Review Article

Effectiveness of Air Polishing in Managing Peri-Implant Diseases: A Review

Akkapol Banlue[1] **and Sukrit Jaiklaew**[1]

[1]Maha Chakri Sirindhorn Dental Hospital, Faculty of Dentistry, Mahidol University, Nakhon Pathom, Thailand

Abstract

Peri-implant diseases, including peri-implant mucositis and peri-implantitis, are inflammatory conditions affecting the tissues around dental implants. Effective management of these diseases is crucial to ensuring the long-term success of implant therapy. Air polishing has emerged as a potential non-invasive treatment modality for managing peri-implant diseases, offering an alternative to traditional mechanical debridement methods like hand scaling or using ultrasonic devices. This technique utilizes a pressurized jet of air, water, and abrasive powder to disrupt biofilm with minimal damage to the implant surface or surrounding soft tissues. Glycine powder air polishing and erythritol powder air polishing have gained prominence in peri-implantitis treatment. *In vitro* studies suggest that glycine powder air polishing and erythritol powder air polishing are highly effective in reducing biofilm and bacterial load with minimal damage to the implant surface. However, clinical studies have demonstrated limited benefits in reducing bleeding on probing and probing depth in peri-implant mucositis and peri-implantitis treatment. Its efficacy may depend on the stage of the disease, the powder used, and the duration of the treatment. Additionally, peri-implantitis is a multifactorial disease. Air polishing holds promise as a valuable tool in the management of peri-implant diseases. Further research is required to determine and improve its clinical outcomes and to compare it with other established treatment modalities.

Keywords: Dental air abrasion, Dental implants, Peri-implant diseases, Peri-implant maintenance

Received date: Jan 5, 2025 **Revised date:** Mar 19, 2025 **Accepted date:** Mar 26, 2025

Doi:

Correspondence to:

Akkapol Banlue, Maha Chakri Sirindhorn Dental Hospital, Faculty of Dentistry, Mahidol University, 888 Borommaratchachonnani Rd., Salaya, Phuttamonthon District, Nakhon Pathom 73170, Thailand. Tel: +662-849-6600 #2004, 2005 Email: akkapol.ban@mahidol.edu

Introduction

Dental implants have revolutionized the field of tooth replacement, providing an alternative to traditional methods of addressing missing teeth. Dental implants offer numerous advantages. They help support the surrounding teeth by preventing them from shifting into the space. In addition, dental implants are highly functional and aesthetically pleasing, blending naturally into the smile of an individual.

Maintaining optimal peri-implant health is critical, as neglecting it may lead to peri-implant diseases. The peri-implant conditions can be categorized into three groups. The ideal state of the peri-implant soft tissue is typically the absence of signs of inflammation, including bleeding on probing (BoP), suppuration (SUP), and redness, and probing depth (PD) of approximately 3-4 mm, a condition referred to as "peri-implant health".[1] As peri-implant diseases progress due to the accumulation of dental plaque around the soft tissue, it can develop into "Peri-implant mucositis". It is described as clinical signs of peri-implant soft tissue inflammation without marginal bone loss.[2] The prevalence of peri-implant mucositis ranges from 27% to 63%.[3] If the condition deteriorates and progresses into "Peri-implantitis", it is defined as a condition in which clinical manifestations of inflammation are detectable and the radiographic evidence demonstrates further crestal bone loss surrounding dental implants.[4] The prevalence of peri-implantitis is vary from 7% to 28%.[3] The progression from peri-implant mucositis to peri-implantitis remains inconclusive. Many studies identified bacterial plaque accumulation as a key etiologic factor, similar to periodontitis. Several contributing factors also play a role, including smoking, diabetes mellitus, titanium particle dissolution, excessive occlusal loading, cement remnants, and genetic predisposition. These factors can lead to microbial dysbiosis, which further contributes to the state of the disease.[5-7] Therefore, prevention through strict plaque control and addressing these contributing factors is essential for maintaining peri-implant health.

Peri-implantitis is treated through a combination of non-surgical and surgical approaches. Non-surgical treatment includes mechanical cleaning using ultrasonic scalers, curettes or air polishing, antimicrobial therapy with antibiotics or antiseptic rinses, and implant surface disinfection to remove plaque and bacteria. Surgical treatment is considered if non-surgical methods fail. Flap surgery may be performed to clean the implant and bone. In some cases, bone grafting and guided bone regeneration can restore lost bone.[8] Regular professional mechanical debridement, combined with routine plaque control, represents the key to long-term success. Although these approaches have been shown to effectively reduce clinical signs of inflammation[9], hand scalers have been found to cause damage to the tissues.[10]

Therefore, the purpose of this review is to critically assess the existing scientific evidence on the effectiveness of air polishing in managing peri-implant mucositis and peri-implantitis. The advantages and limitations of air polishing will be examined in comparison to traditional mechanical debridement, drawing from both *in vitro* and clinical studies. By thoroughly reviewing the current research, this paper aims to offer valuable insights for dental professionals in determining the appropriate role of air polishing in the treatment and maintenance of peri-implant health.

In vitro studies of air polishing for implant surface decontamination

Mechanism of air polishing

Air polishing devices utilize a combination of air, water, and powder particles propelled at high velocity toward the surface. The primary mechanism is the mechanical removal of biofilms and debris through abrasive contact. The choice of powder is crucial for balancing efficacy and safety, particularly on rough implant surfaces. Different powders vary in abrasiveness and particle size, influencing their effectiveness in biofilm disruption and the potential for surface damage.[17]

Effectiveness against biofilm

Several in vitro studies have evaluated the ability of air polishing to remove biofilm from various implant surfaces.[12,18-21] Research shows that erythritol powder air polishing (EPAP) and glycine powder air polishing (GPAP), effectively removes biofilms without significantly altering the surface topography of dental implants compared to other methods.[22,23] Luengo *et al.* compared the cleaning ability of four methods (GPAP, Titanium (Ti) brush, polyether ether ketone tip ultrasonic, and stainless-steel tip ultrasonic) on simulated intraosseous defects with Ti implants. The study showed that while no single method can completely decontaminate, GPAP was one of the most effective.[24] Similarly, Ichioka *et al.* found that air polishing using EPAP outperformed chemical agents, and combining air polishing with chemical agents did not significantly enhance efficiency.[18]

Surface integrity and roughness

Protecting the surface integrity of dental implants is a key consideration during contamination, as surface characteristics influence osseointegration and bacterial adhesion. *In vitro* studies show that air polishing, especially with fine powders, causes minimal changes to implant surfaces compared to more abrasive techniques like ultrasonic scaling or mechanical brushing.[21,25] Matsubara *et al.* compared the effects of GPAP and EPAP to sodium bicarbonate on Ti implant surface roughness, finding that GPAP and EPAP caused significantly less surface damage, making them suitable options for routine peri-implantitis treatment.[26] Additionally, GPAP can roughen Ti disks without negatively affecting fibroblast biocompatibility.[27]

