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Shreekala Subhash Borker
Post-Graduate Student,
Department of Periodontics,
Goa Dental College & Hospital,
Bambolim, Goa, India

Sandeep Anant Lawande
Assistant Professor,
Department of Periodontics,
Goa Dental College & Hospital,
Bambolim, Goa, India

James Samuel
Professor and Head,
Department of Periodontics,
Goa Dental College & Hospital,
Bambolim, Goa, India

Corresponding Author:
Sandeep Anant Lawande
Assistant Professor
Department of Periodontics,
Goa Dental College & Hospital,
Bambolim, Goa, India

Recent advancements in toothbrush systems for improved mechanical plaque control

Shreekala Subhash Borker, Sandeep Anant Lawande and James Samuel

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Abstract

Plaque control is the elimination of dental plaque on a day-to-day basis and prevention of its recurrence. Toothbrushes remain an integral part of the routine oral hygiene practices. The ideal design of a toothbrush should provide patient comfort; achieve efficient plaque removal without causing any trauma to the hard as well as soft tissues of the oral cavity. The present article attempts to highlight the modern developments in the toothbrush systems for providing improved levels of oral hygiene maintenance.

Keywords: Toothbrush, plaque, biofilm, plaque control, oral hygiene

Introduction

Dental plaque is the principal cause of dental caries and periodontal disease. It refers to a highly organized matrix film comprising of numerous microbial communities ^[1]. The regular disruption of the plaque biofilm through professional mechanical plaque removal and home oral hygiene is a critical point in the prevention of periodontal disease and dental caries ^[2]. Till date, globally, tooth brushing is the most commonly practiced method of mechanical plaque control. Even though, a plethora of toothbrush designs are commercially available, a pertinent design relevant to the individual oral needs should be selected. Type of toothbrush used, suitable design of toothbrush, appropriate brushing technique and proper brushing duration are key factors for plaque control to be highly effective ^[3]. Consequent upon continuous research and development, the toothbrush systems have evolved from manual brushes to smart toothbrushes which combine advanced technology for improved oral health.

Disposable toothbrushes

These are single-use toothbrushes and may be indicated for children, elderly and hospitalized patients, persons lacking manual dexterity and travel-friendly individuals ^[4].

A) Chewable toothbrush

A chewable toothbrush is a small, elastic moulded toothbrush with bristles arranged in a single tuft manner. Neither dentifrice nor water is essential for its use. Brush is composed of xylitol, flavouring aqua, and polydextrose. For brushing action, the brush is held between the teeth and swivelled from one side to another followed by movement of the brush around the mouth with the help of tongue. With the chewing action, the bristles interdentially and across the teeth cause dislodgement of plaque with release of xylitol, an anti-caries agent. After use, care should be taken not to swallow the brush remnants but dispose the brush carefully ^[4]. In a care-dependent elderly population, Myoken Y *et al.* found chewable brush to be highly effective in plaque removal ^[5]. On the contrary, Mladenovic R *et al.* failed to demonstrate any significant difference in the efficacy of the chewable toothbrushes as compared to that of conventional toothbrushes when used in the student population ^[6]. (Example – Fuzzy brush™, Fuzzy Brush Ltd., London, UK).

B) Tooth towelette or Tooth wipe

Tooth to welette and tooth wipe may be used for plaque removal when tooth brushing is not feasible, and should never be considered as a substitute for daily tooth brushing routine.

Tooth wipes are small gauze-like pads saturated with xylitol formulated to prevent dental caries in infants and toddlers. Tooth wipe wrapped around a parent's finger has been found effective in removing biofilm and massaging of gingiva [7]. (Example- *Spiffies™*, *DR Products*, *AZ*, *USA*)

C) Foam brush

Foam brush or foam swab includes a stick on which a disposable soft chlorhexidine-soaked sponge is mounted. It may be particularly indicated in elderly and hospitalized patients. The use of a foam brush with the addition of chlorhexidine may result in reduced plaque levels in medically compromised and immune compromised patients who are not able to maintain oral hygiene with traditionally used oral hygiene tools, thus reducing the risk of oral and systemic infections [4]. (Example – *Toothette™*, *Sage Products*, *USA*)

