Toward Building A Theoretical Model of Oral Health Care

Final thesis of Mres study

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CONTENT

I. Abstract Oral health is an essential aspect of general health. Despite tremendous progress over the past century, oral health remains a serious issue worldwide, demonstrating that dental caries is the most common chronic illness. A lack of awareness of the factors that affect oral health may prevent individuals or society from intervening promptly and effectively to address oral problems. The field of oral health has attracted increasing attention in recent years. However, there is still a lack of integrated reviews that can identify areas where significant research has already been conducted and areas where there are still gaps in the knowledge of oral health determinants. This study is dedicated to providing an overview of the factors influencing oral health, based on a user-centered research approach. A pilot study investigates the critical factors extracted from the existing literature, and partial least squares structural equation modelling is applied to test the theoretical framework derived from factor analysis. This paper can serve as an exploratory investigation into the determinants of oral health, providing a theoretical model that can help researchers, designers, and healthcare professionals better target vacancy research and design for effective treatment and intervention for patients with oral problems. Based on the vacancies identified in this paper, a design concept for a toothbrush product is proposed in this paper to assist users in their daily oral care and enhance their oral health.

Index Terms Oral health, human, factor analysis, PLS-SEM, the theoretical model

II. INTRODUCTION

According to the definition proposed by WHO, oral problems can be further differentiated, such as caries, periodontal disease, and malocclusion. Additionally, tooth loss, oral cancer, and traumatic dental injuries can be joint oral health-related problems (Singh et al., 2019) . Research indicates that decreased oral health impacts more than the functions traditionally associated with the mouth (Casamassimo, 2000). Oral health is inextricably related to holistic health. The oral cavity serves as a window into overall health, ; pathologic disorders in the mouth have a more considerable systemic influence than many practitioners realize (Kane, 2017). Dental health problems can directly affect a person's ability to eat and hinder the intake of nutrients (Casamassimo, 2000). More severe oral health issues even act as a risk factor for cardiovascular, diabetic, respiratory, and other systemic disorders (Li et al., 2000).

Oral health inextricably links to overall health. It can also serve as a critical indicator of well-being and quality of life, impacting chewing, eating, swallowing, speaking, facial aesthetics, and social contact (de la Fuente Hernández et al., 2015). As people age, oral problems accumulate, and the impact on social, psychological, and functional aspects becomes apparent. Furthermore, oral illness is exceedingly expensive to treat conventionally, making it the fourth most costly disease to treat in most developed countries (Petersen et al., 2005). The financial strain placed on a family by dental expenses may be enormous, particularly for low-income families. High dental costs might exacerbate the hardships of an already impoverished household, exacerbating discrepancies in oral health status across and within nations (Petersen & Kwan, 2011). The burden of oral illness is disproportionately high for disadvantaged and impoverished population groups in developing and developed countries. Oral health affects the quality of human life in various ways, highlighting the

necessity to address oral health issues.

Despite substantial progress in overall oral hygiene conditions in various countries worldwide, the oral problem is still a global issue (Peres & Heilmann, 2015). It remains the aspect that is under-estimated and under-investigated. Oral problems are often overlooked owing to their chronic progressive growth feature (Cheng et al., 2018). Providing proper prevention-focused interventions is central to addressing oral health problems in the early stages (Kane, 2017). Nowadays, health-related organizations and institutions worldwide (such as WHO and FDI) set oral health targets for the coming years, providing a workable framework for oral health practitioners in each country and region. Before setting goals, it is essential to understand the current status of oral disease and the factors that influence it. Thus, policymakers can better specify targets and standards to guide more health care providers to improve the oral health status of the local population effectively.

During the past two decades, a wealth of literature has centered on the determinants of oral hygiene, especially the social, environmental, and behavioral factors. One research perspective is to learn about factors that cannot be decided or controlled by individuals, primarily environmental elements such as fluoridated water supply, access to oral healthcare facilities, and health insurance policies (Harding & O'Mullane, 2013) (Liu et al., 2016) . Another perspective is to analyze some individual behavior and awareness factors. In particular, researchers are increasingly focused on understanding the drivers of oral health disparities, particularly those that occur between urban and rural regions of the same country (Boynes et al., 2018) (Skillman et al., 2010). The work done by former researchers laid the groundwork for conducting a literature review and building the conceptual model. However, two main problems arise from the current research findings. The first one is that information extraction from the current literature can be difficult and time-consuming for the readers, because the factors impacting human oral health are rather heterogeneous. Some studies also involve a combination of several influencing factors, thus readers may have difficulty centralized effective information efficiently. The second one is that existing research themes are relatively focused, and certain influencing factors have been extensively discussed and validated, but there are still unexplored directions.

This article aims to provide an overview of the factors influencing oral health, based on a user-centered research approach. An encompassing conceptual model with a logical hierarchy is presented based on extensive literature research to summarize the conclusions drawn from the literature review. The empirical experimentation with PLS-SEM assists in determining which variables exhibit stronger associations with oral health. Furthermore, PLS-SEM provides causal explanations for statistical models that are derived by applying a causal-predictive approach to SEM.

In the next section of this study, we present the literature review based on the electronic databases. In Section 3, the empirical study is presented. Results of the structural equation model (SEM) and a summary of hypothesis testing are presented in Section 4. Section 6 is a discussion and implication part, which further explains our experiments and highlights our findings. Section5 shows the design ideas based on the research vacancies. The limitations of this study and outlines

the following steps to be taken are both described in this section. The final section is conclusion part, serving as a summary of the whole paper.

III. LITERATURE REVIEW

A total of 60 papers were read thoroughly and the pivotal oral health influences were summarized in this section. It is demonstrated by the available literature that individuals' dental health is highly variable due to a wide range of factors. The factors influencing oral health can be roughly divided into external and internal factors preliminarily.

3.1 External factor:

External factors here refer to factors beyond the control of the individual, such as the environment, national policies, and socio-economic conditions, which have an indirect, but significant impact on individuals' behavior and performance.

Fluoridated water:
Public health measures such as water fluoridation can significantly reduce dental caries. Despite the availability of other dental services, community water fluoridation is a proven, economical, and widely accepted practice that should be implemented and sustained wherever feasible and socially acceptable (O Mullane et al., 2016) . One of the significant detrimental impacts is the risk of dental fluorosis, which can affect the appearance of the teeth. Fluoridating water provides a reliable method of preventing dental caries, accessible to all residents regardless of the availability of other dental services (Harding & O'Mullane, 2013).

Infection transmission:
In general, dental caries and periodontal diseases are the most common bacterial infections in the mouth (Könönen, 2000). People with close relation are more likely to have infection transmission. A study was conducted in 1993 examining the transmission of oral bacteria between four married couples (Saarela et al., 1993) . It has been verified that the bacteria have been transmitted between individuals residing in close contact since the same hybridization patterns of the dental pathogens have been found among spouses.

Treatment cost:
The high expense of dental care has become a significant impediment to oral health (Sisson, 2007) (Singh et al., 2019). A series of recent studies have indicated that oral problems exacerbate people's financial burden due to the high expense of treatment (Liu et al., 2016) (Nash et al., 2008). Traditional oral disease therapy is exceedingly expensive, oral diseases rank fourth in terms of treatment costs in most industrialized countries (Petersen et al., 2005). The economic burden caused by oral health treatment was pretty high, and this affects the rate of dental service utilization to some extent (Cheng et al., 2018).

Transportation:

The current exploration of the association between transport and oral health has focused on senior citizens. Nevertheless, older adults have lower dental utilization rates than younger adults, and transportation problem is one of the most significant barriers to oral care (Dolan & Atchison, 1993). Studies have demonstrated that multiple transportation modes can impact oral healthcare availability and improve oral health outcomes for older people (Jin et al., 2018). Access to oral healthcare is unevenly distributed, which may assist with the planning of appropriate transportation services.

Income level:
There have been numerous studies highlighting the close relationship between household or individual income and oral health. Studies involving cross-sectional data have confirmed that low household income significantly increases the risk for oral cancer, dental caries prevalence, caries experience, tooth loss, and traumatic dental injuries; low income is also associated with periodontal disease and poor quality of life (Singh et al., 2019). Specifically, it is proven that poverty, in at least one stage of the lifespan, has a detrimental impact on dental caries, oral behaviors, and dental services use (Peres et al., 2007).

Insurance:
Insurance plays a crucial role in the provision and utilization of dental services in some countries (Shetty et al., 2018). Public insurance can reduce residents' personal expenditures on dental healthcare (Kim et al., 2012). However, healthcare expenses are outpacing economic development, and funding for healthcare is becoming increasingly strained as a result of budgetary crises (Shetty et al., 2018). Dental insurance coverage has not increased over the years to keep up with the rising dental expenditures (Haumschild & Haumschild, 2009). As a result of this, the present low rate of public insurance related to oral health cannot alleviate residents' financial burden on oral care (Skillman et al., 2010), which means that out-of-pocket costs could be unaffordable for household finance, especially in some low and middle-income countries (Bernabé et al., 2017).

Access to dental service:
The lack of available dental services can be a barrier hindering people from maintaining oral health (Peres et al., 2007) (Skillman et al., 2010). The reason for this may be the absence of primary oral health care in the area or some other factor that prevents residents from accessing oral health care. The dental services include but are not limited to professional dentists, dental clinics, and oral health promotion primary prevention programs (Wong et al., 2001). Due to unequal regional distribution, patients living in remote areas generally need to travel a great distance for medical help, which will significantly reduce the frequency of regular dental visits of people (Skillman et al., 2010) (Kim et al., 2012). To enhance the delivery of oral healthcare, it is also necessary to tackle the issue of a scarcity of educated dental personnel (Hobdell, 2007).

Community support:
Research points out that socially isolated people are likely to engage in risky behaviors and less health-promoting activities, which may adversely affect oral health (Fisher-Owens et al., 2007). Positive health outcomes are associated with community support (Fisher-Owens et al., 2007).

Empowering the community is an effective initiative to eradicate oral health disparities by transforming paradigms to promote health and by integrating oral health into broader health and social initiatives (Mouradian et al., 2007). Increasing the influence of social groups over the determinants of oral health can be accomplished through community participation, social empowerment, and public opinion(Watt et al., 2001).

