



Design And Development Of A Modular And Customizable Oral Care System For Modern Lifestyles

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Abstract: Oral hygiene plays a vital role in general health, yet many users fail to maintain optimal routines due to time constraints, inconvenience, and fragmented product ecosystems. This paper presents the design and prototyping of a modular oral care cabinet that integrates brushing, water flossing, UV-C sterilization, and ozonated rinsing into a single compact system. A user-centered approach involving surveys, ergonomic studies, and prototyping was employed. The final design features a shared brush-flosser trunk, embedded UV chamber, integrated ozonated water tank, and modular compartments. The concept enhances hygiene, convenience, and sustainability in daily routines. The system's intelligent integration ensures better hygiene while supporting eco-friendly practices. The article presents concept development, technical considerations, and testing outcomes, offering insights into its potential for market viability and user acceptance.

Index Terms - Oral health, modular design, UV sterilization, ozone therapy, sustainability, product integration, water flosser, overall oral care.

I. INTRODUCTION

The oral care industry has witnessed notable advancements in recent years, with innovations in electric toothbrushes, water flossers, UV sterilizers, and smart hygiene accessories reshaping personal care routines. Brands have introduced features such as pressure-sensitive sonic brushing, pulsating water flossers with multiple modes, and standalone UV toothbrush holders that appeal to health-conscious and tech-savvy users. Despite this progress, most of these tools exist in isolation, both functionally and physically. Consumers are often required to purchase, charge, store, and maintain multiple devices from different manufacturers—leading to cluttered countertops, inconsistent hygiene habits, and poor integration within the overall bathroom environment.

Moreover, while electric toothbrushes have become widely adopted, flossing remains the most neglected step in oral hygiene, primarily due to its perceived inconvenience and the lack of an engaging, seamless experience. Even water flossers, though clinically more effective than string floss for many users, are typically bulky, countertop-bound units with visible tubing and manual operation. UV sterilization and ozonated water—both backed by scientific studies for their microbial reduction benefits—are still treated as add-on features rather than core components of a routine. As a result, hygiene is often compromised due to improper storage of brush heads or shared use in unsterile conditions.

In this context, the current landscape reveals a clear gap: while tools exist to improve oral health, they have not yet been unified into a cohesive, hygienic, and space-efficient system that supports the complete oral care workflow. This unmet need—combining cleanliness, usability, integration, and aesthetics—served as the foundation for developing The Oral Care System.

This is envisioned as a smart, self-contained oral care station that houses all essential functions in a single mirrored cabinet—ideal for modern bathrooms. It features a sonic toothbrush dock, temperature-controlled ozonated water flosser, UV-C sterilization, and an integrated toothpaste or mouthwash dispensing unit, all controlled via a touch interface. Its compact, enclosed design promotes better hygiene, minimizes clutter, and supports consistent daily use. By merging multiple devices into one user-friendly system, the developing product addresses the shortcomings of current market offerings and represents a forward-thinking solution for holistic, convenient, and hygienic oral care.

II. RELATED WORK

To learn about the existing methods of oral care practices, oral care solutions in existence and research conducted in this regard, we reviewed research papers and articles to gain insight. We also collected information on some of the existing trends related to oral care

2.1 Literature Survey

The field of oral healthcare is undergoing a technological transformation, with research efforts increasingly focusing on digital integration, user-centered design, and sustainable manufacturing. These advancements aim to improve not only clinical outcomes but also everyday user experience, accessibility, and environmental impact.

