The Role of Electric Toothbrushes: Advantages and Limitations

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Introduction

Maintenance of oral hygiene has been an objective of man since the dawn of civilization. The use of the chewing stick (miswak or siwak) to clean the dentition is an example of an ancient pre-Islamic custom that continues to be used today. Although in the past the chewing stick may have been used with "toothpowders" and "extract of roses", today it is commonly used as a toothbrush but without toothpaste. The chewing stick became the toothbrush, via toothcleaning attempts with sponges and rubbing cloths. Most historians trace the development of the first toothbrushes (hog bristles set in oxbone) to 1498 C.E. in China, although there is evidence that the Chinese used ivory brush handles and bristles made of hair from a horse's mane as early as 1000 C.E. The bristle brush was reinvented in the late 18th and early 19th centuries, but due to the high price of hog bristle, brushes did not become widely used until the end of the 19th century. In the first part of the 20th century in the United States, a family toothbrush was common even among the poor. In the late 1930's, nylon filaments began to replace natural bristles, and wood and plastic replaced bone handles. This made toothbrushes inexpensive enough for virtually everybody to own one. During the past 30 years oral hygiene has improved, and in industrialized countries 80% to 90% of the population brush their teeth 1 or 2 times a day (*Saxer & Yankell* 1997).

Mechanical plaque removal with a manual toothbrush remains the primary method of maintaining good oral hygiene for the majority of the population. When performed well for an adequate duration of time, manual brushing is highly effective. However, for most patients, neither of these criteria is fulfilled. One possible way to overcome the limitations associated with manual brushing was to develop a mechanical brushing device, and as early as 1855 the Swedish clockmaker Frederick Wilhelm Tornberg patented a mechanical toothbrush (Scutt & Swann 1975). The first electric toothbrushes came much later, and were first introduced in the 1960's. They provided a brush head capable of a variety of motions driven by a power source. Over time such devices have become established as a valuable alternative to manual methods of toothbrushing.

The first electric brushes mimicked the back-and-forth motion commonly used with a manual toothbrush. When first introduced there

were many reports of the effectiveness of such devices. However, an early authoritative report reviewed such research and stated that both manual and electric toothbrushes were equally effective in removing plaque (*Ash* 1963). Because of the lack of clear superiority and many problems of mechanical breakdown, powered toothbrushes fell out of favor, and during the late 1960's they gradually disappeared from the market. However, powered brushes continued to be recommended for the handicapped and for persons with reduced manual dexterity.

At the World Workshop in Periodontics in 1966, the consensus was that in non-dentally oriented persons and persons not highly motivated to oral health care, as well as those who have difficulty in mastering a suitable handbrushing technique, "the use of an electric brush with its standard movements may result in more frequent and better cleansing of the teeth" (Greene 1966). Since then, research and development have continued, and many modifications to electric toothbrush design have been made. These include oscillating or rotating brushes and brushes which move at a high frequency (*Fishman* 1997). It was believed that this substitute for the linear, vibratory hand motion applied to manual toothbrushes would lead to more effective plaque and stain removal over shorter brushing times. It has been shown that this new generation of brushes remove plaque significantly better in the approximal area than do conventional manual toothbrushes. This led, in the 1996 World Workshop in Periodontics, to the careful conclusion that limited evidence suggested that electric brushes provide an additional benefit compared to manual brushes (*Hancock* 1996).

This position paper will discuss the current knowledge with respect to modern electric toothbrushes, and will focus on six aspects:

- Research methodology
- Effectiveness
- Abrasion
- Toothbrushing force
- Compliance
- Special patient groups

Impact of research methodology

In trials with electric toothbrushes, all panelists are human. This obvious fact introduces one of many practical considerations which may affect the course and outcome of a clinical trial. The mere fact that people are being carefully evaluated for the presence of plaque and gingivitis can affect their level of oral hygiene (*Overholser* 1988). The exposure of any group of subjects to clinical trial procedures will sometimes result in improvement which is due to a psychological effect rather than a physical effect of the test substance or device. This is known as the "Hawthorne effect" and has been recognized in several trials. If the controlled clinical trial is correctly balanced, this effect should not result in any differential change between the test and control groups (*Cowell* et al. 1975).

In testing the effectiveness of toothbrushes, a double-blind study is virtually impossible. Therefore the novelty effect of the electric toothbrush must be considered in the design of a study on the effect of electric brushes (*Owen* 1972). The novelty effect, or "gadget appeal", as it has been called, may be a simple expression of curiosity, but patients generally show a greater interest in an electric brush and are eager to use it (*Muhler* 1969). One method of minimizing the novelty effect is to test the brushes over a relatively long period

Table 1 Selected studies comparing electric toothbrushes to manual toothbrushes

Authors	Number of Patients	Duration	Brushes	Indices	Results
Glavind & Zeuner (1986)	40	3 months	1) Rotadent 2) Butler GUM 411+ oral hygiene kit	Silness & Löe plaque index Gingival bleeding on probing	Both groups equally effective
Boyd et al. (1989a)	35	12 months	1) Rotadent 2) Oral B + floss, toothpicks, interdental brushes	Silness & Löe plaque index Gingival index Probing pocket depth Bleeding upon probing Attachment loss	Both groups equally effective
Quirynen et al. (1994)	12	3 months	1) Interplak 2) Oral B 30	Quigley & Hein plaque index % sites with approximal plaque Mühlemann & Son sulcus bleeding index Probing pocket depth	Compared to the manual, with the Interplak less plaque and a greater reduction in gingival inflammation and more pocket reduction
Wilson et al. (1993)	32	12 months	1) Interplak 2) Butler GUM 311	Turesky modification Q&H plaque index Barnett-Mühlemann gingival bleeding index Probing pocket depth Objective and subjective abrasion index	The Interplak was more effective in plaque removal. No significant difference in gingival bleeding. No significant abrasion and change in level of recession.
Van der Weijden et al. (1994)	77	8 months	1) Braun/Oral B Plaque Remover 2) Butler GUM 311	Silness & Löe plaque index Turesky modification Q&H plaque index Lobene modification gingival index Bleeding on marginal probing Volpe calculus index Gingival Abrasion	Except for calculus all parameters significantly decreased in favor of the electric toothbrush. No significant gingival abrasion with either brush.
Ainamo et al. (1997)	111	12 months	1) Braun/Oral B Plaque Remover 2) Jordan	Ainamo & Bay visible plaque index Ainamo & Bay modified gingival bleeding index Gingival abrasion	No difference in plaque removal between groups. The electric toothbrush significantly more effective in improving gingival health. No gingival abrasion was observed in either group.

Continuation Table 1 Selected studies comparing electric toothbrushes to manual toothbrushes

Authors	Number of Patients	Duration	Brushes	Indices	Results
Johnson & McInnes (1994)	43	4 weeks	1) Sonicare 2) Oral B 40	Turesky modification of Q&H plaque index Löe & Silness gingival index Ainamo & Bay modified gingival bleeding index	No difference between groups in overall plaque removal. Electric more effective than manual on interproximal and lingual surfaces. No difference for gingival inflammation. Electric brush proved to be safe.
Tritten & Armitage (1996)	56	12 weeks	1) Sonicare 2) Butler GUM 311	Turesky modification of Q&H plaque index Löe & Silness gingival index Bleeding tendency score Bleeding on probing Probing pocket depth Attachment level Gingival abrasion	Electric more effective in removing plaque. Both groups equally effective with regard to gingival inflammation. No significant gingival abrasion.
Terezhalmy et al. (1995b)	54	6 months	1) Sonex 2) Oral B	Turesky modification of Q&H plaque index Löe & Silness gingival index Eastman bleeding index	No significant difference between groups.

of time in order to allow the novelty effect to subside or disappear. Studies of short duration are particularly prone to errors due to the novelty effect (*Ash* 1963).

