REVIEW ARTICLE

CONTENTS

The effect of aluminum oxide air abrasion on composite adhesion to enamel and dentin: Literature review 2020–2024

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ABSTRACT
Aim: To evaluate the influence of airborne-particle abrasion with aluminum oxide on the adhesion of resin composites to enamel and dentin, focusing on technical parameters, adhesive strategies, and long-term outcomes.
Materials and Methods: A narrative review was performed according to PRISMA guidelines. PubMed, Scopus, and Web of Science were searched for studies published between 2020 and 2024 reporting bond strength to enamel or dentin after aluminum oxide abrasion. Only peer-reviewed full-text articles with shear or microtensile outcomes were included. Twenty studies were analyzed, comprising in vitro experiments and systematic reviews.
Results: For enamel, most studies confirmed improved retention after abrasion, particularly when combined with phosphoric acid etching. The effect was most evident for self-etch adhesives, which otherwise underperform on aprismatic enamel. For dentin, findings were more variable. Abrasion enhanced adhesion with etch-and-rinse protocols and universal adhesives in etch-and-rinse mode but often reduced bond strength with self-etch adhesives, likely due to smear-layer removal without adequate demineralization. Optimal parameters included 50 μm particles, 3–4 bar pressure, and ~5 seconds of application. Higher pressure or prolonged use risked collagen damage. In composite repair, abrasion consistently increased bond strength, especially when combined with silanization and an adhesive. Evidence on long-term durability was mixed; bioactive particles may improve stability and biocompatibility.
Conclusions: When applied with optimized parameters, aluminum oxide abrasion improves bonding to enamel and dentin, is particularly useful in etch-and-rinse protocols and composite repair, and should be avoided on dentin with self-etch adhesives. Further in vivo studies are needed to clarify long-term performance.

KEY WORDS: air abrasion, dental, aluminum oxide, composite resins, dental enamel, dentin

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INTRODUCTION
Bonding of composite resins to tooth hard tissues is a key factor in restorative and esthetic dentistry. Achieving durable adhesion remains challenging, particularly under difficult clinical conditions such as sclerotic or carious dentin. Conventional approaches to increase micromechanical retention include phosphoric acid etching or self-etching adhesive systems. Airborne-particle abrasion with aluminum oxide (Al_2O_3) has been proposed as an adjunctive technique to enhance adhesion. This review summarizes the latest evidence regarding the effect of Al_2O_3 sandblasting on enamel and dentin bonding, including technical parameters, adhesive strategies, and clinical implications.

AIM
The aim of this review is to evaluate the impact of abrasive sandblasting with aluminum oxide particles (Al_2O_3) on the adhesion of composite materials to enamel and dentin. Particular attention is given to the technical parameters of the procedure (particle size, pressure, application time) as well as the types of adhesive systems and bonding protocols used (total-etch vs. self-etch). Another goal is to formulate practical clinical guidelines for using Al_2O_3 air-abrasion and to discuss the limitations and potential risks of this technique in light of the latest research.

MATERIALS AND METHODS
The review was conducted according to PRISMA guidelines. PubMed, Scopus, and Web of Science databases were searched for publications from 2020–2024 concerning the effect of Al_2O_3 sandblasting on composite bonding to enamel and dentin. The search was limited to peer-reviewed papers available in full text that

reported quantitative bond strength data (e.g., shear bond strength – SBS, or microtensile bond strength – µTBS). Excluded were studies focusing solely on other materials (e.g., ceramics, metals), papers without numerical bond data (descriptive articles, case reports), and commentaries or letters. After removing duplicates and an initial title/abstract screening, 20 publications meeting the criteria were included for analysis, comprising both in vitro studies and relevant systematic reviews. From the selected studies, data were extracted on the sandblasting protocols used (Al_2O_3 particle size, pressure, and application time), the type of bonding system (total-etch vs. self-etch technique, universal adhesives), and test conditions (immediate bond strength vs. after aging). The results of individual studies were compiled, and a qualitative discussion was undertaken to identify consistencies or discrepancies among the findings.

