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DEVELOPING AN ATUTOMATIC U-SHAPED TOOTHBRUSH FOR CHILDREDN WITH SPECIAL NEEDS

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Abstract: *Various types of toothbrushes are available for children with special needs, including manual toothbrushes with modified handles, electric toothbrushes, and U-shaped manual toothbrushes. Each toothbrush has inherent limitations that result in suboptimal tooth cleaning, particularly in children with mental disorders and/or fine motor skills. The objective of this study is to develop the potential of an automatic U-shaped toothbrush designed to address the specific oral hygiene needs of children with disabilities. The key scientific concepts that underpin the development of an automatic U-shaped toothbrush is an effective toothbrush for children with special needs, which is easy to use and optimal in removing debris and/or dental plaque. The results of the development of this study produced a prototype scale of the U-shaped toothbrush that simply by pressing one button can clean the entire surface of the teeth on the upper or lower jaw. In conclusion, this automatic U-shaped toothbrush is expected to be beneficial for children with poor fine motor skills, intellectual disabilities, or other special needs who have had difficulty cleaning their teeth properly.*

Keywords: *Automatic, Children, Special Needs, Toothbrush, U-Shaped*

Abstrak: Berbagai jenis sikat gigi tersedia untuk anak-anak dengan kebutuhan khusus, termasuk sikat gigi manual dengan gagang yang dimodifikasi, sikat gigi elektrik, dan sikat gigi manual berbentuk U. Setiap sikat gigi memiliki keterbatasan bawaan yang mengakibatkan pembersihan gigi kurang optimal, terutama pada anak-anak dengan gangguan mental dan/atau keterampilan motorik halus. Tujuan dari penelitian ini adalah untuk mengembangkan potensi sikat gigi otomatis berbentuk U yang dirancang untuk memenuhi kebutuhan kebersihan mulut khusus pada anak-anak dengan disabilitas. Konsep ilmiah utama yang mendasari pengembangan sikat gigi otomatis berbentuk U ini adalah menghasilkan sikat gigi yang efektif untuk anak-anak dengan kebutuhan khusus, mudah digunakan, dan optimal dalam menghilangkan sisa makanan dan/atau plak gigi. Hasil pengembangan dari penelitian ini menghasilkan prototipe sikat gigi berbentuk U skala percobaan yang hanya dengan menekan satu tombol dapat membersihkan seluruh permukaan gigi pada rahang atas atau bawah. Sebagai kesimpulan, sikat gigi otomatis berbentuk U ini diharapkan bermanfaat bagi anak-anak dengan keterampilan motorik halus yang rendah, disabilitas intelektual, atau kebutuhan khusus lainnya yang mengalami kesulitan dalam membersihkan gigi dengan benar.

Kata kunci: Otomatisasi, Anak, Kebutuhan Khusus, Sikat Gigi, Berbentuk U

INTRODUCTION

Toothbrushes designed for children with special needs must consider various factors, including motor skills, emotional resistance, and the effectiveness of plaque removal. Research indicates that children with special needs often face significant challenges in maintaining oral hygiene, primarily due to difficulties in executing effective toothbrushing techniques. For instance, a study highlighted that 61.9% of children with special care needs found toothbrushing to be a difficult task, with

many exhibiting emotional resistance towards the activity. [1] The emotional aspect can have a considerable impact on the ability of these individuals to maintain regular oral hygiene practices. This highlights the necessity for the development of specialized toothbrush designs that are able to accommodate the challenges presented by this condition.

The efficacy of electric toothbrushes in plaque removal has been demonstrated to be superior to that of manual toothbrushes, particularly for individuals with neuromuscular disabilities. [2] A randomized controlled trial demonstrated that electric toothbrushes could significantly enhance plaque removal efficiency, which is crucial for children with special needs who may struggle with manual dexterity. [3] Nevertheless, it is important to acknowledge that some studies have identified no statistically significant difference in plaque control when comparing electric and manual toothbrushes among children with special needs. [4] This inconsistency indicates that, whereas electric toothbrushes, though may be beneficial, are not universally effective for all children with special needs.

