

## Methods of Debonding brackets - A literature review

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### Abstract

Orthodontic bracket debonding remains a critical yet understudied phase of treatment that balances efficiency, enamel preservation, and patient comfort. Traditional mechanical methods like pliers and burs effectively remove brackets but risk enamel microcracks, bracket fractures, and adhesive remnants, as noted by Oliver et al. (1988) and Suliman et al. (2015). Innovations including ultrasonic, electrothermal, and laser-assisted techniques aim to minimize iatrogenic damage while addressing bracket-specific challenges—metal brackets respond well to Lift-Off Debonding Instruments (LODI), while ceramic brackets require delamination forces or precise laser irradiation to counter their low fracture toughness. This literature review synthesizes evidence on debonding methods, evaluating mechanical, thermal, and laser approaches alongside advancements like thermally expansive adhesives and modified bracket bases. Key findings highlight reduced enamel damage with ultrasonic and laser methods, although time efficiency and pulpal safety remain significant concerns. Clinical factors such as bracket type, adhesive composition, and operator skill significantly influence outcomes. The review underscores the need for enamel-safe protocols, particularly for aesthetic ceramic brackets, and identifies deficits in long-term enamel integrity studies to guide future treatment protocols.

**Keywords:** orthodontic debonding, enamel damage, ceramic brackets, laser-assisted debonding, electrothermal methods

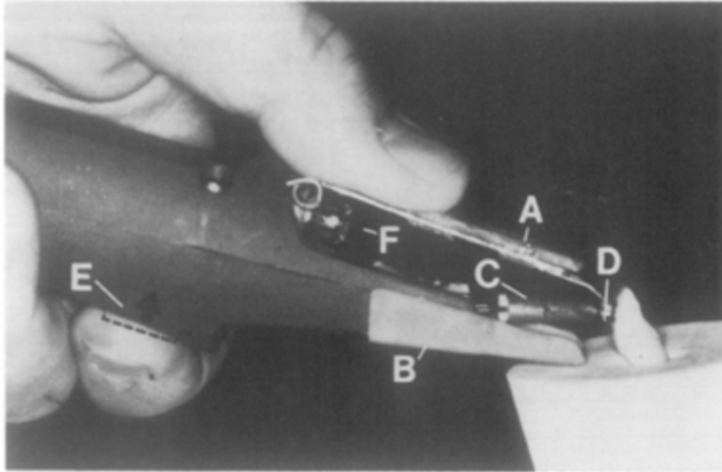
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### Background

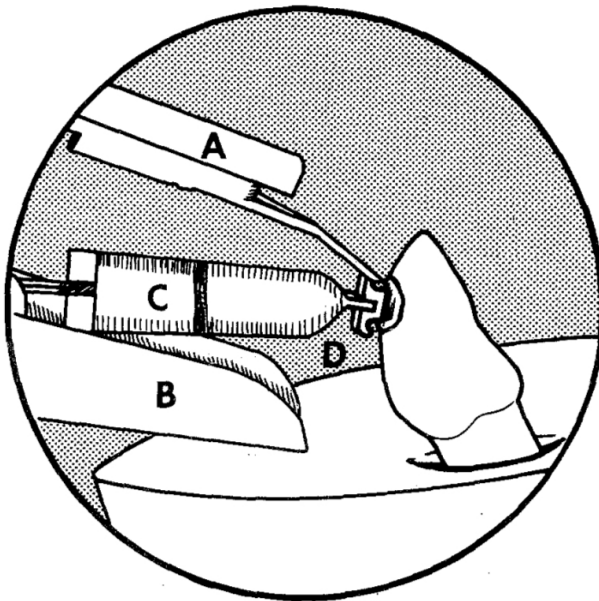
Orthodontic bracket debonding is a clinically important yet relatively understudied stage of fixed-appliance treatment. The procedure is the final clinical stage of fixed-appliance treatment and aims to remove brackets and residual adhesive while restoring the enamel surface as closely as possible to its pretreatment condition. The procedure requires a balance between adequate bond strength during treatment and controlled bond failure during removal, since excessive debonding forces may cause enamel microcracks, enamel fracture, bracket failure, residual adhesive, and patient discomfort. Conventional mechanical techniques remain widely used; however, their outcomes depend on bracket composition, adhesive characteristics, force application, and the method used for adhesive removal. These considerations are particularly important for ceramic brackets because their brittleness and fracture susceptibility may increase the risk of enamel damage during conventional debonding. Consequently, alternative approaches, including ultrasonic, electrothermal, and laser-assisted techniques, have been investigated to reduce debonding forces and improve enamel preservation. Nevertheless, no single technique has demonstrated universal superiority, and the final enamel outcome is strongly influenced by the subsequent adhesive-removal and polishing protocol. Current evidence therefore supports the evaluation of debonding techniques as complete clinical protocols, considering bracket removal, residual adhesive clearance, enamel-surface changes, treatment time, thermal safety, and patient comfort.

