FACULTY OF COMPUTER SCIENCE AND INFORMATION TECHNOLOGY
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FINAL YEAR PROJECT PROPOSAL

ToothyMate:
Smart Oral Health Awareness with AR & AI

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CHAPTER 1

INTRODUCTION

Oral health is an essential aspect of overall well-being but is frequently neglected, especially among adults who may lack the time or motivation to maintain proper oral hygiene routines. Although information about dental care is widely accessible, engagement with traditional educational materials is often low, resulting in inadequate oral care practices. Advances in mobile technology offer new opportunities to promote oral health through interactive and personalized digital tools.

The *ToothyMate* application aims to improve oral health awareness and encourage consistent hygiene habits among adults by integrating Augmented Reality (AR), Artificial Intelligence (AI), and educational content. The application features an AR module that provides an interactive 3D tooth model to visualize tooth anatomy, plaque accumulation, and early decay, an AI module providing non-diagnostic feedback based on user-submitted images of their teeth, and a system for tracking oral hygiene progress over time. By enhancing user engagement and facilitating self-monitoring, *ToothyMate* seeks to support sustainable improvements in oral hygiene practices.

1.1 Problem Statements

Despite brushing their teeth daily, many adults still demonstrate poor oral health habits and limited knowledge. According to Zhang et al. (2025), more than 67 percent of adults believe that professional scaling is harmful. Only three percent understand basic oral hygiene practices, and most brush their teeth for less than two minutes. In addition, 82 percent of adults experience gum bleeding, which is considered an early sign of periodontal disease.

Traditional oral health education methods often lack engaging and interactive components. A study by Romalee et al. (2023) showed that the use of three-dimensional models and augmented reality significantly improved users' understanding of brushing techniques and oral hygiene

tools. This indicates that passive education methods are insufficient in effectively improving awareness and behavioral change.

Many adults are also unaware of their current oral hygiene condition between dental visits. In most cases, individuals only visit the dentist when they begin to feel pain, by which time plaque and cavities may have already formed. According to the CDC (2024), more than 40 percent of adults reported experiencing mouth pain within the past year, and over 80 percent had at least one cavity by the age of 34. These statistics suggest that many oral health issues go undetected until symptoms appear.

Although artificial intelligence has been applied in clinical dental diagnostics, its use for providing simple, educational, non-diagnostic feedback for personal self-monitoring remains limited. Therefore, there is a need for a mobile solution that allows users to visually understand and track common oral health conditions such as plaque and early-stage cavities in a convenient and accessible manner.

1.2 Objective

The primary objectives of this project are:

I. To develop a mobile application aimed at improving oral health awareness among adults by providing a user-friendly and interactive platform.
II. To incorporate Augmented Reality (AR) technology that enables users to explore a 3D tooth model with visualizations of plaque and decay, helping users understand where common oral issues typically occur.
III. To integrate Artificial Intelligence (AI) that provides non-diagnostic, educational feedback based on user-uploaded tooth images. This allows users to self-monitor their oral hygiene and receive simple insights into their current condition.

1.3 Scope

A. System Scope

The system scope of ToothyMate involves the development of several integrated features within the mobile application. Firstly, it includes an Augmented Reality (AR) module that presents an interactive 3D tooth model to help users understand tooth anatomy, visualize plaque build-up, and recognize early signs of decay.

Secondly, the application incorporates a basic Artificial Intelligence (AI) component that provides simple, non-diagnostic feedback based on images of the user's teeth to help users monitor their oral hygiene. The AI functionality is specifically limited to identifying visible signs of plaque accumulation and early-stage cavities. Users will be able to upload weekly photos to track and compare changes in these two areas of concern over time.

Furthermore, the app also contains an e-learning module that delivers educational content covering general oral health, common dental treatments, special care guidelines for specific groups such as pregnant women, and practical tips for managing everyday oral health situations. All data collected will be stored locally on the device, enabling the app to function offline and without requiring user registration.

B. User Scope

The primary users of ToothyMate are adults who are interested in improving or maintaining their oral hygiene through self-monitoring and accessible learning tools. These users may not have regular access to professional dental care or may lack clear understanding of proper brushing techniques, early signs of plaque, and cavity formation.

Users are expected to engage with the app by exploring the 3D tooth model through the AR feature, uploading weekly photos of their teeth for AI-based feedback, and accessing bite-sized educational content. The AI module is designed to provide non-diagnostic guidance focused

specifically on detecting visible signs of plaque and early-stage cavities, helping users track their oral hygiene progress over time.

The app is intended for general adult users and does not require prior dental knowledge. Its offline functionality and no-login setup also make it suitable for users who value privacy and simplicity.

CHAPTER 2

LITERATURE REVIEW

2.1 Review of Related Research Studies

Several recent studies have explored the integration of artificial intelligence (AI), mobile applications, and augmented reality (AR) into oral health education and self-monitoring systems. The following review highlights five relevant academic publications from 2021 to the present.

2.1.1 The Imperative for Improved Oral Health Education and Digital Interventions

Good oral hygiene is fundamental to maintaining one's oral health and serves as a cornerstone for overall health, preventing problems like tooth decay and periodontal diseases that can affect daily life. It can sustain chewing ability, prevent bad breath, and enhance personal social interactions, self-confidence, and happiness (Romalee et al.,2023). Conversely, a significant number of individuals continue to suffer from oral diseases primarily due to incorrect or inadequate knowledge and inappropriate skills in oral care (Chang et al.,2021).

Traditional educational approaches, such as passive lecture-based programs, have shown limitations in effectively delivering oral healthcare education and developing self-care skills, particularly for older adults (Romalee et al.,2023). Even with regular professional reminders, changing patients' oral hygiene behavior remains challenging. Poor adherence to OHIs is a common barrier to proper care, often stemming from patients' difficulty recalling the information they receive (Romalee et al.,2023).

In response to these challenges, mobile applications have been identified as valuable intervention tools for improving self-care efficiency and health service delivery. The potential of app-based interventions in promoting health and well-being is continually growing, leading to an exponential increase in the number of health-related apps (Romalee et al.,2023).