Parental influence:
Parental education and behavior inevitably influence the child's attitude and habits towards oral health. Based on large-scale sample size, a recent study has confirmed the relationship between parental education levels and children's oral health behaviors (Chen et al., 2020). Oral hygiene practices are generally better among children whose parents are more educated; thus, the educational level can directly relate to parental cooperation and participation in children's oral health practices. Parents' behavior is widely accepted as influencing the health of their children. An important conclusion of a current study is that certain health behaviors in parents are powerfully linked to their children's health behaviors (Bozorgmehr et al., 2013).

3.2 Internal Factor

Internal factors also form an essential part of the influencing factors. Internal factors here refer to factors that are more subjectively controlled by the individual, such as his or her state, behavioral habits, and cognitive awareness. A total of 20 peer-reviewed articles have systematically described the effects of multiple personal factors on oral health, including demographic factors, personal behaviors, psychological/physical state.

Demographics:
Gender and age can be seen as the two significant factors associated with oral health. Several studies have revealed differences in oral health behaviors between men and women, demonstrating that women generally exhibit better-regulated behaviors (Al-Shammari et al., 2007) (Lipsky et al., 2021). These behaviors include brushing more frequently, using more fluoride toothpaste, and having more comprehensive oral hygiene knowledge. Reports also state that gender-specific differences in oral health are influenced by individual attitudes towards oral health and dental utilization (FUKAI et al., 1999). Age also plays a crucial role in the quality of life associated with oral health (Steele et al., 2004). Age-related oral health problems such as mouth dryness and dental caries are brought about by the reduction in salivary flow, which can cause difficulty in chewing and perception of taste of foods. (Razak et al., 2014).

Employment:
An unemployed individual is more likely to engage in harmful oral health practices and have poor dental health (Al-Sudani, 2017). Among those that are unemployed, dental visits are infrequent, xylitol is rarely used, and daily smoking and alcohol use is hazardous(Al-Sudani et al., 2016). Unemployment primarily affects oral health through oral health-related behaviors, whereas there was no consistent relationship between unemployment length and oral health-related behaviors.

Early oral care:

Infancy oral health education is especially essential since oral health habits formed in childhood can last a lifetime (Damle et al., 2014). One of the reasons why people tend to overlook oral hygiene is due to its chronic progressive characteristics (Cheng et al., 2018). Formation of oral health awareness should begin in a primary educational institution with the involvement and support of parents (Ahad & Gheena, 2015). The reality, however, is less than ideal. Neglect in the early stages of oral problems will inevitably lead to more serious oral diseases.

Tobacco and alcohol consumption:

There is a universal recognition that the use of tobacco and consumption of alcohol can do harm to the lung, kidneys, and other organs of the human body. However, few people are aware that tobacco use is flagged as a severe risk factor for periodontal disease (Bergström & Preber, 1994). Research has demonstrated that successful smoking cessation may lead to substantial oral health benefits among a wide range of populations (Warnakulasuriya et al., 2010). Meanwhile, studies have been conducted to confirm the correlation between alcohol consumption and oral odor, periodontitis, and oral cancer, respectively (Petersen, 2009; Pitiphat et al., 2003) (Pitiphat et al., 2003). According to WHO Global Oral Health Program, tobacco and alcohol usage are both well-known risk factors for oral illness (Petersen, 2004).

Dietary habit:

Some lifestyle factors have a direct impact on oral hygiene. Maintaining dental health is promoted by healthy eating habits (Wong et al., 2001) (Petersen, 2004). Excessive intake of sugar or sugary snacks will undoubtedly cause a severe burden on the oral environment, and failure to clean appropriately will increase the risk of dental caries (Petersen et al., 2005)

Toothbrushing habit:

The toothbrush is the most effective tool used for maintaining oral hygiene among the numerous oral health care practices (Vijay Lakshmi,2018). The length and frequency of brushing, as well as the brushing technique, and even the choice of toothbrush and toothpaste can have a direct impact on the effectiveness of brushing on oral health. In addition, analysis indicates that using a tainted toothbrush to clean the oral cavity will cause more harm than good (E. S. Anjuga, 2020).

Mental status:

The impact of mental state factors on oral health has been discussed extensively in recent years, which does not seem to be directly related to oral health. Behaviors and lifestyle choices that are detrimental to health can be made due to people's more tremendous psychological pressure (Sisson, 2007), such as poor dietary habits and smoking.

Dental attendance:

Attending routine dental appointments can protect dental health (Almoznino et al., 2015). The main purpose of regular oral examinations is to clean the mouth and teeth, and to detect signs of potential oral problems. It is proved that regular attendees have better self-reported oral health and suffer less tooth loss and decay(Thomson et al., 2010).

Dental fear:

Dental anxiety is associated with greater and persistent fear of the dental environment and dental treatment (Meng et al., 2007). A series of recent studies have indicated that people with high dental fear are easier to miss the best oral treatment opportunity, leading to more extensive oral problems and symptomatic visiting patterns, thus oral diseases prevalence of this group of people is significantly increased (Armfield et al., 2007). People's regular dental visits will also be hindered, which also has a negative impact on the protection of oral health (Sohn & Ismail, 2005).

Physical status:

It was found that a two-way association existed between overall physical status and dental condition. Oral health is an integral part of general health; more than hundreds of diseases and medications affect the oral cavity. Diabetes and periodontal disease are bidirectionally correlated, and there is compelling evidence that treating one condition positively impacts treating the other (Kane, 2017). Drugs prescribed for the treatment of diseases may also negatively affect the oral environment.

Awareness:

Personal oral health awareness is closely related to oral health outcomes. As the research indicated, a lacuna in people's oral health awareness can be diametrically reflected in their oral hygiene habits (Ahad & Gheena, 2015). There is a direct correlation between lack of oral health awareness and illness-seeking behavior. Subsequently, oral healthcare facilities are underused, and patients present late to the clinic with resulting complications (Sofola, 2010). Based on the empirical analysis, it is discovered that there was a lax awareness of oral hygiene and inadequate knowledge regarding oral health, demonstrating the urgent need for a national awareness campaign on oral health at the grassroots level (Ahad & Gheena, 2015). Raising individual awareness of the role of determinants on oral outcomes is urgently needed.

Knowledge:

Ample evidence exists to support the view that insufficient oral care knowledge will worsen people's oral health (Liu et al., 2016). Lack of relevant knowledge will lead to difficulty in achieving ideal brushing behavior (Shetty et al., 2018), such as scientific tooth brushing skills (Wong et al., 2001), sufficient brushing frequency, and using fluoride toothpaste (O Mullane et al., 2016).

EXTERNAL FACTOR TABLE

No	Author Publication year Country	Context	Key Methodology	Main findings
Economic factor				
1	B Thompson (2014) Canada	Determine the oral health status and dental treatment needs of Canadians reporting cost barriers to dental care.	Questionnaire	This study substantiates the potential likelihood of progressive dental problems caused by an inability to treat existing conditions due to financial barriers.
2	Tuti Mohd-Dom (2014) Malaysia	quantify the cost of periodontitis management at public sector specialist periodontal clinic settings and analyse the distribution of cost components.	Data analysis	Cost of providing dental treatment for periodontitis patients at public sector specialist settings were substantial and comparable with some non-communicable diseases.
3	A. Singh (2019) Australia	Summarize tevidence on associations between individual/household income and oral health, between income inequality and oral health.	Systematic review	Low individual/ household income is associated with several adverse oral health outcomes. The evidence on area-level income inequality and poor oral health is conflicting.
4	M. A. Peres (2007) Brazil	Investigate the influence of family socioeconomic trajectories from childhood to adolescence on dental caries.	Examination	Poverty in at least one stage of the lifespan has a harmful effect on dental caries, oral behaviours and dental services use.
5	WOOSUNG SOHN (2005) US	Investigate factors associated with regular dental visits in an adult population.	Questionnaire	Dental insurance perceived oral health status and dental anxiety were associated with regular dental visits. Dental anxiety was an influencing factor in regular dental visit behavior.
6	Haumschild (2009) US	Point out dental professionals, such as the dental hygienists' task to assist in providing expert regular dental care and training to caregivers and other health care professionals in long-term care facilities.	Review	Many people in the United States do not receive adequate dental care, owing to barriers such as lack of both insurance and public programs, fear of dental procedures, and cost. Additionally, dental insurance coverage has not increased over the years to keep up with the rising dental expenditures.
7	Kim (2012) US	Examine age patterns in oral health indicators by race/ethnicity and socioeconomic status related to edentulism, presence of root caries, and periodontal disease.	Review	Lack of resources to pay for care,either out of pocket or through private or public dental insurance, may be one mechanism leading to disparities by SES and race.
8	E. Bernabé (2017) UK	Determine the impact of out-of-pocket payments for dental care on household finances in 40 low and middle income countries.	Review	Households with recent dental care spending were more likely to use a large portion of their disposable income and fall below the poverty line. Policy makers ought to consider including dental care as part of universal health care and advocate for the inclusion of dental care coverage in health insurance packages.
9	Vivek Shetty (2018) US	Discuss the technological innovations and practices borrowed from the e-commerce and tech sectors that could facilitate the move to a sustainable 21st century oral healthcare system.	Interview	Insurance is a major determinant of how dental services are provided and utilized in certain countries. As the numbers of dentally uninsured individuals grow and the out-of-pocket costs of dental care become more and more unaffordable, patients are likely to limit use of dental services and even skip necessary care.
10	Susan M. Skillman (2010) US	Identify the challenges to oral health in rural America and describe areas of innovation in prevention.	Review	Rural populations have lower dental care utilization, higher rates of dental caries, lower rates of insurance, higher rates of poverty, less water fluoridation, fewer dentists per population, and greater distances to travel to access care than urban populations.
11	Liu (2016) China	To review the current oral health status and oral health care models in China in an effort to provide recommendations for the future implementation of these models.	Literature review	More attention should be given to people who are in greater need of oral care, especially those with minimal access to the limited dental health resources due to geographical and financial reasons.
12	Petersen (2005) Switzerland	To point out that the major challenges of the future will be to translate existingknowledge and sound experiences of disease prevention and health promotion into action programmes	Review	To improve the outcomes of the poor requires improving government capacity not only in financial resources but also on ways to manage the complex process of change of health systems towards prevention and health promotion.
13	Hobdell (2007) US	Examine some of the major health consequences and outline some influences on the ways in which governments are trying to ameliorate the situation.	Meeting recording	Clearly, the major oral health problem for people living in low-income countries is a shortageof dentists and other trained personnel capable of delivering oral health care.
14	D.Nash (2008) US	Suggest the imperative of country with an emerging economy developing a strategic national oral healthcare plan. Document the variety of oral health workers in the world.	Examination	Each country must develop a strategic plan for the oral health of the public based on the unique demographics of the country and the epidemiology of its oral diseases. An inadequate oral health workforce is an additional barrier to achieving oral health.
15	L. Chen (2020) China	Explore the relationship between children's oral health behaviors, parental oral health knowledge, parental choices of pit and fissure sealants, and parents' education levels	Questionnaire	Parents with higher education levels tend to have better oral health knowledge and more oral health care needs, children of parents who have better educated parents tend to perform better oral hygiene practices.
16	Susan A. Fisher-Owens (2007) US	Present a more encompassing conceptual model of the influences on children's oral health.	Literature review	Support from families, friends, and communities is associated with better health. In general, social isolation is associated with engaging more in risk-taking behaviors and less in health-promoting activities, which, in turn, could endanger oral health.
17	E. Bozorgmehr (2013) Iran	Evaluate the relationship between oral health behavior of parents and oral health status and behavior of their children in a sample of preschool children in Iran	Questionnaire	some important health behaviors in parents are important determinants of these behaviors in their young children. Children with high-educated mothers had lower plaque index than the others. Promoting parents' knowledge and attitude could affect their children oral health behavior and status.
18	W. E. Mouradian (2007) US	Summarizes key conference themes and insights regarding children's needs and societal priorities, the importance of communities that support children and families, etc.	Meeting recording	To eliminate children's oral health disparities, we must change paradigms to promote health, integrate oral health into other health and social programs, and empower communities.
19	MengLin CHENG (2018) China	Evaluate the use of oral health services, the economic burden of oral diseases and related influential factors in China.	Questionnaire	Percentage of dental service utilization was relatively low, and economic burden was high. Affecting factors include area of residence, educational attainment, household income, oral health status and oral health KAP.
20	Könönen, (2000) Finland	This article presents an overview of the age-related acquisition of oral bacteria and	Clinical study	Most common bacterial infections in the mouth are dental caries and periodontal diseases.