Antimicrobial effects and cytocompatibility

In vitro studies have also assessed the antimicrobial effects of air polishing. Petersilka *et al.* demonstrated that GPAP effectively reduced bacterial loads on contaminated implant surfaces.[28] Drago *et al.* and Fernández *et al.* found that combining EPAP with Chlorhexidine (CHX) exhibited significant antimicrobial and antibiofilm activity.[19,29] Stein *et al.* studied the effect of air polishing on Ti and zirconium (Zr) discs, showing that bacterial activity decreased, and human gingival fibroblasts showed increased viability, with lower cytotoxicity and apoptosis rates. This suggests that air polishing is suitable for decontaminating Ti and Zr implant surfaces.[20]

Comparison with other methods

Various studies have compared air polishing with other decontamination methods, such as ultrasonic scalers, lasers, and chemical agents. These studies consistently show that air polishing is as effective as or superior to many traditional methods in biofilm removal and surface preservation. Air polishing was more effective than citric acid and ultrasonic scaling in reducing bacterial biofilms without altering the implant surface structure.[30] Luengo *et al.* and Ichioka *et al.* demonstrated that ultrasonic and Ti brushes were similarly effective for cleaning implant surfaces in simulated intrabony defects.[18,24] Discepoli *et al.* concluded that GPAP can be effectively used adjunctly to ultrasonic debridement.[31] Stein *et al.* reported that both air polishing and ultrasonic devices effectively inactivated biofilms with favorable cytocompatibility on Ti and Zr surfaces, while chemical agents posed potential cytotoxic effects.[20]

Powder selection and technique

The type of powder used significantly impacts the results of air polishing. GPAP utilizes glycine powder, a substance composed of the amino acid glycine with average diameter 45 microns.[8,32] EPAP employs erythritol, a sugar alcohol with a mean particle size 14 microns.[33,34] Both GPAP and EPAP are typically utilized for supragingival and subgingival cleanings. These modalities are particularly advantageous for patients with periodontal disease or dental implants due to their minimal abrasiveness and efficacy in biofilm removal without compromising the integrity of the implant surface. Sodium bicarbonate, while effective, is more abrasive and may alter rough implant surfaces due to its large particle size (up to 250 microns).[8] Formulated with sodium bicarbonate, this powder is primarily indicated for the removal of extrinsic stains resulting from the consumption of substances such as coffee, tea, and tobacco. Its non-toxic nature and ease of use contribute to its efficacy in supragingival cleaning procedures. Polishing powder is only one factor in successful decontamination; other factors, such as air pressure, the angle between the implant surface and the device, and the depth of the nozzle, also play a role. Tastepe identified air pressure as a key factor influencing cleaning efficiency, with increased pressure extending the cleaning area. Other factors, such as nozzle depth and excessive powder flow, had less impact, though cleaning effects reached deeper than the nozzle physically penetrated.[35] Tuchscheere demonstrated that a 60°–90° angle between the device and the implant surface was more effective than a 30° angle.[36]

Clinical studies of nonsurgical peri-implantitis treatment conditions

Non-surgical treatment in peri-implant mucositis condition

Treatment approaches for peri-implant mucositis aim to achieve complete resolution of BoP around the implant, thereby restoring peri-implant health. Various non-surgical procedures, including mechanical debridement, air polishing, and laser therapy, are commonly used. Research has investigated the efficacy of air polishing powder, both as an adjunct to conventional mechanical debridement and as a standalone treatment, in comparison to mechanical debridement. Studies have specifically examined its effectiveness in reducing BoP[37-39] and bleeding index (BI).[37,40]

GPAP has become a widely used technique for managing peri-implant mucositis. A study by Ji *et al.* demonstrated a reduction in BI one week after combining GPAP with mechanical debridement, compared to baseline, with this positive outcome sustained for up to three months.[37] However, using GPAP may not provide a significant advantage in reducing the BI compared to mechanical debridement alone (Table 1). Furthermore, a greater reduction in inflammation was observed in the mechanical debridement alone group compared to the GPAP treatment.[37] Interestingly, potential benefits of GPAP were observed in patients with mandibular full-arch implant-supported restorations after a six-month follow-up. The study reported negative BI scores in 86% of the GPAP group, compared to 60% in the mechanical debridement group.[40] Further research by Riben-Grundstrom *et al.* compared GPAP with mechanical debridement alone, showing a decrease in the percentage of BoP and diseased sites in both treatment groups at the 12-month follow-up compared to baseline. However, no significant advantage of GPAP over conventional treatment was observed.[38] A recent study using EPAP demonstrated a reduction in BoP at the six-month compared to baseline. However, no significant benefit of EPAP over mechanical debridement alone was observed.[39] Notably, 30.65% of patients treated with EPAP achieved complete resolution of inflammation. A recent systematic review and meta-analysis found no added benefit of air polishing powder compared to mechanical debridement in reducing BoP.[41]

Several secondary outcomes were measured to assess the effectiveness of the air polishing treatment. Studies show a significant reduction in PD following the use of both GPAP and EPAP as adjuncts to mechanical debridement at three months[37,39] and six months[39] compared to baseline PD. However, neither GPAP nor EPAP demonstrated superior benefit when compared to conventional treatment in terms of PD reduction.[37-39] Numerous studies have documented the efficacy of air polishing in reducing plaque index (PI). After the use of air polishing devices, PI significantly decreased and remained lower at three months[37,39], six months[39] and even twelve months[38] compared to baseline. A greater complete reduction in PI was observed in the GPAP treatment group, with 80% of subjects achieving this outcome compared to 33.3% of subjects in the mechanical debridement alone group.[40] However, air polishing treatment did not demonstrate a significant advantage over mechanical debridement in terms of PI reductions.[37-39] While GPAP treatment demonstrated stable buccal keratinized gingiva and mucosal recession, it did not differ from conventional treatment. Patient perceptions of GPAP were similar to those of conventional treatment. Additionally, the perceived ease of use of GPAP was not significantly different from that of mechanical debridement.[40] The available evidence suggests that air polishing devices do not provide a significant additional benefit in treating peri-implant mucositis, as indicated by minimal improvements in BoP, PD, PI, and patient perception.

