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Review Article

Dentistry Section

Adhesive Removal Procedures in Orthodontics: A Literature Review

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ABSTRACT

The removal of residual adhesive after orthodontic bracket debonding is a critical step in restoring enamel surface integrity while minimising damage. Over the years, multiple techniques have been developed to remove orthodontic adhesive, including mechanical, chemical, and laser-based methods. While current methods are effective in removing adhesive residues, many are associated with enamel surface damage, time inefficiency, or patient discomfort. Given the widespread use of adhesive removal instruments by orthodontists, it is essential to have scientific knowledge about these techniques and their biological impact on tooth structure. Consequently, it is crucial to select effective removal methods that minimise damage to the patient at the end of treatment and, whenever possible, preserve the tooth's original condition. Most authors prefer using a combination of abrasives and rotary speeds for effective appliance debonding, although the optimal choice of abrasive and speed remains unclear. Tungsten carbide burs receive the most favourable reviews in the literature, making them the recommended technique. Although the laser is more comfortable due to the lack of noise, vibration, or pressure, it creates a much rougher surface and is less effective compared to conventional methods. The present review aimed to summarise the available evidence on adhesive removal techniques reported in the literature and discuss their effects on the enamel surface and its integrity post-orthodontic treatment.

Keywords: Abrasives, Bonding, Enamel damage, Orthodontic adhesives, Polishing, Residual adhesives, Surface roughness

INTRODUCTION

Orthodontic treatment involving the application of adhesives to bond attachments on tooth surfaces necessitates meticulous adhesive removal procedures after the completion of treatment. While the adhesive bond between the bracket and the tooth is essential for the effectiveness of orthodontic appliances, the process of removing residual adhesive at the end of treatment presents unique challenges for clinicians. Iatrogenic enamel damage can occur after the debonding of brackets and the removal of leftover adhesive [1]. Appropriate adhesive removal procedures following the debonding of attachments can restore enamel surface integrity.

Over the years, various methods and tools for adhesive removal have been developed to minimise risks and ensure that the enamel surface is restored to its original state as closely as possible. However, there is considerable variation in the effectiveness, efficiency, and safety of these methods, which include the use of carbide burs, diamond burs, ultrasonic scalers, and lasers. Polishing discs, rubber cups, and chemical solvents are often used as final steps to smooth and refine the enamel surface, enhancing aesthetics and reducing roughness [1,2].

REVIEW OF LITERATURE

A search for relevant material was conducted in online databases, including PubMed, Scopus, Google, and Google Scholar. This literature review examined current practices, materials used, and techniques employed in adhesive removal post-orthodontic treatment, focusing on efficacy and potential enamel damage. By comparing different methods, this review seeks to provide orthodontists with evidence-based recommendations for choosing the most appropriate adhesive removal procedure, ultimately improving patient outcomes and ensuring the preservation of enamel health.

DISCUSSION

Bonding in Orthodontics

Bonding is a term conventionally used to describe the attachment of brackets to the enamel surface using bonding resins [2]. During the late 20th century, composites were used to attach orthodontic appliances to the tooth surface, enabling various orthodontic procedures [3]. Orthodontic bonding typically involves adhering braces or brackets to teeth using a combination of a bonding agent and composite material [4]. The steps involved in bonding brackets to enamel include surface etching, primer application, and adhesive application. Currently, the types of brackets used include metal, ceramic, lingual, self-ligating, miniature, and customised brackets [5]. Bracket base designs incorporate mesh wires, perforations, and undercuts to provide mechanical interlocking with the resin. In addition to mesh retention, companies utilise micromechanical retention produced through abrasion, etching, or spray coatings [6].

Debonding of Orthodontic Attachments

There are multiple techniques advocated for debonding orthodontic brackets. Mechanical, thermal, ultrasonic, chemical, and laser debonding are some of these methods [7]. The most common debonding procedure for metal brackets is mechanical, utilising a lift-off instrument, bracket-detachable pliers, or Weingart pliers [8]. There is a significant risk that a ceramic bracket might break during mechanical removal, which poses a potential risk of fracture. If the bracket partially breaks, it must be extracted using a diamond bur; neglecting to use coolant during this process could potentially harm the pulp and enamel, and it may also prolong the procedure [7]. Elastic Tie Medium (ETM) 346 pliers, recommended by Great Atlantic and Pacific Company (GAC), and the debonding wrench introduced by Unitek are used for debonding ceramic brackets [7,9].