### Methods

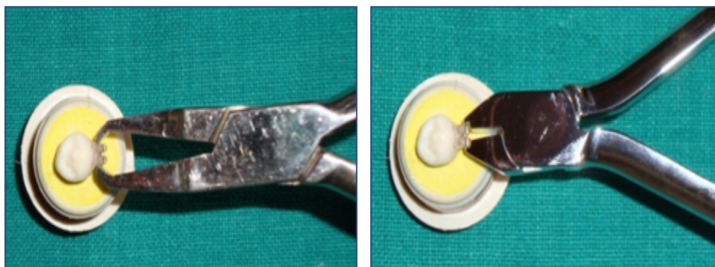
This narrative review synthesizes evidence on orthodontic bracket debonding techniques, focusing on enamel preservation, efficiency, and patient comfort. Literature was identified via PubMed/MEDLINE, Scopus, Web of Science, and Cochrane Library. In vitro studies, clinical trials, systematic reviews, and consensus reports were included if they described debonding methods and reported outcomes such as bond strength, enamel damage, bracket fracture, adhesive remnants, pulpal temperature, or patient discomfort. Techniques were categorized as mechanical, electrothermal, ultrasonic/impulse-driven, or laser-assisted, using metal versus ceramic brackets and different adhesive systems.



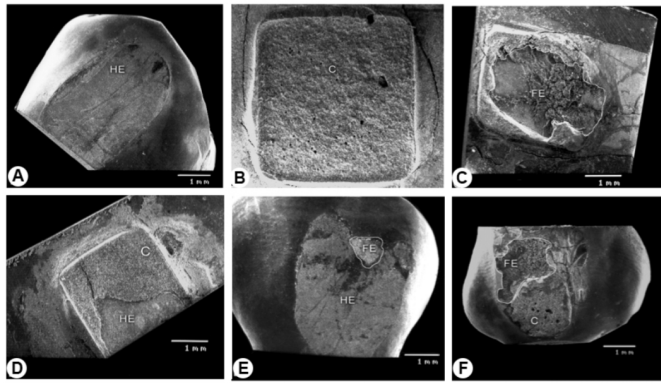
**Figure 1** . ETD unit engaged in bracket slot. A, Thumb-activated lock-on arm; B, lip shield; C, heat element; D, bracket-engaging blade; E, heat transfer button depressed; F, heat-transfer indicating light.



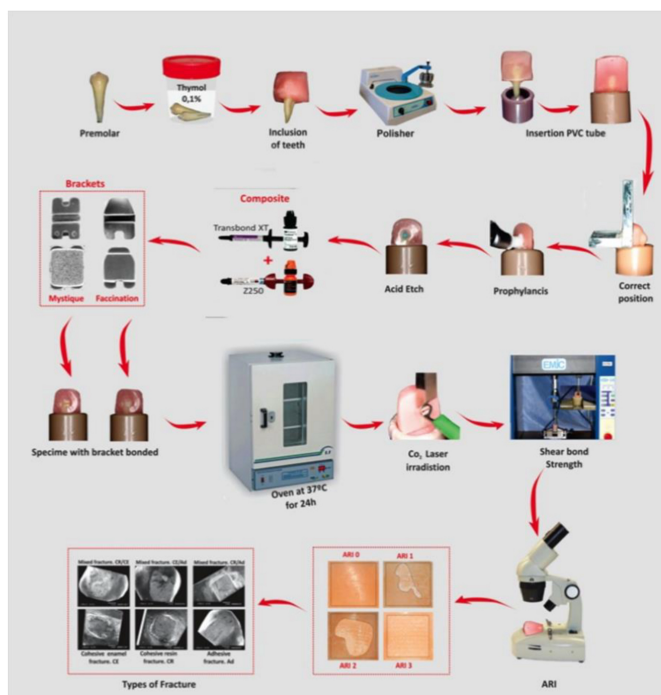
**Figure 2.** Diagrammatic view of ETD blade engaging bracket slot. A, Lock-on arm engaging incisal wings of bracket; B, Lip shield; C, Heat element; D, blade positioned in bracket slot.