Table 1 *Non-surgical treatment of air-polishing device in peri-implant mucositis condition*

Publication	Population (Implant)	Definition	Intervention	Comparison	Treatment outcomes
Ji *et al.* (2014)[37] / RCT, Single blind	• GPAP 12 (17) • Control 12 (16)	Implant with • PD≥4mm • (+) BoP • (-) CBL	Ultrasonic scaler with carbon fiber tips + GPAP	Ultrasonic scaler with carbon fiber tips	BI **Intervention:** 1.7±0.9 (BL), 1.0±1.0* (1 wk.), 1.1±1.2* (1 mo.), 1.1±1.0* (3 mo.) **Comparison:** 1.7±1.0 (BL), 0.5±0.7*,§ (1 wk.), 1.0±1.0* (1 mo.), 0.9±1.1* (3 mo.) **PD Intervention:** 4.6±0.5mm (BL), 3.8±1.0mm* (1 mo.), 3.7±1.0mm* (3 mo.) **Comparison:** 4.5±0.6mm (BL), 3.8±1.0mm* (1 mo.), 3.6±1.0mm* (3 mo.)
De Siena[40] *et al.* (2015)/ Observational Clinical trial	• GPAP 15 • Control 15	Implant with • PD≤3.5mm (+) BoP • CBL≤3mm	Teflon curette and polishing + GPAP	Teflon curette and polishing	BI turns to 0 **Intervention:** 12 subjects (80%) (3 mo.), 13 subjects (86%) § (6 mo.) **Comparison:** 9 subjects (60%) (3 mo.), 9 subjects (60%) (6 mo.) PD **Intervention:** 3.0±0.4mm (BL), 2.6±0.5mm* (3 mo.), 2.4±0.5mm*,§ (6 mo.) **Comparison:** 2.9±0.4mm (BL), 2.9±0.5mm (3 mo.), 3.0±0.6mm (6 mo.)
Riben-Grundstrom *et al.*[38] (2015)/ RCT, Single blind	• GPAP 19 (19) • Control 18 (18)	Implant with • PD≥4mm • (+) BoP±SUP • CBL≤2mm	GPAP	Ultrasonic scaler with plastic coated tips	% BoP **Intervention** 43.9±7.3% (BL), 23.0±6.1% (3 mo.), 16.7±4.6% (6 mo.),12.1±3.8%* (12 mo.) **Comparison** 53.7±7.9% (BL), 25.1±5.6% (3 mo.), 23.2±5.4% (6 mo.), 18.6±6.4%* (12 mo.) % Disease site (PD≥4mm with BoP±SUP) **Intervention:** Decreased 30.0±27.0% **Comparison:** Decreased 35.0±36.0%
Clementini *et al.* (2023)[39]/ RCT, Single blind	• EPAP 25 (62) • Er:YAG 25 (59) • Control 25 (58)	• Implant with (+) BoP±SUP CBL<2mm or • bone level <3 mm	Titanium curette + • EPAP • Er:YAG	Titanium curette	% BoP **EPAP** 85.5% (BL), 35.2%* (1 mo.), 37.6%* (3 mo.), 37.6%* (6 mo.) **Er:YAG** 85.3% (BL), 36.7%* (1 mo.), 40.4%* (3 mo.), 41.8%* (6 mo.) **Comparison** 88.2% (BL), 37.6%* (1 mo.), 39.7%* (3 mo.), 40.2%* (6 mo.) PD **EPAP** 4.0mm (BL), 3.1mm* (1 mo.), 3.2mm* (3 mo.), 3.2mm* (6 mo.) **Er:YAG** 4.0mm (BL), 3.3mm* (1 mo.), 3.3mm* (3 mo.), 3.3mm* (6 mo.) **Comparison** 4.2mm (BL), 3.3mm* (1 mo.), 3.3mm* (3 mo.), 3.3mm* (6 mo.)

Notes: BI-Bleeding index, BoP-Bleeding on Probing, CBL-Crestal bone loss, EPAP-Erythritol powder air polishing, GPAP-Glycine powder air polishing, PD-Probing depth, RCT-Randomized controlled trial, SUP-Suppuration
(*)-Significant difference intragroup comparison compared to baseline, (§)-Significant difference intergroup comparison compared to the same period

Non-surgical treatment in peri-implantitis condition

The treatment of peri-implantitis presents a significant challenge, and air polishing devices are increasingly utilized in managing this condition. The primary objective of peri-implantitis treatment is to reduce BoP and PD. This article focuses on the efficacy of air polishing powder as an adjunct to conventional mechanical debridement or as a standalone treatment compared to mechanical debridement. Comparisons between air polishing and other modalities, such as ultrasound or laser will also be explored.

Air polishing is proposed to eliminate inflammatory reactions by achieving reduced BoP values. Studies by Sahm *et al.* and John *et al.* demonstrated the benefits of GPAP in reducing BoP compared to treatment with carbon curettes combined with the application of CHX. GPAP exhibited a significantly greater reduction in BoP (51.6±28.6%) compared to mechanical debridement (24.8±29.8%) at three months. This effect appeared to be sustained at 12 months (Table 2). However, three studies did not find any significant enhancement in BoP reduction with GPAP or EPAP compared to mechanical debridement alone.[42-44] A recent systematic review and meta-analysis categorized studies into short-term (<6 months) and long-term (≥6 months) outcomes. The air polishing device demonstrated a significant advantage in reducing BoP only in the long-term group.[41] Compared to other modalities, the benefit of air polishing for BoP reduction in peri-implantitis appears limited. Studies by Renvert *et al.* and Persson *et al.* compared GPAP to Er:YAG laser[45,46], while Prosper *et al.* investigated GPAP versus ultrasound.[47] These studies demonstrated comparable BoP reduction with air polishing powder and other modalities.[45-47]

Increased PD around the peri-implant tissue is a key clinical indicator for diagnosing peri-implantitis.[48] Therefore, another pivotal goal of peri-implantitis treatment is to achieve a shallower PD. Five studies found no additional benefit of air polishing treatment in a shallower PD compared to mechanical debridement.[42-44,49,50] A recent meta-analysis similarly concluded that air polishing devices offer no additional benefit for PD reduction.[41] In addition, air polishing seems to yield similar results in decreasing of PD when compared to Er:YAG laser[45,46] and ultrasound treatments.[47]

PI, SUP and crestal bone loss (CBL) are proposed as secondary measures. Studies have shown no additional benefit of air polishing in reducing PI compared to conventional treatment.[43,44,49,50] Similarly, GPAP demonstrated equivalent PI reduction outcomes compared to ultrasound treatment.[47] Existing research suggests no advantage of EPAP over mechanical debridement alone in reducing SUP.[43,44]Additionally, air polishing appears to be equally effective as laser[45,46] and ultrasound[47] in reducing SUP. Three studies compared air polishing to mechanical debridement using radiographic examination to detect CBL. These studies found no additional benefit of air polishing compared to conventional treatment.[42-44] Likewise, no superior effect was observed with GPAP compared to other modalities.[45-47] While air polishing treatment seems to maintain stable buccal keratinized gingiva[42,47] and mucosal recession[42,43,47,49,50], the results do not differ significantly from conventional treatment or other treatment modalities. Consistent with this finding, a recent meta-analysis reported no additional benefit of air polishing treatment in PI and clinical attachment level (CAL). Nevertheless, GPAP demonstrated a significant advantage in preventing further CBL compared to conventional treatment during long-term follow-up.[41] In terms of patient perception, there is no significant difference in discomfort levels between EPAP and ultrasonic scalers[42,43] or patient satisfaction.[44] Conversely, Selimovic *et al.* reported significantly less pain with conventional treatment.[44] Regarding complications, most other studies documented uneventful outcomes.