Finger brush

Finger brush is a soft, flexible, single moulded piece toothbrush with multiple tufts made of soft silicon rubber material. The index finger of the brushing hand is inserted into the hollowed part of the brush. The agility and sensitivity of the finger decides the amount of pressure to be applied for brushing the surfaces of the teeth and gingiva suitably and comfortably. Efficacy of finger brush in terms of plaque removal was reported to be inferior as compared to that of conventional manual toothbrush [4]. (Example – *Silicone Finger Brush™*, *Shenzhen Boonsun Silicone Technology Company Limited*, *China*)

A smaller finger brush was able to remove plaque as efficaciously as manual toothbrush in preschool children between 3 and 6 years of age [8]. (Example – *I-Brush™*, *Tootec Gesellschaft*, *Tubingen*, *Germany*)

Musical toothbrush

As the name indicates, this type of toothbrush includes an inbuilt musical component which begins to play with the onset of brushing and ends upon completion of brushing process. This toothbrush is particularly indicated for children to make brushing more exciting and enjoyable [9]. (Example – *Possi™*, *Kyocera and Lion Corporation*, *Japan*)

Ecological brush

Traditional brushes are made of plastic which is a source of environmental pollution. Researchers have come up with newer, eco-friendly, biodegradable toothbrushes which are manufactured using biodegradable materials such as bamboo, replaceable heads, bioplastics or upcycled handles [10]. (Example - *Zero Waste Toothbrush™*, *The Humble Co.*, *Sweden*)

Curved-bristled toothbrush

This uniquely designed toothbrush includes two outer rows of soft, long curved bristles and a single row of firm, short and straight bristles at the centre. Curved bristles adapt around the convex surfaces of the teeth and provide simultaneous massaging action along the gingival margin in addition to plaque removal. As this type of toothbrush requires less range of motion than conventional toothbrush, it is useful particularly in children, people with orthodontic appliances and individuals with restricted hand or arm movement [11]. (Example - *Collis Curve™*, *Collis-Curve Inc.*, *Minnesota*, *USA*)

Oscillating-rotating electric toothbrush

The electric or powered toothbrush uses the oscillating-rotating (O-R) technology with a small round brush head that adapts to the contours of the teeth. The brush head oscillates and rotates the bristles arranged in different patterns including criss-cross arrangement for gaining access to brushing areas. The oscillating-rotating mode, in which the bristles oscillate and rotate continuously from one direction to another, causes disruption and removal of dental plaque [12]. *Van der Weijden et al.*, in a meta-analysis concluded that oscillating-rotating electric toothbrush provides a strong evidence for the efficacy in terms of achieving greater reduction in plaque and gingival inflammation than manual toothbrush [13]. (Example – *Oral-B Vitality™*, *Procter & Gamble Company*, *OH*, *USA*)

Suction toothbrush

A suction toothbrush is a special type of toothbrush indicated for use in patients in a hospital care setting where self-maintenance of oral hygiene is not possible. This type of toothbrush includes bristles or a swab which form the head portion which connects the hose to a vacuum. The negative pressure performs the sucking action with removal of debris and particles. It is also effective in patients with high risk of aspiration pneumonia [14]. *Sumi et al.* demonstrated effective plaque removal and significant improvement in gingival health in dependent elderly individuals using an oral care support system combining modified electric toothbrush, povidone-iodine delivery system and suction system [15]. (Example – *BALLARD™*, *Avanos Medical Inc.*, *USA*)

Sonic toothbrush

Sonic toothbrush involves a working frequency of 260 Hz with generation of high velocity sonic waves creating a turbulent effect and shear forces that result in plaque removal [16]. A meta-analysis of sonic toothbrushes versus manual toothbrushes by *de Jager et al.* reported that the sonic brushes produced greater reduction in plaque and gingivitis than manually controlled toothbrushes, probably because of better compliance [17]. (Example – *Philips Sonicare Elite™*, *Philips*, *WA*, *USA*)