Following orthodontic treatment, the removal of bonded attachments and the restoration of the enamel surface to its original pretreatment condition as closely as possible are carried out [10]. The debonding process and the removal of remaining resin can cause additional enamel damage, including scratches, cracks, and grooves [11]. It also removes the fluoride-rich outer layer of enamel and increases the roughness of the surface. Rough and uneven tooth surfaces can lead to enamel staining and plaque buildup [12].

Adhesive Removal and Polishing of Enamel

Due to recent advancements in the physical and mechanical properties of bonding materials, effectively removing resin remnants after orthodontic bracket debonding, while preserving enamel integrity, has become a clinical challenge. While some scarring on the enamel surface seems unavoidable following adhesive removal, employing the correct technique can minimise damage to a significant extent. Cardoso LAM et al., and Ye C et al., have proposed various techniques for resin removal and subsequent enamel polishing to prevent iatrogenic damage [13,14]. The removal of adhesive followed by the debonding of brackets is a necessary step and involves various methods, such as scraping with a scaler or adhesive-removing pliers [15], tungsten carbide burs (fine or super fine grit, low or high speed, varied flutes) [3,11-17], diamond burs [16], composite burs [18], zirconia burs [3,19], fiberglass burs [11,13], carbon dioxide, and Yttrium Aluminum Garnet (Er:YAG) laser application [12], Ultraviolet light (UV), fluorescent chemicals, ultrasonic cleaning, intraoral sandblasting, sandpaper discs, and composite burs in a contra-angle handpiece [16,20].

After adhesive removal in orthodontics, polishing methods are employed to smooth the tooth surface, remove any remaining adhesive residues, and create a glossy finish. These methods include rubber cup polishing [12], prophy jet polishing, air polishing, polishing strips, low-speed handpieces with polishing paste, composite polishing disc treatments, Sof-Lex discs [21], Super Snap by Shofu [16], and One Gloss by Shofu [22,23].

Various Methods of Adhesive Removal

1. Adhesive removal pliers and ultrasonic scalers: The methods for removing composite residue can be categorised into three main groups: 1) manual tools like pliers and scalers; 2) rotary instruments such as diamond finishing burs; and 3) carbide burs used at high or low speeds, as well as ultrasonic devices like ultrasonic scalers [3].

Adhesive removal pliers in orthodontics are used to safely and efficiently remove adhesive remnants left behind after the debonding of brackets or other orthodontic appliances. This tool features a scraper on one side and a nylon pad on the opposite side, both of which enable orthodontists to access and scrape off adhesive residue [1].

Cardoso reported the highest damage to enamel surfaces when using adhesive removal pliers, compared to an ultrasonic scaler, which also caused visible enamel damage [13]. While ultrasonic scalers can remove gross adhesive and supragingival calculus, they have been reported to be unsuitable for removing all remnant adhesive [15].

2. Abrasives and burs: In orthodontic practice, abrasives are commonly used for adhesive removal after bracket debonding. Orthodontic professionals need to select the appropriate type and size of bur based on the specific requirements of the case and the condition of the patient's teeth. Additionally, proper technique and adequate irrigation should be employed during the adhesive removal process to minimise thermal damage and preserve tooth structure. These abrasives are designed to efficiently remove the adhesive residue from the tooth surface without causing significant damage. Information on the abrasives and polishing agents reported in the published literature [3,11-14,16-18] has been depicted in [Table/Fig-1].

