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Impact of Technology on the Toothbrush

Impacto de la Tecnología en el Cepillo Dental

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Abstract:

This article analyzes the impact of technology on toothbrush design and functionality, highlighting how innovations have improved oral hygiene and the prevention of dental diseases such as caries. The historical evolution of the toothbrush is reviewed, from its first uses in ancient times to the adoption of synthetic materials such as nylon. In addition, the different designs of manual toothbrushes are explored, such as bristle profile and ergonomic handle shapes, which influence brushing efficiency, along with adaptations for children and people with special needs. The article also discusses the advances in electric toothbrushes since their appearance in the 1960s. It highlights how models with rotating and sonic brush heads have proven more efficient than manual toothbrushes in biofilm removal and gingivitis prevention. Improved ease of use and cleaning of hard-to-reach areas is highlighted as one of the great benefits of these technologies. In addition, it introduces the Smart Toothbrush and Mirror System (STM), which offers real-time feedback on brushing technique, improving learning, especially in children. Finally, it mentions the biodegradable toothbrush as a sustainable alternative to traditional toothbrushes, which contributes to reducing environmental impact and promoting more responsible consumption.

Keywords:

Oral hygiene, Manual toothbrush, Electric toothbrush, Smart toothbrush, Biodegradable toothbrush, Dental prevention.

Resumen:

Este artículo analiza el impacto de la tecnología en el diseño y funcionalidad de los cepillos dentales, destacando como las innovaciones han mejorado la higiene bucal y la prevención de enfermedades dentales, como las caries. Se revisa la evolución histórica del cepillo dental, desde sus primeros usos en la antigüedad hasta la adopción de materiales sintéticos como el nylon. Además, se exploran los diferentes diseños de cepillos manuales, como el perfil de las cerdas y las formas ergonómicas del mango, que influyen en la eficacia del cepillado, así como las adaptaciones para niños y personas con necesidades especiales. El artículo también aborda los avances de los cepillos eléctricos, desde su aparición en la década de 1960, subrayando como modelos con cabezales rotatorios y sónicos han demostrado ser más efectivos que los manuales en la eliminación de biopelícula y la prevención de la gingivitis. La mejora en la facilidad de uso y en la limpieza de áreas difíciles de alcanzar se destaca como uno de los grandes beneficios de estas tecnologías. Además, se presenta el Sistema de Cepillo de Dientes y Espejo Inteligente (STM), que ofrece retroalimentación en tiempo real sobre la técnica de cepillado, mejorando el aprendizaje, especialmente en niños. Finalmente, se menciona el cepillo de dientes biodegradable como una alternativa sostenible a los tradicionales, contribuyendo a reducir el impacto ambiental y promover un consumo más responsable.

***Palabras Clave**:*

Higiene bucal, cepillo de dientes manual, cepillo de dientes eléctrico, cepillo de dientes inteligente, cepillo de dientes biodegradable, prevención dental.

INTRODUCTION

Oral diseases, especially dental caries, represent one of the most prevalent conditions worldwide, affecting millions of people, particularly children. According to the World Health Organization (WHO), oral diseases not only have an immediate impact on health, but also have long-term consequences, affecting quality of life, generating pain, discomfort, and even disfigurement or death in extreme cases. Although it is a preventable disease, its high prevalence among children remains a significant concern for global health systems.[1]

It develops mainly due to the accumulation of a bacterial biofilm that grows on the surfaces of the teeth, favored by a diet rich in

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sugars and a lack of control in oral hygiene. Tooth brushing is one of the most effective techniques to remove biofilm and prevent caries; however, its correct execution, especially in children, requires learning and adequate supervision.[2]

During school age, children experience the eruption of their permanent teeth; they are particularly vulnerable due to their rough anatomy and profound pits. This stage of dental development is marked by challenges in maintaining proper hygiene due to newly erupted primary teeth, which elevates the risk of gingivitis. Active cooperation from both the child and the parent's management of the brushing process is crucial to maintaining proper oral hygiene. However, many parents are unaware of the correct technique for brushing their children's teeth, making it challenging to supervise the process each time.[3]