2.1.2 Leveraging Augmented Reality (AR) in Oral Health Education

According to Romalee et al. (2023), Augmented Reality (AR) is a technology that integrates digital information into the real-world environment, allowing users to interact with virtual objects overlaid onto physical surroundings. Mobile Augmented Reality (MAR), in particular, refers to AR applications accessible via commonly used portable devices such as smartphones and tablets.

In the context of oral health education, AR has demonstrated potential to enhance user understanding and engagement. It has been utilized in various ways, including the visualization of anatomical structures and simulation of dental procedures. A pilot study examining MAR-integrated oral health education for older adults reported notable improvements in oral health knowledge and self-efficacy. The MAR system in the study featured interactive 3D animations and instructional content related to oral hygiene practices. While that implementation focused on demonstrating brushing techniques, the technology's core strength lies in its ability to present complex information visually and interactively.

For the ToothyMate application, AR is proposed as a tool to display a 3D interactive tooth model. This model allows users to explore various aspects of tooth anatomy, plaque accumulation, and early signs of decay. By manipulating the 3D model, users can gain a deeper understanding of oral health issues that are typically difficult to grasp through static images or text alone. This visual and immersive approach aligns with the educational objectives of ToothyMate, making learning more intuitive and impactful.

AR-enhanced learning has been associated with increased retention of information and higher levels of user satisfaction. Furthermore, it supports the principles of ubiquitous learning, enabling individuals to access meaningful content in real time and in various contexts. However,

despite its potential, AR systems have occasionally received lower usability ratings in some studies. This highlights the importance of optimizing user interface design and interaction flow to ensure that educational benefits are not undermined by technical limitations.

2.1.3 Integrating Artificial Intelligence (AI) for Oral Health Monitoring and Feedback

Artificial Intelligence (AI) refers to the ability of machines to imitate human intelligence and behavior through programmed algorithms, with machine learning and deep learning being key applications. AI has significantly influenced the dental healthcare field across diverse applications, including radiographic and photographic diagnosis.

A diagnostic study by Kühnisch et al. (2021) demonstrated the feasibility of using AI, specifically Convolutional Neural Networks (CNNs), for detecting and categorizing caries on intraoral photographs with high accuracy, achieving over 90% agreement for overall caries detection. This provides strong evidence that AI can effectively analyze visual data from teeth. This methodology can be adapted for non-diagnostic feedback related to oral hygiene, such as dental biofilm detection. A scoping review from Tay et al. (2023) further discusses asynchronous monitoring using intra-oral photography for this purpose.

AI-assisted feedback can be broadly categorized into synchronous and asynchronous monitoring. Synchronous monitoring often involves intelligent oral hygiene devices, like toothbrushes, collecting real-time data on brushing motions or biofilm levels. Asynchronous monitoring, more relevant for ToothyMate, involves imaging the dentition after oral hygiene practices, typically via smartphone cameras for self-administered or healthcare provider-captured intra-oral photographs. However, the integration of AI in oral health also comes with significant challenges and limitations:

I. **Image Quality:** There is a critical need for high-quality, standardized intra-oral photographs for effective AI analysis. Poor image quality, characterized by issues such as off-focus, overexposure, glare spots, or low resolution, can directly and negatively affect AI performance for dental biofilm detection.

II. **Coverage Limitations:** Studies have noted challenges in accurately capturing images of posterior, palatal, and lingual surfaces of teeth and gingiva, suggesting that intra-oral photographic detection may currently function best as a general screening tool .

III. **User Engagement and Feedback Personalization:** A significant concern is that AI-generated feedback can sometimes be "templated," boring, or repetitive, potentially leading to user burnout and uncertainty regarding the long-term usage of AI-assisted devices. One study found that combining AI-assisted feedback with human counseling led to better reductions in plaque scores compared to AI assistance alone (Tay et al., 2023). This highlights a need for more varied and "human-like" AI responses to sustain user engagement.

IV. **Ethical Concerns:** The implementation of AI in healthcare raises important ethical risks, including patient privacy protection and the "black-box" problem where the mechanisms and interpretability of AI neural networks are opaque. There are also concerns about the potential for re-identification of individuals even from de-identified data. The lack of transparency regarding proprietary AI systems' data makes independent validation difficult. The current literature shows a low frequency of ethical issues being mentioned in dental publications related to AI, underscoring a pressing need for the field to address these potential social and legal pitfalls.

2.1.4 Impact of Mobile Applications on Oral Hygiene Practices and Outcomes

Two key studies from Nagarajappa et al. (2023) and Chang et al. (2021) provide strong evidence for the positive impact of dedicated mobile applications on oral hygiene.

The "Dent-O-Xpert" Smartphone Application (Nagarajappa et al., 2023):

I. **Effectiveness:** A randomized controlled trial of the "Dent-O-Xpert" smartphone application demonstrated its effectiveness in significantly improving oral health-related knowledge, attitude, and behavior among young adults. The intervention also led to a significant reduction in both plaque and oral hygiene scores.

II. **Behavioral Changes:** The app notably increased toothbrushing frequency, with 96.4% of participants reporting brushing twice a day by the second follow-up, up from 70.2% at baseline. It also remarkably improved brushing techniques, showing a significant increase

in the adoption of the Modified Bass technique to approximately 59.5%. Furthermore, the app encouraged timely toothbrush changes and the use of supplementary oral hygiene aids like dental floss and mouthwash. It even contributed to a reduction in sweet consumption habits.

III. **Contributing Features:** The success of "Dent-O-Xpert" was attributed to its comprehensive features, including educational content, interactive modules, daily push notifications, reminders for oral hygiene routines, demonstrative videos, pictures, and health tips, along with personalized recommendations.

IV. **Comparison to Control:** The study highlighted the value of the app's continuous support, as the control group, which received only a single, one-time health education interaction without ongoing support or reminders, failed to achieve desirable outcomes in oral health knowledge or behavior.

Oral Self-Care App (OSCA) (Chang et al., 2021):

I. **Behavioral Change Framework:** The OSCA was developed based on the Behavior Change Wheel (BCW) framework to engage participants and facilitate behavioral change in oral self-care. Its functions were systematically categorized into capability establishment (providing knowledge and skills, along with personalized information based on clinical examination), motivation enhancement, and opportunity creation (including setting reminders for oral self-care).