Table 2 *Non-surgical treatment of air polishing device in peri-implantitis condition*

Publication	Population (Implant)	Definition	Intervention	Comparison	Treatment outcomes
Renvert *et al.* (2010)[46] and Persson *et al.* (2011)[45] / RCT, Single blind	• GPAP 21 (45) • Laser 21 (55)	Implant with • PD≥5mm • (+) BoP±SUP • CBL>3mm	GPAP	Er:YAG laser	BoP turns to negative **Intervention:** 25% Comparison: 30.9% PD Reduction **Intervention:** 0.9±0.8mm (6 mo.) Comparison: 0.8±0.5mm (6 mo.) Bone changes **Intervention:** -0.1±0.8mm (6 mo.) Comparison: -0.3±0.9mm (6 mo.)
Sahm *et al.* (2011)[50] and John *et al.* (2015)[49] / RCT, Single blind	• GPAP 16 (23) • Control 16 (20)	Implant with • PD≥4mm • (+) BoP±SUP • CBL≤30% (Initial to moderate peri-implantitis)	GPAP	Carbon curette + Irrigation with a 0.1% CHX solution and submucosal application with 1% CHX gel	%BOP reduction **Intervention:** 51.6±28.6% (3 mo.), 43.5±27.7% (6 mo.), 41.2±29.5% (12 mo.) **Comparison:** 24.8±29.8%§ (3 mo.), 11.0±15.7%§ (6 mo.), 16.6±33.4%§ (12 mo.) PD Reduction **Intervention:** 0.8±0.5mm (3 mo.), 0.6±0.6mm (6 mo.), 0.5±0.9mm (12 mo.) **Comparison:** 0.8±0.9mm (3 mo.), 0.5±0.6mm (6 mo.), 0.4±0.9mm (12 mo.) CAL **Intervention:** 0.7±0.5mm (3 mo.), 0.4±0.7mm (6 mo.), 0.6±1.3mm (12 mo.) **Comparison:** 0.8±1.1mm (3 mo.), 0.5±0.8mm (6 mo.), 0.5±1.1mm (12 mo.)
Aloy-Prosper *et al.* (2020)[47] / RCT, Double blind	• GPAP 17 (32) • Ultrasound 17 (38)	Implant with • PD≥4mm • (+) BoP±SUP • CBL≥2mm	Titanium curette + Carbon curette + GPAP	Titanium curette + Carbon curette + Ultrasound	%BOP **Intervention** 86.8% (BL), 5.3%* (3 wk.) Comparison 84.4% (BL), 8.8%* (3 wk.) PD **Intervention** 5.8±1.6mm (BL), 4.2±1.4mm* (3 wk.) **Comparison** 6.1±1.6mm (BL), 4.1±1.4mm* (3 wk.) CAL **Intervention** 7.2±1.5mm (BL), 5.5±1.6mm* (3 wk.) **Comparison** 6.8±1.7mm (BL), 4.9±1.8mm* (3 wk.) Bone loss **Intervention** 3.7±1.2mm (BL), 3.7±1.2mm (3 wk.) **Comparison** 4.1±1.4mm (BL), 4.1±1.4mm (3 wk.)
Merli *et al.* (2020)[42] / RCT, Single blind	• GPAP 16 • Control 16	Implant with • (+) BoP • Presence of CBL	Non- surgical treatment + GPAP	Non-surgical treatment alone	BOP site reduction **Intervention** 0.7±1.3 (6mo.) Comparison- 0.4±0.9 (6mo.) PD reduction **Intervention** 0.1±0.8mm (6mo.) Comparison 0.2±0.7mm (6mo.) CAL reduction **Intervention** 0.1±0.9mm (6mo.) Comparison 0.1±0.6mm (6mo.)
Hentenaar *et al.* (2021)[43] / RCT, Single blind	• EPAP 38 (62) • Control 38 (70)	Implant with • PD≥5mm • (+) BoP±SUP • CBL≥2mm	EPAP	Ultrasonic scalers	%BOP **Intervention** 58.1±30.3% (BL), 49.8±31.5% (3 mo.) **Comparison** 56.2±28.8% (BL), 48.1±29.0% (3 mo.) PD **Intervention** 4.8±1.2mm (BL), 4.3±1.3mm (3 mo.) **Comparison** 5.0±1.5mm (BL), 4.7±1.8mm (3 mo.) Bone loss **Intervention** 4.0±1.9mm (BL), 4.0±1.8mm (3 mo.) **Comparison** 3.9±1.8mm (BL), 4.0±1.8mm (3 mo.)
Selimovic *et al.* (2023)[44] / RCT, Single blind	• EPAP 23 (31) • Control 20 (31)	Implant with • PD≥4mm • (+) BoP±SUP • CBL≥2mm	Ultrasonic scalers + EPAP	Ultrasonic scalers	%BOP **Intervention** 59.7% (BL), 37.8%* (6 mo.), 36.5%* (12 mo.) **Comparison** 58.1% (BL), 32.3%* (6 mo.), 32.3%* (12 mo.) PD reduction **Intervention** 0.4±0.1mm* (6 mo.), 0.3±0.1mm (12 mo.) **Comparison** 0.5±0.1mm* (6 mo.), 0.6±0.1mm*, § (12 mo.) Bone change Intervention -0.3±0.3mm (6 mo.), -0.2±0.3mm (12 mo.) **Comparison** -0.1±0.2mm (6 mo.), 0.3±0.2mm (12 mo.)

Notes: BoP-Bleeding on Probing, CBL-Crestal bone loss, CHX-Chlorhexidine, EPAP-Erythritol powder air polishing, GPAP-Glycine powder air polishing, PD-Probing depth, RCT-Randomized controlled trial, SUP-Suppuration (*)-Significant difference intragroup comparison compared to baseline, (§)-Significant difference intergroup comparison compared to the same period

Clinical studies of surgical peri-implantitis treatment condition

Peri-implantitis often necessitates surgical intervention when non-surgical treatments fail to achieve adequate clinical outcomes. Despite the lack of a gold standard for surgical peri-implantitis treatment, effective decontamination of the bacteria-contaminated implant surface is essential for successful outcomes. Air polishing devices have emerged as a promising approach to achieving this objective. This article reviews the effectiveness of air polishing powder as an adjunct to surgical debridement or in comparison to other modalities, such as Ti brushes or implantoplasty.

Similar to non-surgical treatment, the primary goals of surgical peri-implantitis treatment are to reduce inflammatory conditions. A study by Toma *et al.* compared surgical debridement with GPAP to plastic curettes in patients suffering from peri-implantitis. GPAP demonstrated a significantly lower gingival index (GI) (0.31 ± 0.37) compared to surgical debridement alone (0.91 ± 0.59) at the six-month follow-up. This effect appeared to be sustained at 12 months[51] (Table 3). However, two other studies did not find any additional benefits of air polishing powder in reducing inflammation compared to surgical debridement.[52,53] Compared to other modalities, surgical debridement with the application of a Ti brush appears to be more effective in lowering BoP (16 ± 3.7%) compared to GPAP (23 ± 2.3%) at the six-month follow-up.[52] In addition, the combination of plastic curettes with implantoplasty demonstrated similar BoP outcomes to GPAP.[54] When compared to baseline examination, air polishing powder including sodium bicarbonate55,56 and GPAP[51-54,57] have shown significant reductions in BoP at the three to 12-month follow-up periods.