INTERNAL FACTOR TABLE

No	Author Publication year Country	Context	Key Methodology	Main findings
Demographic factor				
25	KAKUHIRO FUKAI (1999) Japan	Evaluate gender differences in oral health behavior and general health habits in adults.	Questionnaire	Gender specificities in oral health depend on individual attitudes and dental utilization. Understanding the factors would accelerat approaches to modifying oral health behavior of both groups.
26	M. S. Lipsky (2021) Australia	Identify sex and gender related oral health disparities by summarizing the current literature related to differences in oral health between men and women.	Systematic review	Men are more likely to ignore their oral health and have poorer oral hygiene habits. They experience higher rates of periodontal disease, oral cancer and dental trauma resulting from a combination of biologic, social and gender related factors.
27	Steele (2004) UK	Aim to explain how age and tooth loss affect the impact of oral health on daily living using the short form.	Interview	Age, number of teeth and cultural background are important variables influencing oral health-related quality of life.
28	F. Y. Al-Sudani (2016) Finland	Compare the oral health-related behaviors of unemployed people with those of employed people and to assess whether they differ according to the length of unemployment.	Interview	Current unemployment indicated non-regular dental attendance, infrequent use of xylitol, daily smoking, and risky use of alcohol Findings from the LCA supported the assumption that unemployed people could be considered as a risk group for poor oral health-related behaviors.
29	F. Y. Al-Sudani (2017) Finland	Investigate the cross-sectional and longitudinal associations of employment status with OHRBs	Systematic review	Unemployment can be considered as a risk factor for detrimenta oral health-related behaviors and poor oral health. Unemployment mainly affects oral health through oral health-related behaviors pathway, whereas unemployment influences oral health-related behaviors through socioeconomic pathway
30	P. A. Razak (2014) India	Plan treatment for the senior dental patient includes an understanding of the chronic diseases the patient lives with daily.	Review	The major block in oral health care of elderly and the residents would be the underestimation of the oral health care need by them. The main oral health problems of old age that is mouth dryness and dental caries have been attributed to the reduced salivary flow.

No	Author, Publication year Country	Context	Key Methodology	Main findings
31	Poul Erik Petersen (2003) Switzerland	Describe the current situation and development trends at global level and outline WHO strategies in the 21st century	Review	Unhealthy dietary habits, smoking and other tobacco use, alcohol consumption and stress are some of the common risk factors for oral health.
32	Jianghong Gao (2014) China	Describe the oral health status and to analyze the possible risk factors for the oral health status in this population.	Questionnaire Examination	Strong association was found between sweets consumption and the presence of dental caries among 4- to 6-year-old village children. Toothbrushing and oral health knowledge were inversely associated with dental caries and gingival bleeding.
33	M. Peres (2015) UK	Present an overview of the state of knowledge on global oral health inequalities and the actions needed to address this major public health problem.	Review	Health-compromising behaviors (smoking, alcohol intake, physical inactivity, and low intake of fruits and vegetables) predict a fourfold difference in mortality risk. Socio-economic gradients in health behaviors, such as education level of parents.
34	Bergström (1994) Sweden	Prove that tobacco should be considered a major risk factor for chronic periodontal disease	Review	Tobacco, particularly tobacco smoking, has a substantial influence on periodontal health and disease. It is associated with an increased disease rate in terms of periodontal bone loss, periodontal attachment loss, as well as periodontal pocket formation.
35	Pitiphat (2003) US	Examine the association between alcohol consumption and periodontitis.	Questionnaire	The results suggest that alcohol consumption is an independent modifiable risk factor for periodontitis.
36	Petersen (2004) Switzerland	Outlines the current oral health situation and development trends at global level as well as WHO strategies and approaches for better oral health in the 21st century.	Review	Rapidly changing global disease pattern is closely linked to changing lifestyles, which include diets rich in sugars, widespread use of tobacco and increased consumption of alcohol.
37	Petersen (2009) Switzerland	Conclude some common causes of oral cavity cancer, and some actions that have been taken by WHO to assess risk factors and to help the planning of effective national intervention programmes.	Review	Tobacco and alcohol are regarded as the major risk factors for oral cancer. The evidence that smokeless tobacco causes oral cancer was confirm recently by the International Agency for Research on Cancer.
38	S. Warnakulasuriya (2010) Sweden	Review the epidemiologic evidence for the effects of tobacco use and tobacco use cessation on a variety of oral diseases and conditions	Review	Robust epidemiologic evidence exists for adverse oral health effects of tobacco smoking and other types of tobacco use. In addition, there is compelling evidence to support significant benefits of tobacco use cessation with regard to various oral health outcomes.
39	M. Peres (2016) UK	Assess whether sugar-related feeding practices affect dental caries between the ages of 6 and 18	Clinical experiment	Dental caries increment ratio between ages 6 and 18 y was 20% and 66% higher in upward and high sugar consumer groups as compared with low consumers. The higher the sugar consumption along the life course, the higher the dental caries increment.
40	MA Harding (2013) Ireland	Discuss water fluoridation under background, action mode, effectiveness, monitoring of water fluoridation	Review	Water fluoridation is a safe means of preventing dental caries, reaching all populations, irrespective of the presence of other dental services.
41	O Mullane (2016) US	Revise the 1994 document, using the expertise of researchers from the extensive fields of knowledge required to successfully implement complex interventions such as the use of fluorides to improve dental and oral health.	Review	Since the use of fluorides, whether through community programmes, professionally applied or self-applied, have been shown to be effective in reducing dental caries in children and adolescents.