A significant development in this context is the home-based remote smart dental care platform, which leverages augmented reality (AR), artificial intelligence (AI), and Internet of Things (IoT) technologies to enable real-time oral health monitoring and personalized care delivery. These platforms integrate connected toothbrushes, intraoral cameras, and wearable sensors to capture oral health data, which is then analyzed using AI algorithms to provide customized hygiene feedback and remote clinical monitoring (Kim, Lee and Park, 2024; Liu et al., 2020). Such systems support proactive oral health management, particularly in underserved or remote populations, while also raising important concerns related to data security and ethical deployment. Addressing physical accessibility, Colvenkar et al. (2022) propose a novel approach for individuals with reduced manual dexterity through the design of personalized 3D-printed toothbrush and interproximal brush handles. Using silicone grip impressions and polylactic acid (PLA) materials, their study demonstrates how ergonomically tailored oral hygiene tools can significantly improve independence and effectiveness, especially among elderly and disabled users.

A broader perspective on design inclusivity in oral healthcare is provided by Leason and Nickpour (2022), who conducted a systematic review of 104 oral healthcare design projects. Their findings reveal that while there is increasing awareness of inclusive and human-centred design (HCD), the application remains inconsistent. Most efforts concentrate on physical accessibility, with limited attention to cognitive and emotional inclusion. The authors emphasize the need for a deeper integration of inclusive design thinking throughout the problem-framing and solution-development stages of oral healthcare innovation.

Another emerging frontier is the development of oral wearable sensors, which represent a shift from episodic dental visits to continuous, real-time health monitoring. These small, non-invasive devices—mounted on teeth or integrated into mouthguards—can measure a range of biomarkers in saliva, such as pH, glucose, and microbial load, while transmitting data wirelessly for user feedback or clinical review (Li et al., 2022). This approach supports personalized preventive care and connects oral health with broader systemic health conditions, such as diabetes.

Design innovations have also extended into modular mobile dental systems, as demonstrated in a case study presented at Taiwan's 2023 Young Designers' Exhibition. Cheng, Wang and Chiang (2024) highlight a dental care unit that combines modular design with visually intuitive dental motifs. The system is engineered for flexibility, allowing quick assembly, transport, and reconfiguration—making it ideal for pop-up clinics and emergency settings. The incorporation of recognizable dental forms improves user engagement while maintaining functionality and efficiency.

In parallel, the adoption of modular product architecture in the manufacturing of oral care devices has proven beneficial for sustainability and production flexibility. Habib et al. (2023) presents a case study focused on electric toothbrushes and 3D printers, showing how segmenting the product into functional modules enhances customization, simplifies upgrades, and reduces material waste. This modularity aligns with Industry 4.0 principles and enables responsive manufacturing systems capable of adapting to rapidly changing market demands.

Together, these studies illustrate the growing convergence of intelligent technology, inclusive design, modular architecture, and sustainable manufacturing in the domain of oral healthcare. However, a critical gap persists: the lack of a unified platform that seamlessly integrates these innovations into a cohesive, hygienic, and space-efficient oral care solution.

2.2 Current Trends in Oral Care Sector

The oral care industry is evolving rapidly with a focus on enhanced functionality, hygiene, and sustainability. Smart toothbrushes equipped with AI and app connectivity offer real-time feedback, brushing analytics, and pressure control. Electric toothbrushes and ultrasonic water flossers have become mainstream for improved plaque removal. Premium products such as whitening kits, therapeutic pastes, and probiotic formulations are gaining popularity for targeted care. Eco-conscious consumers are increasingly adopting biodegradable brushes, refillable containers, and reusable accessories. Additionally, compact, travel-friendly formats like toothpaste tablets and dissolvable mouth strips support convenience and portability. Aesthetic-focused products, such as glosses and breath fresheners, are on the rise, especially among younger demographics.

Regional oral care practices differ widely, shaped by cultural habits, levels of awareness, and access to products. In India, traditional methods remain common, with a focus on value-driven, low-tech solutions, though interest in electric toothbrushes is on the rise. Japan emphasizes frequent brushing, compact and hygienic setups, and well-organized storage, reflecting its clean and minimalist approach. South Korea blends oral care with beauty and technology, preferring stylish, portable products that align with lifestyle trends. In contrast, the USA, UK, and Europe exhibit high awareness of preventive care, widespread use of smart devices, and a growing preference for sustainable and clinically inspired designs. Southeast Asia prioritizes affordability and freshness, with functional products like breath sprays and multipurpose brushes, while showing gradual adoption of technology. Meanwhile, the Middle East demonstrates a strong demand for high-end, tech-enabled oral care solutions, often featuring premium aesthetics and luxurious finishes.