II. **Frequency of Use & Effectiveness:** This study found a significant correlation between Oral Hygiene Status (OHS) improvement and the frequency of OSCA use, with high-frequency users demonstrating greater improvement. Higher frequency of use was also positively correlated with greater overall likeability of the app.

III. **Factors Affecting Improvement:** OHS improvement was significantly affected not only by the frequency of app use but also by changes in oral hygiene behaviors (OHBs) and smoking habits.

IV. **Limitations:** The study focused on short-term effectiveness (4–8 weeks) and noted that long-term effectiveness needed further confirmation. Additionally, it identified a segment of "low-frequency users" who did not consistently engage with the app, indicating a challenge in achieving universal adherence.

2.1.5 Overall Tracking and Engagement Features

The effectiveness of smartphone applications in promoting oral health is significantly enhanced by their ability to provide comprehensive tracking and engagement features.

I. **Dental Appointment Tracker:** Applications like "Dent-O-Xpert" have successfully integrated reminders for dental appointments alongside oral hygiene routines, serving as a crucial component for consistent oral care. Similarly, the OSCA featured functionalities for setting reminders for daily tooth brushing.

II. **Progress Tracking/Self-Monitoring:** Both "Dent-O-Xpert" and OSCA emphasized the importance of progress tracking and self-monitoring mechanisms to motivate and empower users. The consistent finding that the effectiveness of apps is positively correlated with the frequency of use underscores the critical role of sustained engagement in achieving behavioral change.

III. **Personalized and Evidence-Based Information:** The success of these applications is further attributed to their capacity to deliver personalized and evidence-based information, which directly contributes to user engagement and the facilitation of behavioral change.

2.1.6 Synthesis and Identification of Gaps for ToothyMate

The existing literature provides a strong conceptual and empirical basis for the ToothyMate application, demonstrating that mobile applications, especially those integrating AR for demonstrations and AI for image analysis, are effective tools for improving oral health knowledge, attitudes, and behaviors. The efficacy of structured educational content combined with interactive features and reminders is well-established.However, the review also identifies several opportunities and gaps that ToothyMate can aim to address:

I. **Improving AR Usability:** Given the noted lower usability scores for some MAR systems, ToothyMate has an opportunity to prioritize intuitive design and user-friendly interfaces in its interactive AR tooth model, ensuring that users can easily explore and

understand dental structures, plaque accumulation, and early decay. This shift aims to enhance educational value while maintaining accessibility and engagement.

II. **Enhancing AI Feedback:** The challenge of "templated" and potentially "boring" AI-generated feedback needs to be overcome. ToothyMate can focus on designing more dynamic, varied, and genuinely personalized AI responses that mimic human interaction more closely. This might involve leveraging advanced language models while remaining critically aware of their ethical implications, particularly regarding potential biases and "AI hallucination".

III. **Comprehensive Image Capture:** Addressing the current limitations in capturing images of posterior, palatal, and lingual surfaces for more complete AI analysis is crucial. ToothyMate could explore specific user guidance within the app or consider the integration of external tools to facilitate more comprehensive oral cavity scanning if feasible for a consumer application.

IV. **Sustained Engagement and Long-Term Usage:** The literature points to challenges with user burnout and uncertain long-term usage of AI-assisted devices. ToothyMate can aim to incorporate more advanced behavioral change techniques beyond simple reminders, focusing on fostering intrinsic motivation and continuously delivering value to ensure sustainable improvements in oral hygiene practices.

V. **Ethical Design and Privacy:** Critically, ToothyMate must emphasize its commitment to user privacy and data security, addressing the "black-box" problem by striving for transparency in AI processes where possible and clearly outlining data usage policies. This is a crucial and often overlooked area in existing research, and proactive ethical design will be paramount to building user trust.

Title	Authors	Year	Features & Methods	Dataset	Advantages	Limitations
A mobile augmented reality-integrated oral health education for community dwelling older adults: A pilot study	Romalee, Tsai, Hsu, Hsu, Wang	2023	Developed an AR app (MAKAR) using 3D models to teach oral care to older adults, evaluated usability and learning impact.	24 older adults (65–93 y/o) from Taipei, Taiwan.	Improved oral knowledge and self-efficacy, anytime learning, first MAR app for older adults	Low usability score, no control group, only short-term impact
Caries Detection on Intraoral Images Using Artificial Intelligence	Kühnisch, Meyer, Hesenius, Hickel, Gruhn	2022	Used MobileNetV2 CNN to detect caries from intraoral photos, included saliency maps and tested accuracy.	2,417 anonymized intraoral photographs from permanent teeth.	Over 90% accuracy, expert-level performance, web-based	Ideal images only, excluded other conditions, possible bias
Impact of smartphone application 'Dent-O-Xpert' on oral health related knowledge, attitude and behavior of young adults – A randomized control trial	Nagarajappa, Vyas, Mishra, Gupta, Thippeswamy, Sontakke	2023	Conducted RCT comparing Dent-O-Xpert app (videos, tips, reminders) to traditional sessions over 30 days	168 young adults (18–25) from Indore, India.	Improved knowledge, increased brushing habits, behavior change	Self-reported data, short follow-up, slow initial results

Effectiveness of an App-Based Mobile Intervention for Precision Oral Self-Care in Patients with Periodontitis from Initial Therapy to Re-Evaluation	Chang, Wang, Chang, Lo	2021	Tested OSCA app with knowledge modules and behavior change tool, measured oral hygiene improvements.	150 eligible patients recruited	Clinical improvement with high usage, expert-backed content	No major difference vs control, short-term study
The use of artificial intelligence to aid in oral hygiene education: A scoping review	Tay, Ng, Chow, Sim	2023	Scoping review of 20 studies using AI for oral hygiene education, assessed trends, ethics, and tech use.	20 studies of diverse populations and designs, mostly unstructured image data.	AI is practical, can be used with AR/VR, works in daily life	Small samples, weak ethics discussion, privacy and image quality issues

Table 2.1.1. *Summary of Reviewed Articles for Oral Health Education and Monitoring*

2.2 Existing Mobile Applications Related to Oral Health

Several mobile applications currently exist that aim to promote oral hygiene, provide education, or assist in behavior change. However, most do not integrate AR, AI, habit tracking, and customized e-learning within a single platform. The following are among the most relevant existing apps.