**Figure 3.** A Debonding with utility debonding plier. B- Debonding with ceramic bracket debonding plier



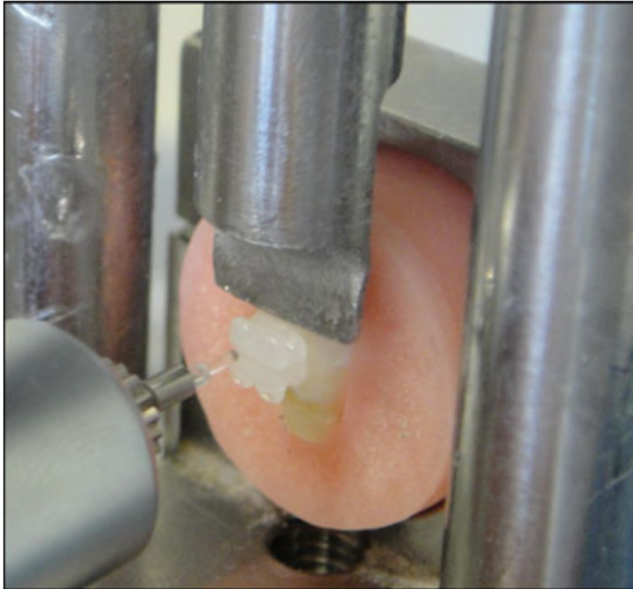
**Figure 4.** Types of fracture and distribution. A- Adhesive fracture, B- Cohesive resin fracture, C- Cohesive enamel fracture, D- Mixed cohesive/adhesive fracture, E- Mixed cohesive enamel/adhesive fracture, F- Mixed cohesive enamel/resin fracture



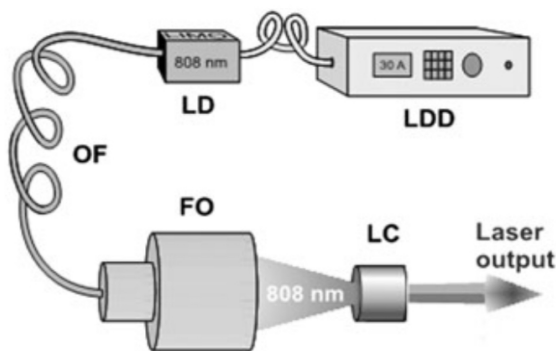
**Figure 5.** The flowchart shows method used for Co2 laser method



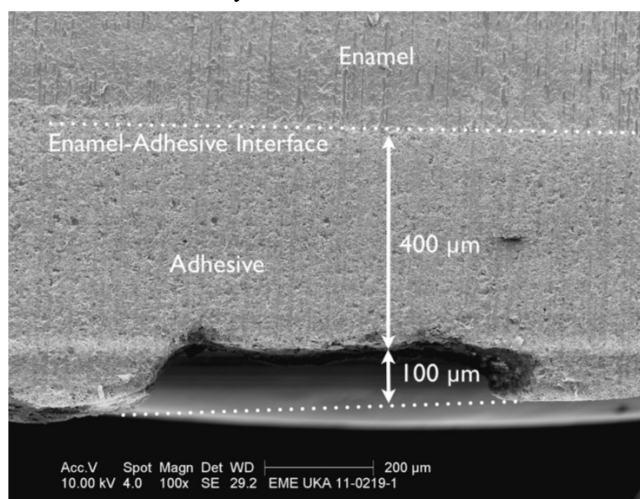
**Figure 6.** Er:YAG laser device (LIGHTWALKER AT S, M021-5AF/1 S, Fotona d.o.o., Ljubljana, Slovenia)