42	K. Hill (2013) UK	Explore the relationships between dental attendance patterns, dental anxiety and oral health-related preventive and risk behaviors	Interview	By 2009, 61% adults said they attended for a regular check-up. Attendance patterns were associated with greater frequency of toothbrushing, use of additional dental hygiene products, lower plaque and calculus levels.
43	Thomson (2010) New Zealand	Investigate whether long-term routine dental visiting was associated with lower experience of dental caries and missing teeth, and better self-rated oral health.	Interview	By age 32, routine attenders had better self-reported oral health and less tooth loss and caries. The longer routine attendance was maintained, the stronger the effect. Routine dental attendance is associated with better oral health.
44	G Almoznino (2015) Israel	Evaluate the impact of health-related behaviors and dental attendance on oral health-related quality of life (OHRQoL).	Questionnaire	Routine dental attendance and better health-related behaviors, such as no alcohol consumption, less smoking pack years, and regular physical activity, had a protective effect on OHrQoL.
45	Vijay Lakshmi (2018) India	Determine brushing techniques, grip and frequency of tooth brushing in children.	Review	Toothbrush is the most common aid used for maintaining oral hygiene. Oral hygiene instructions should be regularly given to children to inculcate health awareness among them.
46	T. Attin (2005) Germany	Review on the proper frequency and time for toothbrushing to maintain oral health and prevent caries.	Literature review	Tooth brushing once per day is sufficient to maintain oral health and to prevent caries and periodontal diseases. Toothbrushing is also regarded as an important vehicle for application of anti-caries agents, such as fluorides.
47	E. S. Anjuga (2020)	Discusses the oral microbial flora and how the contaminated toothbrush affects oral hygiene.	Review	Millions of microorganisms, which may have been the root cause of many unexplained diseases, live on a dirty toothbrush. Cleaning the oral cavity with a dirty toothbrush will do more harm than good
48	Kelly Lorraine Sisson (2007) UK	Provide with an overview of four current explanations for inequalities in oral health.	Review	People experiencing psychosocial stress are more likely to make behavioural or lifestyle choices that are damaging to health. Poor people are restricted by cost of transport and treatment.
49	K. F. Al-Shammari (2007) UK	Explore the relationship between dental fear, self-reported oral health status and the use of dental services.	Questionnaire	People with high dental fear are more likely to delay treatment, leading to more extensive dental problems and symptomatic visiting patterns which feed back into the maintenance or exacerbation of existing dental fear.
50	J. M. Armfield (2007) Australia	Explore the relationship between dental fear, self-reported oral health status and the use of dental services.	Interview	People with higher dental fear visited the dentist less often and indicated a longer expected time before visiting a dentist in the future. Higher dental fear was associated with greater perceived need for dental treatment, increased social impact of oral ill-health and worse self-rated oral health.
51	Meng X (2007) US	Assess the effect of fear on a number of dental utilization behaviors and oral heath outcome in a sample of adult Floridians.	Telephone interview	Dental fear and FDP have independent negative effects on dental utilization behaviors and oral health outcome after controlling for other sociodemographic and general health factors.
52	Steve Kisely (2016) Australia	Discusses the two-way association between oral and mental health.	Review	Dental diseases can lead to teeth loss such that people with severe mental illness have 2.7 times the likelihood of losing all their teeth.
53	Shawn F. Kane (2017) US	Analyse the effects of oral health on systemic health, and recommend primary prevention of disease as the best approach but often difficult to achieve.	Review	Hundreds of diseases and medications impact the oral cavity, diabetes has a true bidirectional relationship with periodontal disease, and there is strong evidence that treating one condition positively impacts the other.
54	Mohammed Ahad (2015) India	Study school children on their awareness of proper tooth brushing techniques and related to knowledge of oral health.	Questionnaire study	Cumulative analysis exposed a lacunae in the awareness of oral hygiene and knowledge regarding oral health, implying an urgent need for awareness initiative for oral health at the grassroots level in primary educational institutions in the implementation of good oral health practices.
55	Petersen PE (2011) UK	Advocate that oral health for all can be promoted effectively by applying philosophy and some major public health actions are outlined	Case study	Creation of high-quality knowledge is vital to a high-performance health system. There is an urgent need to raise awareness of the impact of social factor on oral health outcomes.
56	MM Naghibi Sistani (2013) Iran	Evaluate oral health literacy, independent of other oral health determinants, as a risk indicator for self-reported oral health.	Cross-sectional survey	Low oral health literacy level, independent of education and other socioeconomic determinants, was a predictor for poor self-reported oral health and should be considered a vital determinant of oral health in countries with developing health care systems.
57	M.C.M. Wong (2001) Hong Kong	Describe the patterns of oral health behaviors, knowledge, and attitudes among the 12-year-olds in southern China.	Examination	The prevalence was higher among rural than urban children. Knowledge about gum bleeding and the use of fluoride was low. More oral health education activities should be organized.
58	Satyawan G. Damle (2014) India	Evaluate and compare the oral health status and the impact of supervised toothbrushing and oral health education.	Examination	Oral health education was effective in establishing good oral health habits among school children and in enhancing the knowledge of their parents about good oral health.
59	Sofola (2010) Nigeria	Discuss the implication of low oral health awareness in Nigeria.	Review	When there is low oral health awareness, there is a direct effect on the illness seeking behaviour of the individual and population. There is subsequent underutilization of oral health facilities and late presentation at the clinic with resultant complications.
60	Damle (2014) India	Evaluate and compare the oral health status and the impact of supervised toothbrushing and oral health education among school children of urban and rural areas of Maharashtra, India.	Comparative study	Oral health education was effective in establishing good oral health habits among school children, also in enhancing the knowledge of their parents about good oral health

IV. THE EMPIRICAL STUDY

4.1 Research gap exploration

In addition to the factors initially distilled in the literature review, in the process of reading the health-related literature, we also tried to explore some of the factors that are valued in other health areas but are less frequently mentioned in oral health. ‘Habit of self-assessment’ and ‘Delayed treatment’ were indicated to be factors which were rarely explored in current studies. ‘Self-assessed general health (SAH)’ is one of the most frequently employed health measures in social science research.’, which could aid in determining health status to some extent (Au & Johnston, 2014). As early as 1991, studies have demonstrated that self-assessment of health status is a promising measure of current physical health and mortality risk and may be clinically and epidemiologically useful (Wannamethee & Shaper, 1991). However, there is a lack of understanding of its impact on oral health. The 'treatment delay' refers to the time between when individual first notices a symptom or confirms mental or physical health problem until the time when treatment initiates (Organization, 2006). The issue has attracted considerable attention in other medical fields, such as diabetes, tuberculosis, cancer, and other conditions (Storla et al., 2008) (Hanna et al., 2020) (Paul et al., 2015), but it has received little attention when dealing with oral health. The issue of treatment delay is of critical importance in health care, as it may lead to deteriorated oral health and problem-oriented treatment (Armfield, 2013). ‘Habit of self-assessment’ and ‘Delayed treatment’ are new potential influential indicators identified by this research. In the Empirical research design questionnaire (Table. 1), some relevant questions are designed to validate these conjectures.

4.2 Empirical research design

The basic research aims to investigate whether the influential factors extracted from the literature will impact people's oral health from a user-centered approach. The questionnaire here is a channel to create a connection with the users, ensuring feedback we collect genuine and valid. All questions in the questionnaire are supported by the literature and correspond separately to the influencing factors covered in the literature review section. Participants completed questionnaires to assess the oral-health-related symptoms and the possible influencing factors, concentrating on the behavior, habits, and awareness. All participants completed a 31-item online questionnaire, including items to gather demographic information (age, sex, employment). The questionnaire investigated participants' attitudes towards different oral health impacting factors, starting with factors that may influence oral health as summarized in the literature.

Questions	Options
Gender	A. Male
What is your gender	B. Female
Age	A. Under 18 years
In which category is your age	B. 18-24 years
	C. 25-39 years
	D. 40-55 years
	E. Above 55 years
Employment status	A. A student
	B. Employed for wages
	C. Self-employed
	D. Unemployed
	E. Retired
Oral health condition	
Which of the following oral health problems do you have? (Multi-choice)	A. Dental caries
	B. Missing, broken teeth
	C. Gingivitis, periodontitis
	D. Mouth ulcers
	E. Oral malodor
How many decayed teeth do you have (including those that have been treated)?	A. Over 8 decayed teeth,
	B. 5 to 8 decayed teeth
	C. 4 to 5 decayed teeth
	D. 1 to 3 decayed teeth
	E. No decayed teeth
Do you agree with the following statements?	
The water you use is standard fluoridated water.	A. Totally disagree
	B. Disagree
	C. Not sure
	D. Agree
	E. Totally agree
Transport is not a problem for you to access dental services.	…
You get community help with your oral health.	…
Your parents' good oral health-related behaviours can affect you.	…
Your close family members and close friends do not have serious oral problems.	…
You have the available dental health insurance.	…
Your income is not a barrier to solving your dental problems.	…
The treatment cost for oral problems is not a burden for you.	…
You have knowledge of proper oral care.	…
You do have dental anxiety.	…
You feel psychologically relaxed in your life.	…

Questions	Options
You do not have a habit of smoking.	…
You do not have a habit of drinking.	…
You do not have poor dietary habits (such as excessive intake of sugar, carbonated drinks, etc.).	…
You have good brushing techniques and habits.	…
You have habit of self-assessing your dentition and oral health.	…
You have received good oral care from an early age.	…
You visit the dental clinic regularly for oral health checks.	…
You go to the dental clinic as soon as you notice oral problems.	…
You place great importance on your oral health.	…
You think routine oral health checks are important.	…
You can detect some early signs of oral disease.	…
You can easily access dental care services whenever you need them.	…

Table 1. Questions and options in the questionnaire
('…' is used where the same form of option is omitted.)

An example question is 'Smoking affects your oral health. 'Responses were on a Likert-type scale, ranging from 1 = "Totally disagree", 2 = "Disagree", 3 = "Not sure", 4 = "Agree", 5 = "Totally agree". A negative attitude item was reverse coded during the data analysis so that a higher score on the Likert scale corresponded to a more positive attitude and vice versa.

4.3 Research sample

The characteristics and demographic distribution of participants were summarized in Table 1. A total of 301 people participated in the survey and a screening was conducted to identify univariate outliers. 5 were missing 1 or 2 item responses for a total of 7 missing data points.

To dispose of the missing data effectively, several statistical packages use the Listwise and Pairwise deletion methods to eliminate cases with missing data. However, these are inefficient and rarely recommended (Baraldi & Enders, 2010). According to Schumacker's study, any of the following processing methods is likely to be valid when less than 5% of the data is missing, including mean, regression, multiple, and maximum likelihood (ML) imputation methods, (Schumacker, 2014). Since the missing data represent less than 1% of the data (<5%), the missing data in this study were replaced with the mean value of the variable.

In this study, we use PLS-SEM as method to examine associations among latent variables through the structural model. 'Ten times rule' is widely used for application of recommending the minimum sample size in PLS-SEM. (Chin & Newsted, 1999). In this study, we used a sample size of 301, which is well in excess of the number suggested by the 'Ten times rule' to reduce the concerns of reduced confidence due to insufficient sample size. Among them, 158 were female, accounting for 52.5%, and 143 were male, accounting for 47.5%. The majority of respondents were students (52.5%) who fell within the age group of 18–24 (55.8%).

Demographic variables	Freq. N=301	(%)	∑%
Gender			
Male	143	47.5	47.5
Female	158	52.5	100.0
Age			
Under 18 years	7	2.3	2.3
18-24 years	168	55.8	58.1
25-39 years	44	14.6	72.7
40-55 years	58	19.3	92.0
Above 55 years	24	8.0	100.0
Employment			
A student	147	48.8	48.8
Employed for wages	85	28.2	77.1
Self-employed	31	10.3	87.4
Unemployed	12	4.0	91.4
Retired	26	8.6	100.0

Table 2. Demographic variables

4.4 Method

The applicable methods were adopted in this analysis work. First, a questionnaire was collected for the main factors extracted from the literature as a basis for conducting subsequent data analysis. To further categorize the variables, Exploratory Factor analysis (EFA) enables the large number of variables to be output into a handful of comprehensible underlying factors, and the Principal Component Analysis (PCA) is the factor extraction method adopted in this paper. After establishing the measurement model by factor analysis, associations among latent variables through the structural model was examined by Partial least squares structural equation modeling (PLS-SEM), and the results can indicate whether each of the determinants extracted by EFA has a significant impact on individuals' oral health levels. Finally, the PLS-SEM multi-group analysis (PLS-MGA) was conducted for testing the potential moderating effects of demographic factors, to advance understanding of oral health related elements.