MANUAL TOOTHBRUSH

The history of the toothbrush reveals the evolution of oral hygiene practices over the centuries. In ancient times, people used natural methods such as chewing twigs with aromatic properties to clean their teeth. Pre-Islamic Arabs, for example, used Miswak, a tree root with antibacterial properties, which also helped freshen breath. In the 17th century, Muhammad established rules on dental care, making it a religious obligation.[4]

The first step toward the modern toothbrush occurred in China during the Tang dynasty (618-907 A.D.). There, they created brushes with bristles and handles. However, it was not until 1780 in England that William Addis manufactured the first modern toothbrush, with a bone handle and natural pig bristles. Over time, due to material shortages during the world wars, synthetic materials such as celluloid and later nylon began to be used. The latter improved the effectiveness of the brushes by being more versatile in size and shape.[5]

Since 1990, toothbrushes have continued to evolve, with innovative designs that improve biofilm removal. Scientific research has demonstrated their effectiveness in improving oral health, and organizations such as the International Association of Dental Research have promoted advances in the technology of these devices. In addition, toothbrush marketing has adapted to consumer needs, recommending replacement every three to four months and offering high-tech models. Although some toothbrushes are more expensive, they are still affordable compared to other oral hygiene products.[5,6]

MANUAL TOOTHBRUSH DESIGNS

Manual toothbrushes have experienced a wide diversity regarding size, shape, texture, and design, making them one of the most varied products in oral hygiene. Each toothbrush component plays an essential role in its functionality and adaptation to the individual needs of users. The typical manual toothbrush consists of three main parts: the head, the bristles (called tufts) and the handle. The head divides into two sections (tip and heel), varies in size and shape, and is designed to allow efficient teeth cleaning, with a narrower end that facilitates access to hard-to-reach areas. On the other hand, the handle connects to the head through a constriction known as a shaft, which provides a gripping point.[7]

One of the key features of toothbrushes is the variety of sizes available. Toothbrushes are manufactured in large, medium, and small (or compact) sizes, allowing each individual to choose the most appropriate size for the anatomy of their oral cavity. This size diversity ensures that the brush is comfortable and can reach all areas of the mouth, facilitating effective cleaning.[7,8]

Toothbrushes also vary in the hardness of their bristles, which directly influences their effectiveness and user comfort. Bristles are typically categorized as hard, medium, soft, or extra-soft bristles based on the sensitivity of a person's teeth and gums. Soft-bristle brushes are the most recommended by dental health professionals, as they are less abrasive and gentler on the gums, but equally effective in removing biofilm.[8]

However, despite the wide range of designs, information on the comparative efficacy of various toothbrushes remains contradictory, mainly due to several factors that complicate evaluations, such as the lack of standardized methods for measuring cleanliness (biofilm removal), the wide diversity of brush sizes and shapes, and the different brushing techniques used in the studies. Besides, recent advances in brush head designs, which include variations in bristle lengths and arrangements, have introduced new complexities to determine the most effective design.[8,9]

In response to these complexities, brush ergonomics have improved by adapting the handles to different dexterity levels. It ensures that people with more limited motor skills and more developed dexterity can use the brush comfortably and effectively. Advances in manufacturing technology have also enabled the development of toothbrushes with multi-level heads, which improve access to interproximal areas and facilitate biofilm removal.[9]

PROFILE

When analyzing toothbrushes from a lateral perspective, it is possible to identify four basic profiles that define their design: concave, convex, flat, and multilevel. Each of these profiles has a specific function and is used to better adapt to the cleaning needs of different areas of the oral cavity.[10]