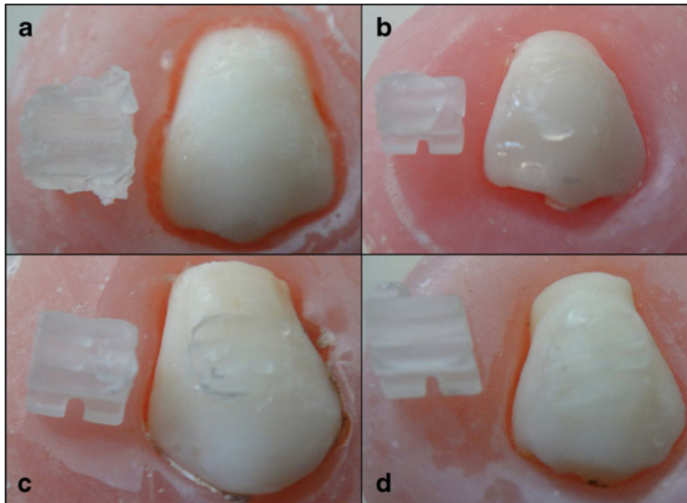
**Figure 7.** The application of Er-YAG laser with the scanning method



**Figure 8.** Tm:YAP laser system



**Figure 9.** SEM image of the cross section of the enamel-adhesive interface at x 100 magnification showing material removal of about 100-120  $\mu\text{m}$  depth at the surface of adhesive, which is well within the adhesive. No damage can be found on the enamel which is still 400  $\mu\text{m}$  below the crater's bottom. Debonding occurred after a single laser pulse.



**Figure 10.** Bracket base and enamel surfaces with ARI scores of 0 through 3. a ARI = 0, b ARI = 1, c ARI = 2, d ARI = 3

### Discussion

Orthodontic bracket debonding often presents clinical challenges due to the mechanical forces used during debonding. When an orthodontic bracket is debonded, adhesive residuals may remain on the enamel surface, and there is a possibility of enamel cracking or enamel detachment during the debonding process. Numerous methods for debonding have been proposed, such as ultrasonic debonding, electrothermal debonding, and using specially designed mechanical instruments for debonding.

Moreover, the experimental use of lasers with various wavelengths for ceramic bracket debonding has been documented since the 1990s. Orthodontic debonding techniques have evolved significantly, with the primary aim of minimizing enamel damage, ensuring patient comfort, and improving procedural efficiency.

#### 1. Evolution of debonding techniques: from mechanical pliers to energy-based systems

The removal of orthodontic brackets has progressed from purely mechanical, pliers-based techniques to **electrothermal, laser-assisted, ultrasonic, and impulse-driven methods**, driven by the need to minimize enamel damage, bracket fracture, and patient discomfort. Conventional debonding pliers apply high localized stress at the bracket–adhesive–enamel interface, often producing enamel cracks, bracket breakage, and excessive adhesive remnants.

Sheridan et al. (1986) introduced **electrothermal debracketing (ETD)** as a controlled alternative, using a cordless device to heat the bracket base and soften the resin adhesive, thereby lowering the force required for separation and reducing the risk of enamel fracture.<sup>1</sup>

In vivo studies show that ETD is generally well tolerated, with most patients reporting only transient warmth or mild discomfort and no clinically significant pulpal necrosis, although some histologic reports describe mild odontoblastic inflammatory changes. The stronger enamel bonding of ceramic and polycrystalline brackets further intensified the search for gentler techniques, prompting the development of **laser-assisted (CO<sub>2</sub>, Nd:YAG, Er:YAG, Er,Cr:YSGG, diode, Tm:YAP, Tm:fiber, Yb-fiber), ultrasonic, and impulse debracketing** systems, each aiming to balance bond-strength reduction, enamel safety, and clinical efficiency.

#### 2. Electrothermal debonding:

Electrothermal debracketing (ETD) operates on the principle that **localized heating of the bracket base** reduces the shear bond strength of the resin adhesive by softening or partially depolymerizing the polymer network, allowing separation at lower mechanical forces. Sheridan's in vitro study demonstrated that ETD could remove brackets with significantly less force than conventional pliers, with most failures occurring at the bracket–adhesive interface rather than at enamel.