The burs and abrasives used for adhesive removal in orthodontics are described below:

- **Tungsten carbide burs:** Highly durable and effective for adhesive removal, tungsten carbide burs are available in various shapes and sizes [24,25]. These burs have been widely reported in the literature. Most authors support the use of low-speed tungsten carbide burs, while high-speed burs, although typically known for their short operating time, can result in a rough surface with deep scratches [12,13,17]. The best practice for cleaning up adhesive following bracket debonding is the subject of much debate in the literature.
- **Diamond-coated abrasives:** These abrasives offer excellent cutting efficiency and precision, making them preferred for smooth removal with minimal enamel damage [24,26].
- **Composite finishing abrasives:** Specifically designed for finishing composite materials, these abrasives are suitable for removing adhesive remnants after bracket removal [27].
- **Zirconia abrasives:** With a non metallic composition, zirconia abrasives reduce enamel damage and allow for efficient adhesive removal with minimal friction and heat [3].

Author's name/Year of study	Method of adhesive removal/polishing	Outcomes measured	Inference
Ahrari F et al., 2012 [12]	Group 1-TC bur in low speed	SR	Least enamel roughness with TC bur at low speed The roughness that occurred from using high-speed TC bur is minimal, while diamond burs and Er:YAG laser didn't revert to its original state, suggesting permanent enamel damage.
	Group 2-TC bur in a high-speed handpiece		
	Group 3-Ultrafine DB		
	Group 4-Er:YAG laser		
Thawaba AA et al., 2023 [3]	Group 1-ZR	*Time in seconds	ZB-Effective, resulting in minimal surface roughness and enamel damage, moderately time-consuming alternative. The TC bur yielded similar outcomes to the ZB but required more time. The WS method caused the highest surface roughness and irreversible enamel damage despite being the quickest.
	Group 2-TC bur-12 flute TF	*Average SR using PFM	
	Group 3-WS	* EDI Score under SEM	
Fan XC et al., 2017 [16]	Gp 1-High speed DFB+OG	*SR with SRT *SR SEM	Enamel treated with DFB showed deep scratches, and grooves, that couldn't be reduced by OG SS-acceptable outcomes, although some scratches were noted OG yielded enamel surfaces closest to intact enamel, but the least efficient method.
	Gp 2-SS		
	Gp 3-OG		
Shah P et al., 2019 [11]	Gp 1-OG Gp 2-EFP Gp 3-FRB Gp-SL with wheel	SR with *SRT *SEM	Post-polishing Ra: FRB-smoothest enamel surface, closely resembling natural enamel, followed by EFP, OG, and SL SEM showed FRB caused the least damage to the enamel surface.
Cardoso LAM et al., [13]	Gp 1-High speed TC bur	SR, ESI	The preferred methods in descending order are SL, FB, TCB, and PL. SL and FB polishing-Capable of restoring enamel to its initial state. US is unsuitable
	Gp 2-SL		
	Gp 3-ARP		
	Gp 4-Ultrasound		
	Gp 5-FB		

Ye C et al., 2013 [14]	Gp 1-TC bur (Adhesive removal)	Colour measurements with SPM	*Colour change is seen greatest in TC group *Least colour changes- TC+SL and TC+PG
	Gp 2-TC+SL (Adhesive removal+Polishing)		
	Gp 3-TC+OG (Adhesive removal+Polishing)		
	Gp 4-TC+PG (Adhesive removal+Polishing)		
Khosravanifard B et al., 2010 [17]	Gp 1-HS TC	SEM	HS TCB-Smooth surface with deep pits and scratches with least working time
	Gp 2-LS TC		LS-TC- Safest method Longer working time Smooth surface with fine scratches
	Gp 3-SB		Sandblast-Rough surface with deep scars
Arbutina A et al., 2020 [18]	Gp 1-TF TC bur (Adhesive removal)	*Duration of adhesive removal *ESI on SEM	ESI score: 1
	Gp 2-Round TC bur		ESI: 3
	Gp 3-CB		ESI: 1 Minor irregularities on enamel surface Most time consuming

[Table/Fig-1]: Summary of studies on various methods used for adhesive removal and polishing [3,11-14,16-18].
TC: Tungsten carbide bur; LS: Low speed; HS: High speed; TF: Thin fissure; DFB: Diamond finishing bur; ZR: Zirconia bur; WS: White stone; FRB: Fiber reinforced bur; CB: Composite bur; OG: One gloss polisher; PG: PoGo polisher; SS: Super snap disk; EFP: Enhance finishing and polishing system; SL: SofLex polishers; SB: Sandblasting; ARP: Adhesive removal plier; US: Ultrasound; SR: Surface roughness; Ra: Average surface roughness; ESI: Enamel topography; SRT: Surface roughness tester; EDI: Enamel damage index; PFM: Profilometer; SPM: Spectrophotometer

- **Fiber-reinforced abrasives:** These abrasives offer strength and flexibility for precise adhesive removal, making them ideal for delicate areas like the gingiva while minimising wear on surrounding tissues [11,25].

