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REVIEW

The role of laser power and frequency on metal surfaces of adhesive bridge in increasing the bond strength of resin cement

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ABSTRACT

Adhesive Bridge is a fixed denture that is attached to the tooth structure, especially the enamel, which has been etched to achieve micromechanical retention. Among other things, adhesive bridge attachment depends on, one important factor is the adhesive bond between the etched enamel and the retained metal. To increase the retention of adhesive bridges, variations of micromechanical surface treatment on metal can be carried out in the form of chemical or electrical etching, air particle abrasion (sandblasting), primary metal, tin plating, silica coating, and lasers. Lasers with different energies, strengths, frequencies, wavelengths, durations and distances can create a thin layer of porous oxide which increases the bonding strength of resin cement for adhesive bridges. The role of laser power and frequency as well as the selection of the right type of resin on the metal surface of the adhesive bridge can increase the bonding strength of the resin cement on the adhesive bridge. The selection of the type of surface treatment such as laser and the right type of resin cement can affect the bond strength of the resin cement on the adhesive bridge. (IJP 2024;5(1):9-13)

INTRODUCTION

Adhesive bridges or resin bonded fixed dentures is the type of denture relies heavily on the bond between the resin cement and the tooth and metal surfaces. An adhesive bridge comprises of a pontic that is fixed to the abutment teeth with the support of a metal wing retainer.[4] Adhesive bridges have the advantage that they require minimal preparation and can maintain more healthy tooth structure than conventional bridges and require minimal clinical time.[4]

Adhesive bridges are indicated in cases where the abutment teeth are in healthy condition, without caries and restorations and there is sufficient enamel for adhesion procedures, fixed retainers after orthodontic procedures, tooth splinting, and in cases where the patient is afraid of anesthetic needles.[5] Adhesive bridges are contraindicated in cases where the abutment teeth do not have adequate enamel for adhesion, the abutments are small or peg shaped, the abutments are malposition and mobile, and in patients who are allergic to cement and proper cementation procedures.[13] The main functions of resin cement materials are to provide adequate adhesion between the restorative material and the tooth, seal the exposed dentin during preparation, and fill the space created between the tooth and the restorative material. The success of a restoration is influenced by the adhesion that occurs between the restoration and cement.[14]

The development of cement materials in dentistry is increasing. Currently, there are two groups of resin cements on the market, namely conventional resin cements that require bonding materials, namely total etch resin cements, and self-etch resin cements, and resin cements that do not require bonding materials (self-adhesive resin cements). The application of resin cement is preceded by the application of bonding materials, in total-etch or self-etch systems.[13,23] The multi-stage application technique of resin cement with this bonding material is quite complex and sensitive, therefore it can affect the effectiveness of the attachment of the restoration to the tooth.[15] One of the major changes in recent years has been the development of resin cements that do not require the application of a bonding agent to attach the restoration. Resin cements that do not require a bonding agent have various names

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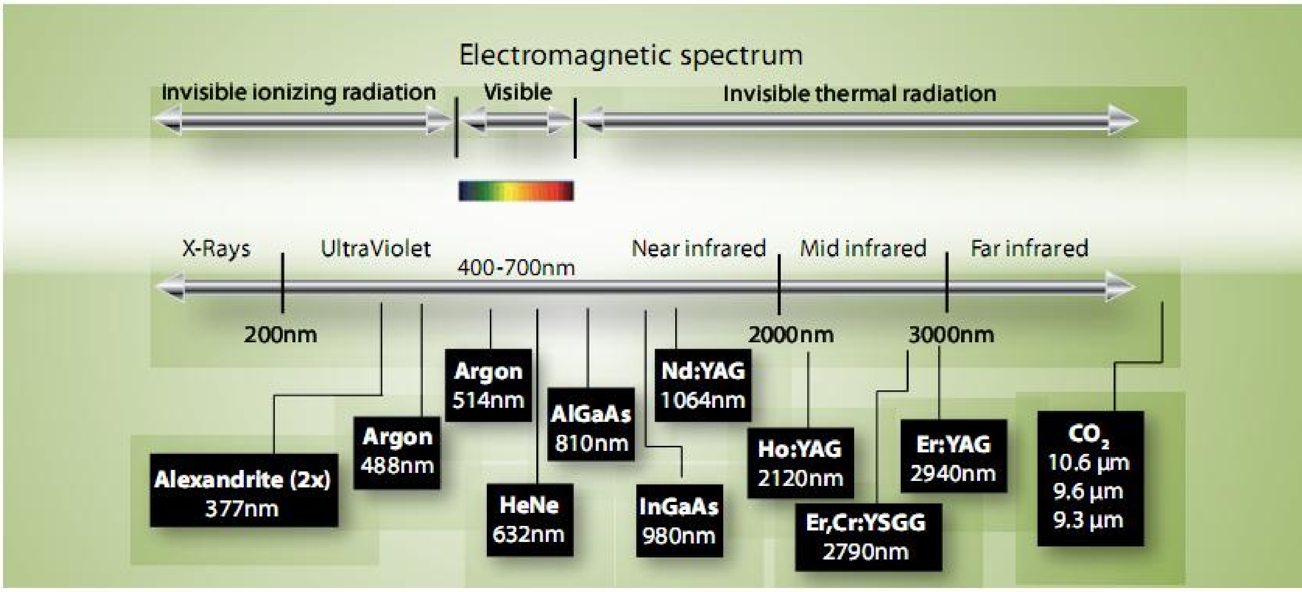

