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The special role of prophylaxis powder in professional mechanical plaque removal – because powder isn't simply powder

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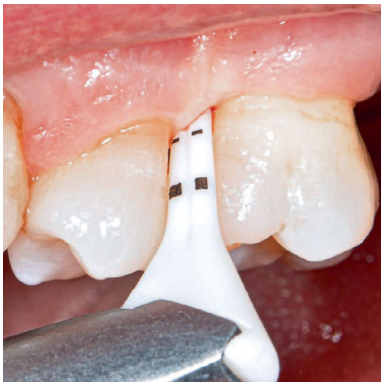

QUINTESSENCE PUBLISHING

Prevention at the ultimate level – the all-rounder

Manufacturer: EMS, Electro Medical Systems GmbH
Product: Prophylaxis Powder Airflow Plus

As a pioneer in state-of-the-art biofilm and dental calculus management, EMS relies on innovative solutions to make oral prevention with the “Guided Biofilm Therapy” (GBT) protocol minimally invasive, efficient and comfortable for both patients and practitioners. A key component of the GBT protocol is the patented, erythritol-based prophylaxis powder Airflow Plus Powder developed by EMS. In perfect harmony with the Airflow Prophylaxis Master as well as the Airflow Max and Perioflow handpieces, this high-tech powder gently and completely removes biofilm and discoloration from oral surfaces. The company‘s own powder production facility and two in-house chemical labs for chemical engineering and biomedical development with 45 employees in Switzerland and Germany guarantee the safety and high quality of the Airflow Plus powder. This enables predictable, safe, efficient and convenient supra- and subgingival biofilm management during GBT treatment.

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Indices

Professional prevention, air-water-powder devices, powder, "Air flowing", "Guided biofilm therapy" (GBT)

Summary

Within the context of professional prevention, biofilm should be removed as completely and as gently as possible. This is achieved with a systematic clinical protocol and with instruments and materials according to current state-of-the-art practice, science, and technology. This paper focuses on the chemical, physical and clinical characteristics of powder products used for air-water-powder devices in the context of professional prophylaxis protocols. "Air flowing" is a technically highly advanced version of this concept which has been documented in studies. This consists of the effective and tissue-sparing use of an optimized powder with compatible devices and instruments. It forms part of the "Guided Biofilm Therapy" (GBT), a modular and systematic clinical protocol from EMS (Nyon, Switzerland) for primary, secondary, and tertiary prevention.

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Introduction

The World Health Organization (WHO) has identified oral diseases as a key health problem and included them in the priority list of non-communicable diseases[33]. The background is their impact on the life expectancy and quality of life of affected patients and the high economic costs for their treatment and prevention. Etiological links are increasingly being recognized, for example between periodontitis on the one hand and cardiovascular disease and diabetes on the other[15,27]. Furthermore, it is known that the oral and pharyngeal mucosa plays a central role in addition to the nose as an entry point for viral infections, to give an example. Oral inflammation could therefore weaken resistance to respiratory infections, including SARS-CoV-2[13]. Links have also been identified between periodontitis and pneumonia, asthma and chronic obstructive pulmonary disease (COPD)[24].

It therefore follows that a healthy oral cavity is also of great importance for health in general. To achieve oral health, both local and systemic risk factors, such as diet, can be controlled[29]. Dysbiotic biofilm is the key etiological factor for both caries as well as periodontitis[16,17,28].

Professional prevention: the development of "Guided Biofilm Therapy" (GBT)

In the second half of the last century, it was already demonstrated that both caries and periodontitis, being biofilm-associated oral diseases, can be prevented or their incidence significantly reduced with continuous professional prevention1,5. The basis of the "prevention session" consisted of explaining the causes of the disease, establishing oral hygiene skills and giving careful oral hygiene instructions.