In vivo investigations reported average debonding times of about **2 seconds per bracket**, with patients generally accepting the procedure well; however, concerns were raised about **pulpal temperature rise and histologic changes**. Dovgan et al. (1995) found that, despite rapid heating, no pulpal necrosis occurred, though some specimens showed mild inflammation and odontoblastic disruption, suggesting that ETD should be used cautiously, particularly in teeth with thin enamel or close pulp proximity.

#### Pulp safety :

Clinically, ETD has been reported to require an average debonding time of approximately 2.1 seconds per bracket, indicating high efficiency. Studies on pulpal safety show that ETD produces only minor intrapulpal temperature increases, well below established critical thresholds, with no evidence of pulpal damage or pathosis when parameters are properly controlled. Air-cooling further reduces temperature rise and

enhances the safety profile of the technique. Overall, ETD is well-tolerated by patients, with most reporting only mild, transient warmth, and is considered a pulp-safe alternative to conventional mechanical debonding methods.

### 3. Conventional mechanical debonding: pliers, force levels, and enamel effects

Conventional debonding with **debonding pliers** remains the most widely used technique for debonding both ceramic and metal brackets, especially for **metal brackets**, because of its simplicity, low cost, and immediate clinical results.

Investigations by Chen et al. (2007) and Bishara & Trulove (1990) demonstrated that pliers can effectively debond brackets but also noted that higher debonding forces are associated with an increased incidence of enamel microcracks and incomplete adhesive removal.<sup>2,3</sup>

The debonding of orthodontic brackets, particularly ceramic brackets, is further complicated by their hardness and brittleness, which make them prone to fracture rather than clean separation from the adhesive. Studies comparing **narrow- vs wide-blade pliers** for ceramic brackets showed that wide-blade designs distribute stress more evenly, reducing the incidence of bracket fracture but sometimes increasing residual adhesive on enamel, whereas narrow-blade pliers generate higher localized stress and are more likely to fracture ceramic wings.

Bishara et al. (1995) systematically evaluated force levels and enamel cracks during ceramic bracket removal, finding that **higher debonding forces correlate with increased enamel microfractures**, particularly when the bracket base is not fully covered by adhesive or when the clinician applies excessive or off-axis force.<sup>4</sup> Krell et al. (1993) compared conventional pliers with ultrasonic debonding and reported that ultrasonic techniques reduced both enamel loss and operator-perceived effort, although total debonding time was similar.<sup>5</sup>

More recent in vitro work quantified enamel loss after ceramic bracket debonding, showing that **even sound enamel surfaces under magnification can have microcracks and roughness**, emphasizing the need for careful finishing with low-speed burs and polishing pastes.

### 4. Laser-assisted debonding: CO<sub>2</sub>, Nd:YAG, Er:YAG, Er,Cr:YSGG, and diode systems

The use of lasers became active in the field of dentistry only by the year 1989. This was largely because of the activities of Dr. Terry Myers who developed and marketed the Nd: YAG laser. Although the laser was dedicated for dental use, it had a low power which made it ineffective for dental use.

Laser-assisted debonding has emerged as one of the most promising energy-based approaches, utilizing the **selective absorption of laser energy by the adhesive or bracket base** to weaken the bond without excessive heat transfer to enamel or pulp. Different wavelengths have been investigated, each with distinct absorption characteristics and clinical implications.

#### Laser-Initiated Debonding Mechanisms:

According to Tocchio et al. the mechanism of laser debonding includes thermal softening, thermal ablation, or photo-ablation.<sup>6</sup> Thermal softening occurs when a laser with low power density irradiates the brackets until the resin softens. The brackets will slide off the tooth surface with gravity.

**Thermal Softening:** Occurs at lower laser energy deposition rates. It involves heating the bonding agent until it softens, and the brackets slide off the tooth. While no measurements were made, the process is expected to lead to a significant rise in both tooth and bracket temperatures.

**Thermal Ablation:** Occurs when the rate of energy deposition is fast enough to raise the temperature of the resin through its fusion range and into its vaporization range before debonding by thermal softening occurs.