Modern oral care is shifting toward personalized, preventive, and holistic practices. Smart devices offer data-driven care with personalized feedback and habit tracking. Minimally invasive procedures and preventive diagnostics are improving user comfort and outcomes. Integrative approaches recognize the link between oral and overall health, encouraging microbiome-friendly products and wellness-based routines. Sustainability is also influencing both clinical and at-home practices through reduced plastic use and biodegradable alternatives. Finally, accessibility and user convenience are driving design decisions in both product and service offerings.

III. DESIGN AND DEVELOPMENT OF PROPOSED SOLUTION

3.1 Primary Research

For primary research interviews were conducted with children, adults, and dental professionals to explore daily oral hygiene habits, pain points, and unmet needs in current oral care routines and survey was taken.

Children (ages 5–11) showed high engagement with toothbrushes that featured characters, lights, music, and flavoured toothpaste. However, brushing was often viewed as boring or forgettable, especially at night. Discomfort from harsh flavours or foaming was common. Many children expressed interest in gamified features—such as earning points or having interactive guidance—suggesting a strong need for play-based, sensory-driven designs.

Adult users maintained regular brushing routines but were inconsistent with flossing and mouthwash due to time, fatigue, or inconvenience. Product choices were influenced by taste, ingredients, and past dental experiences. While some favoured natural products, others prioritized strong cleansing. Many expressed openness to smart tools if they simplified routines and improved consistency, though older users preferred familiar, low-tech options.

Dentists identified common issues such as plaque buildup, gum disease, and enamel erosion, often linked to poor technique or lack of motivation. They emphasized the need for softer brushes, ergonomic designs, and inclusive tools for children, elderly users, and those with special needs. Smart tools were seen as promising—provided they are user-friendly and behaviourally supportive.

Overall, the study highlights a need for modular, inclusive, and engaging oral care solutions that adapt to varying user needs, promote consistent habits, and address both functional and emotional challenges in daily routines.

Insights:

- Children benefit from sensory engagement and gamified experiences that reinforce brushing as a fun habit.
- Adults seek convenience, consistency, and products that align with personal values (e.g., natural ingredients, efficiency, or sustainability).
- Dental professionals call for inclusive, ergonomic tools with behaviour-shaping features and improved adaptability to special care requirements.

These insights form a user-validated foundation for designing a modular, smart oral care system that centralizes essential hygiene functions, accommodates diverse user profiles. By addressing functional barriers, such a system has the potential to significantly elevate oral care adherence, comfort, and outcomes across age groups.

3.2 Concept Generation

The ideation phase of this project focused on translating extensive user research and identified market gaps into a cohesive set of design directions for a modular and customizable oral care system. A structured yet exploratory approach was adopted, using methods such as morphological analysis, open-ended brainstorming, and visual inspiration through theme and mood boards.