Studies involving the Sonex toothbrush are illustrative of this problem. In one study, after 6 weeks there was a significant decrease in the bleeding and gingival indices in favor of the ultrasonic toothbrush (*Terezhalmy* et al. 1995a). However, the results of a 6-month study did not show any difference from a manual toothbrush (*Terezhalmy* et al. 1995b). The initial positive effect may have been the result of the participants being aware of the new brush and therefore using it enthusiastically. This response is negated with time and may well explain why over a 6-month trial period the apparent advantages of the Sonex brush over a manual toothbrush were lost.

At ACTA Amsterdam, we have tried to solve the problems that are associated with studies comparing the ability of toothbrushes to remove plaque and improve gingival health. A short-term plaque model has been designed which attempts to control as many variables as possible, including duration of toothbrushing, manual dexterity, motivation, the frequency of brushing, and the "novelty effect" (*Van der Weijden* 1993a).

In short, subjects are requested not to brush for 24 to 48 hours. The level of plaque is then assessed before and after brushing. In a split-mouth design, brushing can either be done by a professional or by the panelists themselves. Other research groups have now successfully used this same model to test different brushes (*Rapley & Killoy* 1994, *De Jager* et al. 1998).

Short-term gingivitis studies face the problem that in order to get the maximum benefit from a toothbrush, professional instruction and training in using the brush are required (e.g., *Van der Weijden* et al. 1994). This instruction will affect the level of gingivitis of those who participate in the study. Most likely they will become healthier. Therefore, a model was recently suggested that includes a phase of experimental gingivitis in the short-term study in order to re-establish gingivitis after the training period (*Van der Weijden* et al. 1998). This model allowed for a sufficient level of gingivitis in subjects who were adequately trained. The study results showed that gingivitis was resolved within 4 weeks of resuming toothbrushing. It therefore appears to be a valuable study design for testing toothbrushes in relation to gingival health.

Effectiveness

Mode of action

In 1986, an international workshop on oral hygiene concluded that up to that time neither powered nor manual toothbrushes removed more plaque, regardless of the brushing method (*Löe & Kleinmann* 1986). At that time, only what we now call conventional electric toothbrushes were available. This first generation of electric toothbrushes had a brush-head designed as a manual toothbrush which made a (combined) horizontal and vertical motion.

Over the last decade a new generation of electric toothbrushes has become available, and they can be conveniently categorized into two distinct types. First, there has been a move towards more (oscillating) rotary action brushes instead of the traditional side-to-side motion (*Walmsley* 1997). The rotary motion can be either the motion of a single brush or of the individual tufts moving in a counter-clockwise direction. Second, there are brushes which operate with a brush head motion at a higher frequency (*Johnson & McInnes* 1994).

Toothbrushing duration

In general, patients are not willing to spend the time dental professionals recommend to brush and floss, and most patients brush their teeth for less than 1 minute (*Hawkins* et al. 1986). Electric toothbrushes are potentially faster than manual brushes at cleaning tooth surfaces, and the efficiency could potentially improve the plaque control regimen for most adults (*Boyd* et al. 1997b). The Rotadent, for example, has been clinically demonstrated to need only one half as much time as a manual brush to remove an equal amount of plaque (*Preber* et al. 1991). Two studies have focused specifically on the relationship between toothbrushing duration and plaque-removing efficacy (*Van der Weijden* et al. 1993b, 1996a). These have shown that a manual toothbrush removes less plaque than an electric toothbrush given the same brushing time. Even after 6 minutes, the manual toothbrush in the hands of a professional removes only 75% of the plaque which is removed after 1 minute with the electric toothbrush.
With increase in time up to six minutes, the efficacy of a manual toothbrush increases, but there appears to be an optimum effect after at least 2 minutes with the electric toothbrushes. After 2 minutes with an electric toothbrush approximately 84% of the plaque has been removed, whereas after 6 minutes 93% has been removed.

Stain removal and calculus control

Besides plaque-removal efficacy, a few researchers have investigated stain removal. Using an experimental model to induce stain by rinsing for 4 days with an intense chlorhexidine tea regimen (no other form of oral hygiene was allowed), *Grossman* et al. (1996) showed that electric toothbrushes were more effective in removing extrinsic dental stain than manual brushes. This confirmed the "in vitro" findings of *Schemehorn & Henry* (1996). Also, using the chlorhexidine-induced stain model for an extended period up to 4 weeks, both the Braun Oral-B Plaque Remover and Sonicare have been shown to be superior to a manual toothbrush with respect to stain removal (*McInnes* et al. 1994, *Moran & Addy* 1995).
The effectiveness of the electric toothbrush in controlling calculus has been investigated in two studies. *Moran & Addy* (1995) evaluated the development of calculus over a 21-day period. No differences between the electric toothbrushes and the manual brush were observed. *Van der Weijden* et al. (1994) assessed calculus development in an eight-month study and also did not observe a significant difference between the manual and electric toothbrush.

Efficacy data of currently available electric toothbrushes

The main electric toothbrushes which are compared in the literature are the Braun Oral-B Plaque Remover (D5, D7, D9), Interplak, Rotadent, Sonicare and Sonex. These electric toothbrushes have been studied in relation to their ability to remove plaque and improve gingival condition in comparison with either manual brushes or with electric toothbrushes from different manufacturers (*Walmsley* 1997).
Reviewing the literature of the last decade it is apparent that for all electric toothbrushes, papers can be found which show a benefit over a manual toothbrush, but papers can also be found in which the same brush fails to perform better. For this position paper a selection was made of papers which illustrate the specific features of the now-available

electric toothbrushes, realizing that this never can be a fully objective selection. The authors wish to refer to two recent publications which have also reviewed the literature with regard to electric toothbrushes and which made their own choice of studies to include (*Walmsley* 1997, *Saxer & Yankell* 1997). In all investigations of electric toothbrush efficacy, the manual toothbrush has remained as the standard against which any new plaque removal instrument must be judged. The following summarizes what is known about the efficacy of the main currently available modern electric toothbrushes. Some studies comparing electric and manual toothbrushes appear in Table 1.

Rotadent®

This electric brush was the first clinically investigated brush which turned away from the conventional design of electric toothbrushes. It is a rotary-action single-tuft brush with small bristles that reach one surface per tooth. It comes with 3 brushhead designs (short-pointed, elongated and hollow cup brush tip).

Walsh & Glenwright (1984) showed, in a short-term study involving dental students as test subjects which evaluated the efficacy of plaque removal on 3- to 4-day-old plaque, that there was no significant difference between the Rotadent and a manual brush. On the other hand, *Glavind & Zeuner* (1986) found in a test group consisting of periodontal patients, that the "improved" Rotadent was as effective as a combination of manual toothbrushing, flossing and toothpicks. In both the Rotadent and the control group, the plaque level had decreased by the 3-month examination. This is in agreement with the findings of a 12-month study (*Boyd* et al. 1989a) which demonstrated that in a group of periodontal maintenance patients, the Rotadent was just as effective as the comprehensive oral hygiene kit which was used in the study by *Glavind & Zeuner* (1986).

Other short-term studies indicate improved approximal plaque removal with the Rotadent electric toothbrush (*Müller* et al. 1987, *Preber* et al. 1991). *Silverstone* et al. (1992) conducted a 6-week study on 30 subjects comparing Rotadent and the Oral-B 40 soft toothbrush. They reported no differences in gingival inflammation between the two groups.

