Air-Polishing in Subgingival Root Debridement: A Critical Literature Review

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Air-Polishing in Subgingival Root Debridement: A Critical Literature Review

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Abstract

Aims: The objective of this literature review was to assess the new powders used in air polishing (AP) for subgingival debridement in terms of their debridement efficiency, effects on oral hard and soft tissues, and adverse effects. Also, to determine the disadvantages of this technique together with other relevant clinical considerations regarding its use.

Methods: A literature search of five databases (PubMed, Scopus, The Cochrane Library, Web of Science, Embase) was conducted. The keywords used were air polishing, air abrasion, scaling, and subgingival debridement. This was supplemented with hand search of the bibliography or reference list of the relevant papers. Studies not reporting the full text in English, or not evaluating AP in the subgingival environment of natural tooth surfaces were excluded.

Results: Of the 65 abstracts screened, 32 studies were included in the qualitative analysis. Several air polishing powders were assessed in terms of their debridement efficiency, effects on oral hard and soft tissues, and adverse effects.

Conclusion: The current literature indicates that AP is a valid, highly efficient, and convenient treatment approach to subgingival debridement. It also appears to be superior to conventional treatment with respect to patient comfort, safety, and time efficiency. Moreover, air polishing with sodium bicarbonate appears to be the most abrasive procedure to both the soft and hard tissues in the oral cavity.

Keywords: Air polishing; Air abrasion; Scaling; Subgingival debridement

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Introduction

Periodontal diseases are strongly associated with the presence of bacterial biofilms and oral calculus on root surfaces [1]. Therefore, control of the oral biofilm and removal of bacterial plaque from all non-shedding oral surfaces is essential in the treatment and prevention of these diseases [2,3]. It is necessary for periodontal patients to receive frequently performed subgingival debridement in pockets with a probing depth ≥ 4mm in order to maintain periodontal health and adequate infection control, and therefore prevent disease progression. This is of great importance since a pre-treatment composition of subgingival microflora can be re-established after several months [4]. Furthermore, regular supportive periodontal therapy is crucial to maintain the balance between the subgingival microbiota and host immune response(s) [5]. The traditional modalities for both plaque and calculus removal involve the use of hand instruments or ultrasonic devices or a combination of both, with comparable outcomes [6]. These have proven to successfully treat most cases of periodontal diseases and the results can be sustained over a prolonged period of time with regular maintenance visits [7]. However, these procedures are both uncomfortable to the patient, technically demanding, and time consuming. It may, also, lead to severe, substantial, and irreversible root damage [8], and gingival recession over time if applied repeatedly [6,9]. Tooth surface loss is one of the major causes of increased sensitivity and may lead to an increased risk of root fracture [10]. Furthermore, cementum, specifically, is necessary for periodontal health, healing, and regeneration, as this is the site of Sharpey's fibers attachment and a source of growth factors [11]. Additionally, repeated instrumentation will inevitably result in loss of attachment in shallow pockets. For treatment that needs to be repeated, time efficiency, high patient acceptance, and minimal tissue damage are essential requirements. Therefore, the use of other more effective treatment modalities in removing plaque with minimal abrasion to root surfaces is preferable [12]. Numerous attempts have been previously introduced to develop or invent new instrumentation techniques, e.g. plastic microbrushes, vector scaling systems, laser, or air polishing devices [13].

Table 1: Characteristics of the main powders used in AP. Acknowledgement 3M™ Clinpro™ Glycine Prophy Powder Brochure

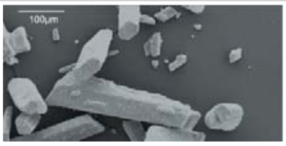
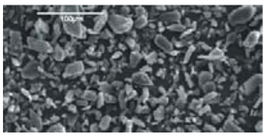
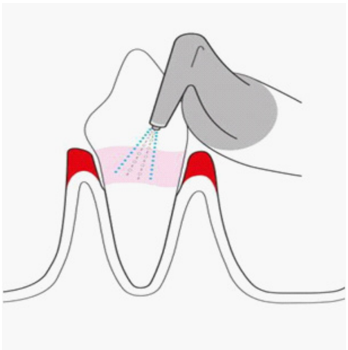
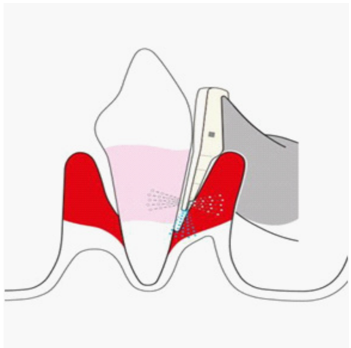
	Sodium bicarbonate	Glycine	Erythritol	Bioactive glasses
Mean particle size	Up to 250 µm	45-60 µm	14-31 µm	1-10 µm
Particle shape	Chiseled and sharp edged	Less chiseled	Extra fine grains	More regular, close to sphere
Defect depth	~50 µm	~2m	Comparable to glycine	No significant surface damage
SEM	 [44]	 [44]		