The design of the toothbrush is also of critical importance regarding its effectiveness. The incorporation of customized handles and specialized grip designs has been demonstrated to enhance the ability of children with disabilities to effectively control their toothbrushes, thereby facilitating enhanced plaque removal. [5] [6] Furthermore, research has demonstrated that the physical condition of toothbrushes used by children with special needs deteriorates more rapidly due to improper brushing techniques, which can further complicate their oral hygiene efforts. [7] It is therefore imperative that toothbrushes designed for this demographic facilitate better handling and be sufficiently durable to withstand the unique challenges faced by these children.

In addition to the physical design of the toothbrush, educational interventions are of great importance in promoting effective toothbrushing habits among children with special needs. The incorporation of visual pedagogy and task analysis in educational programs has been demonstrated to be an effective method for teaching toothbrushing skills, thereby enhancing the autonomy of children with special needs. [8] [9] Such interventions have the potential to assist in reducing the reliance on caregivers, thereby fostering a sense of independence in the management of oral health. Electric toothbrushes are frequently recommended for individuals with special needs due to their potential for enhanced plaque removal and ease of use. Nevertheless, there are several disadvantages associated with the use of electric toothbrushes in this demographic that must be considered.

One significant disadvantage is the complexity of use. Although electric toothbrushes are designed to facilitate the brushing process, some children with special needs may encounter difficulties in operating the device. For example, children with cognitive impairments or limited motor skills may encounter difficulties in effectively maneuvering the toothbrush, which may result in inadequate cleaning. [10] Furthermore, the noise and vibrations produced by electric toothbrushes can be distressing for some children, particularly those with sensory sensitivities, potentially leading to anxiety or refusal to brush altogether. [10] While electric toothbrushes offer certain advantages for children with special needs, such as ease of use and improved plaque removal, their disadvantages, including cost, complexity, sensory issues, and potential over-reliance, must be carefully considered.

The selection of toothbrushes for children with special needs must emphasize ergonomic design, plaque removal effectiveness, and educational support. This study develops an automatic U-shaped toothbrush that, with a single button press, can clean an entire jaw’s teeth without manual hand movement.

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METHOD

This study employs the prototype method, focusing on the design of an automatic U-shaped toothbrush. The system integrates a motor speed regulator circuit using a 5A/90W motor dimmer module, a DC-DC voltage converter (LM2596 buck converter), and a BMS module for managing two 18650 batteries connected in series to achieve 7.4 VDC via a 25A/7.4VDC/3S module. A drive inverter or PWM vibrator is used to control motion. The toothbrush incorporates three vibration modules, each producing 9000 vibrations per minute, resulting in a total of 27,000 vibrations/minute at 150 Hz. The device operates automatically with speed, voltage, and load control, achieving a motor speed of 1875 rpm with an output power of approximately 4.167 W at high speed.

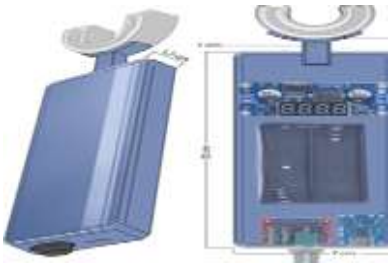

Figure 1 2D design of automatic U-shaped toothbrush version.

The design of both types of brushes comprises several stages, including 2D-3D design, sample scale prototype design, finished scale prototype design, and manufacturing design.

Figure 2 Documentation Of The Toothbrush Sample (Prototype Design).

The image above illustrates version of the toothbrush employs a dimmer module, derived from a voltage of 11.8 VDC, to control the vibrator speed. This module is sourced from an 18650 x 3 cell battery. Additionally, Fig. 2 demonstrates that the toothbrush design has reached 40% scale, indicating that only the physical ignition and operational system are present.

RESULT AND DISCUSSION

There are several supporting modules that are used as references for the design of this toothbrush:

DC-DC STEPDOWN

Stepdown, or often referred to as stepdown converter or buck converter, is a type of electronic power converter used to step down DC voltage from one voltage level to a lower voltage level. These converters are very commonly used in various electronic applications to convert higher voltages into lower voltages, with high efficiency.

