Toothbrushing efficacy

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Chapter 1

General introduction
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Os sanum in corpore sano. A healthy mouth is considered to be part of a healthy body (1). However, this consideration is most likely true primarily from the perspective of the dental professional. Professionals possess the knowledge on how diseases interact. Over the years research has indicated that oral health is related to other health conditions in the human body (2). An important intervention to keep the mouth healthy is to practice adequate daily oral hygiene primarily through toothbrushing. The general population however may have completely different motives regarding the reasons for toothbrushing. When asked, objectives may vary from a need for fresh breath, clean teeth and a dentition free of food remnants or other reasons related to cosmetic rather than preventive dental health reasons (3). As long as there are no serious complications in the individuals’ oral cavity the above mentioned motivations and regular toothbrushing are sufficient. Reasons for toothbrushing may alter when a dental disease emerges and the patient has to upgrade the level of personal oral hygiene to prevent further progress of the disease and to re-create a healthy oral condition. Under these circumstances one has to perform oral hygiene beyond his habitual level, and may need to spend double or triple the amount of time needed to perform the daily oral hygiene routine (4). In order to obtain this level of oral hygiene by the patient, an interaction between the oral care provider and the patient is needed to facilitate the process of better self-care (5).

Improvements in oral hygiene performance can be expected from the individual who uses the product optimally, commonly as a result of the oral care provider’s advice. On the other hand, oral hygiene products themselves are constantly and consistently under development as well. With regard to toothbrushes for example, progress in development has taken place over the past decades from basic straight flat trimmed manual toothbrushes into colourful, ergonomically shaped, multilevel or cross-angled, and powered toothbrushes with varying modes of action (6-9). Manufacturers often test new products against competitors or predecessors and may report their findings in scientific journals. When products are compared research usually mentions whether the observed difference was statistically significant. A more important question in clinical research may be whether an observed statistical significant difference is above all clinically relevant. The first implies that the observed difference is not based on chance, the latter considers whether the observed difference is of such magnitude that it has clinical merits. The interpretation of incremental data in respect to clinical relevance is in principal an arbitrary decision based on clinical expertise.

It is believed that toothbrushes, or devices to clean teeth, first appeared around 3500 BC and that they were used by Egyptians and Babylonians (10). Usually wooden sticks were chewed on in such a way that teeth were cleaned. Later, the branches of the Arak tree, or *Salvadora persica*, were used to chew on until one end of the stick turned into a fibrous end. This brush-like end was then used to clean the teeth and is often called a miswak, siwak or something similar, depending on geographical location. In some countries this kind of natural brushes are still commonly used and may, surprisingly, provide superior results to those reported for a modern toothbrush (11). However, the chewing stick with bristles parallel to the ‘handle’ has its limitation and does not appear as useful for the lingual aspect of the teeth when compared to the vestibular areas.
Manual toothbrushes, in their current shape, with bristles or filaments placed perpendicular into one end of a handle, may find their origin in China approximately 1000 years ago. More recent archaeological excavations in Africa also report on toothbrushes having similar shapes. It seems however that, irrespective of the continent, the use of natural products such as wood, bone, and ivory were commonly used to create handles in which natural hairs from boars, pigs, horses or other animals were inserted. It was not until the 17th century that the toothbrush was introduced in Europe by travellers returning from their journeys to the east. Because of the high costs in those days toothbrushes were not available for everyone and specifically the upper class distinguished themselves by means of personal oral care. An outspoken example of a chic toothbrush is the ‘gold plated, horsehair bristled’ toothbrush which has supposedly been used by Napoleon Bonaparte (fig 1).