4.4.1 Exploratory factor analysis (EFA)

Due to the number of variables and the heterogeneous information extracted from the literature on oral health influencing factors, the variables needed to be categorized by the factor analysis (FA). Factor analysis enables the distillation of a large number of variables into a handful of comprehensible underlying factors, resulting in easy-to-understand, actionable data (DeCoster, 1998). An exploratory factor analysis (EFA) is used in statistical analyses to explain a relationship between variables by referring to more fundamental entities called factors (Cudeck, 2000). The EFA conducted two essential steps in determining an adequate number of factors that will represent the interrelationships among the set of variables: factor extraction and factor rotation and explanation. Factor extraction identifies factors based on the number of factors available, whereas factor rotation allows for an improved explanation of a solution. Three aims of the EFA were to be achieved: 1) identifying the factors, 2) evaluating the validity of the factors (convergent validity,

discriminant validity), and 3) calculating the factor scores for further analysis.
The exploratory factor analysis was conducted using SPSS version 26 with principal component analysis and varimax as extraction and rotation methods.

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.814
Bartlett's Test of Sphericity	Approx. Chi-Square	1984.322
	Df	210
	Sig.	.000

Table 3. Results of KMO and Bartlett's Test

The effectiveness of the correlation matrix was assessed before the EFA was run on the sample. The above table 3 showed that Bartlett's Sphericity Test is significant (chi-square with degree of freedom(df)210=1984.322 with a significance value=0.000). The Kaiser-Meyer-Olkin measure of sampling adequacy was 0.814, above the suggested minimum value. According to the describing of Kaiser of KMO, values greater than 0.8 are considered 'meritorious'(Kaiser, 1974). It is reasonable to consider such findings a basis for moving on to the next phase. Such results indicate that the data are sufficient to proceed with the reduction process.

4.4.2 Extraction Method: PCA (principal component analysis)

In the seven statistical packages provided by IBM SPSS, the Principal Component Analysis (PCA) is the method most widely used to extract factors from a dataset, which is a mathematical method based on the purpose of reducing the dimension of the data while retaining most of its variation (Jolliffe, 2002). Data extraction has been carried out using principal component analysis (PCA) because its primary purpose is to reduce and summarize data, as well as secure the components necessary for representing the structure of a variable. PCA analysis is applied to the entire correlation matrix (including the self-correlations of 1.00 on the diagonal) and seeks to reduce the amount of data while retaining as much statistical information as possible (Norris & Lecavalier, 2010).

The principal axis factoring was performed with a Promax-oblique rotation. It was established that only factors that are equal to or higher than one count as significant. in this study, it can be noted in the gravel map (Fig 1.) in the Result section that the eigenvalues of the six factors are greater than 1, and therefore a six-factor solution was suggested. Furthermore, it is also assumed that at least 50% of the total variance is acceptable, which was proved to be 63.748% in the Result section.

Reliability and validity

In the later stage, the Structural Equation Modeling (SEM) technique of Partial Least Squares (PLS) in SmartPLS version 3.3.7 was used to validate the theoretical model. PLS-SEM emphasizes prediction in estimating statistical models, whose structure is designed to provide causal explanations (Hair Jr et al., 2017). Path modeling based on PLS-SEM can indeed be a

reliable method of estimating causal models in a number of theoretical and empirical instances (Hair et al., 2011).

The exploratory factor analysis (EFA) of the 24 items indicates a six-factor model, as illustrated in the rubble diagram. For brevity, the names of factors in following study are indicated by abbreviations in parentheses: Awareness factor (AW), Economic factor (EC), Intake factor (IN), Oral health (OH), Oral care habit factor (OC), Physical/mental factor (ST), and Social support factor (SS).

	AW	EC	IN	OH	OC	ST	SS
AW	0.759						
EC	0.180	0.842					
IN	0.239	0.500	0.765				
OH	0.270	0.404	0.473	0.887			
OC	0.145	0.189	0.230	0.412	0.763		
ST	0.166	0.079	0.152	0.191	0.018	0.803	
SS	0.218	0.468	0.496	0.403	0.104	0.131	0.827
AVE	0.576	0.710	0.585	0.787	0.583	0.644	0.685

Table 4. Divergent validity analysis

Table 4 also shows the coefficients of determination (CR) for each of the factors. The Cronbach's Alpha and Cronbach's CR values of all factors exceed Hair, Black, Babin, and Anderson's (2010) recommendation of 0.70. The results in this measurement model show a high degree of reliability. The following equation can be used to calculate CR based on Hair et al. (2010):

$$CR = \frac{(\sum_{i=1}^{n} FL_i)^2}{(\sum_{i=1}^{n} FL_i)^2 + (\sum_{i=1}^{n} ME_i)}$$

Where, $ME_i = \sum 1 - \mathrm{FL}_i{}^2$, FLi is the standardized factor loadings of measurement item i, n is the number of items in a factor.

Divergent validity (DV) refers to the ability to determine whether constructs that should not be related actually are not related. This can be confirmed by placing the squared correlations of all latent variables in a matrix and comparing them with their extracted average variance (AVE). Based on Hair et al.(2010), the AVE can be calculated according to the following equation:

$$AVE = \frac{\sum_{i=1}^{n} FL_i{}^2}{n}$$

To confirm DV, Hair et al. (2010) recommended that the squared correlations below the diagonal should be lower than the AVE of each latent variable. It can be seen that the DV of the latent variables is confirmed in Table 4, despite the bus tangible AVE and squared-co-correlation falling in border-line thresholds.

Latent Variables	AW	EC	IN	OH	OC	ST	SS
AW	0.759						
EC	0.18	0.842					
IN	0.239	0.5	0.765				
OH	0.27	0.404	0.473	0.887			
OC	0.145	0.189	0.23	0.412	0.763		
ST	0.166	0.079	0.152	0.191	0.018	0.803	
SS	0.218	0.468	0.496	0.403	0.104	0.131	0.827

Table 5. Divergent validity

Furthermore, the measurement model is well aligned with the data. This can be confirmed by the above table, which provides the index associated with the model fit. Root Mean Square Error Approximation (RMSEA) and Standardized Root Mean Square Residual (SRMR) are 0.059 and 0.062, below the cut-off value of 0.08. According to Kline, CMIN/DF < 3 indicates an acceptable fit between hypothetical model and sample data (Kline, 1998). The CMIN/DF in this study is lower than the recommended value.

Fit coefficient table		
CMIN/DF	RMSEA	SRMR
2.504	0.059	0.062

Table 6. Fit coefficient

Common method bias

Common method bias is commonly encountered in studies in which data for both independent and dependent variables are collected using the same measurement method and same item characteristics from the same subject. Here, Harman's single factor test is used to verify whether the model has such a bias problem. The items summarized in the literature review were analyzed using unrotated exploratory factor analysis with one latent factor. It is estimated that only 24.487% of the variance can be explained by a single factor (below the standard cut-off point of 50%). Hence, common method bias is not of concern in the present study.

V. RESULTS

5.1 Results of Exploratory factor analysis (EFA)

Exclusion of a specific item is primarily on account of low factor loadings and cross-loadings. However, it is challenging to define factors with which factor loadings should be excluded (Peterson, 2000). Even though loadings greater than 0.4 are commonly used to consider a variable as significant, it is recommended in specific papers to consider items with loadings of more than 0.5 in defining a factor. This is because high factor loadings indicate that the variable measured is an accurate representation of the factor (Norris & Lecavalier, 2010). Here, we have the initial factor loading analysis results after performing the initial analysis. Among the 24 factors listed, the factor loadings of traffic, food safety, and infection transmission presented values below 0.5 (0.324, 0.218, and 0.266, respectively), so these three variables were removed at this stage.

After appropriate removal of variables, 21 items remained for EFA, and we obtained the following analysis results. The cumulative percentage of the total variance explained by the factors extracted was 63.748% with considerably reduced the complexity of the data set by using these components with 36.252% loss of information. Cattell's scree plot presented a steep drop from factor 1 to factor 2, supporting a strong general factor.

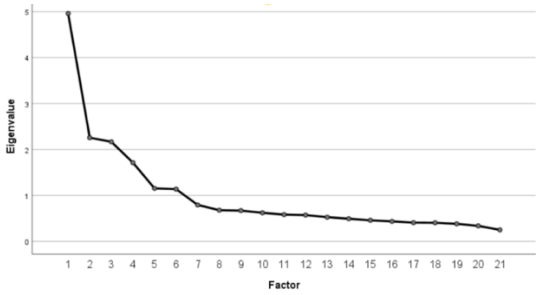

Fig 1. rubble diagram

	Factor					
Scale Item	**1**	**2**	**3**	**4**	**5**	**6**
Dietary habit	0.674	…	…	…	…	…
Smoking	0.734	…	…	…	…	…
Alcohol consumption	0.720	…	…	…	…	…
Fluoridated water	0.712	…	…	…	…	…
Insurance	…	0.857	…	…	…	…
Treatment cost	…	0.757	…	…	…	…
Income level	…	0.739	…	…	…	…
Holistic health	…	…	0.814	…	…	…
Dental anxiety	…	…	0.802		…	…
Mental stress	…	…	0.771	…	…	…
Access to the dental care	…	…	…	0.819	…	…
Community support	…	…	…	0.784	…	…
Parent influence	…	…	…	0.672	…	…
Awareness of importance of oral health	…	…	…	…	0.771	…
Awareness of early signs	…	…	…	…	0.759	…
Awareness of importance of routine check	…	…	…	…	0.735	…
Knowledge of oral health	…	…	…	…	0.723	…
Brushing technique	…	…	…	…	…	0.762
Habit of routine check	…	…	…	…	…	0.772
Habit of self-assessment	…	…	…	…	…	0.782
Delayed treatment	…	…	…	…	…	0.724
Transportation	…	…	…	…	…	…
Infection transmission	…	…	…	…	…	…
Early oral care	…	…	…	…	…	…

Table 7. The rotated component matrix

(Factor loadings < 0.5 are omitted here and are replaced by '...', Excluded factors are marked with

a grey background)

The above table illustrates the factor pattern matrix for the solution, which represents the "loadings" of each item to the factor. 2-4 items were respectively loaded on six factors. There are 3 items were dropped from the analysis due to loading of <.5, including transportation, infection transmission, and early oral care.

