Er:YAG laser in the bonding and debonding steps of orthodontic treatment

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_Introduction

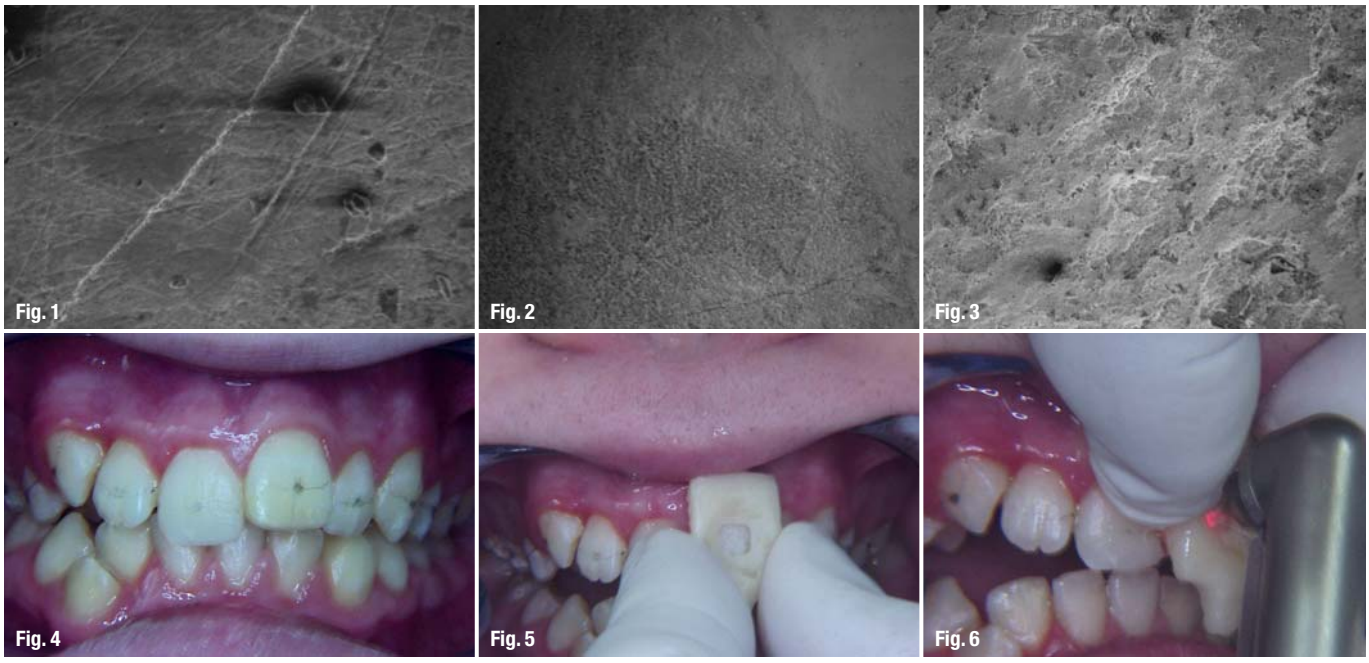
The Er:YAG laser was first proposed in 1990 by Hibst and Keller to ablate hard dental tissues. Today it is employed in conservative dentistry as an alternative to rotating instruments.[1, 2] A study based on patient questionnaires demonstrated that, in term of satisfaction, Er:YAG dental treatment represents an effective technique that may improve patient cooperation and diminish fears associated with the dental office, particularly in pediatric patients.[3] This is also a reason to suggest its application in the field of orthodontics, where cooperation and good relationships between the patient and operator are strictly necessary for full success of a treatment. In this paper we describe the utilisation of the Er:YAG laser in the bonding and debonding steps of orthodontic treatments.

_Enamel preparation

Proper conditioning of the enamel surface is necessary for the bonding of orthodontic attachments to teeth. In orthodontics, as in other fields of dentistry, the most common method of enamel preparation is acid phosphoric etching. The acid etching process prepares the surface by selective removal of inter-prismatic mineral structure, while organic materials are less affected.

The resultant rough and micro-fissured surface is very useful for the retention of adhesive resins, but these structures are also more vulnerable to caries formation. Acid etching removes and demineralises the most superficial and protective layer of enamel and makes the teeth more susceptible to long-term acid attack, especially when

Fig. 1_Non-treated enamel.
Fig. 2_Acid-treated enamel.
Fig. 3_Laser-treated enamel.
Fig. 4_Before the irradiation: the center is marked on each tooth.
Fig. 5_The screen positioned on the tooth.
Fig. 6_Irradiation of the tooth.