Table 2: Nozzle designs. Acknowledgment ems-dental.com.

Metal nozzle	Patented single-use nozzle
Made of stainless steel Not flexible	0.7 mm thickness High flexibility
One outlet for air-powder and water	Three horizontal outlets for air-powder mixture located slightly above the tip and one vertical outlet for water at the tip
Jet directed parallel to the long access of the root into the pocket	Jet directed perpendicular to root surface
High flow and working pressure	Reduced flow and working pressure by up to one bar
Not scaled	Millimeter scale (3mm, 5mm, 7mm, 10mm)
 [45]	 [45]

Subgingival air polishing (AP) has been suggested as a simplified alternative approach for root debridement. AP was first introduced to oral practice in 1945 [14]. AP devices utilize kinetic energy to generate a slurry of pressurized air, abrasive powder, and water which flushes away bacterial plaque [15], polishes, and smooths tooth surfaces. It has been reported that this device was more efficient in subgingival plaque removal than conventional debridement procedures since it resulted in approximately 98% reduction in all viable bacterial counts immediately following the procedure [16]. It can, also, remove plaque and stains on enamel surfaces effectively, safely, and conveniently [17]. Moreover, it is more comfortable and time saving compared to conventional modes of debridement, thus, offering more patient compliance and economic benefits [3,15,16,18-20]. Treatment with AP is three times faster than hand instrumentation and requires 31% less time for root debridement instrumentation compared to curettes.

Method of the Review

Aim of the literature review

The objective of this literature review was to assess the new powders used in air polishing (AP) for subgingival debridement in terms of their debridement efficiency, effects on oral hard and soft tissues, and adverse effects.

A literature search of five databases (PubMed, Scopus, The Cochrane Library, Web of Science, Embase) was conducted to assess the scientific evidence on the use of air polishing for subgingival root debridement. The keywords used were air polishing, air abrasion, scaling, and subgingival debridement. This was supplemented with hand search of the bibliography or reference list of the relevant papers. Studies not reporting the full text in English, or not evaluating AP in the subgingival environment of natural tooth surfaces were excluded. In this review, the efficiency of new powders, their effects on oral hard and soft tissues and adverse effects will be discussed. Also, the disadvantages of this technique together with other relevant clinical considerations regarding the use of AP will also be mentioned.

Results

Of the 65 abstracts screened, 32 studies were included in the qualitative analysis (Figure 1).

Discussion

Powders used in AP procedures

From the late 1970s until 2004, a specially formulated sodium bicarbonate powder was the only abrasive powder available. Currently, several air polishing abrasive powders are commercially available. Powder characteristics, e.g. size, shape, and hardness, substantially influence the abrasiveness of the jet stream [21]. Moreover the mode of clinical application, e.g. treatment time, working distance, water setting, powder emission flow rate and pressure, appears to affect the safety and invasiveness of AP procedure on both hard and soft tissues