2.2.1 Dent AI

Dent AI is a mobile application developed by Openuse.io and released in 2025. It supports dental professionals in clinical documentation, diagnosis assistance, and secure communication. The app incorporates AI for interpreting dental X-rays and streamlining patient management. While technologically advanced, it is intended for clinical use rather than public engagement. It lacks AR tutorials and is not designed for behavior change or daily self-monitoring by general users.

2.2.2 Oral-B App

Developed by Procter & Gamble, the Oral-B app works with Bluetooth-enabled electric toothbrushes to guide users using AI-generated real-time feedback. It provides brushing time tracking, zone-based scoring, and pressure monitoring. This app encourages habit formation through gamified brushing goals. However, it requires specific Oral-B devices, limiting accessibility. It does not include educational resources tailored to different user groups, nor does it employ AR for interactive guidance.

2.2.3 Colgate Mouth Health Coach

The Colgate Mouth Health Coach is an educational and behavior-focused app offering brushing tips, habit reminders, and goal tracking. It emphasizes motivation through daily coaching and progress rewards. Though accessible and informative, it lacks image-based tracking, AR guidance, and AI-generated visual analysis, which limits the depth of feedback available to users.

2.2.4 Smile for Life

Smile for Life is an educational app developed by the Society of Teachers of Family Medicine. It is widely used among healthcare students and providers for oral health curriculum delivery. The app includes detailed modules on fluoride use, brushing techniques, and dental care across different populations. Despite being comprehensive in theory, it lacks interactivity, habit tracking, and visual learning components like AR or AI.

2.2.5 Brush DJ

Brush DJ is a music-based app designed to encourage users to brush for the recommended two-minute duration. It also offers reminders for dental visits and flossing. While suitable for basic behavior encouragement, the app lacks personalized feedback, tracking features, and modern enhancements such as AI or AR.

2.3 Summary and Gap Identification

The reviewed literature provides a strong conceptual and empirical foundation for the development of the ToothyMate application. Research findings consistently demonstrate the effectiveness of mobile health technologies in enhancing oral health knowledge, encouraging positive behavioral change, and increasing user engagement. The incorporation of Augmented Reality has shown clear benefits in improving visual understanding of oral structures and conditions, making it a valuable tool for patient education and self-awareness in oral hygiene, while Artificial Intelligence contributes to visual dental data analysis that supports self-monitoring without clinical diagnosis.

The evaluation of existing mobile applications such as Dent AI, Oral-B, and the Colgate Mouth Health Coach further highlights opportunities for innovation. While these applications successfully implement features such as brushing timers, educational prompts, or AI-driven analysis, most of them are limited in scope. Some require specific hardware or professional usage, while others lack interactivity, personalized learning paths, or visual tracking capabilities. Few offer an integrated solution that combines Augmented Reality guidance, image-based Artificial Intelligence feedback, and progress tracking within a single platform designed for general public use.

ToothyMate aims to address these gaps by unifying interactive AR visualizations of tooth structure, plaque accumulation, and decay, image-based hygiene tracking powered by non-diagnostic AI, and educational content curated for diverse adult users.The application also introduces habit reinforcement features, including oral hygiene scores and appointment history tracking. With a focus on accessibility, ethical design, and long-term user engagement, ToothyMate is positioned to make a meaningful contribution to preventive oral health practices and to support individuals in maintaining consistent oral hygiene behaviors.

Application	Developer	Year Released	Function	Advantages	Limitations
Dent AI	Openuse.io	2025	Clinical documentation, AI-based diagnosis assistance	Advanced AI for radiograph interpretation, supports dental professionals	Clinical use only, no AR, not designed for public engagement or behavior change
Oral-B App	Procter & Gamble	2014	Real-time brushing guidance with AI, brushing timer, feedback	AI-driven feedback, gamification, real-time pressure and time tracking	Requires specific Oral-B devices, no AR or personalized educational content
Colgate Mouth Health Coach	Colgate	2020	Educational tips, habit tracking, motivational coaching	Accessible and motivating includes reminders and goal setting	Lacks AR features and AI-based visual analysis

Smile for Life	Society of Teachers of Family Medicine	–	Educational modules for students and providers	Comprehensive curriculum content, useful for healthcare training	Lacks interactivity, visual learning tools like AR or AI, and habit tracking
Brush DJ	–	–	Music timer to encourage 2-minute brushing, reminders for dental care	Simple and fun, promotes correct brushing duration, encourages routine	No tracking, AI, AR, or personalized feedback

Table 2.2.1 *Comparison of Existing Oral Health Mobile Applications*

CHAPTER 3

METHODOLOGY

This project adopts the Agile methodology as its core development approach. Agile emphasizes iterative development, continuous feedback, and flexibility in responding to user needs. The ToothyMate: Smart Oral Health Awareness with AR & AI mobile application is developed through multiple development cycles, known as sprints, where features are implemented, tested, and refined based on feedback.

Throughout the Agile process, user stories are defined to reflect real-world needs, such as accessing educational content, interacting with 3D tooth models and receiving AI-based feedback. This ensures that the application evolves in alignment with user expectations and provides meaningful solutions to real oral health challenges. Regular reviews and testing during each sprint allow for quick identification of issues, feature adjustments, and usability improvements. Agile's flexibility also supports gradual integration of core features, including Augmented Reality and AI modules, allowing for staged validation and deployment.

3.1 User Requirement Gathering via Pre-Survey

Prior to the development phase, a pre-survey was conducted to gather insights into users' current oral health behaviors, interests, and expectations regarding digital solutions for oral health awareness. The survey collected responses from 43 individuals, including both general public users and dental professionals, ensuring a diverse range of perspectives.