Achieving a shallower PD is a key objective in surgical peri-implantitis treatment. Two studies demonstrated the additional benefits of GPAP in reducing the PD compared to surgical debridement alone.[51,52] Notably, most studies have not shown a significant impact of GPAP on PD reduction.[53,54,57] When compared to other modalities, surgical debridement with the application of a Ti brush appears to be more effective in achieving a shallower PD (3.98 ± 1.43 mm) compared to GPAP (4.71 ± 1.24 mm) at the six-month follow-up. Additionally, surgical debridement followed by implantoplasty demonstrated similar outcomes in PD reduction compared to GPAP.[54] When compared to baseline values, all studies have shown significant reductions in PD with the use of air polishing.[51,52,54-57]

A composite outcome defined as a PD of 5 mm or less, absence of BoP or SUP, and no further bone loss within an acceptable tolerance of 0.5 mm has been proposed to provide a more comprehensive perspective.[58] Studies have reported success rate ranging from 26-56.67% using this composite outcome.[52-54,57] Interestingly, Luengo *et al.* allowed for one BoP site as acceptable for success[57], while other articles required complete absence of BoP.[52-54] This variation may partly explain the higher success rate (56.67%).[57] Overall, these findings suggest that surgical treatment combined with air polishing powder exhibits a relatively low success rate. Luengo *et al.* suggests that achieving complete resolution of BoP remains a significant challenge when using air polishing powder as part of the treatment plan. Furthermore, patient compliance with supportive periodontal therapy (SPT) may significantly impact treatment success. Erratic compliance resulted in a considerably lower implant success rate (30%) compared to complete compliance (100%).[57]

Secondary outcomes, encompassing PI, SUP, CAL, and CBL, also play a vital role in evaluating treatment success. Several studies have shown that surgical debridement combined with air polishing treatment does not provide additional benefits in improving these parameters compared to surgical debridement alone.[51-54] However, some exceptions exist, Toma *et al.* reported a significant reduction in CAL with GPAP compared to plastic curette at 6 months post-surgery.[52] Additionally, Hentenaar *et al.* observed a benefit in terms of SUP reduction when using EPAP.[53] Following surgical treatmentwith air polishing, gingival recession typically occurs within the range of 0.5-1 mm with a net bone gain of up to 0.5 mm.[54,57]

Table 3 *Surgical treatment of air polishing device in peri-implantitis condition*

Publication	Population (Implant)	Definition	Intervention	Comparison	Treatment outcomes
Duarte *et al.* (2009)[55] and Máximo *et al.* (2009)[56]/ Prospective	• $NaHCO_3$ 15 (20)	Implant with • PD≥5mm • (+) BoP±SUP • CBL≥3threads • (-) mobility	Resin curette + Sodium bicarbonate powder	-	%BOP **Intervention** 100% (BL), 52.5±41.3%* (3 mo.) PD **Intervention** 7.5±2.2mm (BL), 4.4±1.1mm* (3 mo.)
Toma *et al.* (2014)[51]/ Retrospective	• GPAP 7 (10) • Control 10 (12)	Implant with • PD≥5mm • (+) BoP±SUP • CBL≥3mm • (-) mobility	Surgical debridement + GPAP	Surgical debridement + Plastic curette	GI **Intervention** 0.9±0.4 (BL), 0.3±0.4*, § (6 mo.), 0.5±0.3*, § (12 mo.) **Comparison** 1.7±0.4 (BL), 0.9±0.6* (6 mo.), 1.0±0.6* (12 mo.) PD **Intervention** 5.1±1.2mm (BL), 3.2±0.7mm* (6 mo.), 3.1±0.9mm*, § (12 mo.) **Comparison** 4.9±1.3mm (BL), 3.7±1.2mm* (6 mo.), 4.2±1.4mm* (12 mo.) Bone loss **Intervention** 5.5±2.0mm (BL), 5.2±2.1mm (12 mo.) **Comparison** 5.3±1.3mm (BL), 5.6±1.3mm (12 mo.)
Toma *et al.* (2019)[52]/ RCT, Single blind	• GPAP 16 (22) • Ti brush 16 (23) • Control 15 (25)	Implant with • PD≥5mm • (+) BoP±SUP • CBL≥2mm • (-) mobility	Plastic curette+ GPAP	Plastic curette	% BoP **GPAP** 59.0±5.2% (BL), 18.0±4.2%* (3 mo.), 23.0±2.3%* (6 mo.) **Ti brush** 62.0±4.7% (BL), 19.0±5.1%* (3 mo.), 16.0±3.7%*, § (6 mo.) **Comparison** 54.0±4.4% (BL), 21.0±2.4%* (3 mo.), 29.0±3.4%* (6 mo.) PD **GPAP** 6.9±1.3mm (BL), 5.8±0.3mm* (3 mo.), 4.7±1.2mm*, § (6 mo.) **Ti brush** 6.5±1.9mm (BL), 4.8±0.2mm* (3 mo.), 4.0±1.4mm*, § (6 mo.) **Comparison** 7.1±1.2mm (BL), 5.5±0.2mm* (3 mo.), 5.4±0.7mm* (6 mo.) CAL **GPAP** 6.9±1.2mm (BL), 5.5±1.6mm* (3 mo.), 4.8±1.4mm*, § (6 mo.) **Ti brush** 7.0±1.4mm (BL), 5.7±1.6mm* (3 mo.), 4.7±1.3mm*, § (6 mo.) **Comparison** 7.5±1.5mm (BL), 6.4±1.6mm* (3 mo.), 5.8±1.5mm* (6 mo.) Bone loss **GPAP** 7.3±1.3mm (BL), 6.4±1.5mm* (6 mo.) Ti brush 7.1±1.2mm (BL), 5.9±1.3mm*, § (6 mo.) **Comparison** 6.5±2.0mm (BL), 6.0±1.8mm (6 mo.)

Table 3 *Surgical treatment of air polishing device in peri-implantitis condition (cont.)*