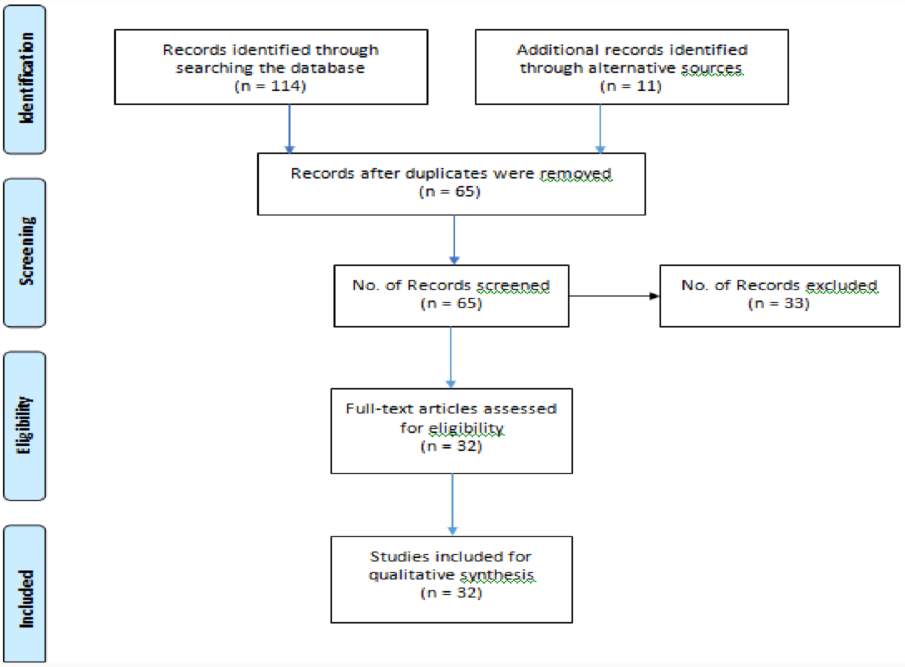


Figure 1: Flow Diagram.

[22]. The amount of powder present in the powder chamber greatly affects powder emission rate and consequently both the effectiveness and efficacy of AP [23]. With use and time, the amount of powder is reduced in the chamber leading to reduction of the powder emission rate. Nozzle angulation did not appear to significantly affect the resultant defect volume or defect depth [24].

Sodium Bicarbonate Based Powders

These are termed the conventional powders and these were the first powders to be used in AP devices [14,25]. Sodium bicarbonate is a non-toxic and water soluble powder. Its crystals have chiseled shape with a mean size up to 250 µm.

Effectiveness

Studies confirmed that sodium bicarbonate AP is both effective and efficient in removing plaque stains compared to conventional scaling [26-28].

Effects on both the hard and soft tissues

The mean particle size and shape of sodium bicarbonate powder has demonstrated AP using sodium bicarbonate was highly abrasive to both root cementum and dentine even within a short application time. Its application however, has been severely limited and even contraindicated on root surfaces, in particular the denuded surfaces, as severe substantial root damage can occur if it is repeatedly performed due to its cumulative effect [29]. The resultant defect may be in excess of 50 µm in depth. In contrast, sodium bicarbonate AP has been demonstrated to be safe on intact enamel surfaces and does not lead to significant surface alterations or tooth surface loss.

Adverse effects

Unpleasant perceptions by the patient and moderate to severe abrasions at the keratin and epithelial layers of the gingiva have been reported [16,30]. The extent of the damage was correlated positively with the exposure time. On the histologic level, biopsies from sites treated with sodium bicarbonate AP displayed a discernible erosion of gingival epithelium with a degree of focal exposure of the underlying connective tissue [13,31]. Moreover the lamina propria showed moderate signs of inflammation. Although all gingival biopsies showed normal structure and uneventful healing 14 days after debridement, application of sodium bicarbonate AP on the gingiva should be avoided to avoid any recession of a thin gingival biotype. Air emphysema has also been reported with the use of sodium bicarbonate AP [32,33]. Air emphysema usually resolves without treatment within 24-72 hours in the otherwise healthy patient and this can occur following the use of any instrument that recruits pressurized air, e.g. high speed hand pieces, air-water syringes, and even impression procedures [33].

Glycine Based Powders

Glycine is a low abrasive amino acid, which consists of non-toxic, biocompatible organic salt crystals that slowly dissolve in water. The abrasiveness of this powder on human teeth is ~80% lower compared to sodium bicarbonate AP. It has approximately one fifth of the abrasiveness on the root surface of the tooth [34]. Therefore, it is softer and infiltrates tissue less than sodium bicarbonate. The mean particle size of glycine crystals is less than 60 µm, which is about four times smaller than that of sodium bicarbonate crystals.