Ultrasonic toothbrush

The ultrasonic toothbrush system comprises of a commercial toothbrush with a piezoelectric ultrasonic emitter (transducer) embedded in the brush head. The ultrasonic emitter works with a frequency of >20kHz, much higher than that of conventional electric toothbrush. Ultrasound waves are generated from the brush head with the conversion of electrical energy to mechanical energy which leads to the movement of the bristle tips. This gives rise to cavitation effect and acoustic micro streaming with resultant agitation and dislodgement of dental plaque. Dentifrice is used to couple the ultrasonic waves to the teeth and soft tissues. Theoretically, gingival fluids in the sulcus can also conduct the ultrasonic waves into the subgingival environment [18]. *Takenouchi et al.* evaluated the effects of ultrasonic toothbrushes in dental hygiene students for a period of four weeks and found these brushes to be highly effective in decreasing the plaque index scores and increasing the flow rate of saliva [19]. (Example - *Emmi-dent™*, *Emmi Ultrasonic*, *Germany*)

Application-connected toothbrush

This toothbrush includes a sensor through which data gets saved in the form of recording or mapping of individual's

brushing behaviour for up to 3 weeks. This data can be uploaded wirelessly on android mobile and shared with the dentist if required or can be recorded for the purpose of personal management and motivation. In addition to this, the toothbrush is also equipped with a two-minute brushing with quadrant indicator which aids in providing oral health information ^[20]. (Example – Beam Brush™, Beam Dental Technology, USA)

Ionic toothbrush

Ionic toothbrush works on the principle of polarity unlike conventional toothbrush which depends only on frictional force. Tooth surface is negatively charged whereas plaque carries positive charge. The brush handle includes a battery which is connected to the titanium rod within the brush. A thin metal band is placed surrounding the handle. When the metal band comes in contact with moist hands just before brushing, a closed circuit is created. At the onset of brushing, positively charged ions from the toothbrush are released as a result of which polarity of tooth surface is changed from negative to positive leading to repulsion of plaque ^[21, 22]. Deshmukh *et al.* demonstrated that ionic toothbrush was safe and effective in elimination of plaque and gingival bleeding in dental student population from day 0 to day 21^[22]. (Example – HyG™, Hukuba Dental Corporation, Japan)

Laser toothbrush

It is an improved version of the modern toothbrush that utilizes low –level laser therapy (LLLT) with the help of diode laser in the toothbrush wool powered with a battery. It is meant to be a home care device in which all the functions are controlled by a built-in micro-computer (micom). No dentifrice is required while using this type of brush as the laser directly irradiates the affected area. Lasers have been successfully attempted in the management of dentinal hypersensitivity. Diode laser within the toothbrush emits red light in the visible spectrum. The desensitizing effect is produced by laser irradiation inducing odontoblastic cellular metabolism hyperactivity which occludes the dentinal tubules by formation of tertiary dentine. In addition to this, laser radiation can cause reduction of cellular membrane action potential and depolarization of nerve fibers thereby blocking pain transmission ^[23]. Studies have found low-level laser-emitting toothbrush to be a safe and effective treatment option for dentinal hypersensitivity ^[24, 25]. (Example – Dr. M™, Medical & Human technology Co. Ltd., Kyeonggi, Korea)

Light-emitting diode toothbrush

Light-emitting diode (LED) technology has been incorporated into electric toothbrush. LED sources are available as blue, red and white lights which have antibacterial, analgesic, anti-inflammatory and wound healing properties ^[26, 27]. Kwon *et al.* investigated the adjunctive effects of LED toothbrush in patients with gingivitis and observed significantly greater reduction in dental plaque and gingival inflammation than non-LED electric toothbrush ^[26]. (Example – SMART E-Care™, Daegu, Korea)

Caries-detection toothbrush

An improved version of the modern toothbrush designed to detect dental caries with the help of laser technology wherein the reflected light from the carious area is collected and sent to a microcomputer chip in the toothbrush handle ^[20]. (Example - C-SMART™, C-Smart Company Limited, USA).