Figure 1 Brainstorming

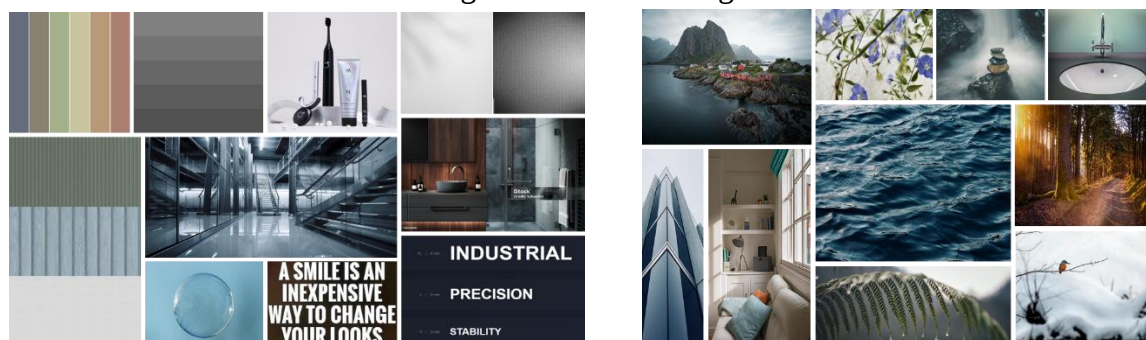


Figure 2 Theme Board and Mood Board

- Three distinct toothbrush concepts were developed. The first featured a 360° soft-bristle head with a long neck and battery operation, aimed at urban users and travelers seeking simplicity and effectiveness.
- The second incorporated a dual-head system with a gentle massager for gums and cheeks, appealing to wellness-conscious users and those with oral sensitivity.
- The third concept combined brushing and flossing in one ergonomic unit with external controls and a modular trunk, supporting better hygiene, durability, and smart integration for tech-forward homes.