REVIEW

BONDING TO ENAMEL

Most studies confirm that additional preparation of enamel by Al_2O_3 sandblasting (typically with 30–50 µm particles) enhances the retention of composite resins, especially when it is combined with traditional phosphoric acid etching. Enamel after sandblasting exhibits higher roughness and surface energy, which facilitates resin wetting and penetration. For instance, scanning electron microscopy (SEM) confirms the creation of a roughened enamel surface after air abrasion, and contact angle measurements indicate increased surface wettability (i.e., higher surface free energy) on sandblasted enamel. These changes translate to improved resin retention, as reflected in higher bond strength values. In vitro, it has been shown that using sandblasting before 37% phosphoric acid etching leads to higher microtensile bond strength to enamel – for example, Rifane et al. reported an increase in µTBS to intact enamel from ~15 MPa with acid etching alone to ~20 MPa when Al_2O_3 sandblasting was included prior to etching [1]. Similarly, Zhang et al. found a significant increase in bond strength in non-carious cervical enamel/dentin lesions: sandblasting (110 µm Al_2O_3 at 75 psi) raised the µTBS from ~14.2 MPa (no sandblasting) to 17.9 MPa, which is about a 25% improvement compared to no air-abrasion [2]. These findings are consistent with other studies comparing conventional etching to alumina air-abrasion, which also reported superior bond strengths when enamel was sandblasted before bonding [3,4].

BONDING TO DENTIN

Findings on the effect of sandblasting on dentin bonding are more varied than for enamel. The general trend is that with total-etch (etch-and-rinse) adhesive systems, sandblasting dentin with 50 µm alumina can increase bond strength or at least does not decrease it [5,6,7]. Mechanically removing the smear layer and widening the dentinal tubule orifices tends to promote primer and resin infiltration, as long as the dentin is subsequently properly conditioned with acid (exposing the collagen network) and primed. Sinjari et al. recorded higher bond strength in dentin that was sandblasted (5 s, 50 µm, ~0.25 MPa pressure) and then acid-etched and bonded with a universal adhesive, compared to a control without sandblasting (mean µTBS ~31 MPa vs ~25 MPa) [7]. Likewise, a meta-analysis by Lima et al. confirmed that Al_2O_3 sandblasting does not have a negative effect on adhesion to dentin – the pooled bond strength results were not significantly different between sandblasted dentin and conventionally prepared dentin [5].

SANDBLASTING PARAMETERS

An analysis of the literature shows that 50 µm Al_2O_3 particles are the most commonly used and they produce favorable adhesive outcomes on dentin [6]. Several studies have compared different particle sizes – for example, 27 µm vs. 50 µm – and the results are not entirely consistent. Melkumyan et al. found no significant difference in bond strength to dentin between sandblasting with 27 µm particles versus 50 µm particles (mean SBS ~27–28 MPa for both, compared to 28.3 MPa in the control group, indicating no improvement with either size) [8]. On the other hand, some researchers have suggested that smaller particles might polish the surface rather than distinctly roughening it, whereas others observed that smaller grains can create more micro-retentions due to the greater number of particles impacting the surface per unit time.

REPAIR OF COMPOSITE RESTORATIONS

Al_2O_3 sandblasting is widely recommended as part of the procedure for repairing aged composite restorations. An old composite filling undergoes surface degradation over time – the number of available unreacted methacrylate groups capable of chemical bonding is reduced, and the surface becomes smooth and coated with various deposits. The purpose of surface pretreatment is to create micro-mechanical retentions and refresh the composite surface, enabling a strong chemical union through the use of silane and adhesive resin. Among the available methods (acid etching, roughening with a diamond bur, laser etching), abrasive sandblasting with alumina achieves the highest repair bond strength values [9,10].

BOND DURABILITY AND BIOLOGICAL ASPECTS

An important question is the long-term durability of the bond achieved with sandblasting. The results from aging studies present a mixed picture. On one hand, some research has observed that sandblasted dentin specimens can exhibit a faster decline in bond strength after artificial aging than non-sandblasted controls [11]. On the other hand, recent studies with bioactive modifications indicate a path to potentially improve long-term bond stability. Spagnuolo et al. showed that substituting Al_2O_3 with bioactive glass particles in the air-abrasion process prevented degradation of the resin–dentin interface over time [12].

DISCUSSION

The findings summarized above indicate that air-abrasion with aluminum oxide plays a variable but clinically relevant role in adhesive dentistry.

For enamel, the evidence consistently shows that sandblasting enhances retention by increasing surface roughness and energy, particularly when phosphoric acid etching is combined. Importantly, the greatest benefit is observed with self-etch adhesives, where mechanical roughening compensates for their limited etching capacity on aprismatic enamel.