A six-factor solution accounted for 63.748% of the variance. The rotation factor loadings in table7 are intended to show both the weighting of variables across factors and the correlation between variables and factors.

Factor 1 received strong loadings (>0.5) from dietary habits, smoking, alcohol consumption, and water quality. These variables can be summarized as those related to Food & drink intake.

Factor 2 contained three items, including insurance, treatment cost, and income level, reflecting concerns about Economics.

Factor 3 contained three items: holistic health, dental anxiety, and mental stress. Factor 3 was labeled as 'Physical and mental status.'

Factor 4 received strong loadings from three social support aspects: access to medical service, community support and parent influence. This factor appears to correspond to peer influence and social support.

Factor 5 reflected the knowledge and awareness aspects and consisted of awareness of the importance of oral health, awareness of early signs of oral problems, awareness of the importance of routine checks, and knowledge of oral health.

Factor 6 consisted of the habit of a routine check, habit of self-assessment, and delayed treatment, which appeared to be a factor for oral checks.

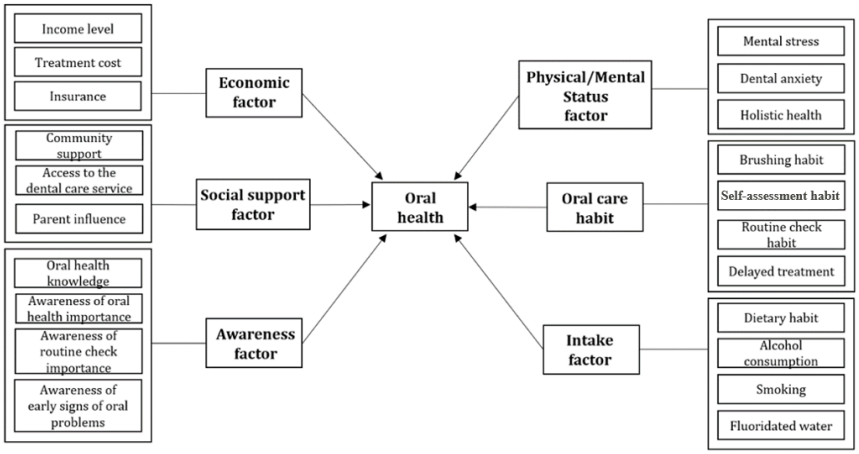

Fig 2. the theoretical model

5.2 Results of Partial least squares structural equation modeling (PLS-SEM)

After establishing the measurement model by factor analysis in the previous article, we proceed to examine associations among latent variables through the structural model.

Constructs	Item	Loading	CA	Rho_A	CR	AVE
Intake factors	IN1	0.807	0.764	0.776	0.849	0.585
	IN2	0.747				
	IN3	0.785				
	IN4	0.716				
Economic factors	EC1	0.881	0.795	0.795	0.880	0.710
	EC2	0.832				
	EC3	0.812				
Social support factor	SS1	0.853	0.765	0.765	0.865	0.681
	SS2	0.823				
	SS3	0.798				
Physical / Mental status factor	ST1	0.837	0.728	0.746	0.844	0.644
	ST2	0.775				
	ST3	0.794				
Oral care habit factor	OC1	0.714	0.771	0.835	0.848	0.583
	OC2	0.755				
	OC3	0.747				
	OC4	0.834				
Awareness factor	AW1	0.775	0.758	0.776	0.844	0.576
	AW2	0.765				
	AW3	0.702				
	AW4	0.791				
Oral health	OH1	0.902	0.771	0.835	0.881	0.788
	OH2	0.873				

Table 8. Measurement items and their reliability

Hypothesis	Path COEF	t	p	Remark
H1: Intake factor→ Oral health	0.214	3.113	0.001	supported
H2: Economic factor→ Oral health	0.135	2.334	0.010	supported
H3: Social support factor→ Oral health	0.167	2.946	0.002	supported
H4: Physical/mental status factor→ Oral health	0.105	2.203	0.014	supported
H5: Oral care habit factor→ Oral health	0.304	7.044	0.000	supported
H6: Awareness factor→ Oral health	0.097	2.082	0.019	supported

Table 9. Summary of hypothesis testing

Based on the SEM model, a summary of hypothesis testing is presented in the table. Results indicate that each of the six external or internal determinants IN, EC, SS, ST, OC, AW has a significant impact on individuals' oral health levels. In total, the six constructs can explain almost 63.748% of the variance in oral health (OH). The six hypotheses are all supported without a negative path coefficient, suggesting an association between these factors and oral health in the predicted direction. Among them, the path coefficient of OC is the highest, with a significant positive relationship with OH ($\beta = 0.304$, $t = 7.044$, $p < 0.001$).

Endogenous LV	$\mathbf{R^2}$ value	$\mathbf{Q^2}$ value
Oral health (OH)	0.395	0.329
Intake factor (IN)		0.312
Economic factor (EC)		0.408
Social support factor (SS)		0.361
Physical/mental status factor (ST)		0.293
Oral care habit factor (OC)		0.311
Awareness factor (AW)		0.296

Table 10. R Square statistic

The R Square statistic (R^2) describes the variance of an endogenous variable explained by the exogenous variable(s). Scholars hold different views regarding the value of R^2 and what it represents. A reasonable R2 value is specified by Falk and Miller as 0.10 or greater for the variance explained by an endogenous construct to be deemed adequate (Falk & Miller, 1992). The R2 values recommended by Chin were: 0.67 (substantial), 0.33 (moderate), 0.19 (weak). The R-squared value in this study is acceptable (Chin, 1998).

We evaluated the model's out-of-sample predictive power (Q2) values in addition to the magnitude of the R2 values as a criterion of predictive accuracy, measuring whether a model has predictive relevance or not (> 0 is good). As shown in Table 10, all Q2 values are significantly greater than zero, thus supporting the predictive relevance of the oral health impacting factor model for all endogenous constructs, explicitly having a good predictive relevance (Q2 =0.329) for the primary target constructs (OH).

5.3 Moderating effects

To advance understanding of oral health related problems, the study is further advanced by examining some potential moderating factors: gender, age and employment. In the result section, we obtained a theoretical model and demonstrated a strong correlation between the factors (Figure 2) and the oral health, however, some moderating variables can affect this relationship. For example, men and women may have varying degrees of oral anxiety or feel different levels of psychological stress, and there are differences in the holistic health of people of different ages groups. To test for disparities among coefficients representing age, gender heterogeneity, the PLS-SEM multi-group analysis (PLS-MGA) was conducted. This methodology is used for testing the existence of significant differences between parameter estimates for predefined (also known as a priori) groups (e.g., outer weights, outer loadings, and path coefficients) (Hair Jr et al., 2017). When two models are identical, MGA helps researchers compare variations between different groups (Cheah et al., 2020). The SmartPLS 3 software was used in this study for comparisons between demographic variables on the basis of Henseler's bootstrap-based MGA (Henseler et al., 2009).

Variable	Groups	Frequency	Percentage
Gende	Males	143	47.5
	Females	158	52.5
Age	Age< 25	175	58.1
	Age≥25	126	41.9
Employment	Employed	116	38.5
	Unemployed	185	61.5

Table 11. Groups for multiple group analysis

The data was divided into male (n = 143) and female (n = 158) subgroups in order to explore the moderating influence of gender, and separate analyses were conducted for each group with the entire model. To meet the sample size requirements, age was rationalized into two subgroups: age <25 (n = 175), age≥25 (n = 126). According to the participants' employment status, data was divided into employed group (n = 116), including people employed for wages and self-employed people, and unemployed group (n = 185), including students, unemployed people and retired people. Based on the 10-times rule (Hair et al., 2011), we require a minimum of 6 * 10 = 60 observations per group in our model since the maximum number of arrows pointing to the dependent variable is six. It is therefore considered that the sample sizes for each of the three moderating variables are sufficient to conduct analysis in the PLS-MGA.

Paths/relationships	Comparison	PLS-MGA		Welch-Satterthwait test	
		Path COEF-diff	*p* value	*t* value	*p* value
Intake → OH	Male VS female	0.096	0.230	0.745	0.229
Economic → OH	Male VS female	-0.047	0.664	0.409	0.341
Status → OH	Male VS female	-0.051	0.700	0.513.	0.304
Social support → OH	Male VS female	-0.081	0.810	0.831	0.204
Awareness → OH	Male VS female	0.208	**0.028**	1.851	**0.033**
Oral healthcare → OH	Male VS female	0.128	**0.092**	1.134	**0.089**
Intake → OH	Age< 25 VS age≥25	-0.084	0.268	0.619	0.269
Economic → OH	Age< 25 VS age≥25	-0.211	**0.038**	1.781	**0.039**
Status → OH	Age< 25 VS age≥25	-0.171	**0.045**	1.623	**0.053**
Social support → OH	Age< 25 VS age≥25	0.096	0.201	0.847	0.199
Awareness → OH	Age< 25 VS age≥25	0.089	0.166	0.971	0.167
Oral healthcare → OH	Age< 25 VS age≥25	0036	0.333	0.419	0.338
Intake → OH	Employed VS unemployed	-0.190	**0.069**	1.498	**0.068**
Economic → OH	Employed VS unemployed	-0.040	0.374	0.329	0.371
Status → OH	Employed VS unemployed	0.191	**0.026**	1.894	**0.030**
Social support → OH	Employed VS unemployed	0.065	0.283	0.590	0.278
Awareness → OH	Employed VS unemployed	0.091	0.180	0.902	0.184
Oral healthcare → OH	Employed VS unemployed	0.028	0.369	0.329	0.371

Table 12. Multigroup comparison test results
(Significance levels < 0.10 are presented in bold)

In one-tailed tests,PLS-MGA results are typically significant when > 0.95 or < 0.05, but for smaller samples, the cutoff level can be set to > 0.90 or < 0.10. This means that P values >0.1

between groups are considered not statistically significant. Minor differences were observed between PLS-MGA and W-S in terms of the significance of group differences for some specific relationships. Due to the fact that PLS-MGA uses a one-tailed test, the p-values in the report indicate whether the path coefficient was significantly greater in the first group (i.e., Males, Age<25, employed people) than in the second group (i.e., Females, Age≥25, unemployed people), thus indicating significant differences between the groups.