According to Banerjee A et al., tungsten carbide burs produced smoother surfaces and reduced enamel loss compared to diamond burs, air-abrasion with alumina particles, or fiber-reinforced composite burs [28]. While diamond burs are not advised, tungsten carbide burs appear to cause less damage. A composite bur produced a smoother enamel surface compared to a tungsten carbide bur, as reported by Karan S et al., and Erdur EA et al., [20,29]. They emphasised that the surface roughness of enamel was reduced by a composite bur, even though it took longer to remove the adhesive.

3. Lasers: The types of lasers used include Er:YAG, CO_2, Nd:YAG, and Gallium-Aluminum-Arsenide (GaAlAs) diode lasers [30]. Multiple studies have shown that using laser irradiation to remove residual adhesive from the enamel surface can cause thermal damage to both the pulp and the enamel [12,31]. A study by Kilinc E et al., confirmed that the Erbium, Chromium-doped Yttrium Silicon Garnet (Er,Cr:YSGG) laser is effective for removing residual adhesive from the enamel surface, provided it is used with the appropriate cooling settings [32]. The lasers employed for adhesive removal, as indicated in the published literature has been depicted in [Table/Fig-2] [12,30,33,34].

Scanning Electron Microscopy (SEM) analysis in the study by Koide K et al., revealed that the Er,Cr:YSGG laser vapourised remaining adhesive and primer while etching the enamel [30]. Using pliers to remove most of the adhesive first, followed by the laser, could help eliminate any unseen adhesive and etch the enamel without acid. This combined approach may reduce adhesive removal time compared to using the laser alone, making it a potential option for clinical use [30]. According to Ahrari F et al., the roughest surface was created during the adhesive removal and finishing phases

Author's name/ Year of study	Method of adhesive removal/polishing	Outcomes measured	Inference
Ahrari F et al., 2012 [12]	Group 1-TC bur in low speed	SR	Enamel clean-up with the Er:YAG laser resulted in the highest roughness measurements. -TC bur at low speed- Safest -High-speed TC- minimal enamel damage Ultrafine diamond burs and Er:YAG lasers-significantly and irreversably increase enamel surface irregularity.
	Group 2- TC bur in a high-speed handpiece		
	Group 3-Ultrafine DB		
	Group 4-Er:YAG laser		
Koide K et al., 2019 [30]	Group 1-ARP	*ESR using SEM *Time	A notable rise in ESR was observed with successive laser removal sequence. The adhesive removal time with the Er, Cr:YSGG laser was significantly longer (3-5 minutes) than with pliers (40 seconds).
	Group 2- Er,Cr:YSGG laser		
Gomez C et al., 2017 [33]	Nd:YAG laser	SR using SEM	Complete adhesive removal from the tooth without any damage to the enamel.
Mady R et al., 2023 [34]	Group 1-TC bur	EDI examined under SM	The surface appearance in Group II (EDI Score-1) is smoother compared to Groups I and III (EDI Score- 2).
	Group 2- Er, Cr:YSGG (2.78 µm wavelength with 2 W average power, 15 Hz repetition rate, 60 µs pulse duration, 133 m J pulse energy)		
	Group 3- Er, Cr:YSGG (2.78 µm wavelength with 2.5 W average power, 30 Hz repetition rate, 700 µs pulse duration and 166 m J pulse energy)		

[Table/Fig-2]: Summary of studies on laser application for adhesive removal [12,30,33,34].
ARP: Adhesive removal plier; Er, Cr: YSGG: Erbium, chromium-doped yttrium, scandium, gallium and garnet; ESR: Enamel surface roughness; SEM: Scanning electron microscope; TC: Tungsten carbide bur; DB: Diamond bur; Nd:YAG: Neodymium-doped yttrium aluminum garnet; Er:YAG: Erbium-doped yttrium aluminum garnet; EDI: Enamel damage index; SM: Stereomicroscope

following the use of the Er:YAG laser for enamel cleaning [12]. The Er:YAG laser was shown to remove both the adhesive resin and the enamel surface [34].