18650 BATTERY

The 18650 battery is a widely used rechargeable cell, named after its size and specifications. It typically has a capacity ranging from several hundred to a few thousand mAh, with a nominal voltage of 3.7 V—rising to 4.2 V when fully charged and dropping to about 3 V when nearly discharged. [5].

DC MOTOR DIMMER

A DC motor dimmer regulates motor speed by adjusting the applied voltage, typically using pulse width modulation (PWM). By varying the duty cycle of the pulses, the average voltage changes higher duty cycles deliver more power and increase speed, while lower duty cycles reduce it. [6].

7.4VDC BMS MODULE

The BMS (Battery Management System) module for 7.4 VDC batteries is an electronic device specifically designed to manage Li-ion or Li-polymer batteries

that have a nominal voltage of around 7.4 VDC. The BMS is responsible for performing several important functions in maintaining the health and safety of the battery, as well as improving the performance and life of the battery [7].

DC MOTOR

A type of electric motor that converts electrical energy into mechanical motion using direct current (DC), The speed and torque of a DC motor can be adjusted by adjusting the voltage applied to the motor or using an external speed regulator. DC motors have good start-stop characteristics and can provide high starting torque [8].

VIBRATION MOTOR

Vibration frequency (the number of times a vibration motor vibrates in one second) and amplitude (the amount of vibration) can vary depending on the design and application of the motor. Some motors can produce vibrations with a high frequency, while others may be lower [9].

Figure 3 3D Design Of Automatic U-Shaped Toothbrush Factory Version.

Buck converters (DC-DC step-down) are essential in electric toothbrushes to reduce battery voltage efficiently for device operation. An 18650 battery provides about 3.7V, but this is often stepped down to suit components like motors and control circuits.. [11]

A buck converter efficiently reduces voltage, making it crucial for battery-powered devices such as electric toothbrushes. PWM control allows precise voltage regulation and minimizes power loss, ensuring stable operation under varying loads [12][13]. Advanced control methods, such as nonlinear techniques, further enhance voltage stability for fluctuating power demands [11][14]. Reducing power losses in converters extends battery life and efficiency, while compact circuit designs with high-efficiency components optimize performance for low-power devices like toothbrushes [15][16][17].

The 18650 lithium-ion battery is widely used due to its high energy density, long cycle life, and safety, providing lightweight power suitable for toothbrushes [18][19]. These batteries improve plaque removal and gingival health when powering oscillating-rotating mechanisms [20][21][22][23][24][25][26]. However, concerns remain regarding overcharging, deep discharge, and environmental impact, underscoring the need for sustainable battery management [18][27][28].

Motor control plays a vital role, with DC motor dimmers and PWM ensuring adjustable speed, torque, and efficiency. BLDC motors are favored for reliability, efficiency, and adaptive brushing modes, while brushed motors remain cost-effective [29][30][31][38][39]. Compact dimmer circuits and adaptive controls enhance ergonomics and personalization [30][31]. The integration of a 7.4V BMS improves safety, thermal management, and cell balancing, prolonging battery life while ensuring stable motor voltage [32][33][34][35][36][37].

Effective vibration motors, operating at 125–150 Hz, enhance plaque removal and gingival health, with oscillating-rotating brushes and micro-vibrations outperforming manual and even sonic toothbrushes [23][36][40][41][42]. Overall, the combination of efficient power electronics, high-performance batteries, advanced DC motors, and optimized vibration systems contributes to superior oral hygiene outcomes. The automatic U-shaped toothbrush, designed for children with special needs, integrates these technologies to provide simplicity, safety, and effective cleaning.

CONCLUSION

The automatic U-shaped toothbrush is an electric toothbrush that is operated by pressing a single button, enabling the user to clean the entire tooth surface throughout the upper and lower jaws with a single action. The device has been modified to vibrate and move in a manner that is effective in removing debris or plaque among children with special needs. Develop an automatic U-shaped toothbrush that is more effective due to it does not require a lot of hand movements that are appropriate for children with poor movement of fine motor skills or mental retardation or others with special needs who have had problems brushing their teeth.

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