According to the results for gender groups (Male and Female), the correlation between awareness (AW) and oral health (OH) was significant (p=0.030). Accordingly, it was implied that the relationship between AW and OH was moderated by gender (male - female). Furthermore, the bootstrapping results were compared to assess the differences between the genders in terms of path coefficients. Males (β=0.278) have a stronger path coefficient than females(β=0.085) group. This asserted that the males had stronger AW – OH relationship than females. Similar relationship was also found in relation between oral healthcare (OC) and OH in gender subgroup. It appeared that males (β=0.341) have a higher path coefficient compared to females (β=0.220) group in the OC - OH relationship, although the significance is not very high (p=0.089). Based on the PLS-MGA analysis, it was found that the relationship between other factors such as intake, economic status, physical/mental health, and oral health was not moderated by gender, since the relationship did not demonstrate a significant p-value (p<0.10).

With regard to the age groups, the results revealed and supported the assertion that the correlation between economic (EC) factors and OH was significant (p=0.040). Oral health was more likely to be affected by EC in the group age ≥25 (β=0.266) compared with group age < 25 (β=0.060). Meanwhile, relationship between physical/mental status (ST) and OH varied in different age groups. Age < 25 group (β=0.016) have a larger path coefficient than age ≥25 group (β=0.173) group, demonstrating a more significant relationship from ST to OH.

For the employment subgroups, it was worth noting that there were significant differences between relationships from intake (IN) to OH and ST to OH. Interestingly, the path from IN to OH was negative and moderately significant (p=0.069), indicating that oral health of unemployed populations (β=0.291) was more significantly linked to intake factors than employed that of populations (β=0.116). Conversely, according to the results of the PLS-MGA, the oral health of employed populations was more likely to be affected by their physical and mental status (p=0.026).

Paths/relationships	Age	Gender	Employment
Economic → OH	Age< 25 VS age≥25		
Status → OH	Age< 25 VS age≥25		
Awareness → OH		Male VS female	
Oral healthcare → OH		Male VS female	
Intake → OH			Employed VS unemployed
Status → OH			Employed VS unemployed

Table 13. Multigroup analysis result

The results of PLS-MGA are summarized in the above table13 to provide a concise visual representation of significant effects determined by demographic variables. For the gender

subgroups, according to the findings, oral health awareness and oral healthcare practices are more likely to affect the oral health of males. It is reasonable to expect such a result. Previous studies demonstrate that females possess a greater awareness of oral health and oral hygiene practices than males (FUKAI et al., 1999) (Al-Ansari & Honkala, 2007) . Thus, poor oral hygiene habits and lack of awareness play a more significant role in the oral health among males. For the age subgroups, it is revealed that the relationship between economic factors and oral health is moderated by age differences. Economic factors tend to affect the oral health of people over the age of 25 more notably. A similar trend occurs in the relationship between physical conditions and oral health. The reason for these may be that as people age, they have to take on more of the financial burden of their families and are therefore more concerned regarding the cost of dental care. The increased life stress and physical health issues may also contribute to oral problems among people over 25 years old. For the employment subgroups, employment status was found to moderate both intake- oral health relationship and physical/mental status- oral health relationship. We hypothesize that this may be due to the fact that the unemployed people are more likely to have poor eating habits, such as irregular mealtimes and poor dietary structure, which may affect their oral health. While, the physical and psychological state of the employed populations may be affected by, high levels of psychological stress and occupational diseases caused by busy schedule, which can accumulate and damage their oral health.

VI. DESIGN SOLUTION

6.1 Overview

Oral disease is one of the most prevalent diseases worldwide, with a serious health and economic burden that significantly reduces the quality of life of those affected (Petersen et al., 2005). Studies indicate a need for an urgent response to oral disease among other non-communicable diseases (NCDs) (Peres et al., 2019). As a strategy to address this global public health challenge, WHO strongly recommends strengthening the research capacity in oral health (Petersen, 2004). Translation of knowledge into action is imperative for improving health by closing the gap between what is known and what is actually done (Petersen, 2005).

In the field of design, attempts have also been made to alleviate the burden of global oral problems. The popularity of health and well-being topics is on the rise, and consumers are actively out health-related products to maintain their well-being (Dittmar, 2007). In recent years, there is a plethora of products associated with oral care, and with modern products such as toothpaste and mouthwash, maintaining good oral hygiene and health has never been easier (Aspinall et al., 2021). A commitment has been made to explore the physical, chemical and structural properties of key ingredients in oral care products, using advanced modern formulations to achieve controlled and prolonged release of ingredients vital to dental health (Aspinall et al., 2021). Natural medicines are also used as dental aids for therapeutic purposes (Chauhan et al., 2020).

Meanwhile, a broader category of oral care is emerging beyond traditional toothpaste and mouthwash brands. Advances in computer-derived data processing and manufacturing have also

led to a trend towards digitalization in dentistry, which is the essence of tele dentistry (Jampani et al., 2011). This trend is strongly supported by big data and analytical algorithms, Internet and communication technologies (ICT) (including digital social media), augmented and virtual reality, and artificial intelligence (AI) (Alauddin et al., 2021). While the trend towards digitalization of oral health is irreversible, it is also important that we come up with more universally applicable and affordable solutions to oral health problems, which are in accordance with policies regarding the implementation of strategies for reducing the disparities in oral health (Peres et al., 2019) (Sheiham et al., 2011).

According to the previous study, 'Delayed treatment' and 'Habit of self-assessment of oral status' have been validated as two factors that adversely affect oral health as conjectured. Though these are not the factors with the highest factor loading value, little attention and research has been dedicated to them, and the severity of the problem can be effectively mitigated through a design approach. Of the 60 papers summarized in the literature review, only one referred to the negative impact of delayed treatment on oral health (Al-Shammari et al., 2007), indicating that these two factors have a dearth of research and design. This will also be addressed in depth in the Discussion section. This study hopes to explore a widely applicable design solution that can practically improve the negative impact of these two factors on oral health. We attempted to seek for appropriate solution that would provide users with timely information about their dental health without waiting for the diagnosis from the dentists.

A domestic toothbrush with test strips for oral problem analysis is proposed, which would provide the users with clear understanding of oral conditions through self-testing, while avoiding delayed treatment as a result of missing early oral problem symptoms. The purpose of this design is to enhance the frequency and efficiency of domiciliary oral testing for users by facilitating their access to the testing at home. Meanwhile, to improve the practicality and circulation of the product, the product should be low-cost and easy to operate.

6.2 Competitor Analysis

Before proceeding with the design, we started with a summary of existing home dental health testing products and briefly outlined their advantages and disadvantages.

Product	Appearance	Features	Pros	Cons
Tooth Inspection Endoscope Camera		a. Used to check the health condition of mouth, teeth and other oral parts. b. It can take pictures and videos, and save them in the mobile phones or computers	a. HD camera More intuitive b. Can effectively improve the efficiency of communication with the doctor	a. High price b. Requires a supporting diagnosis from a doctor
Teeth Inspection LED Mirror		a. Dental mirror has extra bright LED light facilitates the inspection of hard-to-see and areas	a. Supplementary lighting to provide clear view b. Simple to operate	a. High price b. Difficult to operate by one person
Portable dental plaque detector		a. Used for quick indication of plaque location b. Replaceable parts in contact with the mouth	a. Easier and faster than traditional plaque fuel b. Clean and environmentally friendly	a. Can only detects the effectiveness of cleaning, not the actual dental problems
Self-test oral risk strips		a. Used for analysis of oral and periodontal health b. Compare the colour of the test strips to predict oral risk in advance	a. Low price b. More intuitive through colour display c. Can examine several oral problems	a. Additional sampling process, not easy enough b. Measuring cups and droppers are made of plastic, causing pollution and waste
Portable Bad Breath Detector		a. Used to check people's breath quality b. 5 levels result: Very good, normal, not so good, bad, very bad	a. Portable design, small size with compact structure b. Non-contact design, more hygiene	a. High price b. Only a single oral problem can be checked

Table 14. Competitor Analysis Chart

Generally, home use oral health products are predominantly in the daily care category, such as toothbrushes, toothpastes, flossers, and flushers, while a few oral testing products are available. Existing oral testing products can be subdivided into two categories: the first is products used to observe and detect abnormalities inside the mouth, such as oral endoscopes. These products present the patient with a clear view of the lesion, allowing them to take pictures of the inside mouth and transmit them remotely to a dentist for specific treatment advice, so that the patient understands the urgency of treatment. Despite the fact that this kind of products can assist with establishing effective communication between the patient and the dentist, they are often characterized by being expensive and less frequently used. The high price of the products hinders their distribution in the market and only a small number of people with a high consumption level

who value oral health will choose to use these products. Another type of product uses a chemical or digital method to display abnormalities in the mouth via colour rendering. These products provide users with a more visual representation of oral problems and helps them self-assess at home. In spite of this, people may neglect to test because of the complexity of the testing process.

Based on our analysis of existing oral care products, we identified the following areas that could be further enhanced.

- Reduce the cost of oral care products to make them accessible and usable by different income groups.
- Reduce testing steps to make oral health testing easier and faster.
- Improve environmental friendliness and reduce waste from packaging materials and the product itself.