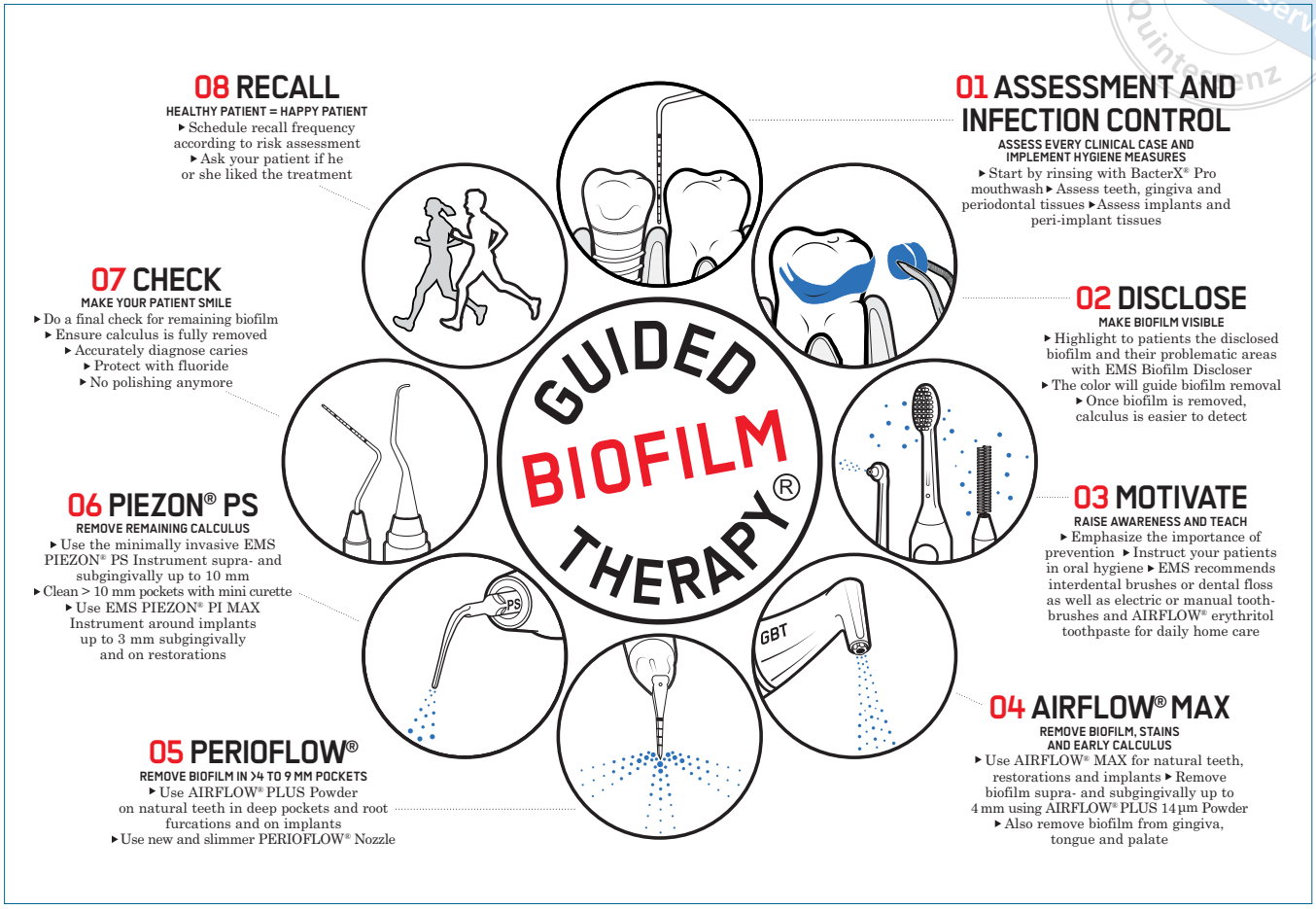

Fig. 1 "Guided Biofilm Therapy" is a modular clinical protocol for systematic and risk-adapted primary, secondary and tertiary prevention (all images courtesy of EMS, Nyon/Switzerland).

An additional major component was the mechanical removal of hard (dental calculus) and soft plaque (biofilm) from teeth and restorations.