Interplak®

This electric toothbrush was the next innovative toothbrush design and was introduced onto the market in the mid-1980's. The Interplak electric toothbrush has a rectangular brushhead with 6 to 8 bristle tufts which individually counter-rotate. *Baab & Johnson* (1989) assessed the ability of the Interplak to remove plaque in a study in which brushing was conducted under professional supervision. Subjects using the electric brush had lower plaque scores due to increased effectiveness of the brush in the approximal regions. In a 3-month trial, *Quirynen* et al. (1994) showed the superiority of the Interplak in plaque removal, reduction of gingival inflammation and pocket depth reduction. *Wilson* et al. (1993) showed in a 12-month study a larger reduction in plaque with the Interplak than with the Butler Gum 311 manual toothbrush; however, no differences with respect to gingivitis were observed. *Killoy* et al. (1993) reported on the cost-effectiveness of a counter-rotational toothbrush (Interplak) in 32 patients with moderate periodontitis. All patients received initial periodontal treatment by a dental hygienist. During and at the end of an 18-month period, subjects using the electric toothbrush did not need any further surgical periodontal treatment. In contrast, subjects in

the group using the manual toothbrush experienced an increased need of treatment. Health insurance systems might prefer to pay for electric toothbrushes rather than therapy related to inadequate oral hygiene (*Saxer & Yankell* 1997).

Braun Oral-B Plak Control (D5/D7 & D9)

This electric brush, which was launched in 1991, has a small circular brushhead which makes an oscillating/rotating movement. Clinical trials with the Braun Oral-B oscillating/rotating toothbrush have shown that this action is superior to that of a conventional electric toothbrush and more effective than a manual toothbrush (*Van der Weijden* et al. 1993a, 1995a, 1995b). *Stoltze & Bay* (1994) compared the Braun D5 to a manual toothbrush (Tandex 40) during a 6-week period. The electric toothbrush was more effective in removing plaque mainly on the approximal surfaces. In an 8-month preventive program the Braun D5 was compared to a manual toothbrush (Butler GUM 311) in a group of gingivitis subjects (*Van der Weijden* et al. 1994). Plaque, gingivitis, gingival abrasion, and calculus were assessed. At the end of the trial, differences in plaque scores and gingival bleeding were found in favor of the Braun/Oral-B Plaque Remover.
In 1996, the frequency of the Braun Oral-B electric toothbrush was increased from 47 Hz to 63 Hz (D9). In addition, the angle of rotation was decreased from 70° to 60°. In a comparative post-brushing study with this new brush, the Braun Oral-B Ultra Plaque Remover (D9), no significant difference from the lower frequency D7 was detected (*Van der Weijden* et al. 1996a). However, in a 5-day study which evaluated efficacy with respect to the removal of extrinsic dental stain, a significant advantage in favor of the D9 over the D7 was observed (*Grossman* et al. 1996).

Philips HP 510

Recently, Philips introduced an oscillating/rotating electric toothbrush (HP 510) which has a circular brushhead design similar to that of the Braun/Oral B Plak Control but which has in addition an active tip at the end of the brushhead which makes a small sweeping motion. At present (June 1998) no published data other than one abstract are available for review. Data on file from the manufacturer indicate that the efficacy of the HP 510 is similar to that of the Braun oscillating/rotating toothbrush (*De Jager* 1998).

Sonicare

The Sonicare electric toothbrush was introduced in 1993 and has a rectangular brushhead with bristles arranged in a saw-tooth design. The side-to-side movement of the Sonicare operates at a high frequency of 260 Hz. In a 4-week study in adults, the Sonicare proved to be more effective in removing plaque from the lingual and approximal surfaces as compared to the manual toothbrush (Oral B 30) (*Johnson & McInnes* 1994). In a recent, 12-week study in gingivitis patients, the Sonicare was more effective in removing plaque but comparable to the manual toothbrush in reducing inflammation (*Tritten & Armitage* 1996).

Sonex

When a prototype of an ultrasonic brush was compared to a manual brush by *Goldman* (1974), patients were not aware of any ultrasonic effect, but the ultrasonic brush produced somewhat improved plaque removal. Twenty years later, a new ultrasonic brush has been marketed. The Sonex is designed with a

piezoelectric transducer operating at 1.6 MHz located in the handle of the toothbrush. It is claimed that these vibrations are passed from the handle along to the head and down the bristles. A short-term study (*Terezhalmy* et al. 1995a) showed that the Sonex brought about a significant reduction in the bleeding and gingival indices. However, at the end of a 6-month study (*Terezhalmy* 1995b) no difference was observed between the groups. As discussed earlier, this may be the result of a "novelty effect" in the group using the electric brush which wore off over time.

Electronic (ionic) toothbrushes

An advertisement in the February 13, 1886, issue of *Harper's Weekly* touted the curative properties of what was perhaps the first electric toothbrush. The handle of Dr. Scotts' Electric toothbrush was said to be ". . . charged with an electromagnetic current, which acts, without any shock, immediately upon nerves and tissues of the teeth and gums . . . arresting decay . . . and restoring the natural whiteness of the enamel" (*Fishman* 1997). This old idea has been marketed over the years in toothbrushes which are designed to send an electronic current through the brushhead. This presumably enhances the efficacy of the brush in plaque elimination. So far, relatively few data are available to support the assumption of a beneficial effect (e.g., *Hoover* et al. 1992). An "electronic" (ionic) brush which sends a 0.15 mA current through the brushhead was subjected to a 5-month evaluation (*Van der Weijden* 1995a). No effect on either plaque scores or bleeding upon probing was evident. In another double-blind 6-month study, a significant reduction in plaque and gingivitis was observed for the "ionic" manual toothbrush as compared to a regular manual toothbrush (*Van Swol* et al. 1996). These conflicting results need further evaluation.

With the above review of electric toothbrushes it has been mentioned a number of times that the better efficacy observed with the electric toothbrushes is mainly the result of improved approximal cleaning. One could argue that subjects who use a manual toothbrush and in addition some interproximal cleaning device will not benefit from an electric toothbrush. However, as has been discussed by *Axelsson* (1993), interproximal cleaning is not a common practice in Europe. In industrialized countries today 15–20% of the population at most perform interdental oral hygiene on a regular basis. Therefore, the electric toothbrush can play an important role in the prevention of periodontal diseases through improved approximal cleaning.
In order to get the maximum benefit from the electric toothbrush, professional oral hygiene instruction appears to be important. This has been observed in a number of studies. Investigations of toothbrushing with no prior professional instruction, or taped instruction, have found no or only minimal differences (*Barnes* et al. 1993, *Stoltze & Bay* 1994). However, when studies included professional instruction in the use of the electric toothbrush, significantly better results were found (*Van der Weijden* et al. 1993a, 1994, *Grossman* et al. 1995). Although in a twelve-month study by *Ainamo* et al. (1997) instructions were given only at the outset and were not repeated, the electric toothbrush was found to be superior to the manual.

Abrasion

In the prevention of oral diseases, proper oral hygiene is of foremost value. Unfortunately, several problems are encountered when

thorough oral hygiene is performed. Due to improper brushing techniques, abrasive toothpaste and hard bristle filaments, people with regular toothbrushing habits sometimes damage the gingiva, the dentin or enamel. They may develop marginal ulceration of the gingiva, gingival recession, exposure of root surfaces and esthetic problems (*Sandholm* et al. 1982, *Vehkalahti* et al. 1989. The most common of these findings is the local recession of the gingival margin (*Sandholm* et al. 1982, *Khocht* et al. 1993).

Abrasion of hard tissues

The hard versus soft bristle brush controversy is an old one among dentists, and Hirshfield, in his book *The Toothbrush—Its Use and Abuse,* quotes advocates for both positions (*Walmsley* 1997). At the beginning of the 20th century, many published papers focused on the side effects of toothbrushes and even questioned the safety of regular use and general acceptance. In contrast, there were also many reports in support of the need for oral hygiene. At the start of this century, toothbrushing was not common and was correlated with fear because of its newness (*Saxer & Yankell* 1997). Variations on hard, natural bristles existed until the late 1930's, when plastic (for handles) and nylon (for bristles) became widely available. By the late 1960's, with the growing awareness of the dangers of enamel abrasion and gingival recession, toothbrushes with soft nylon bristles became the recommendation of choice (*Fishman* 1997).