Solar powered toothbrush

This type of toothbrush features a solar panel attached to the handle towards the base and a rod containing titanium dioxide semiconductor in the head portion of the brush. There is no need for using a dentifrice for tooth brushing. When light hits the solar panel, the electrons are released and transmitted through the water or saliva to the teeth via photo catalytic titanium dioxide. These negatively charged electrons attract positively charged ions from dental plaque causing oxidation and disruption of plaque. In a double-blind, cross-over study in adults, Uswak *et al.* reported that the solar powered toothbrush was highly effective in plaque removal and gingival improvement especially on the buccal and interproximal surfaces ^[28]. (Example - Soladey-J3X™, Japan)

Hybrid toothbrush

The toothbrush designed with a hybrid technology operates either in manual mode (motor off), in powered mode (sonic) or in combined mode. This offers a choice between traditional manual brushing technique, sonic brushing or the combination of the two depending on the individual preference ^[29]. (Example – Inava Hybrid Timer™, Pierre Fabre Oral Care, France)

Mouthpiece toothbrush

This is a U-shaped or horse-shoe shaped automatic electric toothbrush with silicone bristles with a fully automatic and simultaneous action on maxillary and mandibular arches. This type of toothbrush is indicated for individuals with poor dexterity or compliance. The mouthpiece is horse-shoe shaped and resembles a night guard. It consists of two planes with four-rowed silicone bristle arrangement at the oral and vestibular side of the maxillary and mandibular arches. Bristles are aligned at 45 degrees to the marginal gingiva in order to simulate Bass method of tooth brushing. With application of this brush, total brushing time is reduced to about 20 to 30 seconds. However, Nieri *et al.* demonstrated that the mouthpiece brush was not effective in removing dental plaque due to inappropriate bristle alignment and poor fit with diverse dental arches ^[30]. (Example – Amabrush™, GmbH Vienna, AT)

Half-mouth toothbrush

Half-mouth toothbrush is a powered J-shaped toothbrush which surrounds all sides of the teeth. The self-adjustable brush head is customized so that every tooth achieves bristle contact. The brush head operates with the help of a silent pneumatic pump system at a rate of approximately 100 brush strokes per second.

The bristles contact the teeth at a 90-degree angle when appropriate amount of pressure is applied. It takes approximately 20 seconds for complete tooth brushing, 10 seconds for each side. (Example – Encompass™, RYCA Inc., USA)

Optic sensor toothbrush

This type of toothbrush implements optic sensor technology which can detect plaque in the mouth through a light ring around the brush, which will highlight the build-up in blue when discovered. Following this, the light will turn white once the build-up have been removed, signalling the user to move on. The toothbrush produces a dental map of brushed and unbrushed teeth and coaches the individual on how to brush teeth with the help of computer-based application synchronized with a smartphone via Bluetooth technology.

(Example - *Colgate Plaqless Pro™*, *Colgate-Palmolive Ltd., USA*)

Light therapy electric toothbrush

This type of electric toothbrush uses near infrared (IR) and near ultraviolet (UV) light therapy and features three light modes: blue light mode (near UV), red light mode (near IR), dual light mode (both near IR and UV). The blue light causes microbial killing followed by whitening of teeth in due course of time while the red light has an anti-inflammatory effect and is responsible for secretion of collagen and tissue regeneration. Purple light produced by simultaneous emission of red light and blue light has antimicrobial effect. (Example – *Bristl™*, *Bristl Company, USA*)

Toothbrush with water-flosser

This is a water-flossing machine made for the shower. It is available with three different attachments for oral care: dual-headed toothbrush, irrigating tip, and gingival massager. The dual-headed toothbrush brushes all the surfaces of the teeth and also irrigates while brushing. The irrigating tip causes an interdental flushing action and gingival massager uses seven jets of water for gingival massage while flushing. (Example - *ToothShower™*, *LLC, PA, USA*)

Conclusion

Mechanical plaque control remains the best approach for removing the plaque biofilm. Toothbrushing is the most commonly employed method of plaque removal. Advancements in toothbrush designs combined with newer technology have made plaque control easy, less time consuming and effective, especially for those with special needs, old age and children, who lack manual dexterity. Various toothbrush designs are available commercially but superiority in terms of clinical significance has not been demonstrated for any one type of toothbrush. Ease of manipulation by the patient and patient's perception that the brush works well is an important factor. Regardless of the design, the best plaque control is achieved when the patient is well motivated and instructed in its proper use.

Conflict of Interest

The authors have no conflict of interest to declare.

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