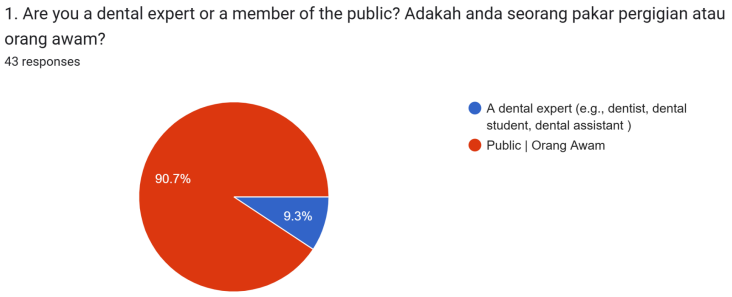


Figure 3.1.1: *Distribution of Survey Respondents by User Type (Public vs. Dental Professionals)*

3.1.1 Demographic Distribution

The age distribution of respondents revealed that the majority (51.2%) were within the 36–50 years age group, followed by 27.9% aged above 50 years. Smaller proportions of participants were aged 18–25 years (16.3%) and 26–35 years (4.7%). This distribution indicates the app's potential relevance across adult age groups, with a stronger appeal among middle-aged and older individuals.

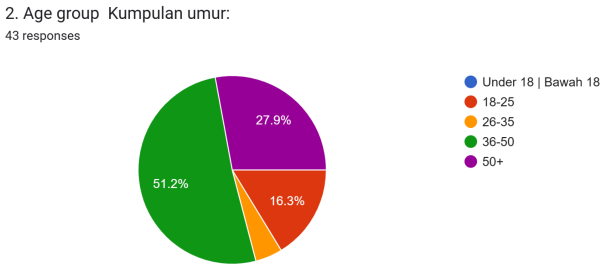


Figure 3.1.2: *Age Distribution of Survey Respondents*

3.1.2 Dental Visit Habits

Regarding dental visit frequency, more than half of respondents (53.5%) indicated that they only seek dental care when experiencing pain. Meanwhile, 20.9% reported visiting the dentist rarely, 16.3% visited once a year, and only 9.3% maintained a routine schedule of visits every 3 to 6 months. These findings suggest a prevalent reactive approach to dental care, highlighting the need for interventions that encourage preventive behavior.

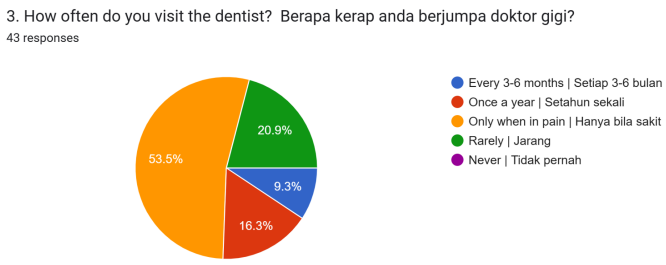


Figure 3.1.3: *Frequency of Dental Visits Among Survey Respondents*

3.1.3 Experience with Dental Apps

A significant majority (95.3%) of respondents reported never having used any dental-related mobile applications prior to this study. Among the few who had, 4.7% mentioned using the Colgate app. This low adoption rate of existing dental apps suggests an untapped opportunity for an engaging and accessible platform tailored to users' needs.

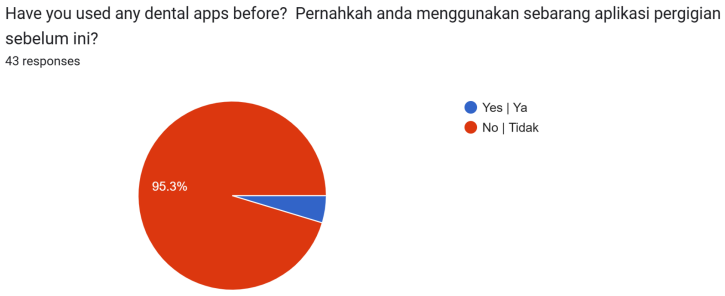


Figure 3.1.4: *Proportion of Respondents Who Have Used Dental Mobile Applications*

3.1.4 User Suggestions for App Functions

The survey also included open-ended questions about the features respondents would like to see in a dental app. Suggestions included:

- Dental care guidance tailored by life stages.
- More engaging and interesting information about teeth to increase user interest.
- Dental appointment management.
- Early detection of at-risk dental conditions.

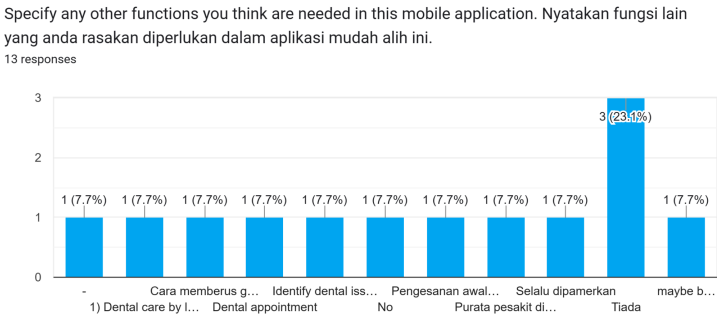


Figure 3.1.5: *Commonly Suggested Features for Dental Mobile Applications Based on Survey Responses*

3.1.5 Common Dental Concerns

Participants were asked about their primary dental worries, with responses as follows:

- 44.2% cited pain as their main concern.
- 34.9% were worried about late detection of dental issues.
- 20.9% expressed concerns over the cost of dental care.

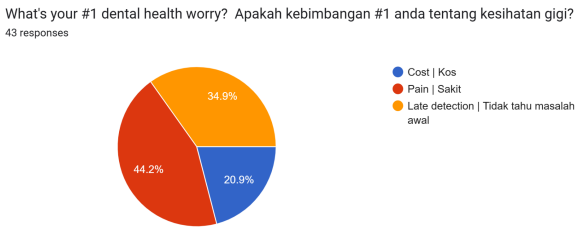


Figure 3.1.6: *Primary Dental Concerns Reported by Survey Respondents*

3.1.6 Perception of AI-Based Detection Features

When asked if they would recommend a mobile app capable of automatically detecting dental issues like plaque or cavities and providing users with detailed information about their dental condition, 100% of respondents answered yes, affirming its usefulness for society. This strongly supports integrating AI-driven educational and detection tools in the app.