The simple act of cleaning away dental deposits from teeth requires that the toothbrush-dentifrice combination possess some level of abrasivity. In the oral cavity four tissues are at risk from the abrasive effect of toothbrushing. These are the enamel, dentine, the gingival tissues and alveolar mucosa. Up till now, few scientific data have been available to help us understand the risks associated with toothbrush abrasion, and in particular, research into the abrasion of hard tissues is difficult. First of all the effect usually takes years to become visible. Second, various factors play a role in the process of abrasion, including the force with which the brush is used, the stiffness of the bristles, the frequency of toothbrushing, the abrasiveness of the toothpaste, and the erosiveness of the food which is consumed (*Davis & Winter* 1980). The amount of dentifrice applied to a particular brush may also contribute to the potential abrasion of dental tissues (*Harte & Manly* 1976). These factors make it difficult to perform clinical research into the effect of the toothbrush itself.

Slop (1986) used an "in vitro" model to investigate the extent to which the enamel will wear down as a result of brushing. Although some wear was observed, there appeared to be no potential danger for extensive abrasion of this tissue. There is also little known about the abrasion of dentin. This holds true for both manual and electric toothbrushes. One approach is to assess the relative dentin abrasion "in vitro", using a model which has been developed at Indiana University (USA) and approved by the ADA primarily to assess the abrasiveness of toothpastes (*Hefferren* 1976, *Schemehorn* et al. 1993). In short, radioactive dentin specimens are brushed using a standard slurry, brushing force and number of strokes. After a standard brushing time the scintillation within the slurry is measured. The test brush and test slurry are compared to an ADA reference brush and an ADA reference abrasive. The results of several studies carried out in Indiana (*Van der Velden* et al. 1993, *Schemehorn* et al. 1993, *Schemehorn & Zwart* 1996) indicate that oscillating/rotating electric toothbrushes are safe

with respect to dentin abrasion. However, recent studies carried out in Zurich (*Imfeldt & Sener* 1998), apparently using the same model, appear to contradict these findings. The origin of these differences could be the result of minor but trivial deviations from the original model and should be the object of future studies.

Gingival abrasion

Epstein & Tainter (1943) described several variables that affect toothbrush abrasion, of which brushing pressure and bristle type were directly related to the brushing itself. The stiffness and unfavorable shape of toothbrush bristles have been claimed to be an etiologic factor in the origin of gingival injury (*Hirshfeld* 1931, *Lange* 1977).

Frequent brushers tend to show more signs of traumatic gingival lesions buccally and on the line angle of the marginal gingiva. These injuries may produce recession of the gingiva (*Serino* et al. 1994, *Joshipura* et al. 1994).

First reports on safety with electric toothbrushes have focused on those brushes with a side-to-side motion. Studies have looked at the number of gingival abrasions that have occurred with the use of the Braun Oral-B D3 (conventional electric toothbrush) and compared their occurrence to the potential damage caused by manual toothbrushing (*Niemi* et al. 1986). Visual scoring of the number of abrasion sites was made, the examiner being pre-trained in the interpretation of abrasions. Results demonstrated a greater amount of abrasions following use of the manual brush. *Walsh* (1989) found no differences between electric and manual toothbrushes with respect to gingival abrasion of the soft tissues.

The Sonicare brush has been subjected to safety testing in dogs (*Engel* et al. 1993). Following brushing for 7.5 minutes daily for 2 months, no damage was evident on clinical or histological examination.

Recently, *Danser* et al. (1998) conducted a study to establish the incidence of gingival abrasion as a result of toothbrushing, using a manual toothbrush and the Braun Oral-B D9 electric toothbrush. This investigation showed that both the electric toothbrush and the manual brush cause minor gingival abrasion as a result of the brushing.

In two longitudinal investigations of gingival abrasion with an electric toothbrush, the indirect effect on the gingival tissues was studied (*Van der Weijden* et al. 1994, *Wilson et* al. 1993). None of the electric toothbrushes caused more gingival abrasion than was observed with the manual toothbrush. *Wilson* et al. (1993) also measured gingival recession. They observed that neither the manual nor the electric group developed significant changes in the level of gingival recession over the one-year study period.

In a one-year study with the Rotadent, the participants using the Rotadent lost 0.12 mm attachment level on the buccal sides, whereas users of the manual toothbrushes lost only about 0.05 mm (*Boyd* et al. 1989a). These differences were not statistically significant, although 0.1 mm attachment loss in one year is higher that the epidemiological average in patients in a prophylactic program (*Saxer & Yankell* 1997).

Toothbrushing force

Several experimental and clinical studies support the assumption that excessive force in brushing is partly responsible for the origin of toothbrush trauma (*Arnim & Blackburn* 1961, *Alexander* et al. 1977, *Niemi* et al. 1986). *Mierau & Spindler* (1984) observed that in a

group of subjects without recession the mean brushing force with a manual toothbrush was 2.12 N (± 0.31), whereas a group with multiple recession had a mean force of 3.75 N (± 0.47). *Abbas* et al. (1990) showed that mechanical oral hygiene basically is a traumatic procedure. They observed increased bleeding upon probing scores shortly after oral hygiene procedures.

With some electric brushes it has been attempted to limit or reduce the brushing force by giving feedback to the brusher that a certain threshold has been reached. One of these systems was investigated in a study by *Van der Weijden* et al. (1995b), in which it was shown that a pressure control at 350 grams was not able to reduce the force used, compared to a brush without this feedback system.

A recent study evaluated the habitual brushing force individuals use with various toothbrushes (*Van der Weijden* et al. 1996c). In addition to a manual toothbrush, three electric toothbrushes were examined: the Rotadent, the Interplak and the Braun D7. The results showed that with a manual brush considerably more force was used than with the electric brushes, the difference being more than 100 grams. *Danser* et al. (1998) studied the relation between force and gingival abrasion. No correlation was observed, which indicates that other factors (e.g., brushing itself, tooth anatomy, bristle form) appear to be more important than the force used with an electric brush.

Compliance

A number of studies have compared electric toothbrushes (e.g., *Van der Weijden* et al. 1993b, 1996b, 1996c; *Grossman & Proskin* 1997; *Bader & Williams* 1997; *Robinson* et al. 1997), but the data from these studies are not conclusive. The data indicate that, in terms of current standards, the Rotadent, Interplak, Braun Plak Control and Sonicare electric toothbrushes are all very efficient toothbrushes. A choice should therefore be based on aspects other than plaque removal efficacy. This will be discussed later in this paper.

Ease of use

Ease of use is difficult to determine since it depends on the individual, and according to *Cancro & Fishman* (1995), the best toothbrush is the one the patient uses properly. The ease of use of the electric toothbrush is due to the fact that the brush takes care of the brushing action and the patient can concentrate on placing the brush at those sites in the oral cavity that need cleaning.

Patient acceptance of the electric toothbrush should be one aspect of clinical studies. This can be illustrated by a study in which the Braun Oral-B electric toothbrush was compared for a two-month trial period with a sonic toothbrush. The volunteers using the Braun Oral-B Plaque Remover wished to continue with the toothbrush, whereas 25% of the Sonicare group did not like the device and discontinued its use (*Grossman* et al. 1995). A preference for the Braun Oral-B Plaque Remover was also found in a study by *Van der Weijden* et al. (1996b). In a study in which it was compared with the Philips HP 500, a toothbrush which has a movement similar to that of a conventional electric toothbrush, subjects were allowed to keep one toothbrush at the end of the study (*Van der Weijden* et al. 1995b), and the majority preferred the oscillating/rotating toothbrush (Braun Oral-B Plaque Remover). In an investigation of long-term compliance, *Baab & Johnson* (1989) conducted a telephone survey 6 months after their investigation into the efficacy of the

Interplak electric toothbrush, and found that most subjects were not using the electric brush twice a day as they had done during the study period.