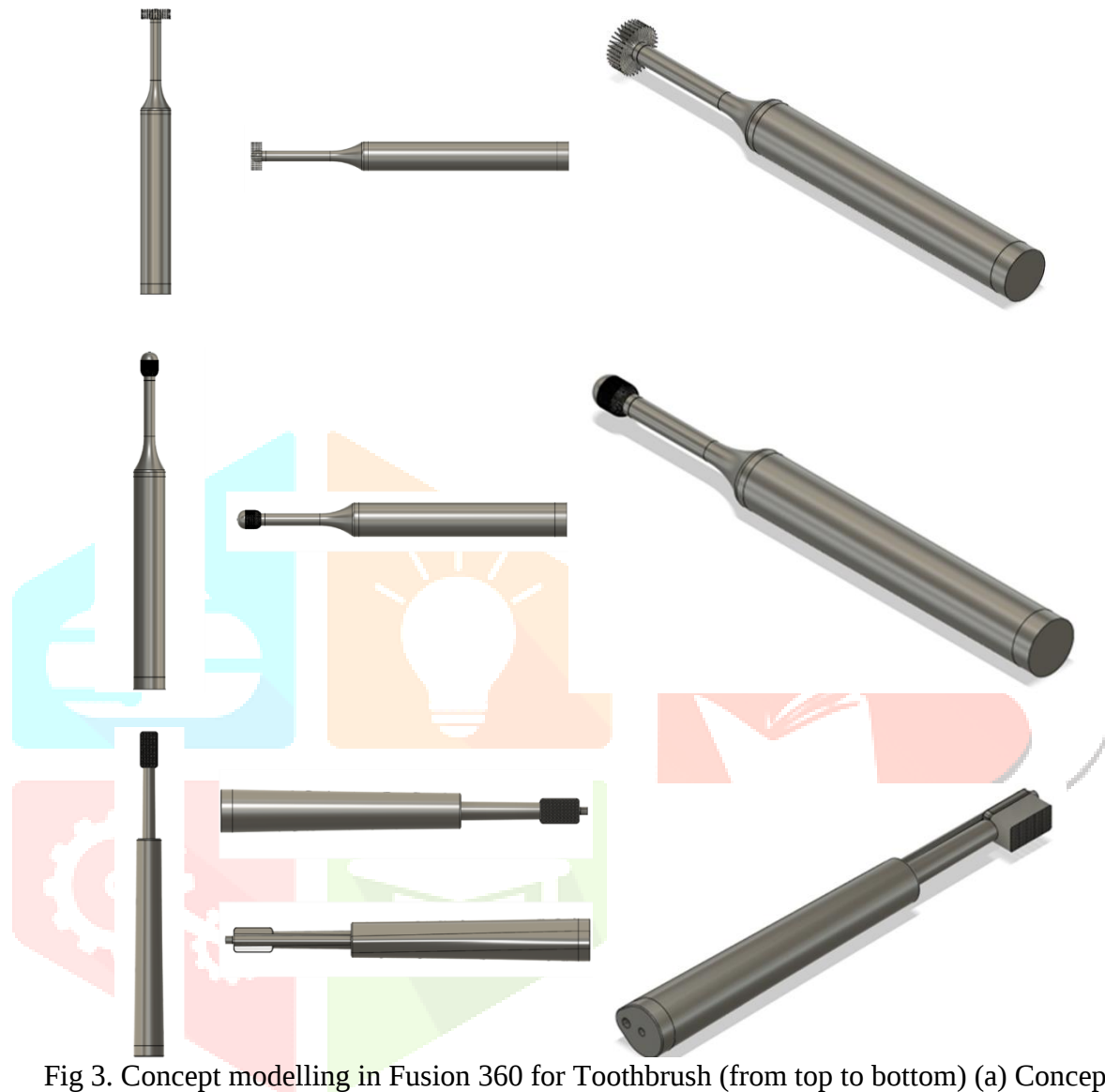


Fig 3. Concept modelling in Fusion 360 for Toothbrush (from top to bottom) (a) Concept 1
(b) Concept 2 (c) Concept 3

Complementing these were five system-level concepts, from a basic UV storage pod to a fully integrated multi-function cabinet. These ranged in complexity and functionality to suit different user scenarios—whether minimal, shared, or premium. Features such as ozonated water flossing, UV sterilization, modular brush docks, and smart dispensing systems were thoughtfully integrated to enhance hygiene and streamline daily routines. Overall, the ideation outcomes reflect a user-centered, scalable approach to oral care—merging convenience, customization, and long-term sustainability.

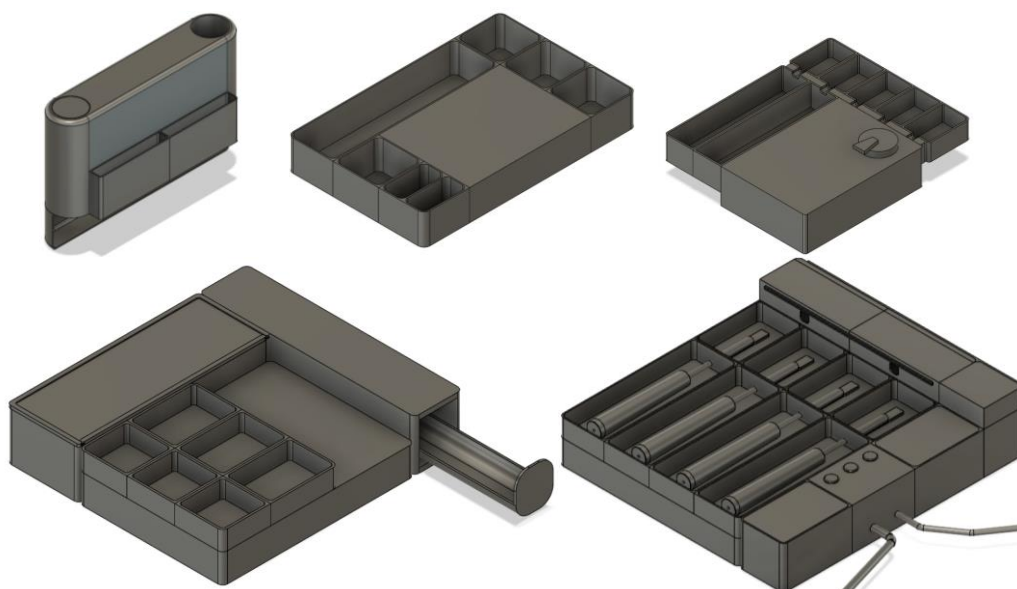


Fig 4. Concept modelling in Fusion 360 for Oral Care System (clockwise from top left) (a) Concept 1 (b) Concept 2 (c) Concept 3 (d) Concept 4 (e) Concept 5

3.3 Selection of Concept

As part of the development process, five different oral care system concepts were created—each offering unique ways to improve hygiene, convenience, and user interaction. To choose the most suitable design for further development, a Pugh Matrix was used. This tool helped compare the concepts based on important factors like overall functionality, hygiene features, space efficiency, ease of use, and innovation.