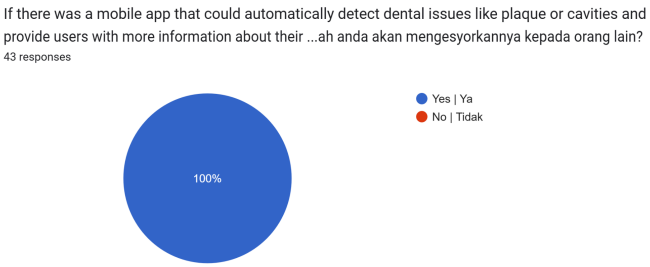


Figure 3.1.7: *Respondents' Willingness to Recommend an AI-Powered Dental App*

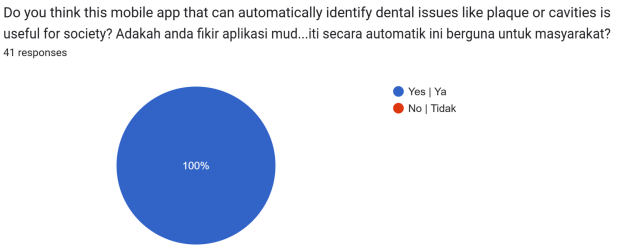


Figure 3.1.8: *Respondents' Perception of the App's Usefulness to Society*

3.1.7 Trust and Credibility Factors

When asked what would make users trust a dental app, the majority highlighted that approval or endorsement by dental professionals is crucial. Reflecting this, the development of ToothyMate involved collaboration with Klinik Pergigian Dr. Karthi, ensuring that the app's content and features are credible and professionally validated. This partnership enhances user confidence and supports the app's goal of providing reliable oral health guidance.

Figure 3.1.10: *Trust and Credibility Factors Influencing User Confidence in Dental Apps*

3.1.8 Topics of Interest in Oral Health

Participants identified dental topics they were most interested in learning about. The most popular response was dental treatment explanations at 67.4%, followed by early cavity and tooth damage detection at 51.5%, and gum disease prevention at 41.9%. Additionally, 25.6% expressed interest in proper brushing techniques, while a smaller portion (2.3%) were interested in dental prosthetics such as dentures and crowns. These preferences informed the content focus of the app's E-Learning Library.

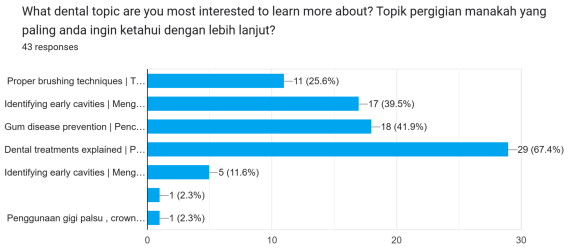


Figure 3.1.11: *Survey Respondents' Topics of Interest in Oral Health Education*

3.1.9 Attitudes Toward AR and Gamification Features

Participants gave an average rating of 4.40 out of 5 for the perceived usefulness of Augmented Reality (AR) integration in the app, indicating strong interest in interactive and visual learning tools for dental education. Furthermore, 81.4% of respondents agreed that a "streak system", a gamified feature rewarding users for consistent dental check-ups would motivate them to attend dental visits more regularly. This supports the inclusion of behaviorally driven features aimed at promoting long-term oral health habits.

Figure 3.1.12: *Respondents' Attitudes Toward Augmented Reality and Gamification Features in the Dental App*

3.1.10 Perceived Usefulness of App Functions

Respondents were introduced to the proposed core features of the ToothyMate app and asked for feedback on their perceived usefulness:

- AR Tooth Model: An interactive 3D model to visualize tooth structure, plaque buildup, and potential decay.
- AI Scan (Educational Purpose): A photo-based feedback tool to help users identify plaque or potential cavities.
- E-Learning Library: Bite-sized learning materials covering dental procedures and daily oral care techniques.
- Appointment Streaks: A motivational tool encouraging users to regularly visit the dentist by tracking check-ups.

The majority of participants expressed high interest and confidence in the usefulness of these features, indicating strong alignment between user expectations and the app's objectives. This pre-survey not only validated the app's core components but also provided essential guidance for tailoring content and features to user preferences.

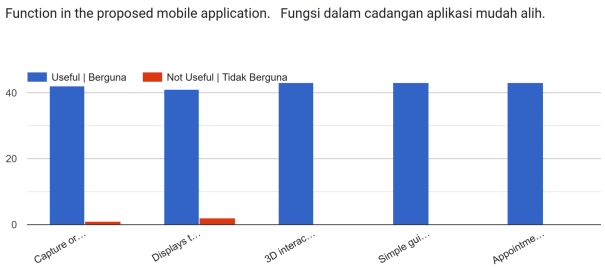


Figure 3.1.13: *Respondents' Perceived Usefulness of Proposed Core Features in the ToothyMate App*

3.2 Design Phase

The design phase of the ToothyMate application focused on translating the system requirements and objectives into an organized and user-oriented mobile application structure. The primary design goal was to ensure simplicity, ease of navigation, and alignment with the core components of the project: Augmented Reality (AR), Artificial Intelligence (AI), and e-learning content

The flowchart illustrates the sequential interaction between the user and the ToothyMate application, beginning with the launch of the app and the display of the main menu. The user is then prompted to select one of the available features. If the user selects "View AR Tooth Model," the application first displays a 3D tooth interface on-screen, allowing the user to explore various dental conditions interactively. The user may then proceed to the AR mode, where the system attempts to detect a marker using the device camera. If the marker is successfully recognized, the application renders the 3D tooth model in augmented reality. If the marker is not detected, the user is prompted to point the camera at the appropriate target. In the "Upload Tooth Image" function, the system generates AI feedback after analyzing the user's submitted tooth photo. The "Access E-Learning Library" function allows users to read oral health content in a modular and interactive format. The complete application flow is presented in Figure 3.2.1.