A recent study assessed the frequency of use of electric toothbrushes in periodontal patients (*Stålnacke* et al. 1995). It showed that the compliance level was high, with 62% using their brush daily.

It is well documented that plaque removal increases with the brushing time and that most individuals brush for only 60 seconds (*Van der Weijden* et al. 1993b, 1996b, *Huber* et al. 1985). As stated before, the optimal brushing time is at least two minutes (*Van der Weijden* et al. 1993b, 1996b), and therefore emphasis should be placed on increasing regular brushing time. Since most modern electric toothbrushes are equipped with a timer, this could represent an important feature that will encourage electric toothbrush users to brush for a longer time than if they were using a manual brush. The fact that an electric toothbrush will remove more plaque than a manual brush in the same time also plays a role in ease of use (*Van der Weijden* et al. 1993b).

A matter of choice

Several factors not based on scientific data but on practical aspects can play a role in the choice of an electric toothbrush, namely size of the brushhead, the size and weight of the handle, and the capacity of the "battery".

For children, a small brushhead should be available, and in those cases where the children brush their teeth themselves, a light and small handle is more suitable. A small brushhead is also practical for adults, since the back teeth are difficult to reach. This can be illustrated by a study in which the Braun Oral-B Plaque Remover and the Philips toothbrush, both with oscillating/rotating action, were compared (*De Jager* et al. 1998). Although no significant difference was found between the two brushes, the Philips was more effective in the molar area, which was considered to be the result of the reduced height of the brushhead. In the front teeth the effectiveness was reversed, however, probably the result of another factor other than the brushhead height.

For those who travel and in those families where more than one member uses the electric toothbrush, a toothbrush with long-lasting batteries should be the prime choice.

Special patient categories

Periodontal maintenance patients

Supragingival plaque control is an important factor in preventing periodontal breakdown in patients undergoing periodontal maintenance. Patients with sub-optimal plaque control usually need more frequent maintenance visits and are more likely to develop loss of attachment (*Lindhe & Nyman* 1984). It is well established that the use of electric toothbrushes has a particular advantage in controlling plaque accumulation in patients with low compliance to oral hygiene. *Hellstadius* et al. (1993) reported on a group of patients with low compliance who had been referred for specialist periodontal treatment. These patients had previously received extensive oral hygiene instruction with manual aids, over a period extending up to 40 months, and still there remained less-than-acceptable plaque control, with plaque scores of 48%. Substitution of their manual brushes with electric toothbrushes reduced their mean plaque score to 12%. This was maintained for the period of observation up to 3 years. The results of a study by *Yukna & Shaklee* (1993) showed that in a comparable patient group

the electric toothbrush proved to be a useful adjunct in maintaining reduced plaque levels and favorable gingival conditions.

Children

Most published studies on the use of electric toothbrushes by children describe only electric toothbrushes developed in the 1960's. In one early study, *Lefkowitz* et al. (1962) compared the use of an electric toothbrush with that of a manual brush in two groups of children. One group was aged between 7 and 9 years and another group between 10 and 12 years. In both groups more plaque was removed by the electric brush. In contrast, a crossover study involving younger children with a mean age of approximately 4 years which compared use of an electric and a manual toothbrush found no statistically significant difference between the two groups with respect to plaque removal (*Owen* 1972). A recent study compared plaque control efficacy of a new electric toothbrush (oscillating/rotating) designed specifically for use by children with that of a children's manual brush (*Grossman* et al. 1995). Results showed that in this population aged between 8 and 12 years, the electric brush achieved significantly greater plaque removal. Electric toothbrushes can be particularly beneficial for parental brushing of children's teeth. In studies with electric toothbrushes where the panelists were brushed by a professional, a high efficacy was obtained (*Van der Weijden* et al. 1993a, 1993b, 1996b).

Patients with a disability

In the literature it has been suggested that electric toothbrushes are especially useful for disabled patients (e.g., *Cancro & Fishman* 1995). However, controlled clinical studies are sparse. Two studies have shown that electric toothbrushes are valuable for mentally disabled children and for disabled children with poor manual dexterity (*Kelner* 1963, *Smith & Blankenship* 1964). The few recent studies available have shown that electric toothbrushes are valuable for disabled adults (*Bratel & Berggren* 1991, *Bratel* et al. 1988, *Blahut* et al. 1991). *Martin* et al. (1987) reported on a study of institutionalized elderly patients with limited manual dexterity. The patients were not given any oral hygiene instruction and were assessed for oral cleanliness and gingival health both before and after the study. The results suggested that the increased efficacy of the electric toothbrush may be of value to institutionalized elderly patients in the maintenance of their oral hygiene.
Again, professional brushing with the electric toothbrush has been shown to be highly effective (*Van der Weijden* et al. 1993a, 1993b, 1996a). Therefore, as has been stated above for children, in those cases where a "caretaker" is responsible for oral hygiene, the electric toothbrush can be a useful tool.

Orthodontic patients

Adolescent orthodontic patients often show ineffective plaque control because of the difficulty of removing plaque while fixed appliances are in place (*Boyd* 1997). The efficiency of the Interplak has been investigated in orthodontic patients by both *Yankell* et al. (1985) and *Wilcoxon* et al. (1991). Results from both studies were in agreement, with the latter, two-month cross-over study involving 20 orthodontic patients showing an improvement over a manual toothbrush for both gingivitis and plaque. In another study which compared the Sonicare toothbrush with a manual brush over a period of one month, adolescent orthodontic patients with existing

gingivitis showed, after oral hygiene instruction, an improvement in both plaque and bleeding which was superior with the electric brush (*Ha & Niederman* 1997). A recent three-month study using the Sonicare toothbrush (*White* 1996) also concluded that this electric toothbrush may help orthodontic patients to improve their oral health. However, this study was not blinded. Comparative efficacy in orthodontic patients was observed when three electric toothbrushes (Interplak, Braun/Oral-B Plak Control, Rotadent) were evaluated in relation to a manual system consisting of a toothbrush, floss and interspace toothbrush (*Jost-Brinkman* et al. 1994). The only long-term clinical trial evaluating the effectiveness of an electric brush on the periodontal health of orthodontic patients is a study by *Boyd* et al. (1989b) using the Rotadent electric toothbrush. The results of this 18-month study show that the Rotadent can be more effective than conventional manual toothbrushing.

Conclusions

In reviewing many of the published reports over the past two decades, one comes to the conclusion that the electric toothbrush has become, compared to the old design, more effective in the removal of supra-gingival plaque and controlling gingivitis.

- The difference between manual toothbrushes and electric toothbrushes is primarily in the increased ability of the electric brushes to remove plaque from the approximal area.
- Professional instruction and reinforcement in the use of powered toothbrushes seems important to achieve optimal results.
- Although the etiology of hard and soft tissue abrasion is not fully understood, toothbrushing is one of the factors involved. No adverse reactions or trauma involving either oral soft or hard tissues have been attributed to the long-term (8–12-month) use of electric brushes when compared to manual toothbrushes.
- Clinical trials over the past 10 years show that in controlled trials electric toothbrushes appear to be superior to manual brushing. Modern design features are responsible for this.

References

Abbas, F., Voss, S., Nijboer, A., Hart, A. A. M. & Van der Velden, U. (1990) The effect of mechanical oral hygiene procedures on bleeding on probing. Journal of Clinical Periodontology **17,** 199–203.

Ainamo, J., Xie, Q., Ainamo, A. & Kallio P. (1997) Assessment of the effect of an oscillating/rotating electric toothbrush on oral health. A 12-month longitudinal study. Journal of Clinical Periodontology **24,** 28–33.