The concave profile, for example, helps improve the cleaning of the facial surfaces of the teeth. Its shape allows better contact with these areas, which facilitates biofilm removal. In contrast, brushes with a convex profile appear to be more effective for cleaning the lingual surfaces of the teeth, as the curved shape of the brush allows better access and coverage of this harder-to-reach area.[11]

Brushes with a flat profile are the most traditional, but in clinical and laboratory studies, they are less effective than those with a multilevel design. Multilevel profiles, which include bristles arranged in different heights or shapes, have shown a higher ability to clean interproximal areas, i.e., the spaces between teeth. This feature is crucial, as biofilm and food debris

accumulation often occur in these places, which can lead to caries and gingival disease if not cleaned properly.[12]

In the studies conducted, brushes with multilevel profiles were more effective than flat design brushes, especially when monitoring interproximal effectiveness, because bristles of different lengths and positions allow more precise contact with the spaces between teeth, improving biofilm removal in areas that traditional brushes may miss. This innovative design has led to multilevel profile brushes becoming a popular alternative in dental practice, since they provide a more thorough and efficient cleaning.[13]

BRISTLE SHAPES

Recently, advances in toothbrush manufacturing technology have resulted in new bristle shapes and textures, which have revolutionized the design and effectiveness of these products. These innovations include bristles in multiple diameters, textures, and shapes, allowing for greater customization in toothbrushing. Rounded, feathered, and diamond-shaped bristles have been introduced, which are more effective than standard round bristles.[14]

Laboratory studies have supported these improvements, highlighting the superiority of bristles with more specialized shapes. For example, rounded bristles are less abrasive to the gums and provide gentler cleaning. Feather and diamond-shaped bristles offer greater penetration and biofilm removal in hard-to-reach areas, such as interproximal spaces or spaces where standard bristles cannot access as effectively. These innovative shapes allow the brush to reach specific areas of the oral cavity more precisely, improving brushing quality and contributing to a deeper, more thorough clean.[14,15]

The use of specialized bristles is associated with reduced irritation of the gum tissue, making them better suited for individuals with sensitive gums or those requiring more gentle dental care. Additionally, these new textures and shapes help to distribute pressure more effectively while brushing, which reduces the risk of damaging or wearing down tooth enamel while improving the removal of biofilm.[15]

ROUNDED TIP

In the early days of toothbrush design, bristles were cut in bundles, often resulting in sharp ends. However, a seminal 1948 study by Bass pointed out that these sharp tips could damage the mouth's soft tissues. In response, Bass recommended bristles with round, smooth, obtuse tips, because they were significantly less abrasive to gums and teeth. Although Bass' research did not follow a strict protocol, his findings have endured for more than 40 years and continue to be cited, even by toothbrush manufacturers, who promote round bristles as a safety measure to prevent oral tissue damage. Despite this widespread recommendation, more recent studies have questioned the uniformity of "round" bristles. To the naked eye, many bristles marketed as round appear to have a smooth shape. Under higher magnification, some of these bristles show irregular configurations, such as sharp or worn tips. With continued use, the bristles become milder and rounder, but they also tend to expand and disperse. In turn, it can lead to differential wear, which depends on brushing pressure and the amount of toothpaste used, among other factors.[16,17]

HANDLE DESIGN

In recent years, toothbrushes in the United States have undergone a series of design innovations, especially related to the handle. These changes aim to enhance brushing comfort and efficiency by incorporating ergonomic and functional elements that facilitate the brushing experience. Common examples of these advances are the triangular extrusions or indentations on the sides of the handles, which provide a better grip, and the "thumb positions" at the back to improve comfort during brushing. In addition, angled handles have been introduced to allow better access to different areas of the mouth. This angled design has been compared to professional dental instruments, such as dental mirrors, due to their similar shape and ability to reach difficult areas. Brushes with this angled design, also known as "dental instrument brushes," offer high precision and ease of use, similar to procedures used by dentists in the clinic. In addition, some models have handles aligned with the bristle tips, which improve coordination during brushing, as the bristle contact points are aligned with the longitudinal axis of the handle.[18]