Effectiveness

Glycine AP has been demonstrated to be more efficient in biofilm removal compared to sodium bicarbonate AP, which is more abrasive than glycine in nature. Petersilka demonstrated in a series of studies that AP using this powder resulted in efficient plaque removal when used for subgingival root debridement. Complete plaque removal was achieved *in vitro* within 5-10 s of glycine AP. The authors, also, observed a significant greater reduction in the viable counts of subgingival bacteria immediately after therapy for glycine AP compared to the conventional hand instrumentation. However, this study was performed on pockets no deeper than 5mm (Table 1). A later publication by the same investigators, reported that with the use of this method a median debridement depth of ~2 mm apical to the gingival margin was achieved and that the relative debridement depth decreased with increasing probing depth, leveling off at ~30% in a probing depth of approximately 6 mm or more. Thus, the authors proposed that in sites with probing depth of ≥5 mm, conventional mechanical instrumentation might be superior to glycine AP; but AP was as effective in subgingival biofilm removal as hand curettes or ultrasonic scalers in pockets with probing depth up to 4 mm [34].

Other studies, which also used the low abrasive glycine powder, have used a new nozzle design to allow access to moderately deep pockets (5-9 mm) with minimal force (Table 2) [3,12,18,35]. One study reported significant reduction in bleeding on probing (BOP) and in the number of positive sites specific to periodontal pathogens following treatment with AP or hand curettes but these reductions were more pronounced after hand instrumentation than following subgingival AP. However, these observations were after 7 days of treatment, which was insufficient to allow for the healing of the periodontal tissues. Another study also reported similar microbiological effects of subgingival AP and ultrasonic debridement. Moreover, comparable improvements in BoP, probing depths, and relative attachment level after subgingival AP or ultrasonic debridement were observed. Although the effect on subgingival microflora was relatively short-term, as the figures at day 14 post-treatment were comparable to those prior to treatment, the improvements in the clinical parameters lasted for a longer time period. The clinical results, however, do not appear to be strongly related to the microbiological findings. Hence, it may be suggested that a change in the subgingival ecological environment might occur as a consequence of improved tissue conditions following AP treatment, and this could provide a less favorable environment for the growth of disease associated subgingival microbiota.

A third study, reported that subgingival AP resulted in a significantly lower subgingival total viable bacterial counts compared to hand instrumentation. Also, the reduction in total counts of *P. gingivalis* at day 90 after therapy was still significantly more for full mouth AP compared to hand scaling and root planing [35]. This finding was in contrast to the two previously mentioned studies; this difference may be attributed to the adoption of an additional debridement of the oral cavity using full mouth AP approach in this study. However, no relevant differences in BoP between the two treatments were detected. The investigators therefore concluded that subgingival AP was more efficacious in removing biofilm in moderate to deep pockets when compared to hand instrumentation and that the resultant shift in oral microbiota following full mouth AP was similar to the one observed following a full mouth disinfection approach [35]. A recent 6-months study, demonstrated that the improvement in pocket depths was significantly greater for both hand or ultrasonic instrumentation compared to subgingival AP at all time points. However, the microbiological data from the same study indicated no differences between AP and the other conventional modalities. It is noteworthy to mention that long term maintenance of periodontal patients, for up to 16-months following treatment, revealed no differences in pocket depth between teeth treated with glycine AP or curettes. So, whether glycine AP is superior to hand or ultrasonic instrumentation is a matter of debate from the number of the available studies, but it is more likely to be equivalent or comparable to it.

Effects on tooth structure

This powder causes minimal root substance alterations and significantly less root surface abrasion and roughness than the earlier commonly used sodium bicarbonate. The maximum depth of the resultant surface abrasion did not exceed 2 µm. Root damage was also considerably lower compared to hand, sonic and ultrasonic scalers. No clinically visible changes in the hard tissues following AP therapy were evident. Also, an *in vitro* evaluation of root substance loss following *in vivo* root instrumentation demonstrated that, glycine AP produced the least amount of cementum loss and virtually the greatest retention of residual cementum when compared to hand or ultrasonic instrumentation, however, all methods removed a statistically significant amount of cementum. Moreover, when different particle diameters of glycine powder, 63 µm and 100 µm, were compared, there was no significant difference in the resultant defect volumes of both sizes on root dentine.

Adverse effects

Without the administration of anesthesia, patients described treatment with glycine AP as significantly more comfortable than with hand instruments, or ultrasonic instruments. AP was also the most widely preferred patient option for the next treatment session. No significant gingival damage or other major adverse effects, e.g. gingival recession or increased tooth sensitivity, were observed by the operator or reported by the patients following subgingival AP [3,12,15,16,18,34,35]. This may be attributed to the low abrasive properties of this powder allowing for gentle cleaning of the pocket without harm or major disruption of periodontal tissues and exposed root surfaces, or to the use of a specially designed nozzle that directs the powder air jet perpendicularly towards the root surface thus reducing the flow pressure.