Alexander, J. F., Sattir, A. J. & Gold, W. (1977) The measurement of the effect of toothbrushes on soft tissue abrasion. Journal of Dental Research **56,** 722–727.

Arnim, S. & Blackburn, E. M. (1961) Dentifrice abrasion. Report of a case. Journal of Periodontology **32,** 43–48.

Ash, M. M. (1963) A review of the problems and results of studies on manual and power toothbrushes. Journal of Periodontology **34,** 375–379.

Ash, M. M., Rainey, B. L. & Smith, W. A. (1964) Evaluation of manual and motor-driven toothbrushes. Journal American Dental Association **69,** 321–325.

Axelsson, P. (1993) Mechanical plaque control. In Proceedings of the 1st European Workshop on Periodontology, eds. Lang, N. P. & Karring, T., pp. 219–243. Berlin: Quintessenz.

Baab, D. A. & Johnson, R. H. (1989) The effect of a new electric toothbrush on supra-gingival plaque and gingivitis. Journal of Periodontology **60,** 336–341.

Bader, H. & Williams, R. (1997) Clinical and laboratory evaluation of powered electric toothbrushes: Comparative efficacy of 2 powered brushing instruments in furcations and interproximal areas. Journal of Clinical Dentistry **8,** 91–94.

Barnes, C. M., Weatherford, T. W. & Menaker, L. (1993) A comparison of the Braun Oral-B plaque remover D5 electric and a manual toothbrush in affecting gingivitis. Journal of Clinical Dentistry **4,** 48–51.

Blahut, P., Gerger, K. & Parker, W. (1991) Clinical trial of an electric toothbrush in a geriatric population. Compendium of Continuing Education in Dentistry 1993, suppl **16,** 606–610.

Boyd, R. L., Murray, P. & Robertson, P. B. (1989a) Effect on periodontal status of rotary electric toothbrushes vs. manual toothbrushes during periodontal maintenance. I. Clinical results. Journal of Periodontology **60,** 390–395.

Boyd, R. L., Murray, P. & Robertson, P. B. (1989b) Effect of rotary electric toothbrush versus manual toothbrush on periodontal status during orthodontic treatment. American Journal of Orthodontics and Dentofacial Orthopedics **96,** 342–347.

Boyd, R. L. (1997) Clinical and laboratory evaluation of powered electric toothbrushes: Review of the literature. Journal of Clinical Dentistry **8,** special issue, 67–71.

Boyd, R. L., McLey, L. & Zahradnik, R. (1997) Clinical and laboratory evaluation of powered electric toothbrushes: In vivo determination of average force for use of manual and powered toothbrushes. Journal of Clinical Dentistry **8,** 72–75.

Bratel, J., Berggren, U. & Hirsch, J. M. (1988) Electric or manual toothbrush? A comparison of the effects on the oral health of mentallly handicapped adults. Clinical Preventive Dentistry **10,** 23–26.

Bratel, J. & Berggren, U. (1991) Long-term oral effects of manual or electric toothbrushes used by mentally handicapped adults. Clinical Preventive Dentistry **13,** 5–7.

Cancro, L. P. & Fishman, S. L. (1995) The expected effect on oral health of dental plaque control through mechanical removal. Periodontology 2000 **8,** 60–74.

Cowell, C. R., Saxton, C. A., Sheiham, A. & Wagg, B. J. (1975) Testing therapeutic measures for controlling chronic gingivitis in man: a suggested protocol. Journal of Clinical Periodontology **2,** 231–240.

Danser, M. M., Timmerman, M. F., Itzerman, Y., Bulthuis, H., van der Velden, U. & Van der Weijden, G. A. (1998) Evaluation of the incidence of gingival abrasion as a result from toothbrushing. Journal of Clinical Periodontology **25** (in press).

Davis, W. B. & Winter, P. J. (1980) The effect of abrasion on enamel and dentine after exposure to dietary acid. British Dental Journal **148,** 253–256.

De Jager, M., Wiedemann, W., Klinger, H., Melzer, B. & Sturm, D. (1998) Plaque removal efficacy of 2 counter-rotational electric toothbrushes. Journal of Dental Research **77,** 664 (abstract 257).

Engel, D., Nessly, M., Morton, T. & Martin, R. (1993) Safety of a new electronic toothbrush. Journal of Periodontology **64,** 941–946.

Epstein, S. & Tainter, M. L. (1943) The relationship of particle size and other properties of dentifrice ingredients to toothbrush abrasion of enamel. Journal of Dental Research **22,** 335–338.

Fishman, S. L. (1997) The history of oral hygiene products: How far have we come in 6000 years? Periodontology 2000 **15,** 7–14.

Glavind, L. & Zeuner, E. (1986) The effectiveness of a rotary electric toothbrush on oral cleanliness in adults. Journal of Clinical Periodontology **13,** 135–138.

Goldman, H. M. (1974) Effectiveness of an ultrasonic toothbrush in a group of uninstructed subjects. Journal of Periodontology **45,** 84–87.

Greene, J. C. (1966) World Workshop in Periodontics, eds. Ramfjord, S. P., Kerr, D. A. & Ash, M. M., pp. 399–443. Ann Arbor, MI.: American Academy of Periodontology.

Grossman, E., Dembling, W. & Proskin, H. M. (1995) A comparative clinical investigation of the safety and efficacy of an oscillating/rotating electric toothbrush and a sonic toothbrush. Journal of Clinical Dentistry **6,** 108–112.

Grossman, E., Cronin, M., Dembling, W. & Proskin, H. (1996) A comparative study of extrinsic tooth stain removal with 2 electric toothbrushes and a manual brush. American Journal of Dentistry **9,** 25–29.

Grossman, E. & Proskin, H. (1997) A comparison of the efficacy and safety of an electric and a manual children's toothbrush. Journal American Dental Association **128,** 469–474.

Ha, P. H. & Niederman, R. (1997) Effectiveness of the Sonicare sonic toothbrush on reduction of plaque, gingivitis, probing pocket depth and subgingival bacteria in adolescent orthodontic patients. Journal of Clinical Dentistry **8,** 15–19.

Hancock, E. B. (1996) Prevention. In Annals of Periodontology, eds. Genco, R. J. & Newman, M. G., pp. 223–249. Chicago, Illinois: American Academy of Periodontology.

Harte, D. B. & Manly, R. S. (1976) Four variables affecting magnitude of dentifrice abrasiveness. Journal of Dental Research **55,** 322–327.

Hawkins, B. F., Kohout, F. J. Lainson, P. A. & Heckert, A. (1986) Duration of toothbrushing for effective plaque control. Quintessence International **17,** 361–365.

Hefferren, J. J. (1976) A laboratory method for assessment of dentifrice abrasivity. Journal Dental Research **55,** 563–573.

Hellstadius, K., Asman, B. & Gustafsson, A. (1993) Improved maintenance of plaque control by electrical toothbrushing in periodontitis patients with low compliance. Journal of Clinical Periodontology **20,** 235–237.

Hirshfeld, I. (1931) Toothbrush trauma recession. A clinical study. Journal of Dental Research **11,** 61–63.

Hoover, J. N., Singer, D. L., Pahwa, P. & Komiyama, K. (1992) Clinical evaluation of a light energy conversion toothbrush. Journal of Clinical Periodontology **19,** 434–436.

Huber, B., Rueger, K. & Hefti, A. (1985) The effect of the duration of toothbrushing on plaque reduction. Schweizerische Monatsschrift für Zahnmedizin **95,** 985–992.

Imfeldt, T. & Sener, B. (1998) Relative dentin abrasion (RDA) by electric toothbrushes. Journal of Dental Research **77,** 1236 (abstract 233).