such as all-in-one resin cement, universal resin cement or self-adhesive resin cement.[13]

Self-adhesive resin cements were introduced to overcome several problems conventional resin cement systems. The aim of developing this cement was to combine the ease of use of conventional cements with micromechanical advantages.[16] Sandblasting with Al2O3 particles is the most commonly used method to obtain micromechanical retention. These particles have different sizes. Preparation with 50µm Al2O3 particles resulted in the highest shear bond strength of Ni-Cr metal.[17]

Previous studies on adhesive bridges have used different methods to improve retention such as using perforated retainers or fabricating micromechanical features to improve retention by using electrochemical etching or particle roughening. Studies show that micromechanical retention features are more efficient than macro-mechanical retention. Various surface treatment methods have been tried to improve the retention and resistance of fixed prostheses. The most common method used is sandblasting with alumina particles. An alternative to conventional surface treatment methods is laser.

With the application of lasers, it is possible to carry out the treatment of many soft tissue conditions and in prostheses which are often a challenge in prosthodontics. Lasers can affect the overall aesthetics of the result, and provide an easier method of handling. Before using a laser, it is very important to understand how this system works, the steps involved, and the precautions to be taken (e.g., eye protection), and troubleshooting steps.[21]

LITERATURE STUDIES

Adhesive bridge

An adhesive bridge is a fixed denture that is attached to the tooth structure, especially the enamel, which has been etched to achieve micromechanical retention of the luting material from the resin.[22] An adhesive bridge consists of one or two pontics supported by thin metal retainers that are placed lingually and proximally to the abutment teeth. Adhesive bridge attachment depends, among other things, on the adhesive bond between the etched enamel and the retention metal.[3] Some other names of adhesive bridges that are often used by several authors include Rochette bridge, Maryland bridge, Minimal-preparation bridge, Direct bonded retainer, Resin bonded fixed partial denture, Resin bonded prosthesis and Resin retained cast metal prosthesis.

Factors Affecting the Success of Adhesive Bridges

Dentures are made to restore occlusal stability and enhance oral, cosmetic, and dental function. According to certain research, adhesive bridges have a 5-year success rate of 87.7%.[4] The effectiveness of adhesive bridge restoration can be affected by a number of things. The factors related to the patient, the choice of the abutment teeth, the adhesive bridge design (such as wing retainer coverage), aesthetic considerations, the design of the pontic, and the adhesive bridge materials (such as full porcelain, metal porcelain, and fiber-reinforced resin composite). The success of adhesive bridges is also influenced by clinical procedures including abutment preparation and cementation. For example, wax up coping, casting, porcelain application, porcelain firing, and metal surface treatment are some of the processes employed in the lab. A combination of macro-, micro-, and chemical treatments on metal parts as surface treatment can help in increasing the retention of metal surfaces in adhesive bridges.

Resin Cement

Resin cements, also known as adhesive resins, are resins containing adhesives such as 10-methacryloyloxydecyl dihydrogen phosphate (MDP), organophosphate, or 4-methacryloxyethyl trimethylate anhydride (4-META); In dentistry, resin cement describes the adhesive material used to attach fixed dentures and veneers to metal.[22] Resin cement is the newest type of cement for attaching restorative materials indirect with teeth. The advantages of resin cement are it has the following properties like higher mechanical strength compared to conventional cement and insoluble in liquid in the oral cavity so that the marginal margins are closed better. Resin cement, also known as bonding cement, is cement that has the property of adhering to the interior of the restoration and to the abutment tooth structure.