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Fig. 7


Fig. 8


Fig. 9


Fig. 10


Fig. 11


Fig. 12

Fig. 7_Bonding procedure completed.
Fig. 8_The thermo-formed tray inserted into the model.
Fig. 9_Thermo-formed tray with holes for laser irradiation.
Fig. 10_Laser irradiation.
Fig. 11_Bonding procedure completed.
Fig, 12_X-Runner, Fotona.

resin monomers cannot sufficiently fill the demineralised area due to saliva contamination or air bubbles.[4] Since the prevalence of white spot lesions is very high among orthodontic patients, the prevention of enamel demineralisation is of great importance in orthodontics.[5]

There has been extensive research to find an alternative conditioning method to overcome the main disadvantage of phosphoric acid etching, i.e. the potential for producing decalcification. Some researchers have worked on conditioning enamel with poly-acrylic acid or pre-treatment of the enamel surface with a sandblast of aluminium oxide to reduce the rate of enamel loss during etching,[6, 7] however, these methods failed to achieve adequate bond strength to resist intraoral forces.[8]

Table 1_Values (in MPa) of the force necessary to detach the brackets.

	ACID [MPa]	LASER [MPa]	ACID + LASER [MPa]
	11.04	2.34	10.18
	10.58	1.56	9.2
	6.26	8.62	15.1
	9.2	5.92	10.58
	6.86	7.36	16.86
	11.48	4.5	17.84
	5.34	4.3	7.06
	1.98	3.32	13.52
	6.26	5.36	4.5
	7.5	5.08	4.12
	4.78	7.06	7.44
	3.06	4.5	11.36
Media	**7.02**	**4.99**	**10.64**
Dev. Standard	**3.07**	**2.05**	**4.52**

_Laser in orthodontics

Er:YAG laser preparation has become one effective alternative to acid etching of enamel. Laser etching is painless and does not involve either vibration or heat; also, the easy handling of the apparatus makes this treatment highly attractive for routine clinical use.[9]

The employment of a laser with orthophosphoric acid etching to enhance the strength adhesion of composite resins has been proposed by several authors in conservative dentistry, as well as for bracket bonding in orthodontics.[10] An *in vitro* study at our university[11] on 36 human extracted molars, divided into three groups on the basis of enamel conditioning (acid only, laser only and laser plus acid) and analysed by traction tests by measuring the force necessary to detach the brackets, gave the results reported below (Tab.1 and 2).

Recently, another interesting *in vitro* study,[12] based on strength analysis by traction test and morphological analysis by SEM and Atomic Force Microscope, showed the same effects with Er:YAG irradiation alone as with acid etching. This was obtained by using the so-called "QSP" mode (Fotona, Ljubljana, Slovenia) in which each pulse is split into several shorter pulses that follow each other at an optimally fast rate. In this way, a specific surface roughness is achieved, representing a real alternative to acid etching. Microscopic observation of the samples ob-

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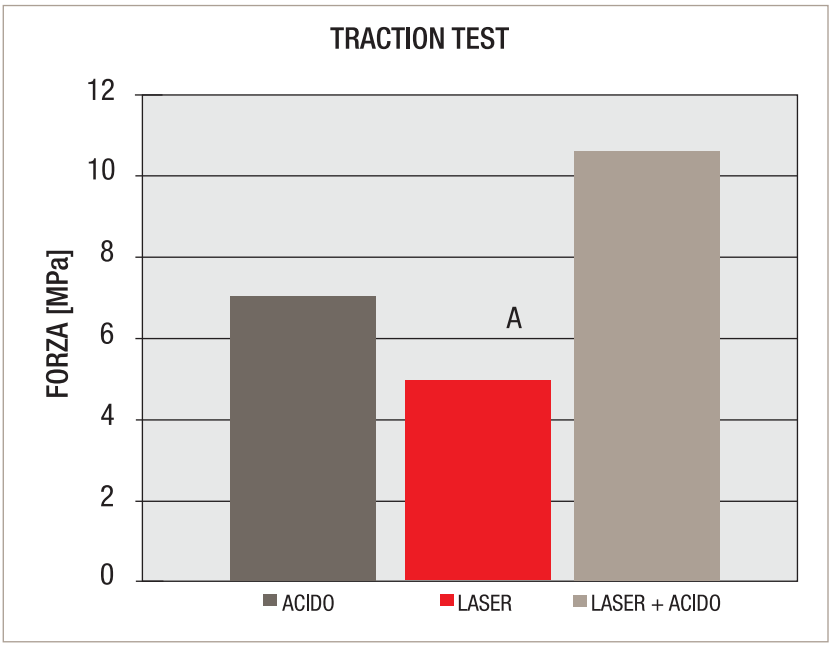


Table 2_Comparison of the three samples groups.

tained by the first study (University of Parma) (Figs. 1–3) demonstrated that the enamel laser irradiation creates micro-fissures that are ideal for resin penetration.[13]

The surface produced by laser irradiation is also acid resistant. Laser irradiation of the enamel modifies the calcium-phosphate ratio and leads to the formation of more stable and less acid-soluble compounds, thus reducing the susceptibility to caries attack.[14, 15]

Because water spraying and air drying are not needed with laser etching, time can be saved.[16, 17] From a clinical standpoint, saving chair time also improves adhesion because it reduces the risk of salivary contamination.