Johnson, B. D. & McInnes, C. (1994) Clinical evaluation of the efficacy and safety of a new sonic toothbrush. Journal of Periodontology **65,** 692–697.
Joshipura, K. J., Kent, R. L. & DePaola, P. F. (1994) Gingival recession: Intraoral distribution and associated factors. Journal of Periodontology **65,** 864–871.
Jost-Brinkman, P. G., Heintze, S. D. & Loundos, J. (1994) Studie zur Wirksamkeit elektrischer Zahnbürsten bei Multiband-Patienten. Kieferorthopädie **8,** 235–246.
Kelner, M. (1963) Comparative analysis of the effects of automatic and conventional toothbrushing in mental retardates. Pennsylvania Dental Journal **30,** 102–108.
Khocht, A., Simon, G., Person, P. & Denepitiya, J. L. (1993) Gingival recession in relation to history of hard toothbrush use. Journal of Periodontology **64,** 900–905.
Killoy, W. J., Love, J. W., Love, J. D. & Tira, D. E. (1993) Clinical and cost effectiveness of the counter-rotational brush in private practice. Compendium of Continuing Education in Dentistry **16,** 599–605.
Lange, D. E. (1977) Über den Einfluß verschiedener Zahnbürstentypen auf die Gingivaoberfläche. Zahnärztliche Mitteilungen **67,** 729–736.
Lefkowitz, H., William, B. & Robinson, G. (1962) Effectiveness of automatic and hand brushes in removing dental plaque and debris. Journal of the American Dental Association **65,** 351–361.
Lindhe, J. & Nyman, S. (1984) Long-term maintenance of patients treated for advanced periodontal disease. Journal of Clinical Periodontoogy **11,** 504–509.
Löe, H. & Kleinmann, D. V. (1986) Dental plaque control measures and oral hygiene practices. Oxford, England: IRL Press.
Martin W. E., Kiger, R. D., Levy, S. M. & Feller, R. P. (1987) A clinical evaluation of mechanical and conventional toothbrushing by institutionalized elderly patients. Journal of Dental Research **66,** 235 (abstract 1020).
McInnes, C., Johnson, B., Emling, R. C. & Yankell, S. L. (1994) Clinical and computer-assisted evaluations of stain removal ability of the sonicare electronic toothbrush. Journal of Clinical Dentistry **5,** 13–18.
Mierau, H. D. & Spindler, T. (1984) Beitrag zur Etiologie der Gingivarezessionen. Deutsche Zahnärtzliche Zeitschrift **39,** 634–639.
Moran, J. M. & Addy, M. (1995) A comparative study of stain removal with 2 electric toothbrushes and a manual brush. Journal of Clinical Dentistry **6,** 188–193.
Muhler, J. C. (1969) Comparative frequency of use of the electric toothbrush and hand toothbrush. Journal of Periodontology **40,** 265–270.
Müller, L. J., Darby, M. L., Allen, D. S. & Tolle, S. L. (1987) Rotary electric toothbrushing. Clinical effects on the presence of gingivitis and supragingival plaque. Dental Hygiene **61,** 546–550.
Niemi M.-L., Anaimo, J. & Etemadzadeh, H. (1986) Gingival abrasion and plaque removal with manual versus electric toothbrushing. Journal of Clinical Peridontology **13,** 709–713.
Niemi M.-J. (1987) Gingival abrasion and plaque removal after toothbrushing with an electric and manual toothbrush. Acta Odontologica Scandinavia **45,** 367–370.
Overholser, C. D. (1988) Longitudinal clinical studies with antimicrobial mouthrinses. Journal of Clinical Periodontology **15,** 517–519.
Owen, T. L. (1972) A clinical evaluation of electric and manual toothbrushing by children with primary dentitions. Journal of Dentistry for Children **39,** 15–21.
Preber, H., Ylipaa, V., Bergstrom, J. & Ryden, H. (1991) Comparative study of plaque removing efficiency using rotary electric and manual toothbrushes. Swedish Dental Journal **15,** 229–234.
Quirynen, M., Vervliet, E., Teerlinck, J., Darius, P. & van Steenberghe, D. (1994) Medium- and long-term effectiveness of a counterrotational electric toothbrush on plaque removal, gingival bleeding, and probing pocket depth. International Journal of Periodontics & Restorative Dentistry **14,** 365–377.
Rapley, J. W. & Killoy, W. J. (1994) Subgingival and interproximal plaque removal using a counter-rotational electric toothbrush and a manual toothbrush. Quintessence International **25,** 39–42.
Robinson, P. J., Maddalozzo, D. & Breslin, S. (1997) A 6-month clinical comparison of the efficacy of the Sonicare® and the Braun Oral-B® electric toothbrushes on improving periodontal health in adult periodontitis patients. Journal of Clinical Dentistry **8,** 4–9.
Sandholm, L., Niemi, M. L. & Ainamo, J. (1982) Identification of soft tissue brushing lesions. A clinical and scanning electron microscopic study. Journal of Clinical Periodontology **9,** 397–401.
Saxer, U. P. & Yankell, S. L. (1997) Impact of improved toothbrushes on dental diseases. II. Quintessence International **28,** 573–593.
Schemehorn, B. R., Ball, T. & Bloom, B. (1993) A model to determine the relative abrasiveness of rotary toothbrushes. Journal of Dental Research **72,** 413 (abstract 2480).
Schemehorn, B. R. & Zwart, A. C. (1996) The dentin abrasivity potential of a new electric toothbrush. American Journal of Dentistry **9,** 19–20.
Schemehorn, B. R. & Henry, G. M. (1996) A laboratory investigation of stain removal from enamel surface: Comparative efficacy of 3 electric toothbrushes. American Journal of Dentistry **9,** 21–24.
Scutt, J. S & Swann, C. J. (1975) The first mechanical toothbrush? British Dental Journal **139,** 152.
Serino, G., Wennstrom, J. L., Lindhe, J. & Eneroth, L. (1994) The prevalence and distribution of gingival recession in subjects with a high standard of oral hygiene. Journal of Clinical Periodontology **21,** 57–63.
Silverstone, L. M., Tilliss, T. S. I., Cross-Poline, G. N., Van der Linden, E., Stach, D. J. & Featherstone, J. (1992) A six-week study comparing the efficacy of a rotary electric toothbrush with a conventional toothbrush. Clinical Preventive Dentistry **14,** 29–34.

Slop D. (1986) Abrasion of enamel by toothbrushing. Academic Thesis, University of Groningen, The Netherlands.

Smith, J. F. & Blankenship, J. (1964) Improving oral hygiene in handicapped children by the use of an electric toothbrush. Journal Dentistry in Children **31,** 198–203.

Stålnacke, K., Söderfeldt, B. & Sjödin, B. (1995) Compliance in use of electric toothbrushes. Acta Odontologica Scandinavia **53,** 17–19.

Stoltze, K. & Bay, L. (1994) Comparison of a manual and a new electric toothbrush for controlling plaque and gingivitis. Journal of Clinical Periodontology **21,** 86–90.

Terezhalmy, G. T., Gagliardi, V. B., Rybicki, L. & Kaufman, M. J. (1995a) Clinical evaluation of the efficacy and safety of the Ultrasonex toothbrush: a 30-day study. Compendium of Continuing Education in Dentistry **15,** 866–874.

Terezhalmy, G. T., Iffland, H., Jelepis, C. & Waskowski, J. (1995b) Clinical evaluation of the effect of an ultrasonic toothbrush on plaque, gingivitis and gingival bleeding: a six-month study. Journal of Prosthetic Dentistry **73,** 97–103.

Tritten, C. B. & Armitage, G. C. (1996) Comparison of a sonic and manual toothbrush for efficacy in supragingival plaque removal and reduction of gingivitis. Journal of Clinical Periodontology **23,** 641–648.