According to ISO 4049 adhesive resin cements are classified into 3 classes based on their polymerization activation, namely chemical activation without irradiation (self-cured, class 1), with irradiation (light-cured, class 2), and activation chemically and with or without irradiation (dual-cured, class 3).[23] Dual-cured resin cements are attractive as luting agents because of the development of resins for fillings, the advantages of acid etching techniques for bonding resins to enamel and the potential for bonding to dentin by organic or inorganic acid treatment. Some cements are made for general use and some for specific uses, such as cementation of ceramic crowns and fixed dentures.[12]

Content of Resin Cement

Resin cements use monomers that are aromatic or aliphatic acrylates. Bis-GMA, urethane dimethacrylate (UDMA) and triethylene glycol dimethacrylate (TEGDMA) is a dimethacrylate commonly used in dental composites.[12] Bis-GMA (bisphenol A Glycidyl Methacrylate) and UDMA (Dimethacrylate Urethane) developed by Foster and Walker to make monomers with lower viscosities, such as the free hydroxyl Bis-GMA and UDMA (Ilie & Hickel, 2011). Bis-GMA is the most commonly used monomer polymer for resins composites on teeth. To improve Bis-GMA processing performance, usually added extra monomer polymers such as UDMA and TEDGMA to reduce the viscosity of the resin cement. Uses of Glycidyl Methacrylate (Bis.) matrix GMA is to form strong cross-linked polymers in composite materials and control the consistency of the composite resin. Bis-GMA plays an important role in reducing volumetric shrinkage, increasing composite reactivity and increase the conversion rate to some extent. Small polymerization shrinkage, high fatigue resistance, high fracture resistance, resistance to pressure, low heat conduction coefficient, and meet the aesthetic requirements of the teeth several important characteristics for the desired composite.[15]

Resin Cement Bonding Mechanism

The use of a dentin bonding agent prior to resin cement application is critical to success, unless the enamel has been prepared. Several mechanisms for bonding to the dentin surface include: tagging of dentinal tubules, bonding to precipitates on pre-manipulated dentin, chemical incorporation with inorganic components, chemical incorporation with organic componentc, production of dentin layers by impregnation with resins.[18] Resin cement is polymerized through a chemical mechanism, hydrophilic monomers that have polymerized will enter through the collagen layer into the dentin apatite that has been demineralized by etching. Adhesion of the dentin to the resin cement is achieved by primary infiltration of the resin into the mineralized portion of the dentinal tubule, resulting in an interlocking mechanical bond. The resin cement cementation procedure requires several steps. First the acid is applied to remove the smear layer, the dentinal tubules are exposed and demineralization occurs with a thickness of 2-5 microns of dentin. The acid then dissolves and the apatite mineral extract normally coats the collagen fibers of the dentinal matrix and opens a 20-30 m deep channel around the collagen fibres. The cement will achieve mechanical retention by the entry of hydrophilic monomers into the channel.[19]

The adhesive resin will form a hybrid layer. This hybrid layer is a structure formed on mineralized hard tooth tissue then infiltrated by monomer and will be followed by a monomer polymerization process. This hybrid zone indicates resin penetration into the intertubular dentin as deep as 5-10 m and the formation of micromechanical interlocking with dentinal collagen.[8] Meanwhile, according to Smith (2007) the attachment of cement to metal is more of a mechanical retention. The mechanical retention is obtained from the surface roughness of the metal restoration. The liquid cement fills the roughness. After hardening, cement acts as a bond between the two surfaces (dentin and metal).[6,8]

Surface treatment

Surface treatment is a treatment process that is applied to change the properties / characteristics of the metal on the metal surface. Variations of micromechanical surface treatment on metals in the form of chemical or electrical etching, air particle abrasion (sandblasting), primary metal, tin plating, and silica coating have been investigated and are intended to increase the adhesive strength of restorations on cement. Surface treatment of the metal adhesive bridge retainer aims to increase the retention between the adhesive bridge retainer and the resin cement. On adhesive bridges, macro mechanical, micromechanical, and chemical surface treatment can be carried out.