Table 1. Pugh Matrix for Selection of Concept

Criteria	Concept 1	Concept 2	Concept 3	Concept 4	Concept 5
Functionality Breadth	–	–	+	+	++
Hygiene & Sterilization	++	+	+	+	++
Compactness & Form Factor	++	+	0	++	–
Water Flow Integration	–	–	++	+	++
Ease of Use / Accessibility	++	+	+	0	+
Temperature Control	–	–	++	–	++
Storage & Organization	+	–	+	++	+
Aesthetic / Visual Appeal	+	+	+	++	+
Scalability (Tiered Offerings)	0	0	+	+	+
Innovation / Uniqueness	+	+	+	++	++

Table 2. Summary Table for Pugh Matrix

Concept	Score (++)	Score (+)	Score (–)	Net Score	Rank
Concept 1 – UV Hygiene Organizer	2	4	3	$(2 \times 2) + (4 \times 1) - (3 \times 1) = 5$	2
Concept 2 – Dual Holder	0	5	4	$(0 \times 2) + (5 \times 1) - (4 \times 1) = 1$	5
Concept 3 – Smart Floss Dock	2	5	1	$(2 \times 2) + (5 \times 1) - (1 \times 1) = 8$	3
Concept 4 – Twin Trunk Hub	2	5	2	$(2 \times 2) + (5 \times 1) - (2 \times 1) = 7$	4
Concept 5 – Multi Oral Care Cabinet	4	4	2	$(4 \times 2) + (4 \times 1) - (2 \times 1) = 10$	1

Among all, Concept 5—the Multi Oral Care Cabinet—stood out as the most complete and well-balanced solution. It combines brushing, flossing, sterilization, and toothpaste or mouthwash dispensing in one compact unit. With smart features like a control interface, shared ergonomic trunk, and enclosed UV storage, it is designed to fit smoothly into modern bathrooms while addressing everyday oral care needs. Its design is clean, organized, and easy to use—making it ideal for families or individuals who value hygiene and simplicity. Other concepts had their strengths—Concept 1 focused on portability and hygiene, while Concept 3 offered a user-friendly flossing setup—but they didn't offer the same level of all-in-one integration. Concept 5 proved to be the most future-ready, combining multiple tools in one thoughtful design that supports better routines and lifestyle fit.

This selection process highlights the value of structured design evaluation and how a well-integrated product can enhance both daily use and long-term user satisfaction.

3.4 Detailed Explanation of Concept

This a compact, all-in-one solution designed to integrate brushing, flossing, sterilization, and smart control into a single user-friendly system. The product development was approached in three progressive phases. At first, the core functionality was established by combining a sonic toothbrush and a water flosser into a shared handheld trunk. This trunk design allows for easy handling, while an internal pump connected to an ozonated water tank enables hygienic and efficient flossing. The toothbrush features multiple vibration modes to suit various oral care needs, and the system is powered and charged through a docking base integrated into the cabinet.

Next, we focused on hygiene and storage. A UV-C sterilization chamber was introduced, which automatically activates when the cabinet door is closed. This keeps additional brush heads and flosser tips germ-free, especially important in shared settings. Modular slots are provided to store each user's attachments separately, minimizing the risk of cross-contamination. The final phase added a smart touch interface, allowing users to control modes, monitor water temperature, and personalize their brushing experience. These upgrades not only make the system intuitive and inclusive but also future-ready for connected oral health tracking.

