used in patients.

Keywords: orthodontics; laser Er-YAG; shear bond strenght;

1. INTRODUCTION

Orthodontic practice prevents and corrects occlusion irregularities in order to improve aesthetics and function of the stomathognatic system. The brackets are a fundamental part in orthodontic treatment and so it must remain well fixed to the teeth throughout the therapy. Initially, those devices were stuck to the teeth through orthodontic bands. However, this mechanism made it difficult for the patient to perform the oral hygiene, induced aggression to gingival tissues, leading to an aesthetic commitment and slow rhythm of its clinical execution, as well as countless other disadvantages.[1]

The etching, introduced by Buonocore in 1955, brought the possibility of adhesion between the bracket base and the tooth surface, through the creation of mechanical retentions resulting from the resin imbrication in microporosities produced by the acid. In this way, since the 1970's, the use of composite resin for bonding orthodontic brackets has been carried out. The adhesion strength between the enamel surface and the bracket must be enough to support the mechanical and thermal effects of the oral environment. According to Reynolds[2],the shear bond strength, when observed in a laboratory level, made from a suitable material for bonding, must be between 5.9 and 7.8 MPa.

Recently, alternative methods have been studied to help the conditioning of dental surfaces, such as laser irradiation, which main advantage is the inhibitory effect of caries on the irradiated enamel, already observed in some studies. [3,4,5,6]

The laser irradiation of dental hard tissues modifies the calcium-to-phosphorus ratio, reduces the carbonate-to-phosphate ratio, and leads to the formation of more stable and less acid-soluble compounds, thus reducing susceptibility to acid attack and caries. [5,7]

Bearing in mind that the adhesion failure of the brackets ends up being frustrating for the orthodontists, it affects the efficiency of the braces, has an important economic impact and it may significantly delay the progress of the treatment[8,9], the objective of this study was to evaluate the conditioning ability of the dental surface irradiated with Er:YAG laser, by comparing and measuring this adhesion strength to the traditional way of conditioning by the phosphoric acid.

2. MATERIAL AND METHODS

This study was conducted after approval by the Ethics Committee on Animal Use of UFPE, under protocol number 23076.015869/2015-65. Forty freshly extracted bovine teeth were selected for sample preparation.

The teeth were stored for at least 48 hours in a Chloramine-T 1% solution for disinfection. After this period, their roots were sectioned and their buccal surface was sanded and polished so the naturally present deeper grooves were eliminated and the surface is then more similar to human teeth. The crown was included in a PVC cylindrical support on which it was poured acrylic resin so that the buccal surface is parallel to the barrel edge. The specimens were stored in distilled water at room temperature until the moment of bonding.

Samples were randomly divided into 2 groups with 20 teeth each: group 1 (G1), phosphoric acid + primer + adhesive; group 2 (G2), Er:YAG laser + primer + adhesive.

The teeth surface of all specimens were submitted to prophylaxis with rubber cup, pumices and water, being careful to renew the rubber cup at every twenty prophylaxes. Next, they were washed with water jets (15 seconds) and dried with humidity-free jets (15 seconds). To prepare the surface, group G1 was conditioned with 37% phosphoric acid (Condac 37% - FGM Produtos Odontológicos, Joinville, Santa Catarina, Brazil) for 15 seconds and after this period, they were washed with air/water jets for more 15 seconds. After the surface conditioning, the Primer was applied (Primer Transbond XT - 3M Unitek, Monrovia, California, United States) with a microbrush and then photoactivated for 20 seconds (Radii cal LED, SDI, Bayswater, Australia), according to the instructions of the manufacturer.

For all the collages, we used the Roth Max Morelli® brackets (Dental Morelli, Sorocaba, São Paulo, Brazil) of upper incisors with a base area of about 14 mm². These brackets were chosen due to their anatomy similarities of the lower incisors of bovines to the upper central incisors of humans.

Brackets with the Transbond XT light cure adhesive were placed in the center of the buccal face and pressed by a device to standardize the strength put in the bonding – 350 g – and then, the thickness of the resin film. With the device placed, the excess of resin was removed and then a photoactivation was performed for 10 s in each face of the bracket (mesial, distal, cervical and incisal).