Handle design and length are also relevant factors concerning comfort and efficiency. A well-designed handle makes it easier to control the brush and can improve the brushing quality, allowing more precise and comfortable movements. It is especially relevant for toothbrushes intended for children, as their motor skills are not yet fully developed. With easier-to-handle handles, children can perform more efficient and less complicated brushing.[19]

TEXTURE

The nylon bristles used in toothbrushes have controlled design characteristics that include uniform diameter and predictable texture, which is essential in determining brushing efficiency. Bristle texture, which refers to its resistance to pressure applied during use, is often classified by firmness, stiffness, or hardness. These characteristics are affected by bristle composition, diameter, length and the number of bristles. [20]

Bristle diameter is a key element in determining texture, especially when bristle length is within a range of 10 to 12 mm in most toothbrushes. In adult toothbrushes, bristle diameter typically ranges from 0.007 to 0.015 inches. These parameters allow controlling bristle firmness during manufacturing, ensuring consistent texture in each product.[20]

It is important to note that bristle texture can alter with time and use. Factors such as temperature, the bristles' ability to absorb water (hydration), and the brush's use frequency affect the stiffness and effectiveness of the bristles. This natural wear alters bristle properties, influencing brushing performance.[21]

One of the challenges in the toothbrush industry is the lack of standardization in bristle texture labeling. Manufacturers often

label their products based on internal testing criteria, which leads to confusion, as what one manufacturer considers “soft” could be stiffer for another, who regards it as “medium.” To address this problem, the International Organization for Standardization (ISO) has established testing procedures that allow manufacturers to label brushes consistently and coherently, ensuring greater clarity for the consumer. As a member of ISO, the American Dental Association (ADA) contributes to this effort by promoting global standards to improve the quality of dental products.[21]

ELECTRIC TOOTHBRUSH

Electric toothbrushes began to gain notice in the mid-20th century, initially being advertised in 1986 in Harper's Weekly magazine and gaining prominence in the U.S. market in the early 1960s with the introduction of Broxadent. However, while the early models were a breakthrough, battery-powered products had significant limitations, such as short usage times and mechanical failures, which caused enthusiasm for electric toothbrushes to wane. For a time, these devices were recommended primarily for people with disabilities because of their ease-of-use advantages.[22]

It was in the 1980s that the electric toothbrush category experienced a revitalization with the appearance of the InterPlak model. This “second generation” of electric toothbrushes innovated with a rotating head and long-lasting rechargeable batteries, improving efficiency significantly. Studies published during that period consistently showed that electric toothbrushes were more effective than manual toothbrushes in removing biofilm. Over the years, “third-generation” ultrasound-based models were developed, showing to be even more effective in removing biofilm, especially in long-term studies. These brushes are available in two main types of head design: rotating, which has a small, round head the size of a molar crown, and oscillating with sonic vibration or rotational movements. These advances have shown that both rotary and sonic brushes have similar efficacy in biofilm removal, and periodontal therapeutic effects are evident, especially in individuals with periodontal pockets of ≤5 mm.[23-25]

In developed countries, the use of electric toothbrushes has significantly increased in recent years, particularly in Switzerland, where regular usage of these devices has grown from 10% to 30% over the last decade. However, epidemiological studies have also documented that, in various populations, excessive use of oscillatory electric toothbrushes is associated with increased enamel wear and gingival recession. In comparison, Sonic toothbrushes have been shown to cause much less damage to people’s gums. Additionally, Sonic models are known for their durability, as the bristles hardly show any signs of wear even after 6 to 12 months of use.[26]

BRISTLES AND DESIGN

The electric or mechanical toothbrushes’ heads are usually smaller than manual toothbrushes, allowing for better maneuverability and easier access to harder-to-reach areas in the oral cavity. In addition, most of these brushes have interchangeable heads, allowing them to be replaced periodically, thus guaranteeing optimal performance for longer. This constitutes a significant advantage in terms of hygiene and efficiency.[27,28]