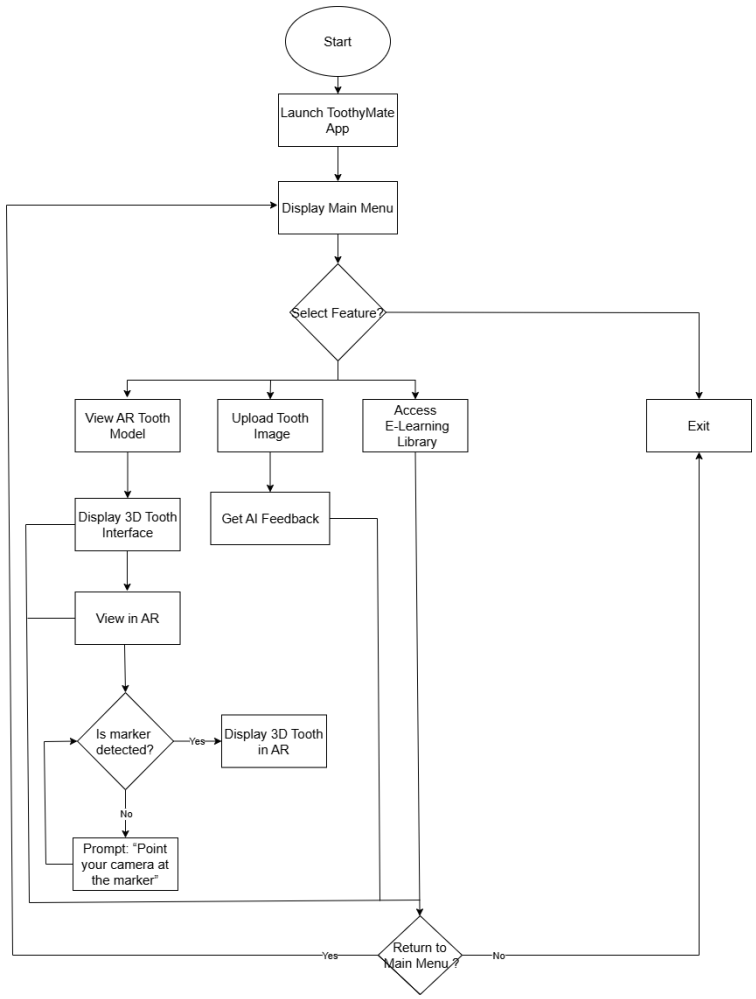


Figure 3.2.1: *Flowchart of ToothyMate Mobile Application*

Additionally, the use case diagram represents the key functional interactions between the user and the ToothyMate application. The primary actor in this system is the user, who is able to engage with the application through several core features. These include viewing an interactive 3D tooth model, uploading a tooth image to receive AI-generated feedback, accessing the e-learning library, and logging dental appointments which may trigger streak notifications. The "View AR Tooth Model" use case contains two embedded functions. Initially, the user is presented with an on-screen 3D model for interaction. If the user chooses to activate the augmented reality (AR) view, the system will attempt to detect a physical marker and, upon successful recognition, render the 3D tooth model in the real environment. Similarly, the "Upload Tooth Image" use case incorporates the AI module, which provides non-diagnostic visual

feedback to the user based on the submitted photo. The use case diagram is presented in Figure 3.2.2.