Moreover, other authors have underscored the result by using lasers to prepare the enamel surface to make it more resistant to decay[18] due to the modification of the hydroxyapatite crystals. Additionally, it is very important in the prevention of decalcification zones around the brackets, particularly in patients with scanty oral hygiene.[19]

In recent years, several techniques have been proposed with the same goal: to prepare a very small surface of enamel, exactly of the same dimension of the bracket, in line with the concept of modern "minimally invasive dentistry".

The first method[20] consisted of the use of a ceramic screen with a central window; the disadvantage consisted of the necessity to move the screen from one tooth to another for irradiation, after first marking the centre of each with a pencil (Figs. 4–7).

Parameters:	Laser source: Er:YAG, 2940 nm (Fidelis Plus III, Fotona)
Pulse duration:	MSP
Energy:	80 mJ defocused
Frequency:	18 Hz
Handpiece:	R02, 4/6 water/air spray

An evolution of this technique was performed with the introduction of thermo-formed individual trays,[21] which, after placement into the mouth, allowed for the irradiation of all the teeth of the arch (Figs. 8–11).

Parameters:	Laser source: Er:YAG, 2940 nm (Fidelis Plus III, Fotona)
Pulse duration:	MSP
Energy:	80 mJ defocused
Frequency:	18 Hz
Handpiece:	R02-C, 4/6 water/air spray

With the introduction of digitally-controlled technology in laser dentistry, which led to the realisation and commercialisation of the "X-Runner" laser handpiece (Fotona, Ljubljana, Slovenia), the method became significantly easier and faster, without the need to employ screens and/or trays.[22] In fact, using the laser system's touch screen, it is very simple to program the size and dimensions required, and then automatically irradiate an area equivalent to the bracket surface (Figs. 12–14).

_Debonding

Enamel damage, whether in the form of enamel fractures or cracks, detracts from the aesthetics of the tooth and may require costly restorative treatment. It may even compromise the tooth's integrity by increasing the risk of eventual tooth fracture.

Fig. 13_Irradiation of the central incisor.
Fig. 14_Irradiation of the premolars.
Fig. 15_Bonding procedure completed.


Fig. 13


Fig. 14


Fig. 15


Fig. 16


Fig. 17


Fig. 18

When the required force for bracket removal exceeds the cohesive strength of the enamel, fracture of the enamel surface is inevitable. With the introduction of ceramic brackets in the mid-1980s, the problem became more important: in fact, the low fracture toughness of ceramics may cause partial or complete bracket fracture during removal. This precludes reuse of the same bracket at a corrected position and may result in eye damage, ingestion or aspiration of bracket fragments. In addition, removal of a bracket fragment on the tooth may require the use of diamond burs, a process that is time consuming and can damage the pulp and enamel surface.[23, 24]

Since the early 1990s, lasers have been used experimentally for the debonding of ceramic brackets. The use of lasers eliminates problems such as enamel tear outs, bracket failures, and pain that are encountered during conventional ceramic bracket removal techniques.[25]

Additionally, lasers have the advantage of decreasing the debonding force and operation time. In most previous studies, carbon dioxide lasers, whose wavelength is more easily absorbed by the ceramic brackets, had been preferred for debonding.[25] In others,[26] Nd:YAG was proposed, although with this wavelength, approximately 69–75 % of the incident light reached the enamel surface, which has the potential to cause pain or damage to the tooth structure.

Oztoprak et al. preferred the Er:YAG laser since it has a lower thermal effect than the Nd:YAG or CO_2 lasers. They stated that the Er:YAG laser is effective for reducing the shear bond strengths of orthodontic polycrystalline ceramic brackets from high values to levels that are safe for removal from the teeth.[27]

All these methods described are based on thermal softening of the resin by the beam, but are active only in the case of ceramic brackets. The technique we propose may be used both on ceramic and metallic brackets, and consists of the utilisation of a H14-C handpiece with chiselled fiber tip (LightWalker AT, Fotona, Ljubljana, Slovenia). It is assumed that the vibrations produced by the photo-mechanical effects of this wavelength play the main role in the process of bracket detachment.

The fiber tip is placed tangentially to the crown surface and inserted between bracket and enamel as close to the metal bracket as possible at a 45 degree angle. This way, the laser energy is directed to the adhesive. Ten laser pulses are delivered at each side of the bracket. After that, the metal bracket is removed, with a very low strength, with the help of a spatula normally used to mix the cement. In this way, there are no complications during the debonding procedure and no damage to the enamel surface. As the energy is set relatively low in MSP mode, there is also no danger for intra-pulpal temperature rise. Patients report absolutely no stress during the procedure (Figs. 16–18).

Parameters:	Laser source: Er:YAG, 2,940 nm (LightWalker AT, Fotona)
Pulse duration:	MSP
Energy:	80 mJ
Frequency:	10 Hz
Handpiece:	H14-C with chiseled fiber tip, 4/6 water/air spray

Editorial note: A list of references is available from the publisher.

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