On the histological level, biopsies from sites treated with glycine AP displayed intact gingival epithelial layers with a normal structure of the underlying lamina propria. Only a small number of cases showed signs of mild inflammation. On the other hand, both ultrasonic and hand instrumentation resulted in considerable soft tissue damage. In most cases, curettes had completely removed the epithelial layers leaving the underlying connective tissue exposed. Thus, the histological scores following glycine AP were significantly lower than hand instrumentation or ultrasonic debridement or sodium bicarbonate AP.

Despite the frequently reported safety of glycine powder AP in several studies, Petersilka reported on five cases of air emphysema which appeared to resolve simultaneously within 4 days without further sequelae. Thus, the estimated incidence of emphysema after AP with glycine powders was considered to be remarkably low, ~1 in 666,666 applications [36].

Erythritol Powder

Erythritol has slightly lower abrasiveness and smaller particle size, 31 µm, compared to glycine. It is a non-toxic, chemically neutral, and highly water soluble polyol. It is widely used as an artificial sweetener and as food additive [37].

Effectiveness

Erythritol AP resulted in clinical outcomes comparable to hand or ultrasonic instrumentation when applied using a specially designed nozzle in pockets deeper than 4 mm [19,38], similar to those nozzles used in previous glycine AP studies. Similar improvements in BoP, probing depths, and clinical attachment level following erythritol AP or curettes or ultrasonic debridement, were detected [19,20,38]. Moreover, a recent publication revealed an inhibitory effect of erythritol to some periodontal pathogens, e.g. P. *gingivalis* [39], and another reported lower frequency of sites positive to A. *actinomycetemcomitans* following erythritol AP. However, the microbiological changes following erythritol AP or hand instrumentation or ultrasonic debridement were minor and almost the same. Therefore, erythritol AP may be comparably effective and alternative to hand instruments or glycine AP for removal of both supra- and subgingival soft deposits.

Effects on tooth structure

No hard tissue damage was observed following erythritol AP. Erythritol is also unlikely to cause additional problems in comparison to glycine due to its lower abrasiveness. It may be comparable to glycine regarding the effects on root surface alterations.

Adverse effects

Erythritol AP showed superiority in terms of patient comfort and tolerance compared to hand or ultrasonic instrumentation. No soft tissue damage or adverse events were observed by operators or reported by patients following the procedure.

Bioactive Glasses

Bioactive glasses are biocompatible, non-toxic, non-inflammatory, and non-immunogenic agents. They have the ability to interact directly with living tissues and form chemical bonds. Once the bioactive glass dissolves, it forms a hydroxyapatite or fluorapatite like structure. Natural hydroxyapatite, derived from bone tissue [40], or synthetic hydroxyapatite like compounds, derived from a bioactive glass, such as 45S5, are mainly composed of calcium and phosphorus along with traces of other microelements, e.g. magnesium, sodium, and natrium. It has also been used in pulp therapy, and to treat dentine hypersensitivity and enamel defects. The particles are regular in shape, close to sphere, with a diameter of approximately 1 to 10 µm [40].

Effectiveness

AP with hydroxyapatite was able to remove plaque, tartar and stains on enamel and cementum surfaces [40,41].

Effects on tooth structure

An *in vitro study*, reported that enamel treated with hydroxyapatite AP was almost the same as non-treated enamel. The concentration of calcium and phosphorus was very similar on both specimens. This finding was in accordance with other studies which reported on the safety of AP on sound enamel surfaces. However, on treated abraded cementum surfaces, retention of hydroxyapatite was noticed and confirmed by changes in the chemical composition following AP. Thus, cementum gained substantial benefits and modifications from the treatment. For example, the retention of hydroxyapatite reduced dentine permeability by occluding the open dentinal tubules, subsequently reducing dentinal hypersensitivity [41]. Additionally, the treated enamel and cementum surfaces were covered with a layer rich in hydroxyapatite which was resistant to a water spray. This high saturation of superficial enamel and cementum layers with both calcium and phosphate ions support natural mineralization of the tooth hard tissues. Moreover, cementum surface treated with hydroxyapatite AP demonstrated no damages or cracks although some grooves were evident.