Nowadays, systematically conducted professional prevention or tooth cleaning (PMPR) is an oral medical service recognized by science and practice, and performed as standard according to guidelines[28]. However, a study conducted by the German consumer protection organization, Stiftung Warentest, in dental practices indicates that the results with normal use are not comparable to the clinical standard[31]: the interproximal biofilm was mostly not removed completely. In addition, rotary instruments and pastes are often used for dental cleaning. These make it difficult to remove biofilm, as it can only be accessed to a limited extent in fissures or around orthodontic brackets for technical reasons.

For these reasons, EMS (Nyon, Switzerland) developed the clinical "Guided Biofilm Therapy" protocol (GBT[4]; Fig. 1) in close collaboration with experts from academia and practice.

This involves a modular, systematic and risk-adapted clinical protocol for primary, secondary and tertiary prevention. It can be considered to be a modern version of Axelsson and Lindhe's "prevention session" – with an extension of indications to the subgingival area and thus for the prevention and treatment of periodontal and peri-implant inflammation.

The original method is significantly improved by using special powders and powder jets to remove the biofilm ("Air flowing")[10]. The following paper explains the requirements for the powder products, devices and handpieces used, as well as the technical features that are important for their clinical use in the indications mentioned.

Powder requirements

Same as with the original "Air polishing", the technology is based on the acceleration of powder and water using compressed air.

The resulting kinetic energy causes the accelerated powder-water mixture to impact on the surface to be treated. The powder used, the device and handpiece with nozzle and the type of clinical application act in synergy to achieve the maximum effect.

The powder plays a special role here. The assumption that this consists of spheres identical in size is not correct. The efficacy, biocompatibility and efficiency of prophylaxis powders are also determined by a number of chemical and physical characteristics:

1. Powder usually displays a random geometry which only partially resembles a sphere. This also applies to products offered as "pearls" (Figs. 2 to 4).
2. Powders have different average particle sizes depending on the indication. The smaller the particles, the lower the momentum – with a correspondingly more gentle experienced effect on hard and soft tissue. The impact of large particles is perceived as unpleasant or painful.
3. All powder products have a size distribution, in other words, particles of different sizes. These can increase the abrasive effect on impact with the surface – even when the average value is basically good.
4. The desired particle size can be achieved with individual or an agglomerate of small particles. This can also influence the abrasive effect.
5. For example, the material used for the powder can influence whether it can act as a nutrient for bacteria. This is of crucial importance in subgingival application.
6. The material also determines the density and therefore the specific weight of the powder used (Fig. 5). The heavier a particle is for a given size, the more damage it can cause on impact with a surface.
7. Hardness is a property that has a major influence on the surface of materials. Harder particles generate fractures more easily on the target surface and cause a loss of tooth substance (Fig. 6). The hardness of prophylaxis powders should therefore be optimized to effectively remove biofilm and discoloration without damaging the enamel or dentin. Powders with hard surfaces can also lead to damage of the devices and instruments used for treatment (e.g. handpieces) (Fig. 7).

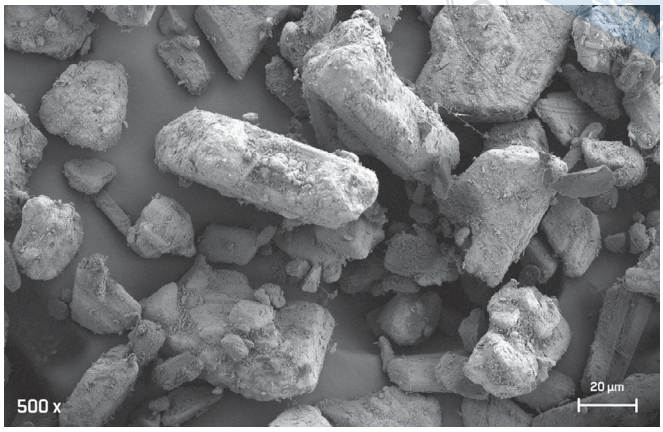

Fig. 2 Prophylaxis powder based on sodium bicarbonate for optional application in case of severe discoloration (Airflow Classic Comfort, EMS). The average particle size is 40 µm (SEM image at 500x magnification).