Laser methods required notably more time for complete resin removal compared to traditional bur techniques [31]. While the absence of noise, vibration, or pressure makes the laser less uncomfortable, it produced a much rougher surface than the other conventional methods examined and was less effective [35].

Polishing

In a clinical setting, polishing devices are used to provide an aesthetically pleasing enamel surface following various adhesive removal techniques. These technologies can also prolong the time it takes to remove adhesive.

Various polishing methods: One-Gloss Complete System by Shofu Dental Corporation, which employs a high concentration of aluminum oxide with a silicone binder; Super Snap Polishing System by Shofu Dental Corporation; Enhance Finishing and Pogo Polishing System by Dentsply, which comprises polymerised urethane dimethacrylate resin, aluminum oxide, silicon dioxide, and fine diamond powder [36].

Sof-Lex discs, with their extra-thin profile and varying grits, contain aluminum oxide particles ranging from coarse to superfine (50 to 80 μm), while the spiral wheels feature diamond particles embedded in thermoplastic elastomer [11].

The Stainbuster composite bur, enriched with zircon-rich glass fiber from Abrasive Technology Inc., features a unique glass fiber-reinforced resin, which is gentle on the tooth surface, ensuring a smooth and clean finish [12]. According to Sfondrini MF et al., rubber cups (36.70%) and abrasive discs (21.35%) used alone, or rubber cups combined (11.60%), were the most frequently utilised tools [21]. It has been demonstrated that abrasive discs cause less harm than low-speed burs made of carbide and fiber [1]. Additionally, it has been validated that discs cause fewer scratches than fiber burs, which are specifically made to remove coloured coatings, stains, and cement from enamel surfaces. They can gently grind cement, dentin, and filling composites without abrading ceramic or dental enamel [20].

Shah P et al., evaluated enamel surface roughness using four different finishing and polishing systems: the One-Gloss Complete System, Enhance Finishing and Pogo Polishing System, Stainbuster Composite Bur, and the 3M Sof-Lex System, alongside the Sof-Lex Spiral Wheels containing diamond particles embedded in thermoplastic elastomer [11]. The Sof-Lex group exhibited the highest post-polishing roughness, followed by the One-Gloss system, Enhance system, and finally the Stainbuster bur [12].

According to Fan XC et al., the One-Gloss polisher yielded the smoothest surface with minimal shallow scratches, closely resembling the original enamel surface under SEM examination, though it necessitated the longest operating duration [16]. Cleaning with Super Snap resulted in satisfactory outcomes, although some deep scratches remained on the enamel surfaces.

Methods of Evaluating the Surface Topography after Enamel Polishing

Various methods can be employed to assess surface topography following orthodontic debonding, including Atomic Force Microscopy (AFM), contact profilometry, stereomicroscopy, non contact white light 3D profilometry, and SEM.

Visual inspection provides initial observations, while clinical photography captures detailed images for documentation. SEM offers high-resolution images at the microscale, revealing enamel damage and adhesive remnants [37]. Confocal Laser Scanning Microscopy (CLSM) provides non invasive three-dimensional visualisation of surface irregularities and adhesive remnants. AFM [38] measures nanoscale surface roughness, and three-dimensional surface profilometry [12] offers quantitative data on adhesive remnants and enamel damage. Combining these methods enables a comprehensive evaluation of surface topography post-debonding.

CONCLUSION(S)

Most authors favoured a combination of abrasives and rotary speeds to achieve successful appliance debonding, even though the choice of abrasive and rotary instrument speed appears to be uncertain. The literature contains more favourable comments on tungsten carbide burs than on any other technique, making them the most recommended procedure.

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