Electric toothbrushes work thanks to a motor that generates movement in the brush head, which follows three basic movement patterns: reciprocating (back and forth movement), arcing (up and down movement), and elliptical (a combination of reciprocating and arcing movements). These automatic movements require no user effort and provide a more consistent and effective cleaning action than manual brushing, where the movement depends on the individual’s skill and technique.[28,29]

Numerous studies have shown that electric toothbrushes are more effective than manual toothbrushes in removing biofilm and preventing gingivitis. In particular, the differences in effectiveness are more noticeable when comparing an electric toothbrush versus a manual toothbrush. Because the automatic movements of electric toothbrushes allow for deeper, more uniform cleaning, reducing the risk of plaque buildup in hard-to-reach areas and improving overall periodontal health.[30-32]

MOTIVATION

Motivation to improve oral hygiene is a key factor in patients' decision to purchase electric toothbrushes. According to an ADA survey, among electric toothbrush owners, 21.6% used them regularly, while 25.2% did so only occasionally. However, the survey does not specify the frequency of use among the rest of the respondents (53%). This data reflects a usual pattern: although electric toothbrushes can increase the frequency of use in the first months, many users do not maintain the routine in the long term. A recent study indicated that most users do not use the electric device twice per day, even six months after completing a clinical research on its effectiveness.[33]

Success in the prolonged use of electric toothbrushes seems to be linked to education and adequate support during the first months. Proper instruction and monitoring during the first six months can improve brushing effectiveness significantly. However, despite advances in electric toothbrush technology, especially when introducing these devices’ second and third generations, recent publications on sustained use have not yet reached definitive conclusions.[33]

The work of Weinstein et al. (1997) discusses motivation failures and points out the importance of treating each patient individually. The dentist and dental hygienist must have the ability to listen to the patient and understand their attitude towards oral hygiene before offering personalized instructions. Education about effective brushing can only occur when the professional knows the patient’s needs and habits. Furthermore, the teaching process must follow a defined sequence; the health professional must be patient, since it is not probable to expect drastic improvements from one session to the next.[34]

A well-structured preventive program is essential for each patient, and it should begin with a detailed medical history.

Afterward, the patient must follow the oral care program to achieve the objectives. Continuous evaluation of the patient's progress, both in the short and long term, is crucial to ensure the plan's effectiveness. Besides, dentists must be able to accept failure and have an alternative strategy to improve the approach, in case the patient does not achieve the expected results. This comprehensive approach is essential to ensure success in preventing and improving long-term oral health.[34]

AMERICAN DENTAL ASSOCIATION ACCEPTANCE PROGRAM

The ADA has established rigorous guidelines to authorize the use of its seal of acceptance on dental products, including manual and electric toothbrushes. In 1996, the ADA's Council on Scientific Affairs proposed new criteria for obtaining this seal, which require laboratory documentation demonstrating acceptably rounded bristle ends, compliance with good manufacturing practices (GMP), and equivalence in clinical effectiveness in reducing plaque and gingivitis when compared to reference products provided by the ADA.[35]

Standard-design manual toothbrushes meeting these guidelines, do not require additional clinical testing. However, manual brushes with new designs and mechanical brushes are only required to demonstrate equivalence in biofilm and gingivitis reduction compared to ADA products. These guidelines ensure that the products effectively clean and reduce gingivitis when used as part of an appropriate oral hygiene program, complementing regular professional care.[35]

The protocol for ADA-approved toothbrushes includes rigorous testing for safety and effectiveness. In the case of electric toothbrushes, the ADA has also developed specific criteria for acceptance. These criteria include: 1) evidence of electrical safety, ensuring no risk of electrical shock, 2) clinical safety to soft and hard tissues under unsupervised conditions, 3) clinical effectiveness in reducing biofilm and gingivitis compared to an ADA approved toothbrush, and 4) evidence of appropriate labeling and advertising, highlighting efficacy in reducing biofilm without mentioning improvements in pre-existing oral disease.[36]