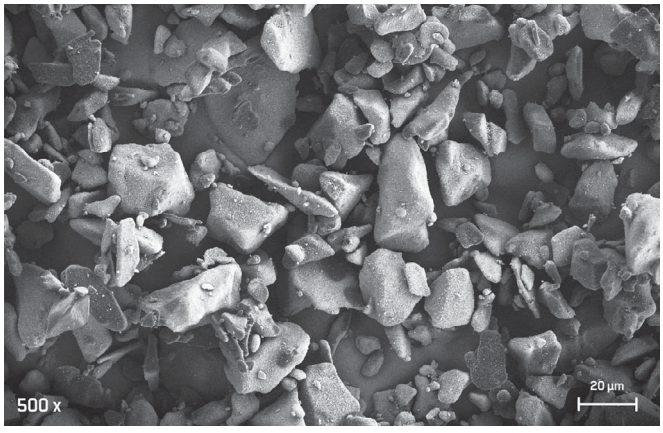

Fig. 3 Prophylaxis powder based on erythritol for universal application in oral prevention including subgingival indications (Airflow Plus, EMS). The average particle size is 14 µm (SEM image at 500x magnification)..

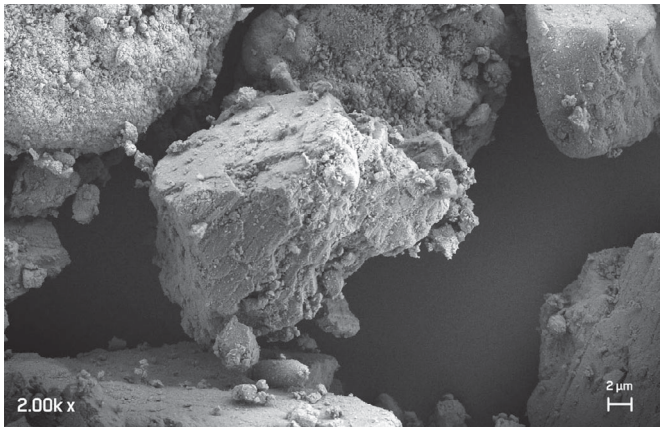

Fig. 4 Prophylaxis powder based on calcium carbonate ("pearls"). The average particle size is 45 µm and, despite the product name, the particles are not round but heterogeneous in shape (SEM image at 2,000x magnification)..

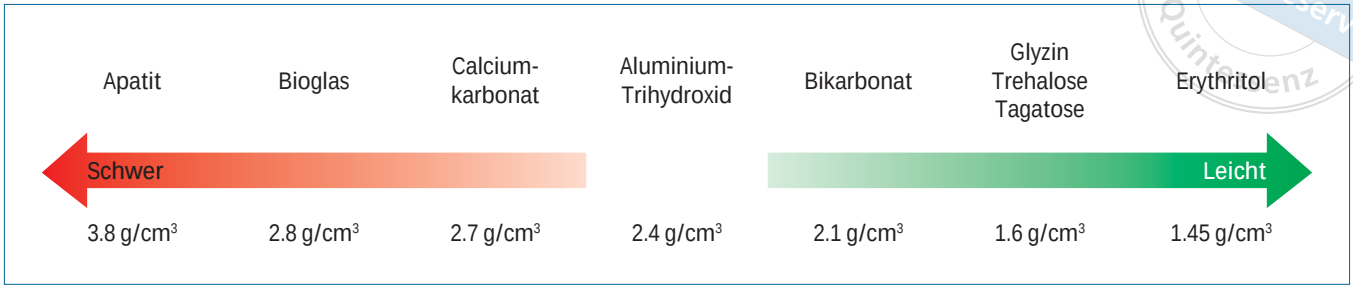

Fig. 5 Density of different powder types used for prevention, removal of discoloration or subgingival biofilm management.