**Photoablation:** Involves the photochemical breakdown of the adhesive material due to the absorption of photons from the laser. It is a rapid process that results in minimal heat generation.

| Laser type and wavelength | Mechanical/Clinical application | Main findings | Limitations |
|---------------------------|---------------------------------|---------------|-------------|
|                           |                                 |               |             |

|                    |                                                                                                                             |                                                                                                                                                |                                                                                                                                                 |
|--------------------|-----------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Co2 laser</b>   | Strong absorption by water and organic components of the adhesive softens the resin and facilitates bracket removal.        | Reduces debonding force, particularly for ceramic brackets, and promotes failure at the bracket–adhesive interface with limited enamel damage. | Excessive power or prolonged exposure may increase pulpal temperature; standardized parameters and adequate cooling are essential.              |
| <b>Nd:YAG</b>      | Absorption by pigmented materials and metallic components may assist debonding of ceramic brackets and pigmented adhesives. | Reduces bond strength and generally produces adhesive-failure patterns with minimal reported enamel damage.                                    | Effectiveness depends on bracket composition and laser parameters; thermal effects require careful monitoring.                                  |
| <b>Diode laser</b> | May be absorbed by pigmented adhesive or metallic components and used for ceramic and metal brackets.                       | Pulsed irradiation at appropriate settings can reduce shear bond strength while maintaining pulpal temperatures within reported safe limits.   | Often requires longer exposure than CO <sub>2</sub> or erbium lasers and may be less effective with reflective or non-absorptive bracket bases. |

|                         |                                                                                                                          |                                                                                                                                                    |                                                                                                                                                    |
|-------------------------|--------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Er:YAG laser</b>     | High absorption by water and hydroxyapatite enables adhesive softening and precise, enamel-sparing debonding.            | Reduces debonding force, enamel microcracks, and pulpal temperature changes; may be particularly comfortable for monocrystalline ceramic brackets. | Excessive energy or prolonged exposure can cause enamel alteration or unacceptable thermal increases; cooling and parameter control are necessary. |
| <b>Er,Cr:YSGG laser</b> | Absorbed by water and hydroxyapatite and used for controlled debonding of ceramic and metal brackets.                    | Produces reduced bond strength, favourable adhesive-remnant patterns, and limited enamel damage compared with conventional debonding.              | Requires optimized energy, pulse duration, scanning technique, and cooling. Its water absorption is lower than that of Er:YAG.                     |
| <b>Tm:YAP Laser</b>     | Laser energy is directed through the ceramic bracket while simultaneous water cooling limits heat transfer to the tooth. | Enables precise ceramic bracket removal with minimal reported enamel damage.                                                                       | High equipment cost, technical complexity, and limited clinical evidence restrict routine use.                                                     |

|                                |                                                                                                       |                                                                                                                           |                                                                                          |
|--------------------------------|-------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|
| <b>1940-nm Tm: fiber laser</b> | Facilitates adhesive softening and reduces the mechanical force required for ceramic bracket removal. | May reduce the risk of enamel damage, with reported intrapulpal temperature increases remaining within acceptable limits. | Evidence remains limited, and optimal clinical parameters require further investigation. |
|--------------------------------|-------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|

### 5. Ultrasonic and impulse-driven debonding: vibration-based alternatives

Ultrasonic debonding uses **high-frequency vibrations** transmitted through a scaler-like tip to disrupt the bracket–adhesive interface, reducing the need for high-force mechanical peeling. Studies comparing ultrasonic instrumentation with different scaler-tip angulations found that proper angulation and light pressure can significantly reduce enamel damage and residual adhesive, although operator skill remains a critical factor. Knösel et al. (2010) compared impulse debracketing with conventional debonding and reported **less enamel damage, fewer bracket fractures, and reduced need for post-debonding polishing**, although the equipment cost may limit widespread adoption.<sup>7</sup>

### 6. Chemical Aided Debonding

Chemical-aided debonding involves applying agents such as acetone, ethanol, or peppermint oil to weaken the bracket–adhesive or adhesive–enamel interface and reduce the mechanical force required for bracket removal. However, current evidence indicates that these agents, particularly peppermint oil, produce only minimal reductions in shear bond strength and offer limited protection against enamel damage or bracket fracture. Compared with chemical methods, ultrasonic and laser-assisted debonding techniques demonstrate greater bond-strength reduction, more favourable adhesive-retained failure patterns, and improved enamel preservation. Therefore, chemical-aided debonding cannot presently be recommended as a standalone clinical technique and requires further refinement and validation.