Publication	Population (Implant)	Definition	Intervention	Comparison	Treatment outcomes
Lasserre *et al.* (2020)[54]/ RCT, Single blind	• GPAP 15 (20) • Implantoplasty 16 (22)	Implant with • PD≥5mm • (+) BoP±SUP • CBL≥2mm	Plastic curette + GPAP	Plastic curette + Implantoplasty	%BOP **Intervention** 87.4±22.3% (BL), 30.8±27.1%* (3 mo.), 26.3±23.2%* (6 mo.) **Comparison** 94.7±10.7% (BL), 33.4±28.6%* (3 mo.), 33.3±24.2%* (6 mo.) PD **Intervention** 5.6±1.6mm (BL), 2.8±1.1mm* (3 mo.), 2.3±1.5mm* (6 mo.) **Comparison** 6.7±1.8mm (BL), 3.4±1.9mm* (3 mo.), 2.7±1.6mm* (6 mo.) Bone loss **Intervention** 5.2±2.1mm (BL), 4.7±2.1mm* (6 mo.) **Comparison** 4.7±2.7mm (BL), 4.5±3.1mm* (6 mo.)
Hentenaar *et al.* (2021)[53]/ RCT, Single blind	• EPAP 27 (54) • Control 31 (40)	Implant with • PD≥5mm • (+) BoP±SUP • CBL≥2mm	Scaler tip + hand instrument + EPAP	Scaler tip + hand instrument	%BOP **Intervention** 52.2±30.4% (BL), 40.0±28.0% (3 mo.), 33.4±25.1% (6 mo.), 34.0±25.8%* (12 mo.) **Comparison** 58.3±30.4% (BL), 42.4±26.0% (3 mo.), 41.0±27.2% (6 mo.), 44.4±26.7%* (12 mo.) PD **Intervention** 4.9±1.6mm (BL), 3.4±1.1mm (3 mo.), 3.5±1.2mm (6 mo.), 3.3±0.8mm (12 mo.) **Comparison** 4.6±1.0mm (BL), 3.5±1.2mm (3 mo.), 3.7±1.4mm (6 mo.), 3.5±1.4mm (12 mo.) Bone loss **Intervention** 4.3±1.7mm (BL), 4.5±1.7mm (3 mo.), 4.3±1.6mm (6 mo.), 4.5±1.7mm (12 mo.) **Comparison** 3.7±1.7mm (BL), 3.9±1.8mm (3 mo.), 3.7±1.7mm (6 mo.), 3.8±2.0mm (12 mo.)
Luengo *et al.* (2022)[57]/ Prospective	• GPAP 30	Implant with • PD≥5mm • (+) BoP±SUP • CBL>2mm	Curette + Ultrasonic + GPAP + Systemic ATB	-	%BOP 90.0±17.3% (BL), 27.8±17.7%* (6 mo.) PD 5.8±1.12mm (BL), 3.7±0.7mm* (6 mo.) Bone loss 3.8±1.2mm (BL), 3.8±1.3mm (6 mo.)

Notes: ATB- Antibiotics, BoP-Bleeding on Probing, CBL-Crestal bone loss, EPAP-Erythritol powder air polishing, GI-Gingival index, GPAP-Glycine powder air polishing, PD-Probing depth, RCT-Randomized controlled trial, SUP-Suppuration, Ti-Titanium (*)-Significant difference intragroup comparison compared to baseline, (§)-Significant difference intergroup comparison compared to the same period

Complication associated with air polishing devices in dental implant treatment

Air polishing devices have been associated with certain complications, including subcutaneous air emphysema and tissue swelling. This article reviews four case reports of emphysema documented over the past decade. Two cases involved routine maintenance cleaning around healthy peri-implant tissues.[59,60] One case described the non-surgical treatment of peri-implantitis[61], while the fourth involved the debridement of infected implant surfaces using an air polishing device following an open flap debridement for peri-implantitis condition.[62] Immediately following air polishing, patients in these cases reported unilateral facial swelling and crepitus in the affected area, followed by pain. Some patients also presented with eyelid ptosis, dysphagia, and dyslalia.[59] Radiographic examination was commonly employed to delineate the extent of the emphysema, which was observed to spread to spaces such as the submandibular, retropharyngeal, and buccal spaces, with the potential to extend to the mediastinum. Management across all reported cases consisted of prophylactic antibiotic administration to mitigate infection risk, and analgesics for pain management. Close patient monitoring was maintained until the emphysema resolved, typically within four to ten days. In addition to emphysema, Merli *et al*. reported instances of tissue swelling, inflammation, and profuse bleeding associated with air polishing.[42] However, it is important to note that the majority of studies report uneventful outcomes[40,43,51-54], suggesting that complications during air polishing procedures are infrequent.

Concerns have been raised regarding residual powder following air polishing procedures. Sygkounas *et al.* demonstrated that air polishing powders, including sodium bicarbonate, GPAP, and EPAP, decreased the viability/density of gingival fibroblasts, periodontal ligament fibroblasts, and epithelial cells. Currently, this observed effect remains limited to *in vitro* studies, with a lack of corroborating clinical evidence. Further research is therefore warranted.[63]

Conclusion

The management of peri-implant diseases remains a significant clinical challenge. Air polishing devices, such as those utilizing GPAP and EPAP, have emerged as promising tools for managing this condition. *In vitro* studies have demonstrated the effectiveness of air polishing in reducing biofilm and bacterial load, with minimal damage to the implant surface. The use of biocompatible powders further enhances the safety and efficacy of this minimally invasive approach. However, while air polishing has shown potential benefits, its clinical efficacy requires additional investigation. Several studies have reported limited success in reducing BoP and PD in both non-surgical and surgical peri-implant diseases treatment.

To establish definitive clinical practice guidelines for the incorporation of air polishing into peri-implant disease management, further research is necessary to evaluate its clinical efficacy and impact on patient outcomes.

Reference

1. Araujo MG, Lindhe J. Peri-implant health. ***J Periodontol*** 2018;89 Suppl 1:S249-S56.
2. Heitz-Mayfield LJA, Salvi GE. Peri-implant mucositis. ***J Clin Periodontol*** 2018;45 Suppl 20:S237-S45.
3. Apaza-Bedoya K, Galarraga-Vinueza ME, Correa BB, Schwarz F, Bianchini MA, Magalhaes Benfatti CA. Prevalence, risk indicators, and clinical characteristics of peri-implant mucositis and peri-implantitis for an internal conical connection implant system: A multicenter cross-sectional study. ***J Periodontol*** 2024;95(6):582-93.
4. Schwarz F, Derks J, Monje A, Wang HL. Peri-implantitis. ***J Clin Periodontol*** 2018;45 Suppl 20:S246-S66.
5. Fragkioudakis I, Tseleki G, Doufexi AE, Sakellari D. Current Concepts on the Pathogenesis of Peri-implantitis: A Narrative Review. ***Eur J Dent*** 2021;15(2):379-87.
6. Ng E, Tay JRH, Mattheos N, Bostanci N, Belibasakis GN, Seneviratne CJ. A Mapping Review of the Pathogenesis of Peri-Implantitis: The Biofilm-Mediated Inflammation and Bone Dysregulation (BIND) Hypothesis. ***Cells*** 2024;13(4):1-16.
7. de Araujo Nobre M, Mano Azul A, Rocha E, Malo P. Risk factors of peri-implant pathology. ***Eur J Oral Sci*** 2015;123(3):131-9.
8. Herrera D, Berglundh T, Schwarz F, Chapple I, Jepsen S, Sculean A, *et al.* Prevention and treatment of peri-implant diseases-The EFP S3 level clinical practice guideline. ***J Clin Periodontol*** 2023;50 Suppl 26:4-76.

9. Jepsen S, Berglundh T, Genco R, Aass AM, Demirel K, Derks J, *et al.* Primary prevention of peri-implantitis: managing peri-implant mucositis. ***J Clin Periodontol*** 2015;42 Suppl 16:S152-7.

10. Latheef P, Sirajuddin S, Gundapaneni V, Mn K, Apine A. Iatrogenic Damage to the Periodontium Caused by Periodontal Treatment Procedures. ***Open Dent J*** 2015;9:203-7.