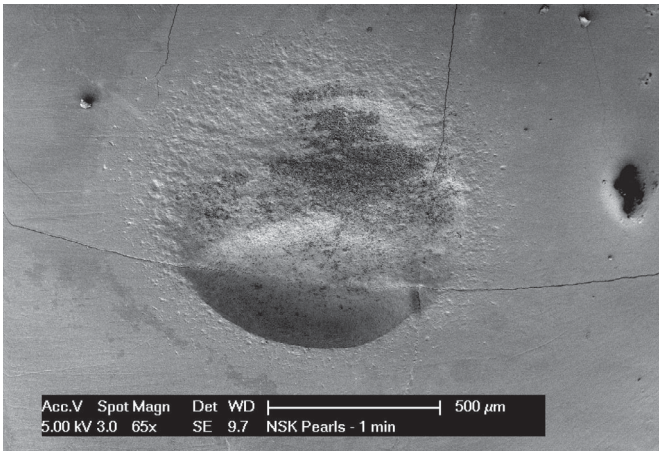

Fig. 6 Damage to an enamel surface after application of the calcium carbonate powder depicted in Figure 4 (SEM image at 65x magnification).

Fig. 7 The powder used must be perfectly matched to the instrument to ensure patient safety and a long service life. The image depicts the damaged nozzle of an Airflow handpiece after using a powder coated with apatite (see Fig. 5).

8. To provide good patient comfort, the powder should be of acceptable taste.
9. The powder must be biocompatible and thus harmless when it is swallowed or comes into contact with the skin.
10. Furthermore, the powder must not cause any problems in the lungs when inhaled. In addition to excluding systemic or cell toxicity of the material, this property can be achieved by using a water-soluble powder. Should powder particles reach the lungs, they are absorbed, thus avoiding long-term risks.

These 10 properties form the guiding framework for the development of prophylactic powders. As changing a single parameter can influence the others, this poses a major challenge. On the other hand, this represents an opportunity, as the product properties can be fine-tuned in this way. The complexity of the various properties mentioned above also explains why no two identical powders can be found on the market: Differing development approaches can never achieve exactly the same properties.

Specifying the basic characteristics of the powder, defines its final functionality. Only then can the desired clinical properties be achieved. For example, flavors, preservative additives and flow enhancer are added for this purpose. Flow enhancers perform an important function in the case of water-soluble powders by preventing clumping at high humidity. The device can therefore continue to operate well even after a functional interruption.

Amorphous, hydrophobic silicon dioxide is used for this purpose. This is responsible for the hydrophobic behavior of an otherwise readily soluble material. It is only absorbed on the surface of the powder particles and separates from the powder during application. This liquefying and protective material is also selected for its good biocompatibility[19,25].

Device requirements

The crucial component for the operation of a prophylaxis device for "Air polishing" or "Air flowing" is the powder chamber. While the device builds up the pressure required for kinetic acceleration, the powder chamber charges the incoming air with powder. Another factor to ensure optimum function is the amount of powder delivered to the treatment field: if this is too low, the biofilm is not removed effectively, and treatment is not successful. However, if the amount of powder is too large, this leads to accumulation which inhibits the flow of powder and the desired standardized impact of further particles.

In other words, there is a corridor for the amount of powder that must be adhered to for effective treatment.

A uniform powder flow contributes to keeping powder consumption lower and therefore more economical and making treatment predictable and comfortable for both practitioners and patients (Fig. 8). There is no need to pay attention as to whether too much or too little powder flows from the device at any given time[10]. This allows full attention to be focused on the biofilm areas currently being treated. In addition, the consistent flow of powder makes it easier to control the aerosol generated when using the devices[11].

Another benefit is that there are no interruptions during the prevention session, for example due to refilling with