As a result of this process, over 140 toothbrushes, both manual and electric, have the ADA approval. Among electric toothbrushes, ten models have the ADA seal of acceptance, of which five are distributed by Water Pik Technologies. This acceptance process ensures that products are safe, effective, and have labels that accurately reflect their benefits without making unverified claims.[36]

This rigorous approach not only supports the quality of approved products, but also gives consumers confidence that toothbrushes with the ADA seal meet the highest standards of safety and effectiveness in promoting oral health.[37]

SMART TOOTHBRUSHING SYSTEM AND SMART MIRROR (STM)

Recent advancements in information technology have significantly transformed the healthcare sector, including dentistry. Researchers have created devices like electric and oscillating/pulsating toothbrushes to enhance the effectiveness of tooth brushing. However, while these devices help in removing biofilm, they do not assess whether users are employing the correct brushing technique or provide guidance on how to brush properly.[38-44]

The STM, developed in South Korea, is one of the most recent innovations that combines technology with dental education. This system integrates a smart mirror connected to a computer monitor and a toothbrush modified with 3D motion sensors. Sensors capture brush movements and provide real-time feedback on brushing technique. In addition, the system allows users to adjust the difficulty level and customize the brushing method, making the learning process more interactive and efficient for children.[38-44]

The STM not only makes learning the correct technique easier, but it does so in a fun and interactive way, transforming the brushing process into a playful experience. This approach has proven particularly effective in children, who learn better when the process becomes a game.[38-44]

Several studies have evaluated the efficiency of STM in reducing biofilm and improving brushing technique. The results are promising, as these systems can significantly reduce biofilm indices. A similar study observed a 39.88% reduction in biofilm index using a 3D motion tracking system. This reduction is comparable to traditional dental hygiene education methods, but with the advantage of providing immediate feedback tailored to each child's needs.[38-44]

STM systems improve the brushing technique and enhance children's commitment to their oral health. By making brushing more interactive and engaging, children become more competent at the task and develop better oral hygiene habits. Additionally, the system allows remote monitoring, which is helpful when parents cannot supervise brushing. [38-44]

Telemedicine and virtual monitoring are gaining ground in various healthcare areas, including dentistry. In particular, virtual oral hygiene education helps children to improve knowledge levels and improving brushing habits. In countries like Saudi Arabia, where schools have adapted to virtual management due to the COVID-19 pandemic, virtually supervised toothbrushing is considered a possible alternative to traditional methods.[38-44]

A recent study compared the effectiveness of virtual versus traditional instruction in improving oral hygiene habits and found that virtual education had a significantly positive impact on biofilm reduction. This finding suggests that virtual supervision may be as valid as face-to-face supervision in promoting proper oral hygiene in children and may even be more effective.[38-44]

Preventing dental cavities in children is essential to ensure their long-term oral health and improve their quality of life. Brushing teeth with fluoride toothpaste is one of the most effective methods for preventing cavities, but only if done correctly. In this sense, incorporating technologies such as the STM and

virtual supervision can be key tools to improve dental education in children and reduce the prevalence of dental caries.[38-44]

These technological advances offer an innovative solution that improves the brushing technique and transforms the process into a more engaging and efficient experience for children. As studies continue to evaluate the effectiveness of these tools, we are likely to see broader adoption of the technology in oral disease prevention, which could significantly impact overall dental health, especially in children.[38-44]

BIODEGRADABLE TOOTHBRUSH

Nowadays, plastic is present in almost every aspect of our daily lives, and its disposal represents a considerable environmental challenge. Every year, approximately 700 million plastic toothbrushes are sold, contributing significantly to the accumulation of waste. To reduce this negative impact and aid in environmental restoration, we must replace plastic toothbrushes with recyclable alternatives. Applying the 4Rs principle (reduce, reuse, recycle, and rethink) offers a path to a more sustainable future.[45]