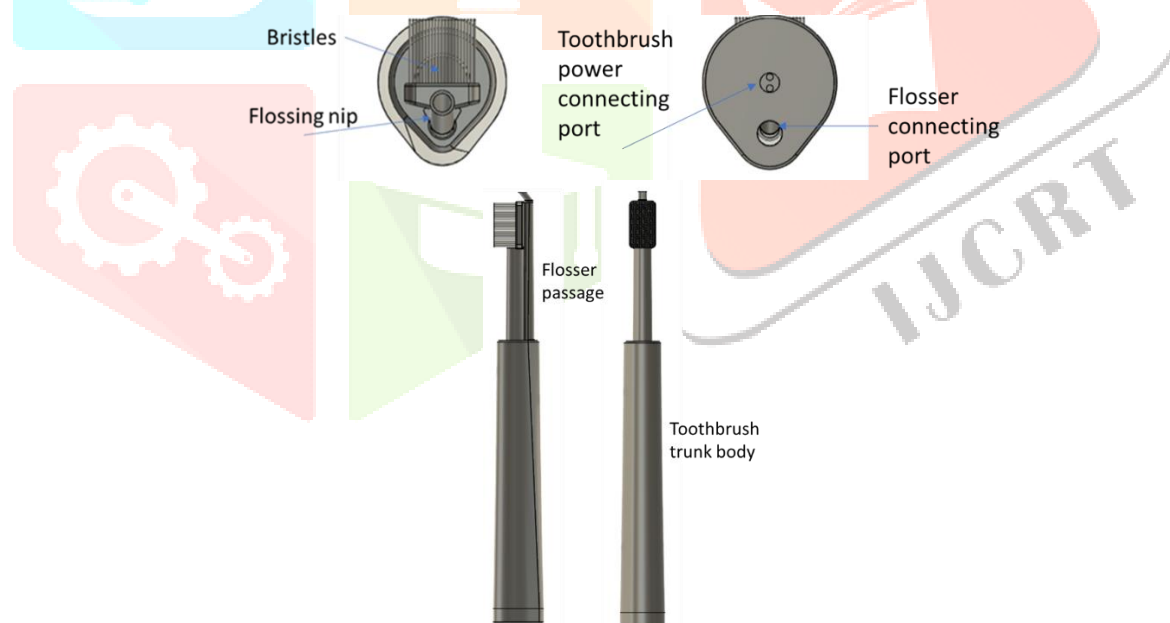


Figure 5. Components of Toothbrush

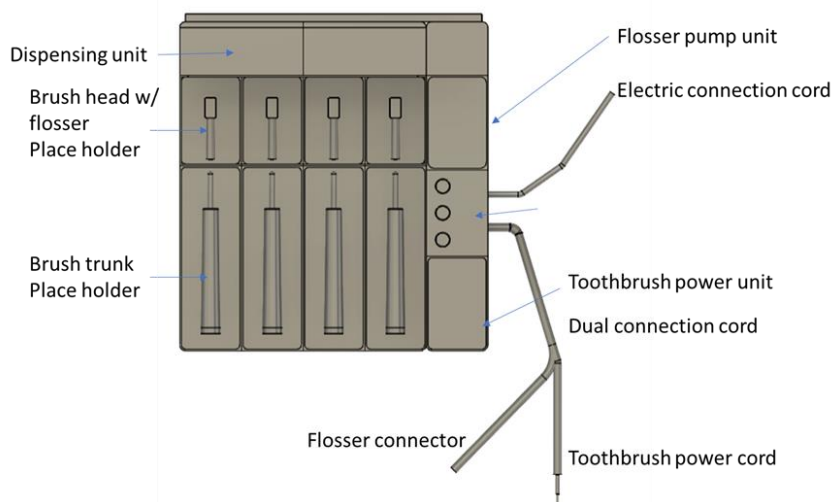


Figure 6. Components of Oral Care System

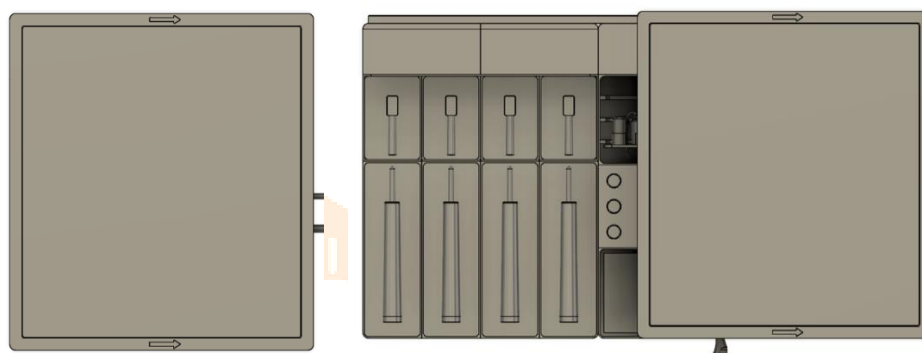


Figure 7. Visualization in closed and opened state of Multi Oral Care Cabinet

The toothbrush itself is modular and designed for ease of use. It features a detachable head with wide bristles and a built-in water flossing nozzle. The internal channel in the neck guides both water and vibration, while the waterproof motor is housed in the handle. To simplify the design and increase durability, all control functions are handled via a separate remote or interface. The cabinet houses key components such as the water tank, heater, pump, UV-C unit, and charging dock—all neatly arranged for both aesthetics and convenience. Every feature is designed to make oral care more efficient, hygienic, and aligned with modern lifestyle expectations.



Figure 8. Render Visualization

3.5 Physical Prototype

The working prototype of the *Multi Oral Care Cabinet* was built over three weeks by the design team using accessible materials like sunboard, cardboard, and NC putty. The process involved two main phases: constructing the cabinet structure with compartments, storage slots, and a mirror-finished door, followed by integration of functional elements including a shared brush-flosser trunk, mini water pump, UV-C light, and simple electronics.



Figure 9. Prototype Model

The internal layout was organized to demonstrate essential functions—brushing, flossing, and sterilization—using silicone pipes, battery-powered systems, LED indicators, and modular holders. The prototype was carefully finished with NC putty, sanding, and spray painting to achieve a clean, modern appearance. This functional model helped visualize the design intent and evaluate user interaction, form, and component integration.

IV. RESULTS AND DISCUSSION