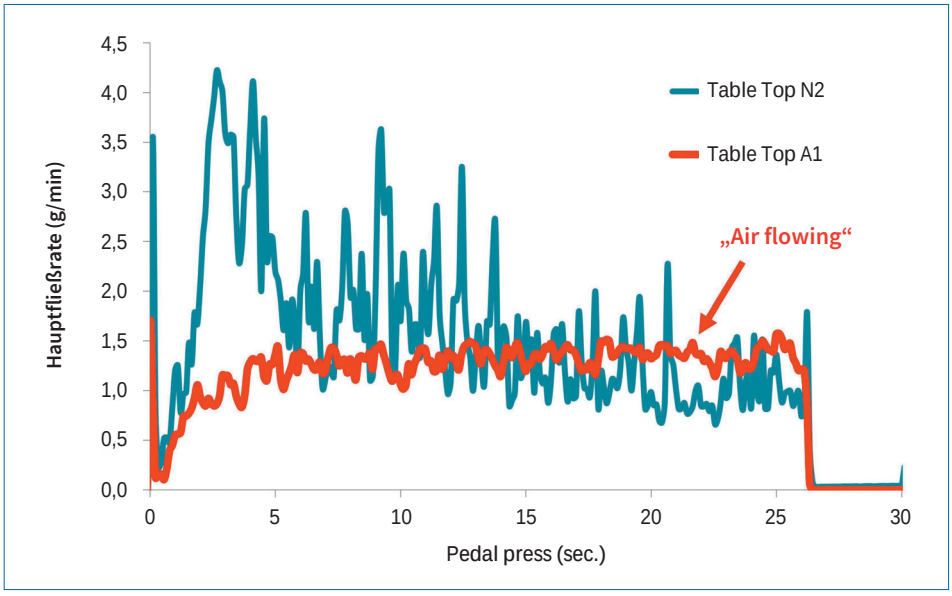

Fig. 8 Powder fluctuations with standard air-water-powder devices (table top): only the device compatible with "Air flowing" (see Fig. 10) with its specifically designed powder chamber (Fig. 11) guarantees a consistent flow of powder[10].

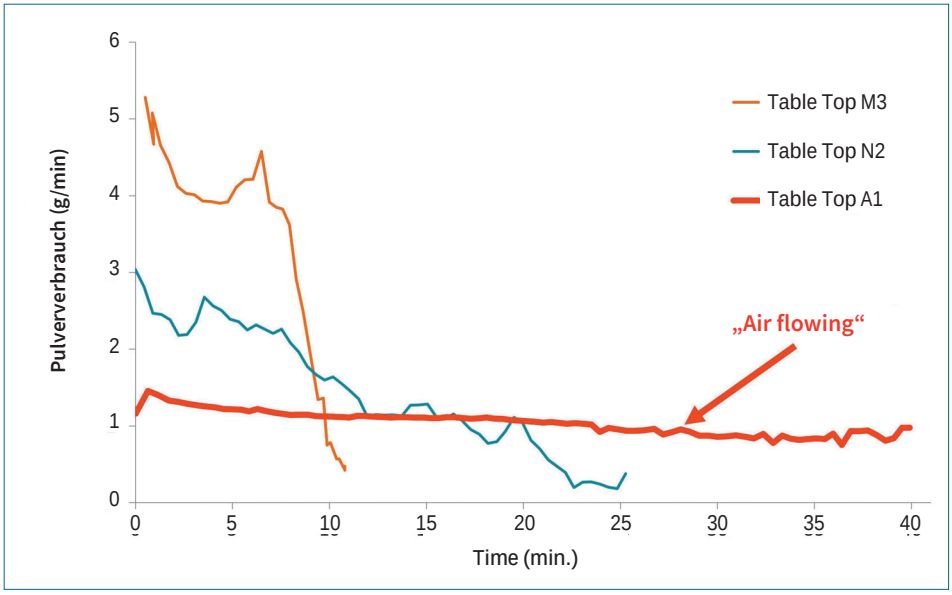

Fig. 9 Up to four patients can be treated with the Airflow Prophylaxis Master (AFPM, EMS), a maximum of two patients with other products[10].

Fig. 10 The combination of the air-water-powder component of the AFPM with Max or Perioflow handpiece and Plus powder enables the patented "laminar airflow technology".

Fig. 11 The consistent and efficient powder flow achieved with "Air flowing" is significantly supported by the powder chamber of the AFPM (see Figs. 8 and 9).

powder. To ensure an efficient practice workflow, a device with a powder supply for half a treatment day is more favorable than a product which can only treat a maximum of one patient (Fig. 9). At present, only devices with an "Air flowing" capability meet the requirements for a continuous powder flow and a longer operating time without refilling[10] (Figs. 10 and 11).