Macro mechanical Surface Treatment; Surface treatment of adhesive bridges in macro mechanical way was first made by Rochette. Rochette bridges formed perforations on metal wing retainers as additional retention for resin materials. Then macro mechanical surface treatment on adhesive bridges can also be found on Virginia bridges in the form of results from the use of the lost salt technique.

Micro mechanical Surface Treatment; Micro mechanical surface treatment of adhesive bridges can be found on Maryland bridges. On the Maryland bridge, surface treatment was carried out with electrolysis etching using 3.5% nitric acid and an electric current of 250mA/cm2 for a period of time.

Laser

A laser consists of three main parts, namely the energy source, the amplifier medium and the optical cavity or resonator. In order for amplification to occur, energy is delivered to the laser source by a pumping mechanism of energy through a strobe flash lamp, electric current, or electric coil. This energy is then delivered to the active medium in an optical resonator, and then produces spontaneous photon emission. Further, the amplification obtained by stimulated emission acts as a reflected photon through a reflective medium in an optical resonator before being ejected through the coupler path. In the case of dental lasers, laser light is delivered to the target tissue via fiber optic cables, hollow wave guides or articulated arms. The wavelength and other properties of the laser are determined primarily by the composition of the active medium, which can be a gas, a crystal, or a solid semiconductor.[21,25]

Dental laser: argon laser

Argon laser, an active medium in the form of argon gas, produces light with two wavelengths, blue light with a wavelength of 488 nm which is commonly used to initiate polymerization of restorative composite materials. Blue-green light with a wavelength of 514 has maximal tissue absorption

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consisting of pigmented molecules such as hemosiderin and melanin. Both wavelengths produced by the argon laser have poor absorption in non-pigmented and hard tissues. This type of laser is often used to control bleeding during gingival surgery, and to detect cracks and damage to the tooth surface using the transillumination technique.[7]

Erbium laser

Currently, the erbium laser is the type most often used in dentistry. The types of erbium lasers that are often used are the Er:YAG and Er, Cr:.YSGG types. The Er:YAG (2940 nm) laser has YAG as the active medium, while Er, Cr:YSGG (2790 nm) has solid yttrium, scandium and garnet as the active medium. Both wavelengths show the highest absorbance level in hydroxyapatite and the highest absorbance in water compared to other systems. Since bones and teeth are composed of large amounts of hydroxyapatite and water, the erbium laser can be used in hard tissue removal. For such applications, as the moisture content of the tooth evaporates, removal of the surrounding soft tissue can be carried out with minimal thermal effect on the pulp.[7]

Neodymium-doped yttrium aluminum garnet (Nd: YAG) laser

With YAG doped crystals and neodymium as the active medium, it is the first laser system created specifically for dental applications. Unlike CO2 and Er:YAG lasers, which absorb in water and tissue with a greater pigment content, this laser has a wavelength of 1,064 nm. Because of the substantial coagulation layer, Nd:YAG has a long-lasting hemostatic effect. In addition to surgical uses, this kind is also employed in the removal of soft tissue, and researchers have looked into nonsurgical sulcus debridement. This technique is safe to use for applications in soft tissue surgeries since it only affects the hard tissues of the teeth, which have a close structural relationship to the teeth. Numerous studies have used the Nd:YAG laser to modify the ceramic's surface prior to bonding. Before bonding, this laser has been recommended as an efficient approach for surface roughening and wettability. The Nd:YAG laser has been used for zirconia under various power and irradiation settings.[1]

Laser Parameter

Recently, dental practitioners using lasers in the fields of cavity preparation, dentin caries treatment cream, surface conditioning, and also indirect restoration surface treatment, the recommended laser in this case is the use of the erbium:yttrium aluminum garnet laser (Eh: YAG).[11,24] Due to the synchronization of wavelengths and absorption peaks and because of the good absorption by the OH groups in hydroxyapatite, the erbium:yttrium aluminum garnet (Er:YAG) laser is often used in dentures with ceramic materials. Carbon dioxide (CO2) lasers are commonly used intraoral especially in soft tissue and hard tissue applications. Since the ceramic completely absorbs all long CO2 lasers, the CO2 laser is particularly suitable for surface treatment of ceramic materials. CO2 laser etching can represent an effective method for surface conditioning of zirconia, improving micromechanical retention and increasing strength.[11]