11. Petersilka GJ. Subgingival air-polishing in the treatment of periodontal biofilm infections. ***Periodontol 2000*** 2011;55(1):124-42.

12. Kamionka J, Matthes R, Holtfreter B, Pink C, Schluter R, von Woedtke T, *et al.* Efficiency of cold atmospheric plasma, cleaning powders and their combination for biofilm removal on two different titanium implant surfaces. ***Clin Oral Investig*** 2022;26(3):3179-87.

13. Flemmig TF, Arushanov D, Daubert D, Rothen M, Mueller G, Leroux BG. Randomized controlled trial assessing efficacy and safety of glycine powder air polishing in moderate-to-deep periodontal pockets. ***J Periodontol*** 2012;83(4):444-52.

14. Petersilka GJ, Steinmann D, Haberlein I, Heinecke A, Flemmig TF. Subgingival plaque removal in buccal and lingual sites using a novel low abrasive air-polishing powder. ***J Clin Periodontol*** 2003;30(4):328-33.

15. Moene R, Decaillet F, Andersen E, Mombelli A. Subgingival plaque removal using a new air-polishing device. ***J Periodontol*** 2010;81(1):79-88.

16. Ng E, Byun R, Spahr A, Divnic-Resnik T. The efficacy of air polishing devices in supportive periodontal therapy: A systematic review and meta-analysis. ***Quintessence Int*** 2018;49(6):453-67.

17. Barnes C. An In-Depth Look at Air Polishing. ***Dimens Dent Hyg*** 2010;8(3): 32,34-6,40.

18. Ichioka Y, Virto L, Nuevo P, Gamonal JD, Derks J, Larsson L, *et al.* Decontamination of biofilm-contaminated implant surfaces: An *in vitro* evaluation. ***Clin Oral Implants Res*** 2023;34(10):1058-72.

19. Amate-Fernandez P, Figueiredo R, Blanc V, Alvarez G, Leon R, Valmaseda-Castellon E. Erythritol-enriched powder and oral biofilm regrowth on dental implants: an *in vitro* study. ***Med Oral Patol Oral Cir Bucal*** 2021;26(5):e602-e10.

20. Stein JM, Conrads G, Abdelbary MMH, Yekta-Michael SS, Buttler P, Glock J, *et al.* Antimicrobial efficiency and cytocompatibility of different decontamination methods on titanium and zirconium surfaces. ***Clin Oral Implants Res*** 2023;34(1):20-32.

21. Tan NCP, Khan A, Antunes E, Miller CM, Sharma D. The effects of physical decontamination methods on zirconia implant surfaces: a systematic review. ***J Periodontal Implant Sci*** 2021;51(5):298-315.

22. Huang YS, Hung CY, Huang HH. Surface changes and bacterial adhesion on implant abutment materials after various clinical cleaning procedures. ***J Chin Med Assoc*** 2019;82(8):643-50.

23. Delucchi F, Ingegnieros L, Pesce P, Baldi D, Canullo L, Bagnasco F, *et al.* Efficacy and safety of erythritol air-polishing in implant dentistry: A systematic review. ***Int J Dent Hyg*** 2025;23(1):44-62.

24. Luengo F, Sanz-Esporrin J, Noguerol F, Sanz-Martin I, Sanz-Sanchez I, Sanz M. *In vitro* effect of different implant decontamination methods in three intraosseous defect configurations. ***Clin Oral Implants Res*** 2022;33(11):1087-97.

25. Alabbad M, Silikas N, Thomas A. Effect of mechanical instrumentation on titanium implant surface properties. ***Dent Mater*** 2025;41(4):383-90.

26. Matsubara VH, Leong BW, Leong MJL, Lawrence Z, Becker T, Quaranta A. Cleaning potential of different air abrasive powders and their impact on implant surface roughness. ***Clin Implant Dent Relat Res*** 2020;22(1):96-104.

27. Bennani V, Hwang L, Tawse-Smith A, Dias GJ, Cannon RD. Effect of Air-Polishing on Titanium Surfaces, Biofilm Removal, and Biocompatibility: A Pilot Study. ***Biomed Res Int*** 2015;2015:1-8.

28. Petersilka G, Faggion CM, Jr., Stratmann U, Gerss J, Ehmke B, Haeberlein I, *et al.* Effect of glycine powder air-polishing on the gingiva. ***J Clin Periodontol*** 2008;35(4):324-32.

29. Drago L, Bortolin M, Taschieri S, De Vecchi E, Agrappi S, Del Fabbro M, *et al.* Erythritol/chlorhexidine combination reduces microbial biofilm and prevents its formation on titanium surfaces *in vitro*. ***J Oral Pathol Med*** 2017;46(8):625-31.

30. Esposito M, Grusovin MG, Worthington HV. Treatment of peri-implantitis: what interventions are effective? A Cochrane systematic review. ***Eur J Oral Implantol*** 2012;5 Suppl:S21-41.

31. Discepoli N, Mirra R, Vesentin C, Marruganti C, Ferrari M. Artificial biofilm removal in a peri-implant mucositis model: Efficacy of air polishing technology as adjunct to ultrasonic debridement alone and impact of the site and the depth of mucosal tunnel-An *in vitro* study. ***Clin Implant Dent Relat Res*** 2022;24(2):242-50.

32. Aimetti M. Nonsurgical periodontal treatment. ***Int J Esthet Dent*** 2014;9(2):251-67.

33. Muller N, Moene R, Cancela JA, Mombelli A. Subgingival air-polishing with erythritol during periodontal maintenance: randomized clinical trial of twelve months. ***J Clin Periodontol*** 2014;41(9):883-9.

34. Hagi TT, Hofmanner P, Eick S, Donnet M, Salvi GE, Sculean A, *et al.* The effects of erythritol air-polishing powder on microbiologic and clinical outcomes during supportive periodontal therapy: Six-month results of a randomized controlled clinical trial. ***Quintessence Int*** 2015;46(1):31-41.

35. Tastepe CS, Lin X, Donnet M, Wismeijer D, Liu Y. Parameters That Improve Cleaning Efficiency of Subgingival Air Polishing on Titanium Implant Surfaces: An *In Vitro* Study. ***J Periodontol*** 2017;88(4):407-14.

36. Tuchscheerer V, Eickholz P, Dannewitz B, Ratka C, Zuhr O, Petsos H. *In vitro* surgical and non-surgical air-polishing efficacy for implant surface decontamination in three different defect configurations. ***Clin Oral Investig*** 2021;25(4):1743-54.

37. Ji YJ, Tang ZH, Wang R, Cao J, Cao CF, Jin LJ. Effect of glycine powder air-polishing as an adjunct in the treatment of peri-implant mucositis: a pilot clinical trial. ***Clin Oral Implants Res*** 2014;25(6):683-9.

38. Riben-Grundstrom C, Norderyd O, Andre U, Renvert S. Treatment

of peri-implant mucositis using a glycine powder air-polishing or ultrasonic device: a randomized clinical trial. ***J Clin Periodontol*** 2015;42(5):462-9.