Adverse effects

There are limited data available that have evaluated the effect of hydroxyapatite AP on soft tissues.

Other Powders

Calcium carbonate

Calcium carbonate consists of uniformly shaped spherical crystals with an average size of 45 µm. Although, it is smaller than sodium bicarbonate and very close to the size of glycine particles, it produced defects on root dentine greater than that of sodium bicarbonate [42]. Also, it has modest water solubility and this limits its subgingival application.

Aluminium trioxide

It was introduced as an alternative powder for patients with a sodium restricted diet. However, it is not water soluble and this may complicate its use in subgingival debridement.

No powder

The use of AP devices with water but without powder, in vitro, did not remove plaque on freshly extracted teeth. Therefore, the plaque removal and bacterial reduction effects following AP must be attributed to the abrasive powder.

Disadvantages and Special Considerations

Due to these powders' low abrasiveness, AP alone failed to remove hard calculus deposits and heavy stains on tooth surfaces and this still needs to be removed with more aggressive instruments, e.g. curettes or machine driven scalers. AP could however, remove calculus if it is applied long enough, however, this is not suitable for clinical use. The use of ultrasonic scalers in conjunction with AP was able to remove all calculus deposits on root surfaces. Therefore, a combination of AP for supra- and subgingival debridement and hand- or machine-driven instruments for calculus removal can be adopted. Alternatively, initial periodontal therapy can be performed with hand- or ultrasonic instruments in order to ablate hard and tenacious subgingival calculus. Therefore, AP can be used in the supportive periodontal therapy, since the newly formed subgingival deposits may not have been mineralized between the two maintenance visits. Previous studies have demonstrated that only 4.7% of the subgingival root surfaces were covered with calculus after 3 months of recolonization in instrumented teeth, so, the need for subgingival calculus removal in supportive periodontal therapy seems to be minimal [43-45]. It is noteworthy that the presence of calculus did not significantly impair the subgingival debridement efficacy of AP and subgingival biofilm removal was evident irrespective of the presence of calculus.

White spots on enamel, which may indicate that the surface is hypomineralized, or heavy plaque accumulation, which initiates slight demineralization of the surface, render the area vulnerable to abrasion from AP. AP treatment may, also cause microscopic root surface roughness, but it nevertheless renders the surface intact, unlike conventional instrumentation which leave no cementum in the instrumented area. Thus, it may also be useful to consider applying fluoride after AP which will make the surface more resistant to the erosive effects of the diet and reduce dentine hypersensitivity. Since AP devices entail the use of compressed air, it poses a potential risk of developing air emphysema. However, with the use of specially designed nozzle, no emphysema has been currently reported. Education and training on the correct use of subgingival AP devices is, therefore, important. Moreover, the use of AP may be contraindicated near extraction sites and in cases with extensive loss of bony support and very deep periodontal pockets. AP devices also produce a considerable aerosol effect during the procedure, and this may result in air embolisms. Hence, the use of a high volume evacuation or aerosol reduction device is recommended.

The earlier powders had a high sodium and bicarbonate content, therefore, the use of AP was contraindicated in patients with some medical conditions, e.g. hypertension, renal insufficiency, metabolic alkalosis, and sodium restricted diet, since changes in blood PH, sodium, chloride, and potassium levels might occur. Currently, several powders containing no sodium or small amount of sodium are available, e.g. glycine, erythritol, and bioactive glasses. It is also noteworthy that, regular maintenance and care of the device is essential in order to avoid malfunction or harm to the patient or the operator.

Conclusion

The current literature indicates that AP is a valid, highly efficient, and convenient treatment approach to subgingival debridement. The procedure also appears to be superior to conventional treatment with respect to patient comfort, safety, and time efficiency. Long term studies on the microbiological effect and clinical performance of repeated subgingival AP are, however, lacking and it would be of great value to compare this modality to conventional treatment or other novel approaches of biofilm removal. The impact of full mouth AP approach on long term microbiological and clinical outcomes, also, remains to be assessed. A further study on the effects of air polishing on both the sulcular and junctional epithelium is also of interest in order to have a comprehensive and meaningful understanding of this mode of debridement. Furthermore, the long-term safety of both hard and soft tissue following AP need to be studied.

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