Today, toothbrushes made with bamboo handles and natural bristles are recyclable and more ozone-friendly. There is currently no scientific evidence comparing the durability of nylon bristles to that of biodegradable toothbrushes. Natural fibers such as bamboo, coconut, and ridge gourd are useful for toothbrush bristles. Bamboo and coconut bristles are effective in removing dental plaque, with bamboo bristles being notably wear-resistant and having anti-inflammatory, abrasive and plaque-inhibiting properties.[45]

Regarding user satisfaction, many users of bamboo toothbrushes report feeling comfortable with them. Considering durability, a bamboo toothbrush has a similar lifespan to a plastic toothbrush, i.e., 3 to 4 months, provided it has proper care. This duration is in line with the dental industry's recommendation, which suggests replacing toothbrushes every 90 to 120 days due to bristle wear and bacteria buildup.[45]

One of the main advantages of bamboo toothbrushes is that either the handle and bristles are recyclable or biodegradable, i.e., their environmental impact is considerably less than that of traditional toothbrushes. In addition, the amount of bacteria on bamboo toothbrushes is comparable to that of conventional toothbrushes, which shows that they offer similar hygienic maintenance.[45]

In terms of their environmental impact, bamboo toothbrushes have the lowest impact compared to other available options, which is due to their more sustainable life cycle. In addition, they contribute to the reduction of water scarcity and lower global warming potential due to their lower greenhouse gas emissions.[45]

Bamboo brushes reduce water consumption, generate less particulate matter, and have the lowest human carcinogenic toxicity. Furthermore, these brushes are packaged in recyclable cardboard, increasing the recyclable materials and reducing landfill waste.[45]

ORAL HEALTH PROMOTION

The conceptual model of Fisher-Owens et al. proposes multilevel influences on children's oral health, highlighting the importance of individual, family and community factors. At the family level, parents and caregivers significantly influence children's oral health during preschool years, as children spend most of their time with them. Children's dietary and oral health behaviors are closely related to parents' health knowledge, attitudes, and practices. Research indicates that parents possessing comprehensive knowledge of oral health and confidence in their understanding are more likely to promote the development of effective oral hygiene practices within the home environment. (Figure 1).[46]

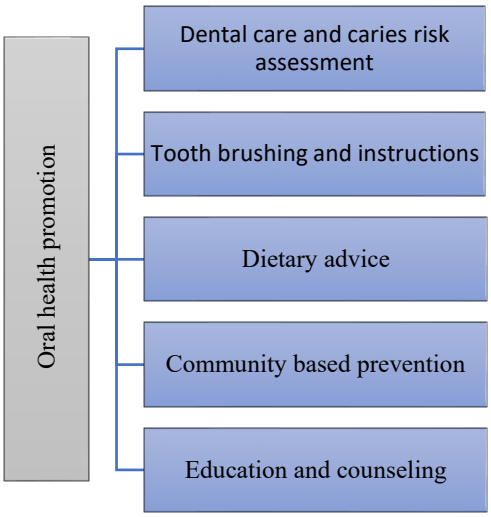

Figure 1. Promotion of children's oral health.[46]

Through these approaches and preventive education programs, we can improve children's oral health from an early age and reduce the prevalence of oral diseases that affect their quality of life and general development.[47,48]

CONCLUSION

The toothbrush evolution reflects significant advances in oral hygiene, with options such as manual toothbrushes, which remain popular for their accessibility, and electric toothbrushes, which offer more efficient and gentle cleaning. In addition, the Smart Toothbrush System has transformed the brushing experience, making it more interactive, especially for children. On the other hand, biodegradable toothbrushes represent a step towards sustainability, enabling more environmentally friendly dental care. These advances underline the importance of promoting good oral hygiene habits from childhood, adapting to the needs of each individual, and taking care of both dental health and the planet.

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