In order to achieve desired results, it will be essential to choose the appropriate laser processing parameters, which directly determine the produced surface topography and microscale surface roughness. The principle for increasing bond strength is surface roughening to enable micromechanical interlocking. For the strengthening and durability of the restoration, all the parameters such as such as pulse, power, and duration are very important. It is evident that surface roughness tends to increase and become more variable in high energy laser scenarios, while it tends to stay low and become less variable in low energy laser situations. However, more laser exposure under low energy settings causes the roughness to increase; in contrast, more exposure under high energy conditions results in a smoothing effect. This could be explained by the fact that consecutive exposures at different scan angles tend to homogenize the roughness profile when more material is melted with a higher laser energy during a single pass.[20]

DISCUSSION

Adhesive bridges are dentures with minimal intervention. The main criterion for the success of an adhesive bridge is the occurrence of a strong and permanent bond between the tooth surface and the metal surface. One of the factors that cause the most failure of adhesive bridges is the failure of the adhesion of the adhesive bridge between metal and resin cement.[3]

Laser technology has been considered in almost all areas of dentistry. Several recent investigations studied the effect of laser irradiation on the resin bond strength of ceramic restorative materials. It has been reported that compared to conventional sandblasting and acid etching techniques, there is no significant difference associated with the application of Er:YAG or Nd:YAG lasers for bonding resin cement to dental porcelain, so laser surface treatment of porcelain may be as effective as conventional methods.[9]

Abraham et al. concluded that the laser irradiated ceramic surface was more effective due to the low surface energy and rough surface created by the laser beam. When the ceramic surface treated with an Nd:YAG laser is observed under a scanning electron microscope (SEM) (×200 magnification), the surface pattern shows areas that appear to be liquid with the presence of pores and craters, a water droplet-like pattern thereby increasing the surface undercut which enhances adhesion.[10] On the other hand, the surface morphology with sandblasted regions results in a surface with irregularities with no visible defects on the surface. Moslehifard et al. made similar observations on the surface of a nickel-chromium alloy treated with an Nd:YAG laser. They concluded that during laser energy discharge, surface changes were observed at the time of the laser micro blast action resulting in the formation of craters and pores. The deposition of the droplet is possible due to the cast material's proximity to the laser point application. All features of the laser etched onto the surface contributing to increased retention are due to mechanical micro-cutting.[26]

Surface roughness increased significantly in the laser sandblasted polished surface sequence based on the study by Ghoveizi et al. The sandblasting roughness was significantly increased compared to the specimens with polishing treatment.[27] This is because each particle size collides with the surface, the appearance of the particles leaves a mark on the surface, and at this time, it is not only affected by the particle size, but also the particle injection pressure significantly. It is confirmed that the bond strength between the porcelain and the metal alloy increases due to the increased contact area compared to the polished sample. Also, the Ni-Cr and Ni-Cr-Ti specimens

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using the FS laser surface treatment had a higher Ra value (mean surface roughness) than the polished samples. Especially the microporosity pores will play a role in increasing the adhesive strength. Therefore, the results of the roughness test can determine the effect of the interfacial bond strength between porcelain and metal alloys.[28]

CONCLUSION

Adhesive bridges or resin bonded fixed dentures have been known for more than 40 years ago. The adhesion resistance of this type of denture relies heavily on the bond between the resin cement and the tooth and metal surfaces. An adhesive bridge consists of a pontic anchored to the abutment teeth using a metallic wing retainer made of metal. The drawback of the adhesive bridge is the lack of success rate of the adhesive bridge. The main cause of failure of adhesive bridges is debonding or detachment of dentures due to masticatory forces.

One of the main factors in bonding adhesive bridge restorations to resin-based cements is their surface roughness. Surface treatment on metal wing retainers and the type of resin cement used can affect the bond strength of the adhesive bridge. Therefore, different methods have been used to create this roughness, including sandblasting and laser treatment. Laser is the best part in increasing the surface roughness of the metal on the adhesive bridge in increasing the adhesive strength of the resin cement on the adhesive bridge.

SUGGESTIONS

In today's digital world, patients interact almost instantly with social media and internet so they have a better understanding in diagnosis and treatment options. They are more likely to accept recommendations for treatment, and they are definitely willing to invest in a procedure that they value and as long as it is comfortable for them. If the patient's experience with the laser is positive, then it will invite more references in using it. In short, lasers can enable dentists to make better quality dentistry. Awareness of the different laser wavelength types and laser parameters will encourage clinicians to explore a wider range of research. Courses at various levels of intensity, subject matter and complexity about lasers will be promoted more frequently at scientific conferences in dentistry.

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