Handpiece requirements

Next to the device and the powder chamber, the handpiece also plays an important role. The nozzle at the end of the handpiece regulates the velocity at which the air-water-powder mixture performs its selective cleaning task. A water channel is routed to the end of the nozzle. This creates an envelope of water around the accelerated air-powder mixture. Water reduces the amount of particle dust generated after impact with the surface. Furthermore, it removes impinging particles so that the subsequent accelerated particles are presented with a clean surface.

Due to the fine nozzle opening and the velocity of the air-powder outlet, the water envelope is reduced to fine droplets which effectively shield the air-powder mixture against its environment. If this conversion into droplets is poorly executed technically, then the nozzle sprays the mixture far into the treatment area. This is unpleasant for practitioners as many of the droplets end up on the glasses making it difficult to see, as well as for patients whose faces get wet. Furthermore, this requires additional attention to personal protective measures to avoid contamination with pathogenic microorganisms including viruses[11]. In a further developed handpiece (Airflow Max, EMS), 6 water channels with a small diameter are arranged in such a manner that they atomize the water in a small laminar jet approx. 1 mm in front of the nozzle ("laminar airflow technology"). As a result, the droplets are produced more regularly and evenly than with other commercially available handpieces. This in turn leads to improved visibility and also makes suctioning easier.

At the powder level, the air flow is the driving force for accelerating the particles. As a rule, the nozzle has a chan-

nel with a small cross-section to provide maximum acceleration of the air and thus impart velocity to the particles. This resulted in a certain amount of noise at the transition to the outside air. In the latest generation of nozzles, the sound barrier has been shifted to the inside using a special geometry (Fig. 12). This makes treatment more comfortable for practitioners and patients (Fig. 13) – while maintaining the same level of effectiveness[10].

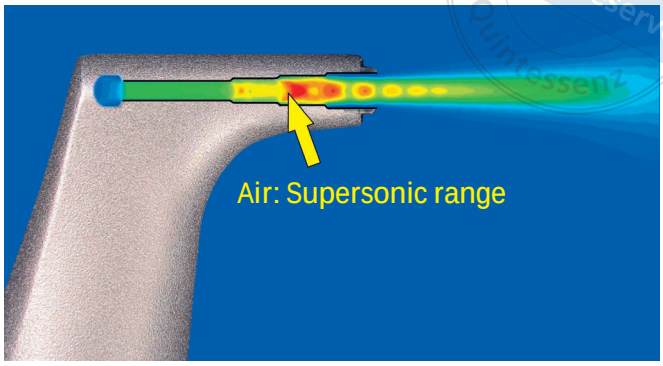

Fig. 12 Simulation of the airflow in an optimized handpiece (Airflow Max): the highest acceleration is in the supersonic range (600 m/sec.; see red coloring). This takes place inside the handpiece – with a correspondingly reduced noise level.

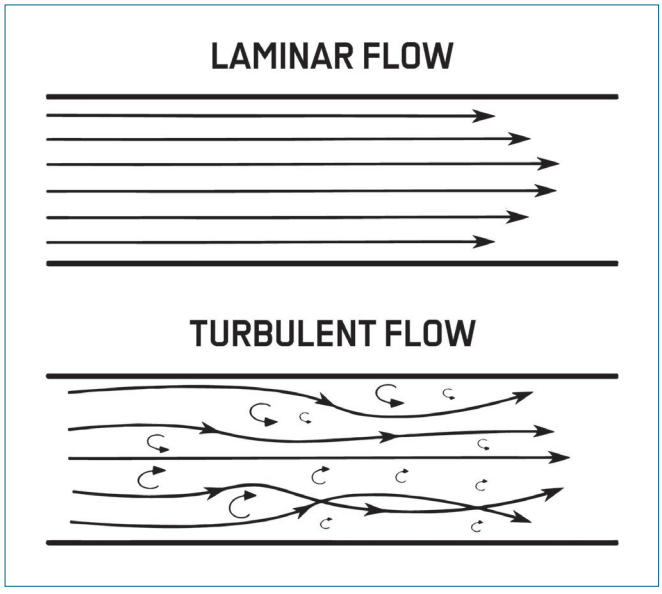

Fig. 13 With the patented "laminar airflow technology", the air-water-powder mixture exits the nozzle at a regulated and constant flow rate (see Fig. 9). This makes biofilm management more efficient and more comfortable for patients.