In group G2 the surfaces of the teeth were conditioned with the application of the Er:YAG laser (2940 nm central wavelength, Fidelis Plus III, Fotona, Slovenia) using 120 mJ, 10 Hz and 1.2 W in a MSP mode (Medium Short Pulse mode). Irradiation parameters were defined after the pilot study previously conducted. In order to standardize the laser irradiation, we employed a step motor that moved the sample at a constant speed of 3.8 mm/s and a fixed post as a support so the distance between the tip of the laser hand piece and the dental surface is always the same (12 mm) in every specimen, thus maintaining the irradiation energy. Besides, the step motor is translated laterally after each line scan, so the irradiation lines do not overlap themselves, promoting a homogeneous conditioned surface (Fig.1 and Fig.2)

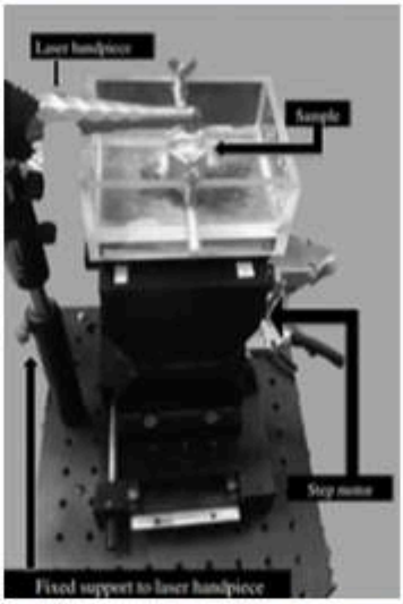

Fig. 1 – Step motor and fixed haste of support the laser handpiece.

Subsequently, as the group G1, there was the application of the primer with microbrush and photoactivation for 20 seconds. The brackets were placed with the Transbond XT and photoactivated for 10 seconds in each of its face. After the bonding, the specimens were stored in distilled water in a biological sterilization at 37ºC for a minimum of 24 hours, to simulate temperature changes in the oral cavity.

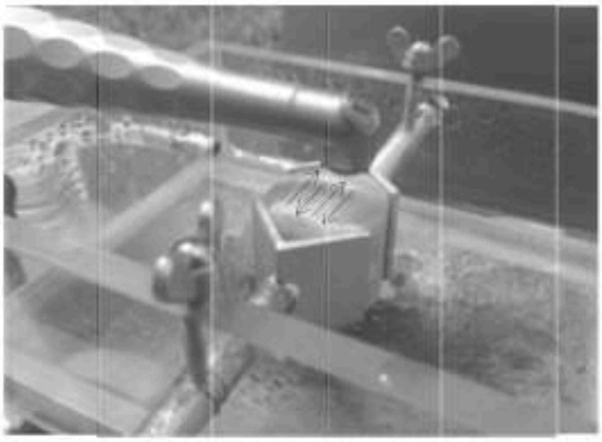

Fig. 2 – Demonstration of the sample movement, through the step motor, during the irradiation with Er:YAG laser.

All the samples were submitted to thermocycling (Nova Ética model 521-E, Ética Equipamentos Científicos S/A, São Paulo, SP, Brazil) in a total of 500 cycles between 5°C to 55°C during 30s to stimulate the differences of temperature in the mouth. After the thermocycling, the specimens were prepared for the shear bond strength test, made using the Universal Testing Machine (Kratos Equipamentos Industriais Ltda, Modelo K2000MP, Taboão da Serra, São Paulo, Brasil) with chisel at a speed of 0.5 mm/s and load cell of 200 kgf.

After debonding, the teeth were examined with the aid of a stereomicroscope (Stemi 2000-C, Zeiss, Oberkochen, Germany) with a zoom of 20x and classified according to the Adhesive Remnant Index (ADI), proposed by Artun and Bergland[10], with scores from 0 to 3, that indicated:

- Score 0 = no adhesive remnant left on the tooth.
- Score 1 = less than 50% adhesive remnant left on the tooth.
- Score 2 = more than 50% adhesive remnant left on the tooth.
- Score 3 = 100% adhesive remnant left on the tooth.

3. RESULTS

Shear bond strength test, expressed in MPa, and the descriptive statistics are presented in Table 1. When evaluating the shear bond strength of a specimen, the size of the bracket base has a meaningful importance, since the bigger the base, the greater sustaining, so the values were measured taking into account the rupture strength and the size of the bracket base. The values obtained in Newtons were converted to Megapascal. This conversion was made using the following formula: Mpa=F/A, that is, (Mpa) is the strength in Megapascal, (F) is the debonding force in Newtons and (A) is the bracket base area in mm².