### 7. Debonding of ceramic vs metallic brackets:

Ceramic and polycrystalline brackets have unique challenges for debonding because of their **high bond strength, brittleness, and tendency to fracture** rather than peel cleanly from enamel. Bishara et al. (1990) conducted a two-part in vitro study comparing different debonding techniques for ceramic brackets and concluded that **conventional pliers often result in bracket fracture and higher enamel crack rates**, whereas **electrothermal and laser-assisted methods tend to produce adhesive-failure modes and preserve bracket integrity**.<sup>8</sup>

Subsequent work by Özcan et al. (2008) and others emphasized that **bracket base design, silanization, and adhesive composition** significantly influence debonding behavior, with silanized bases and modified adhesives sometimes facilitating cleaner separation.<sup>9</sup>

### 8. Enamel integrity, adhesive remnants, and finishing protocols

Regardless of the debonding method, **residual adhesive on enamel** is nearly inevitable and must be removed carefully to avoid iatrogenic damage. Oliver (1988) and later investigators evaluated different debonding techniques and found that **electrothermal and laser-assisted methods often leave more adhesive on enamel but with fewer enamel cracks**, whereas **conventional pliers tend to remove more adhesive at the expense of higher enamel fracture risk**.<sup>10</sup>

Patient-centered outcomes are increasingly recognized as critical factors for evaluating debonding methods. Clinically, **conventional pliers remain the most familiar and widely used**, but newer technologies such as **laser-assisted and impulse debonding** are gaining favor in specialized practices, particularly for ceramic brackets and high-aesthetic-demand cases. Future studies should focus on **standardized protocols, multicenter clinical trials, and long-term follow-up** to establish evidence-based guidelines for debonding in different clinical scenarios (e.g., ceramic vs metal brackets, adult vs adolescent patients, high-aesthetic vs routine cases).

### CONCLUSION

Laser-assisted debonding is a promising minimally invasive alternative to conventional mechanical

bracket removal, particularly for ceramic brackets. By reducing debonding forces, bracket fracture, and enamel cracking, lasers such as Er:YAG and Er,Cr:YSGG may improve enamel preservation and operator efficiency, while reported pulpal temperature increases generally remain below the critical 5.5°C threshold when appropriate parameters are used. However, thermal safety is highly dependent on laser type, power, exposure time, cooling, and enamel thickness; therefore, standardized protocols and well-designed clinical trials are required before routine clinical adoption. Patient-centred outcomes, including discomfort, chair time, sensitivity, and long-term enamel integrity, should be prioritized in future research.

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#### **CONFLICT OF INTEREST**

The authors declare no conflict of interest.

#### **ETHICS**

Not applicable. This is a literature review; it did not involve direct human participant recruitment, patient data or animal experimentation and therefore did not require institutional Ethics Committee approval.

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No funding was received for this work.

#### **AUTHORS' CONTRIBUTIONS**

Dr. E.K.Sujitha : conceptualisation, literature search, source verification, data extraction and synthesis, drafting of the original manuscript and preparation of figures.

Dr. Sushil Chakravarthi.N.C : conceptualisation, supervision, source verification, critical revision of the manuscript for important intellectual content and final approval.

Dr. Davis.D : conceptualisation, supervision, source verification, critical revision of the manuscript for important intellectual content and final approval.

Dr. Shreya Kishore : conceptualisation, supervision, source verification, critical revision of the manuscript for important intellectual content and final approval.

Dr. Janani.R : conceptualisation, supervision, source verification, critical revision of the manuscript for important intellectual content and final approval.

Dr. Bharathi : conceptualisation, supervision, source verification, critical revision of the manuscript for important intellectual content and final approval.

All authors reviewed and approved the final version of the manuscript and agree to be accountable for all aspects of the work.