Van Swol, R. L., Van Scotter, D. E, Pucher, J. J. & Dentino, A. R. (1996) Clinical evaluation of an ionic toothbrush in the removal of established plaque and reduction of gingivitis. Quintessence International **27,** 389–394.

Van der Velden, U., Timmerman, M. F. & Van der Weijden, G. A. (1993) Abrasie, geen elektrisch probleem! Nederlands Tandartsenblad **48,** 549.

Van der Weijden, G. A., Danser, M. M., Nijboer, A., Timmerman, M. F. & Van der Velden, U. (1993a) The plaque-removing efficacy of an oscillating/rotating toothbrush. A short-term study. Journal of Clinical Periodontology **20,** 273–278.

Van der Weijden, G. A., Timmerman, M. F., Nijboer, A. & Van der Velden, U. (1993b) A comparative study of electric toothbrushes for the effectiveness of plaque removal in relation to toothbrushing duration. A timer study. Journal of Clinical Periodontology **20,** 476–481.

Van der Weijden, G. A., Timmerman, M. F., Reijerse, E., Danser, M. M., Mantel, M. S., Nijboer, A. & Van der Velden, U. (1994) The longterm effect of an oscillating/rotating toothbrush. An 8-month clinical study. Journal of Clinical Periodontology **21,** 139–145.

Van der Weijden, G. A., Timmerman, M. F., Reijerse, E., Mantel, M. S. & Van der Velden, U. (1995a) The effectiveness of an electronic toothbrush in the removal of established plaque and treatment of gingivitis. Journal of Clinical Periodontology **22,** 179–182.

Van der Weijden, G. A., Timmerman, M. F., Reijerse, E., Snoek, C. M. & Van der Velden, U. (1995b) Comparison of two electric toothbrushes in plaque removing ability-professional and supervised brushing. Journal of Clinical Periodontology **22,** 648–652.

Van der Weijden, G. A., Timmerman, M. F., Snoek, I., Reijerse, E. & Van der Velden, U. (1996a) Toothbrushing duration and plaque removing efficacy of electric toothbrushes. American Journal of Dentistry **9,** 31–36.

Van der Weijden, G. A., Timmerman, M. F., Reijerse, E., Snoek, C. M. & Van der Velden, U. (1996b) Comparison of an oscillating rotating electric toothbrush and a "sonic" toothbrush in plaque-removing ability. Journal of Clinical Periodontology **24,** 1–5.

Van der Weijden, G. A., Timmerman, M. F., Reijerse, E., Snoek, C. M. & van der Velden, U. (1996c) Toothbrushing force in relation to plaque removal. Journal of Clinical Periodontology **23,** 724–729.

Van der Weijden, G. A., Timmerman, M. F., Piscaer, M., IJzerman, Y. & Van der Velden, U. (1998) A comparison of the efficacy of a novel electric toothbrush and a manual toothbrush in the treatment of gingivitis. American Journal of Dentistry (in press).

Vehkalahti, M. (1989) Occurrence of gingival recession in adults. Journal of Periodontology **60,** 599–602.

Walmsley, A. D. (1997) The electric toothbrush: A review. British Dental Journal **182,** 209–218.

Walsh M. (1989) Comparison of manual and power toothbrushing, with and without adjunctive oral irrigation, for controlling plaque and gingivitis. Journal of Clinical Periodontology **16,** 419–427.

Walsh, T. F. & Glenwright, H. D. (1984) Relative effectiveness of a rotary and conventional toothbrush in plaque removal. Community Dentistry and Oral Epidemiology **12,** 160–164.

White, L. (1996) Efficacy of a sonic toothbrush in reducing plaque and gingivitis in adolescent patients. Journal of Clinical Orthodontics **30,** 85–90.

Wilcoxon, D. B., Ackerman, R. J., Killoy, W. J., Love, J. W., Sakumura, J. S. & Tira, D. E. (1991) The effectiveness of a counterrotational action power toothbrush on plaque control in orthodontic patients. American Journal of Orthodontic and Dentofacial Orthopaedics **99,** 7–14.

Wilson, S., Levine, D., Dequincey, G. & Killoy, W. J. (1993) Effects of two toothbrushes on plaque, gingivitis, gingival abrasion, and recession: A 1-year longitudinal study. Compendium of Continuing Education in Dentistry **16,** 569–579.

Yankell, S. L., Emling, R. C., Cohen, D. W. & Vanarsdall, R. (1985) A four-week evaluation of oral health in orthodontic patients using a new plaque removal device. Compendium of Continuing Education in Dentistry **6,** 123–127.

Yukna, R. A. & Shaklee, R. L. (1993) Evaluation of a counterrotational powered brush in patients in supportive periodontal therapy. Journal of Periodontology **64,** 859–864.

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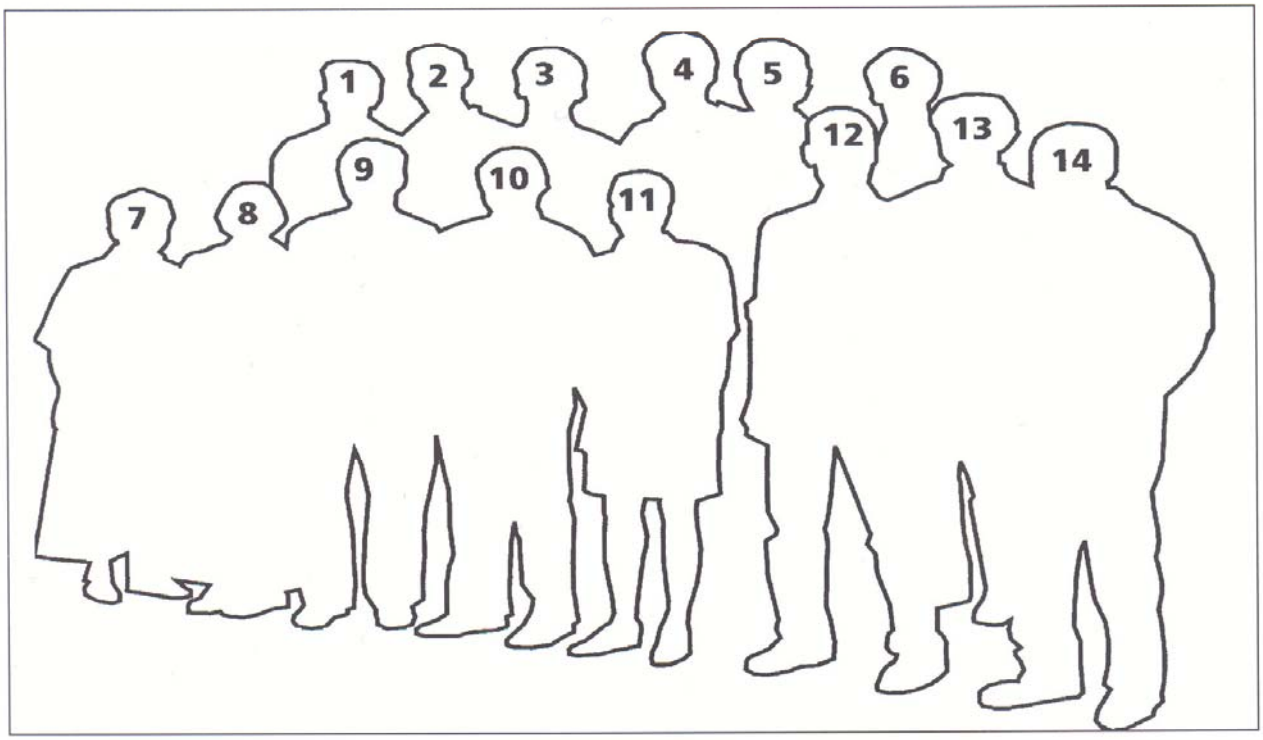
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