Table 1 also shows that groups irradiated with the laser, G2, presented a lower average than the groups conditioned with acid, G1, with no statistically significance difference among them.

Table 1 – Descriptive statistics regarding the shear bond strength test.

Statistics	G1	G2	Value of p
Average (2)	10,32 (A)	7,25 (B)	$p^{(1)} = 0,030$*
Standard Deviation (2)	4,83	2,96	
Coefficient of Variation (%)	46,80	40,83	
Median (2)	9,71	7,36	
Minimum (2)	3,62	3,15	
Maximum (2)	19,30	13,48	

(*): Significant difference at 5.0%
(1): Through the t-Student test with unequal variances for the comparison between groups G1 and G2.
(2): Measures in Mpa

For the evaluation of the Adhesive Remnant Index, samples were observed in a stereoscopic microscope and classified by the score according to figure 3. The obtained results are shown in table 2.

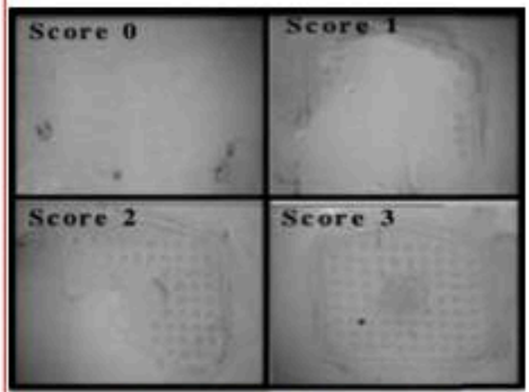

Fig. 3 – Illustrative images of the Adhesive Remnant Index

Table 2 – Evaluation of the Adhesive Remnant Index according to the group

ADHESIVE REMNANT INDEX	G1		G2	
	n	%	n	%
No remnant	7	38,9	17	94,4
Less than 50%	1	5,6	1	5,6
More than 50%	7	38,9	-	-
100% of the remnant	3	16,7	-	-
TOTAL	**18**	**100,0**	**18**	**100,0**

4. DISCUSSION

The success of the union of tooth and bracket in orthodontics involves a combination of three basic factors: mechanical or chemical retention of a surface; correct choice and manipulation of the adhesive materials; and the retentive potential of the accessories or brackets to be used.[11]

The chosen protocol for this procedure over the last years has been prophylaxis, cleaning and drying, followed by the conditioning of the enamel acid, washing, drying, application of the bonding agent and fixing the orthodontic accessory to the enamel with composite.[12,13] This procedure has been providing satisfying bonding results. However, the technique should be careful and the steps correctly followed, otherwise the adhesion of the accessories can be compromised.[12] Besides, the presence of the bracket and the resin predispose to an increased plaque accumulation[14], which may cause white spot lesions that may occur after the first four weeks of the orthodontic treatment.[15] These changes appear mainly in the cervical region of the upper incisors.[14] The risk of demineralization can be prevented by a plaque control and fluorine application [14,15], however, we observed that the brushing program with fluoride toothpaste did not prevent the decalcification of the enamel around the brackets, because the effectiveness of the plaque control depends on the daily routine followed by the patient.[16]

This way, as observed in some studies [3,4,5,6,17], laser irradiation on the dental surface is able to protect the enamel against the carious attack, which is considered to be one of its advantages. Nevertheless, the use of Er:YAG and Nd:YAG lasers when treating enamel surfaces and dentin has been presenting diverse results when it comes to dental adhesion. Therefore, more studies are necessary to find parameters that lead to an ideal bonding between the bracket and the enamel. This research had the objective of testing these parameters and establishing reproducible norms for other studies.

Agreeing with Lee[18] and Sagir[19], when they demonstrate there is a small decrease or non-interference on the adhesive resistance when applying Er:YAG and Nd:YAG lasers, this study presented results with significant statistical difference of the shear bond strength when the groups (conditioned with phosphoric acid and conditioned with laser) were compared. However, Reynolds[2] suggests that the necessary adhesive resistance for the clinic is between 5.9 and 7.9 MPa [20], proving that all resistance results obtained in this study were satisfying.

One of the hypotheses to obtain better results presented in this study, regarding others[21,22] which did not recommend the use of Er:YAG laser as an option to condition the surface, could be due to the establishment of the strict methodology, especially when it comes to the process of irradiation of the dental surface. The use of a fixed support kept an equal distance between the tip of the hand piece of the laser and the tooth, and there was the use of a step motor that moved the sample in a standardized way, rather than in a hand-free method, possibly allowed the obtainment of a more regular and homogeneous retentive surface.