The magic of powders – cleaning mechanisms

The powder particles accelerated at the outlet of the nozzle ensure that the surface is cleaned through the impact. Here, the effect of the particles depends on the angle of incidence. The tangential angle of incidence of the powder allows deposits to be "sheared" from the surface. Furthermore, a high number of particles should impact the surface continuously and without fluctuations in quantity. In this case, the number of pulses is so large that the particle jet removes the biofilm from all oral surfaces quickly, effectively and gently. The duration of the application, the power setting and the water supply are also important for the effectiveness and tissue protection during treatment.

Very small particles are not noticeable when they impact soft tissue and can be used safely[6,7]. The "magic" of highly developed powders is therefore based on the duality of a very small particle diameter and a large number of particles. One example for such a product is an erythritol-based powder (Airflow Plus, EMS) with an average particle size of 14 µm. Erythritol is a slightly sweet-tasting sugar alcohol with caries-inhibiting properties[9,22,23]. After the application of biocompatible powders with a small particle size, processing with rotary instruments and pastes is no longer necessary due to the minimal surface changes[24]. This also holds true for dentin when applying Airflow Plus[8].

Indications and clinical effectiveness

To protect hard and soft tissues, but also restorations or orthodontic appliances, the correct indication-related selection of the powder product is of great significance2,3 (see Fig. 6). Valuable tooth substance can otherwise be lost, particularly on dentin surfaces in the area of tooth necks or subgingivally after removal of cementum.

Originally, air-water-powder systems were developed for invasive cavity preparation and later used primarily to remove discoloration. Sodium bicarbonate-based powders are still commonly used for the latter indication, but these may only be used on enamel due to their relatively high abrasiveness. Defined application is not always easy to ensure clinically on small surfaces.

A paradigm shift was the development of glycine-based powders that can be used both supra- and subgingivally in periodontal plaque removal[12,21].

The last step for the time being was to develop sugar alcohols with low abrasiveness. Studies using the erythri-

Fig. 14 Clinical application of "Air flowing" on an orthodontic patient: compared to rotary rubber cups and paste, the air-water-powder mixture cleans more effectively.

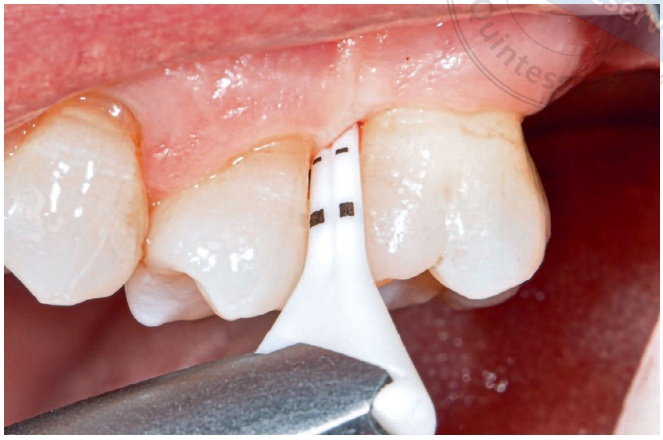

Fig. 15 Clinical application of Perioflow: special handpieces and instruments can be used for deep subgingival pockets around teeth or implants, also in combination with Airflow Plus powder.

tol-based Airflow Plus powder discussed above show that this product, in combination with compatible devices and handpieces ("Air flowing"), is indicated for biofilm removal in the majority of supra- and subgingival indications and is very well tolerated by patients[18,20,26,30,32] (Figs. 14 and 15).

Author's declaration

Dr. Marcel Donnet is a chemical engineer and works as an expert in powder technology and fluid mechanics in the EMS Research Department.

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