A small step for toothbrushes, but a giant leap for brush kind, was the introduction of the nylon filament by DuPont in 1938. As nylon, in contrast to the natural filaments, could be easily mass produced, toothbrushes were gradually fitted with nylon filaments. Handles have also changed from the use of natural products into using the nowadays more common thermoplastics. As a result of a decreasing price tag toothbrushes became available for the general population. It took however a few more decades until, at least in the western countries, almost everybody owned a toothbrush. Over the past four decades great effort has been put into further development of toothbrushes. Originally, the handles were straight and flat. Nowadays, ergonomically shaped and curved handles have been designed to enhance the users’ performance by providing easier access hard to reach areas (12). The brush heads have also been subject to changes to improve toothbrushing efficacy and/or the patients’ comfort. Brush heads originally had a rectangular shape. Current, oval shaped and various other creatively shaped brush heads are available (6-7). Furthermore, modern filaments also had their share in toothbrush development. End-rounded, crimped, tapered and splayed filaments ranging from hard to soft have been proposed (13-14). The most basic toothbrush is flat-trimmed, meaning that all filaments are of the same length and usually inserted perpendicular into the handle. With regard to more sophisticated brushes the insertion angle of the filaments into the handle may vary (not being 90°) which can result in a ‘cross-angled’ design (15). Other brushes have ‘multi-levelled’ filaments which means that multiple filament lengths are used within the same brush head (16). Consequently, there have been numerous investigations regarding the efficacy of new features resulting in an overwhelming variety in toothbrushes which are available alongside the, until this day, still manufactured natural brushes.

Parallel to the above described development of manual toothbrushes the introduction of powered toothbrushes in the 1940’s can be considered as another step forward when it comes to toothbrushing effectiveness. As many manual devices have their electric counterparts, also toothbrushes were to become ‘powered’. It took however more than half a century after the very first powered toothbrush was introduced until these oral hygiene products were accepted by the dental society and considered to be safe (17). Forerunners of today’s powered toothbrushes were connected to a power outlet by
wires and especially for handicapped and elderly this was considered a safety risk. In many countries legislation also required an in-built step-down transformer for safety reasons and decades passed until some powered toothbrushes were judged being safe to use in the bathroom and being more effective as compared to manual brushes.

The early powered toothbrushes can be considered as mechanized manual toothbrushes. Power brushheads were similar in shape as manual brushheads and the mode of action mimicked the movement as applied with a manual brush. An electromotor was used to convert electric energy into a mechanical action which was then transferred to a shaft that propelled the brushhead. Gradually powered toothbrushes were equipped with batteries (disposable or rechargeable) and lost the electricity wires. Ever since, further development to increase efficacy in plaque removal consisted of changes relatively similar to the above described development seen for manual brushes. Different brushhead designs, alterations in filament arrangement, increased speed and/or other motions, and compliance enhancing features have all been under review in order to improve the results obtained from powered toothbrush use (18). This has resulted in a variety of powered toothbrush types with different power supply, applying different modes of action such as sonic, ultra-sonic, rotating, counter-rotating, oscillating-rotating, back and forth, and side to side (19).

As mentioned before, reasons for using oral hygiene products vary among individuals. Basically one would use anything available that is suitable to remove some annoying pieces of food debris stuck in between teeth. However, research has shown that not only food debris may have a negative influence on the oral tissues. Bacteria also play an essential role and the presence of these bugs on teeth was first discovered by Van Leeuwenhoek in the 17th century. After he scraped plaque off from his teeth he could actually see the ‘small animals’ through his self-made microscope. These ‘small animals’ are now called bacteria which can be divided into clusters or groups according to several characteristics such as mobility, shape, metabolic properties, or common bits of DNA (20-22). Over the years the number of species which possibly can be found in the oral cavity has increased. This is mainly a result of improved process and detection techniques which made it possible to further differentiate between species (23). It is unlikely however that one individual will host all of the possible bacterial species. Usually humans harbour common clusters of bacteria which can be found in the oral cavity in a biofilm. In a biofilm many of these bacteria can be considered relatively harmless to oral tissues and may act in a complex which forms one of the first lines of defence of the human body towards unwanted intruders such as viruses and fungi (24-25).

Some bacteria may cause unwanted effects when not effectively and periodically removed. Centuries have passed until it was understood that bacteria could cause oral diseases such as caries and periodontal disease. In the 1960’s it was shown that an inflamed situation of the gingival tissues could be experimentally induced in individuals with a healthy gingiva by cessation of all daily oral hygiene procedures. This classic experimental gingivitis study by Löe et al. (1965) showed that the quantity of bacterial dental plaque and the degree of gingivitis was highly related. It was also shown that this inflammation was resolved when the dental plaque was removed and for a consecutive period of time
good oral hygiene was maintained. Thus, a superficial inflammation of the gingival tissues seems to be reversible (26).