39. Clementini M, Fabrizi S, Discepoli N, Minoli M, De Sanctis M. Evaluation of the adjunctive use of Er:YAG laser or erythritol powder air-polishing in the treatment of peri-implant mucositis: A randomized clinical trial. ***Clin Oral Implants Res*** 2023;34(11):1267-77.

40. De Siena F, Corbella S, Taschieri S, Del Fabbro M, Francetti L. Adjunctive glycine powder air-polishing for the treatment of peri-implant mucositis: an observational clinical trial. ***Int J Dent Hyg*** 2015;13(3):170-6.

41. Huang N, Li Y, Chen H, Li W, Wang C, Ou Y, *et al*. The clinical efficacy of powder air-polishing in the non-surgical treatment of peri-implant diseases: A systematic review and meta-analysis. ***Jpn Dent Sci Rev*** 2024;60:163-74.

42. Merli M, Bernardelli F, Giulianelli E, Carinci F, Mariotti G, Merli M, *et al.* Short-term comparison of two non-surgical treatment modalities of peri-implantitis: Clinical and microbiological outcomes in a two-factorial randomized controlled trial. ***J Clin Periodontol*** 2020;47(10):1268-80.

43. Hentenaar DFM, De Waal YCM, Stewart RE, Van Winkelhoff AJ, Meijer HJA, Raghoebar GM. Erythritol airpolishing in the non-surgical treatment of peri-implantitis: A randomized controlled trial. ***Clin Oral Implants Res*** 2021;32(7):840-52.

44. Selimovic A, Bunaes DF, Lie SA, Lobekk MA, Leknes KN. Non-surgical treatment of peri-implantitis with and without erythritol air-polishing a 12-month randomized controlled trial. ***BMC Oral Health*** 2023;23(1):1-12.

45. Persson GR, Roos-Jansåker AM, Lindahl C, Renvert S. Microbiologic results after non-surgical erbium-doped:yttrium, aluminum, and garnet laser or air-abrasive treatment of peri-implantitis: a randomized clinical trial. ***J Periodontol*** 2011;82(9):1267-78.

46. Renvert S, Lindahl C, Roos Jansaker AM, Persson GR. Treatment of peri-implantitis using an Er:YAG laser or an air-abrasive device: a randomized clinical trial. ***J Clin Periodontol*** 2011;38(1):65-73.

47. Aloy-Prosper A, Pellicer-Chover H, Penarrocha-Oltra D, Penarrocha-Diago M. Effect of a single initial phase of non-surgical treatment of peri-implantitis: Abrasive air polishing versus ultrasounds. A prospective randomized controlled clinical study. ***J Clin Exp Dent*** 2020;12(10):e902-e8.

48. Berglundh T, Armitage G, Araujo MG, Avila-Ortiz G, Blanco J, Camargo PM, *et al.* Peri-implant diseases and conditions: Consensus report of workgroup 4 of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions. ***J Periodontol*** 2018;89 Suppl 1:S313-S8.

49. John G, Sahm N, Becker J, Schwarz F. Nonsurgical treatment of peri-implantitis using an air-abrasive device or mechanical debridement and local application of chlorhexidine. Twelve-month follow-up of a prospective, randomized, controlled clinical study. ***Clin Oral Investig*** 2015;19(8):1807-14.

50. Sahm N, Becker J, Santel T, Schwarz F. Non-surgical treatment of peri-implantitis using an air-abrasive device or mechanical debridement and local application of chlorhexidine: a prospective, randomized, controlled clinical study. ***J Clin Periodontol*** 2011;38(9):872-8.

51. Toma S, Lasserre JF, Taieb J, Brecx MC. Evaluation of an air-abrasive device with amino acid glycine-powder during surgical treatment of peri-implantitis. ***Quintessence Int*** 2014;45(3):209-19.

52. Toma S, Brecx MC, Lasserre JF. Clinical Evaluation of Three Surgical Modalities in the Treatment of Peri-Implantitis: A Randomized Controlled Clinical Trial. ***J Clin Med*** 2019;8(7):1-12.

53. Hentenaar DFM, De Waal YCM, Stewart RE, Van Winkelhoff AJ, Meijer HJA, Raghoebar GM. Erythritol air polishing in the surgical treatment of peri-implantitis: A randomized controlled trial. ***Clin Oral Implants Res*** 2022;33(2):184-96.

54. Lasserre JF, Brecx MC, Toma S. Implantoplasty Versus Glycine Air Abrasion for the Surgical Treatment of Peri-implantitis: A Randomized Clinical Trial. ***Int J Oral Maxillofac Implants*** 2020;35(35):197-206.

55. Duarte PM, de Mendonca AC, Maximo MB, Santos VR, Bastos MF, Nociti FH. Effect of anti-infective mechanical therapy on clinical parameters and cytokine levels in human peri-implant diseases. ***J Periodontol*** 2009;80(2):234-43.

56. Maximo MB, de Mendonca AC, Renata Santos V, Figueiredo LC, Feres M, Duarte PM. Short-term clinical and microbiological evaluations of peri-implant diseases before and after mechanical anti-infective therapies. ***Clin Oral Implants Res*** 2009;20(1):99-108.

57. Luengo F, Solonko M, Sanz-Esporrin J, Sanz-Sanchez I, Herrera D, Sanz M. Clinical, Microbiological, and Biochemical Impact of the Surgical Treatment of Peri-Implantitis-A Prospective Case Series. ***J Clin Med*** 2022;11(16):1-15.

58. Carcuac O, Derks J, Charalampakis G, Abrahamsson I, Wennström J, Berglundh T. Adjunctive Systemic and Local Antimicrobial Therapy in the Surgical Treatment of Peri-implantitis: A Randomized Controlled Clinical Trial. ***J Dent Res*** 2015;95(1):50-7.

59. Bocchialini G, Ambrosi S, Castellani A. Massive Cervicothoracic Subcutaneous Emphysema and Pneumomediastinum Developing during a Dental Hygiene Procedure. ***Case Rep Dent*** 2017;2017:1-4.

60. Alonso V, Garcia-Caballero L, Couto I, Diniz M, Diz P, Limeres J. Subcutaneous emphysema related to air-powder tooth polishing: a report of three cases. ***Aust Dent J*** 2017;62(4):510-5.

61. Lee ST, Subu MG, Kwon TG. Emphysema following air-powder abrasive treatment for peri-implantitis. ***Maxillofac Plast Reconstr Surg*** 2018;40(1):12.

62. La Monaca G, Pranno N, Annibali S, Vozza I, Cristalli MP. Subcutaneous Facial Emphysema Following Open-Flap Air-Powder Abrasive Debridement for Peri-Implantitis: A Case Report and an Overview. ***Int J Environ Res Public Health*** 2021;18(24).

63. Sygkounas E, Louropoulou A, Schoenmaker T, de Vries TJ, Van der Weijden FA. Influence of various air-abrasive powders on the viability and density of periodontal cells: An *in vitro* study. ***J Biomed Mater Res B Appl Biomater*** 2018;106(5):1955-63.