It is believed that the adhesive failure happening between the enamel and the bonding system is an advantage[23] because there will be less adhesive remnant and, consequently, less time will be spent to remove it, and also a reduced chance of excessive wear. However, most of the authors[24,25,26] seem to accept that the safest place to debond is between the adhesive system and the bracket, which guaranteed the risk reduction of cracks and fractures of the enamel. The result obtained in this research, as observed on Table 2, showed that Score 0 and Score 1 were the most prevalent when considering all the groups tested, which demonstrates the fracture happened mainly between the dental surface and the adhesive system. This would follow the line of though of Bishara's study.[23]

5. CONCLUSION

We reported the evaluation of shear bond strength of teeth prepared for orthodontic bracket bonding with 37% phosphoric acid and Er:YAG laser, in two groups of samples. Based on the findings of this study and considering the limitations of an *in vitro* study, it is possible to conclude that the group that presented greater resistance to the shear bond strength test was the group of teeth conditioned with phosphoric acid using the Transbond XT resin as an adhesion material and there was significant statistical difference between the group conditioned with phosphoric acid and the group irradiated with Er:YAG laser.

Another important fact is that most of the adhesion failures happened between the enamel and the resin, characterizing a failure of the adhesive material. Finally, the group were irradiated with Er:YAG laser showed shear bond strength values considered clinically acceptable, so the protocol used for laser irradiation is technological feasible for clinical use, with appropriate adaptations.

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ANEXO A – Parecer do Comitê de Ética em Uso de Animais (CEUA – CCB/UFPE))

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Centro de Ciências Biológicas

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Recife, 25 de agosto de 2015

Ofício nº 80/15

Da Comissão de Ética no Uso de Animais (CEUA) da UFPE
Para: Prof.° Anderson Steves Leonidas Gomes
Departamento de Prótese e Cirurgia Buco Facial
Universidade Federal de Pernambuco
Processo nº 23076.015869/2015-65

Os membros da Comissão de Ética no Uso de Animais do Centro de Ciências Biológicas da Universidade Federal de Pernambuco (CEUA-UFPE) avaliaram seu projeto de pesquisa intitulado **"Avaliação da Força de adesão dos brackets ortodônticos após tratamento da superfície do esmalte por ácido fosfórico e laser Er: YAG".**

Concluímos que os procedimentos descritos para a utilização experimental dos animais encontram-se de acordo com as normas sugeridas pelo Colégio Brasileiro para Experimentação Animal e com as normas internacionais estabelecidas pelo National Institute of Health Guide for Care and Use of Laboratory Animals as quais são adotadas como critérios de avaliação e julgamento pela CEUA-UFPE.

Encontra-se de acordo com as normas vigentes no Brasil, especialmente a Lei 11.794 de 08 de outubro de 2008, que trata da questão do uso de animais para fins científicos e didáticos.

Diante do exposto, emitimos parecer favorável aos protocolos experimentais a serem realizados.

Origem dos animais: Frigorífico Bandeira; Animal; Bovino Nº total de dentes a ser utilizado; 80

Atenciosamente,

Prof. Dr. Pedro V. Carelli
Presidente da CEUA / CCB - UFPE
SIAPE 1801584

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These guidelines are supplemental to the Guidelines for Original Articles, which describe how to meet general submission requirements, such as figure formats, reference style, required releases, and blinding.

Systematic Review and Meta-Analysis Guide for Authors

You can access a link to an annotated example of a Model Orthodontic Systematic Review. Further explanation of reporting practices is given in the accompanying Explanation and Elaboration document. These documents have been prepared in accordance with PRISMA guidelines and the "PRISMA Statement for Reporting Systematic Reviews and Meta-Analyses of Studies that Evaluate Health Care Interventions: Explanations and Elaboration" (http://www.plosmedicine.org/article/info:doi/10.1371/journal.pmed.1000100).

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However, we have made these guidelines more relevant to orthodontics and have adapted the reporting template to encourage transparent and pertinent reporting by introducing subheadings corresponding to established PRISMA items.

Further information on reporting of systematic reviews can also be obtained in the Cochrane Handbook for Systematic Reviews of Interventions (http://www.cochrane-handbook.org).

Guidelines for Randomized Clinical Trials

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