However, in man a great variety in the degree of gingival inflammation has been observed in response to a certain quantity of plaque (27). Some individuals can withstand more plaque than others until gingival inflammation will develop (28). To what extend this varies is still not completely unravelled, however it has been shown that higher levels of oral hygiene are associated with a healthier periodontal condition. A review study by Van der Weijden & Hioe (2005) concluded that in adults with gingivitis the quality of habitual self-performed mechanical plaque removal using a manual toothbrush is not sufficiently effective (29). If the level of oral hygiene is not sufficient there is a higher risk for gingivitis to develop. If gingivitis is not resolved there is an increased risk of further development into periodontitis which affects not only the soft tissues surrounding the teeth but also the supporting tissues. For the long term prognosis it was stated by Lang et al. (2009) that gingivitis is a risk factor for tooth loss (30). Thus the need for good oral hygiene to prevent or resolve inflammation is established. The goal of toothbrushing is therefore to reduce the biofilm to such an extent that the host’s defence system is capable of maintaining a healthy condition of the teeth and gums.

Unfortunately, the majority of the world’s population does not perform oral hygiene at a required level which prevents the periodontal tissues to become inflamed. This can be the result of poor technique, short duration or insufficient frequency of brushing or a combination of these. The average performance with respect to plaque removal after a brushing episode in general is quite poor. A systematic review by Slot et al. (2012) reported a 42% plaque score reduction using a manual toothbrush based on 212 unique experiments and showed an increase in efficacy when the available time to brush was elongated (7). The problem however is that the average time used for toothbrushing hardly reaches the often recommended 2 minutes. Studies assessing brushing duration report average brushing times ranging from 45 sec to 90 sec (31-32). Therefore people should be encouraged to brush longer and reach with the brush all surfaces of the dentition.

Given the fact that a proportion of plaque will remain present on the teeth after brushing and that only a very small part of the population seems to be resistant for periodontal disease the risk of the development of gingival inflammation can be considered as substantial. Numerous studies have been performed in order to investigate the prevalence of gingival inflammatory diseases. The observed prevalence of periodontal disease may vary depending on factors such as population, level of dental care, geographic location, and the method of measurement (33-36). A large part of the world’s population is at risk of oral disease. The primary goals of dental professionals are to cure and prevent oral diseases by stimulating the motivation of patients for self-care and by providing the tools, the skills, and the knowledge which are required for a healthy dentition.

This thesis will explore the most meaningful aspects which are considered to be of interest regarding the efficacy of toothbrushes. One could discuss efficacy by means of plaque removal as well as by
means of the effect on gingival inflammation. Plaque removal may be considered as a surrogate effect whereas effects on gingival inflammation can be considered more as an effect related to oral health. Some of the following papers in this thesis focus on instant effects such as plaque removal and may also assess gingival abrasion as a means to assess safety to soft oral tissue.

The aim of this PhD research is to provide an overview on the efficacy of toothbrushing. Efficacy relates to numerous factors such as the time spend to brush, the frequency of brushing, the brushhead type, filament type and arrangement, the age of the toothbrush, and with regard to powered toothbrushes, the mode of action.

Specific objectives were:

1. The toothbrush: Outdated or state of the art? (Chapter 2)
2. Effects of school-based brushing on gingivitis (Chapter 3)
3. Toothbrush age: Is an old brush less effective as compared to a new brush? (Chapter 4)
4. Brushhead design: Is a multi-level toothbrush more effective than a flat-trimmed toothbrush (Chapter 5)
5. Manual versus Powered. Are powered toothbrushes more effective than manual brushes? (Chapter 6 and 7)
6. Powered versus Powered. Which mode of action of powered toothbrushes is more effective? (Chapter 7 and 8)
7. Plaque removal efficacy. On average, how much plaque is removed after a single brushing episode using a powered toothbrush? (Chapter 9)
References

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