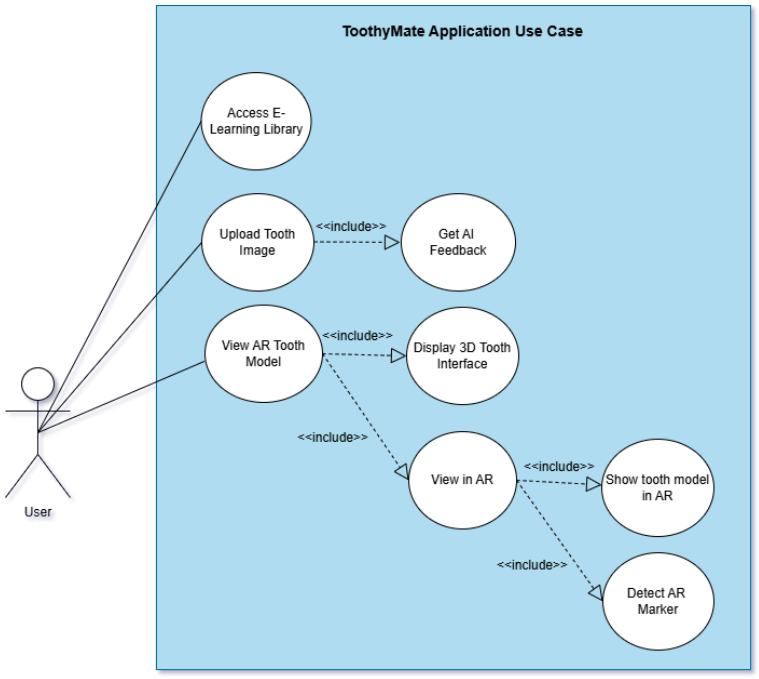


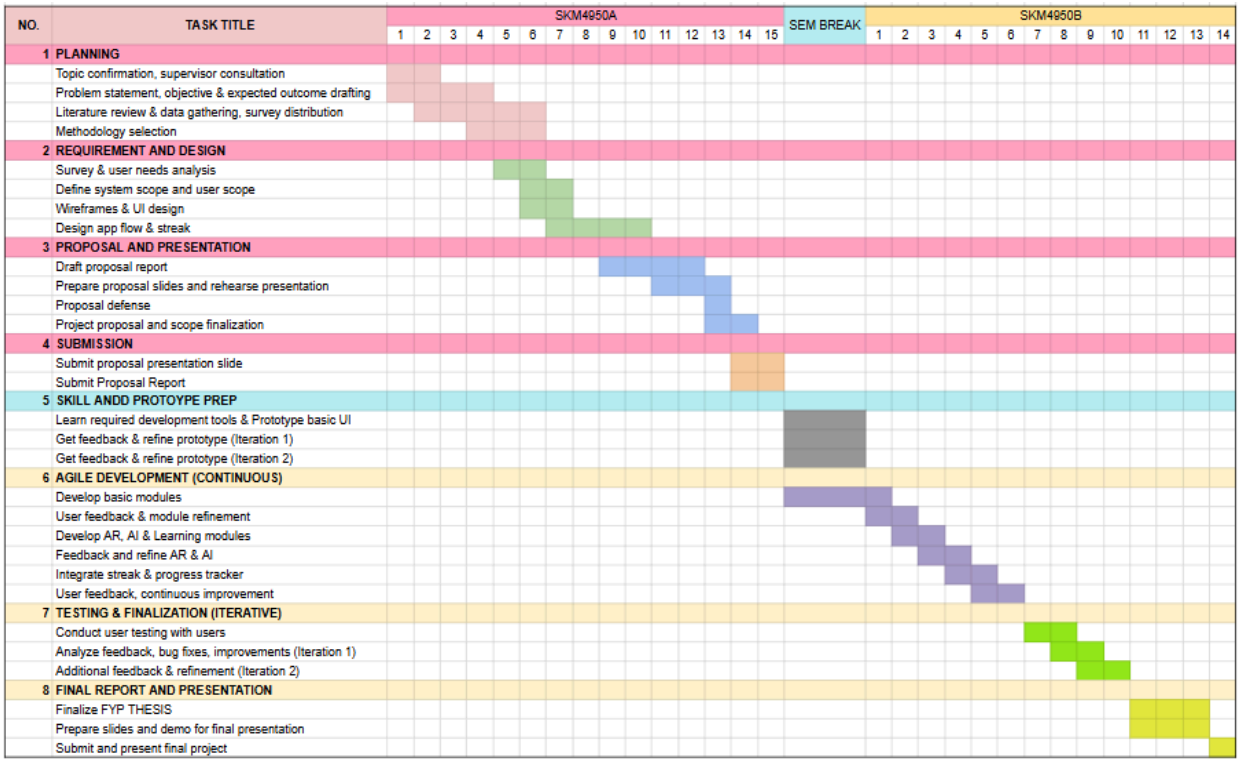
Figure 3.2.2: *Use Case Diagram of ToothyMate Mobile Application*

The overall application design ensures that users can independently navigate the system, access visual and textual educational content, and engage with feedback tools that support sustained oral hygiene behavior.

3.6 Tools and Programming Languages

Several tools and programming platforms were employed in the development of this project. Flutter served as the main development framework, with Dart as the programming language. AR capabilities were achieved using Flutter AR plugins compatible with ARCore. TensorFlow Lite facilitated the integration of the AI module, and Firebase was employed for backend services, including data storage and authentication. Figma was used for designing the user interface, while Google Forms was utilized for collecting survey and evaluation data.

3.7 Gantt Chart



3.8 Expected Output

The expected outcome of this project is a fully functional mobile application that leverages AR and AI technologies to raise awareness of oral health and encourage consistent oral hygiene practices among adults. The application aims to deliver an engaging and informative experience through its educational content, visual interactivity, and personalized feedback mechanisms. It is anticipated that the app will positively influence users' oral health behaviors and serve as a model for the integration of digital technologies in preventive dental care.

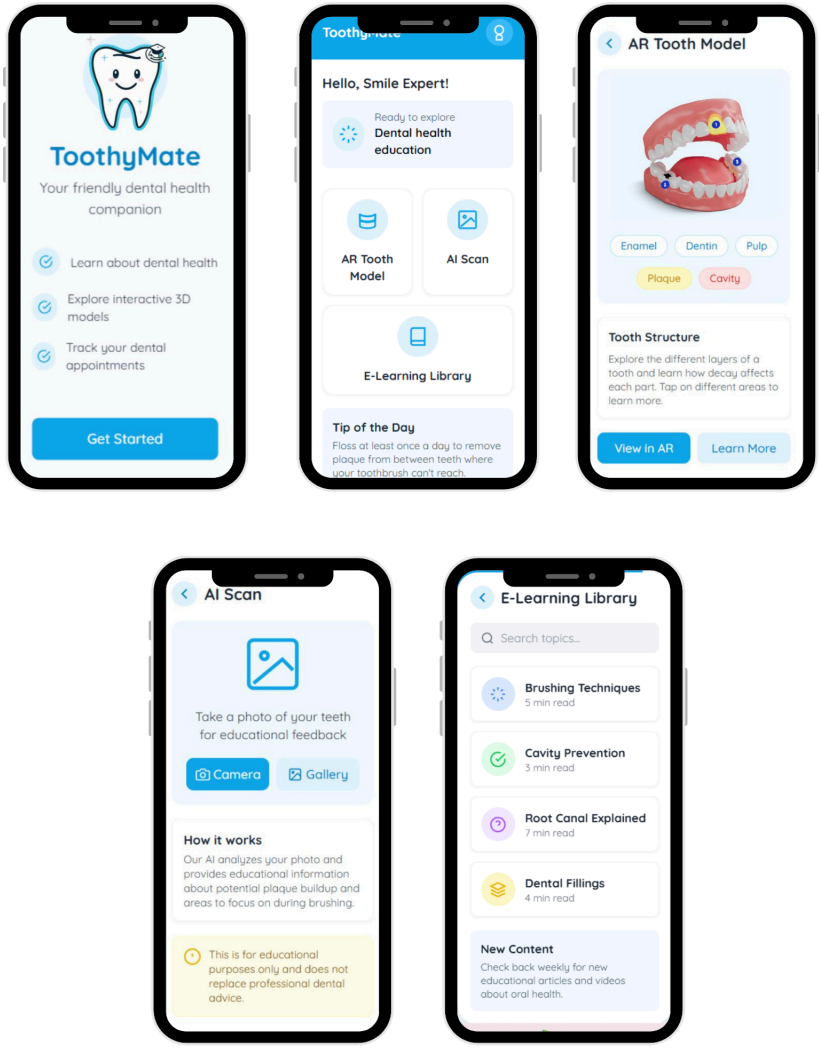


Figure 3.8.1: *Expected Outcome*

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