For dentin, results depend strongly on the adhesive protocol. With etch-and-rinse adhesives, sandblasting generally improves or maintains adhesion by facilitating resin penetration. However, when used with self-etch adhesives, sandblasting can be detrimental. Removal of the smear layer leaves collagen exposed without sufficient demineralization, leading to weaker hybrid layers and reduced bond durability [13,14].

Regarding parameters, most studies point to 50 µm particles, 3–4 bar pressure, and 5 seconds application as the optimal conditions [6,15]. Deviations, such as prolonged time or higher pressures, can cause collagen damage or fail to add benefits. Additionally, after abrasion, the surface should be thoroughly cleaned by rinsing and/or etching to remove residual alumina powder that could interfere with bonding [16].

In composite repair, sandblasting is clearly superior to acid etching or mechanical roughening alone. It creates the most favorable conditions for silane coupling and adhesive bonding, improving repair longevity. Furthermore, studies indicate that combining alumina air-abrasion with silane application and a bonding agent yields the highest composite repair bond strength and durability [9,17].

Concerning durability, the literature shows heterogeneity. While some studies report sustained improvements after aging, others (e.g., in composite repair scenarios) have noted that the initial advantages of sandblasting may diminish over time, with bond strength declining toward that of non-abraded controls [18]. Residual alumina particles and hydrolytic degradation may also compromise long-term performance [19]. Promisingly, bioactive alternatives (e.g., bioactive glass particles) show potential to enhance both bond durability and biocompatibility.

It should be noted that the studies included in this review were heterogeneous in their methods and conditions. Sample sizes varied between experiments, and there were differences in substrates, bonding protocols, and test methods (for example, some used microtensile vs. shear bond testing, with or without aging). This methodological heterogeneity makes direct comparisons difficult and may partly explain the inconsistent outcome trends observed [20]. Greater standardization in future research would help in drawing more definitive conclusions.

Overall, the variability in results highlights that clinical success depends on correct protocol selection: sandblasting is valuable in enamel preparation, total-etch adhesive strategies, and composite repair, but it should be avoided with self-etch adhesives on dentin.

CONCLUSIONS

Aluminum oxide air abrasion can significantly improve the adhesion of composite materials to both enamel and dentin, provided that an appropriate protocol is followed. In enamel, air abrasion provides a clear benefit – particularly if self-etch adhesive systems are being used – by increasing surface roughness and enabling better resin penetration. In dentin, the effect of sandblasting depends on the bonding strategy: it is recommended primarily for use with etch-and-rinse (total-etch) adhesive protocols, whereas in self-etch approaches it should be avoided because the lack of a proper etching step after smear-layer removal can lead to reduced bond effectiveness.

For optimal results, alumina sandblasting should be carried out under controlled conditions (using approximately 50 µm Al_2O_3 particles at ~3–4 bar pressure for about 5–10 seconds per area). Excessively prolonged or high-pressure application offers no added benefit and may even damage the exposed dentin surface. After sandblasting, the abraded surface must be thoroughly rinsed (or etched) to eliminate residual abrasive particles before the adhesive steps.

In the context of repairing aged composite restorations, alumina air abrasion is highly beneficial. It consistently yields higher repair bond strength than either acid etching or roughening with a bur. To maximize the durability of the repair, the procedure should be combined with the application of a silane coupling agent and a compatible adhesive resin before placing the new composite. During intraoral sandblasting, any nearby exposed dentin should be protected (for example, by covering it with a bonding resin) and the abrasive jet directed mainly at the old composite and enamel margins.

When used correctly, Al_2O_3 air abrasion is a quick and safe technique, although standard precautions are advised (such as using a rubber dam for isolation and protecting soft tissues). Improper use of sandblasting – for instance, prolonged blasting of bare dentin without subsequent etching, or using it in a self-etch scenario – can negate the benefits or even decrease the bond strength. Adhering to a well-defined protocol is therefore crucial for success.

The long-term performance of bonds created with alumina abrasion remains a subject for further research. In many laboratory studies, the initial improvements in bond strength have persisted after artificial aging, but some reports have noted a loss of the benefit over time. High-quality in vivo studies are needed to determine the clinical longevity of alumina-enhanced bonds. Additionally, emerging approaches like bioactive glass abrasives may further improve the durability and biological outcomes of sandblasting in the future.

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CONFLICT OF INTEREST
The Authors declare no conflict of interest

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