The *Multi Oral Care Cabinet* prototype successfully demonstrated its core functions—integrated brushing, flossing, UV sterilization, and organized storage—in a compact, modular form. User testing showed that some of participants experienced improved oral care efficiency, and most of them appreciated the reduction in bathroom clutter. The UV-C chamber was effective in sanitizing brush heads, and the intuitive touch interface and modular design were well received.

However, some users suggested improvements such as a smaller flosser tank and a quieter pump. The prototype's bulk and reliance on a power source were noted as limitations. These results highlight the importance of compact, hygienic design for urban users, and future developments will focus on reducing size and improving energy efficiency.



Figure 9. User Validation

V. CONCLUSION AND FUTURE WORK

This study presented the design and development of the *Multi Oral Care Cabinet*, a compact, integrated solution aimed at enhancing oral hygiene routines. By combining brushing, water flossing, UV sterilization, heating, and organized storage, the product addresses common pain points such as clutter, hygiene inconsistency, and limited user convenience in modern bathrooms. Despite challenges like power

management and compact water integration during prototyping, the concept effectively demonstrated its potential for improving hygiene and user experience in daily routines.

Moving forward, the project can benefit from further refinement in areas such as ergonomic design, digital interface integration, and sustainable material choices. Future developments will also explore modular features, broader user testing, and cost optimization for market scalability. These efforts aim to transform the prototype into a user-friendly, inclusive, and commercially viable oral care solution suited for evolving urban lifestyles.

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