The analysis and comparison of existing products indicate that Self-test oral risk strips are an efficient and cost-effective method that is more suitable for self-testing oral problems at home. However, the current product still leaves something to be desired. The product is poorly promoted and is still slightly cumbersome due to its separate sampling procedure, users may not be able to carry out regular self-tests due to forgetfulness. Furthermore, the packaging, measuring cups, and droppers that are included in the package are all made of plastic, which are non-recyclable and can lead to material waste and environmental pollution.

Fig 3. The current product and its packaging

The current test strip has three colorful areas, displaying ‘acid resistance’ ‘PH’ ‘Oral bacteria’. The Users can have a preliminary judgment of the different indicators of the oral cavity according to the displayed color, and the strip can assist the user in determining the oral health condition to a certain extent.

We intend to improve on the current strip product and design a more user-friendly and environmental-friendly product for at-home oral care.

6.3 Concept

The primary objective of the product is to cleverly address the two identified gaps ‘delayed treatment’ and ‘Habit of self-assessment of oral status’ through a design approach. We try to

reduce the number of additional steps associated with oral testing, by combining it with the daily oral care routine. Brushing is the most common oral care procedure and has a positive impact on the prevention of tooth decay and periodontitis (Attin & Hornecker, 2005). By integrating the oral testing process with the daily brushing process, the product helps in performing regular oral examinations at home, which will assist in the detection of oral problems in a timely manner and allowing the user to avoid missing the optimal opportunity for treatment due to the control of early symptoms.

This product is mainly composed of the toothbrush head, toothbrush bar and the oral test strips. Apart from its primary function of removing plaque from the teeth, the toothbrush head has a recess at its bottom for inserting oral test strips. The toothbrush bar is further divided into two cavities, the upper part for collecting mouthwash for oral testing and the lower part for storing unused test strips. The basic principle of the test strip is to reflect the health of the oral environment by analyzing the composition, PH and other indicators of oral saliva and shed oral mucosa. Aside from the part that relates to color development, the remainder of the test strip is constructed of waterproof paper, which retains the paper's environmental friendliness while also preventing it from becoming wet.

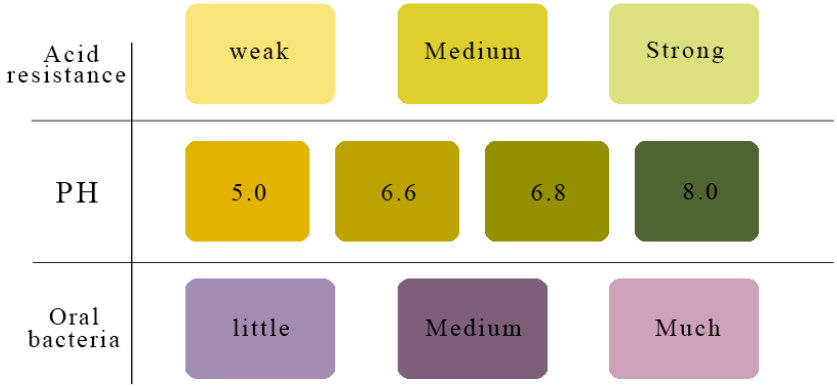

Fig 4. Color rendering comparison image

Using test strips involves three main steps: sampling, testing, and comparing the results. A detailed description of the procedure can be found in the Usage process part. A test strip consists of three-color zones that indicate acid resistance of oral saliva, pH of oral saliva, and the number of bacteria in the oral cavity. The information corresponding to the specific colors is shown in the image above. Once users complete the test, they can compare the colors shown on the test strip with the image to get an insight into oral health.

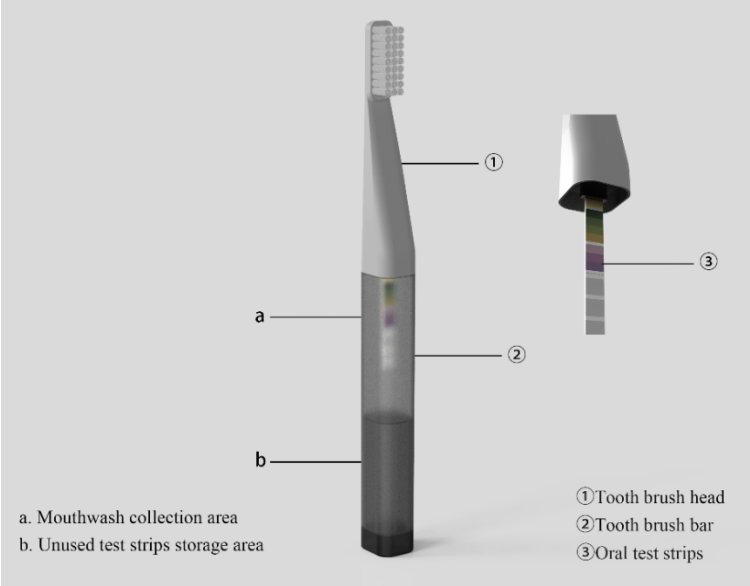

Fig 5. Toothbrush composition diagram

The toothbrush should be designed in accordance with the dimensional specifications set out by the American Dental Association (ADA). The ADA specifies acceptable manual toothbrush sizes of 1-1.25 inches(25.4-31.8mm) in brush surface length and 5/16-3/8 inches (7.9-10.5mm) in brush surface width (Mehta et al., 2020). The exact dimensions of the product are shown in the product dimension diagram below.

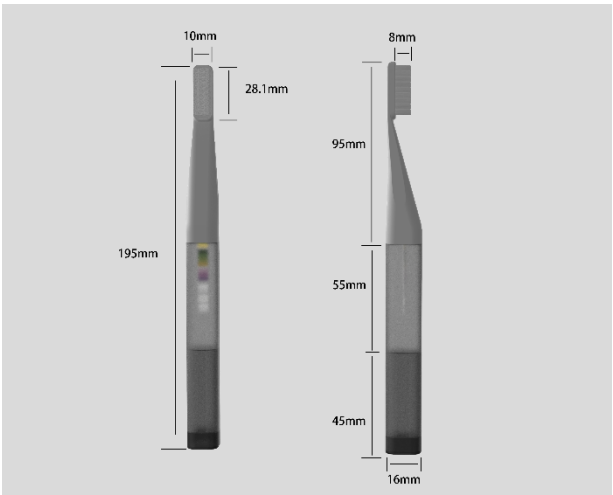

Fig 6. Product dimensions

This product also intends to indirectly encourage users to replace their toothbrush on time. Evidence shows that a worn toothbrush is significantly less effective than a new toothbrush in removing plaque (Conforti et al., 2003). Generally, dentists advise their patients to replace their toothbrushes every 3 months if the bristles become bent or splayed (Abraham et al., 1990; Baruah et al., 2017). There are a total of 12 test strips in each toothbrush, which can be used once a week over a period of up to three months. Once the test strips are used up, it is time to replace the toothbrush.

However, it is worth noting that this product mainly serves as an aid to diagnosis at home and is not a substitute for professional advice. When self-examination reveals oral problems, users should follow dentist's advice for appropriate oral care and treatment, and if necessary, go to a dental hospital for further examination.

6.4 Usage process

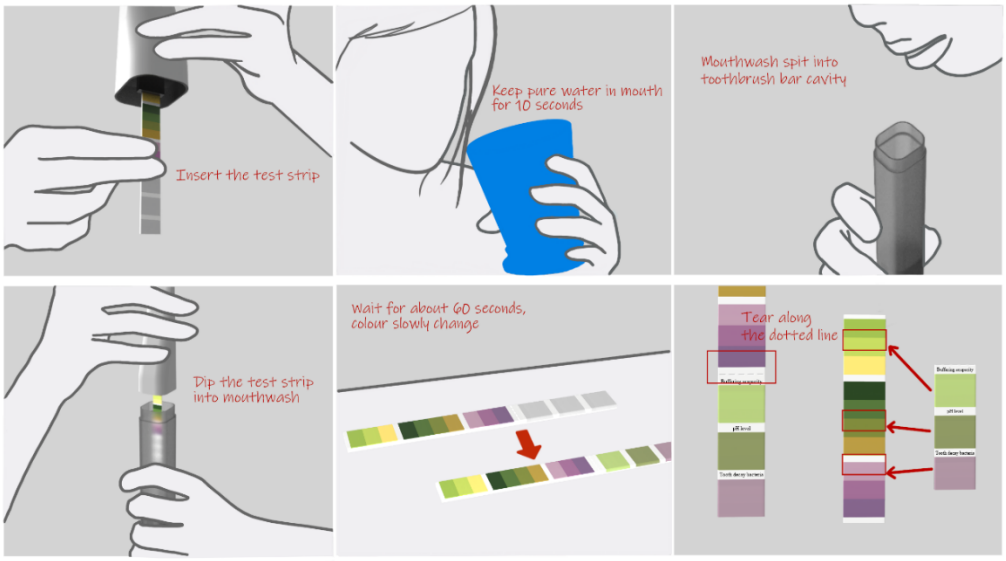

Fig 7. Usage flowchart

In order to perform the test, the users first remove the cap from the bottom of the toothbrush bar, take out the test strip with dry hands, and insert it into the groove at the bottom of the brush head. Then they keep pure water in the mouth for about 10s to ensure it spreads throughout the mouth. The mouthwash is then spat into the cavity of the toothbrush bar and the test strip is dipped into the mouthwash, ensuring that each test block is in contact with the mouthwash. Following that, test strips are removed and left to stand for about 60s. Finally, the user tears the test strip along the dotted line to obtain two parts: the test result and the colorimetric card. The users should compare their test strip with the corresponding area of the colorimetric card to obtain information on the oral health condition.

The color development area of the test strip is divided into three parts, which test the buffering capacity, pH and tooth decay bacteria of the oral cavity, and evaluate the user's risk of tooth decay based on the combined performance of the three areas.

6.5 Prototype & test

A 1:1 resin sketch model was printed using 3D printing technology after the product design was completed. This model will be used in subsequent user tests to give respondents a better visualization of the product's functionality and its application method.

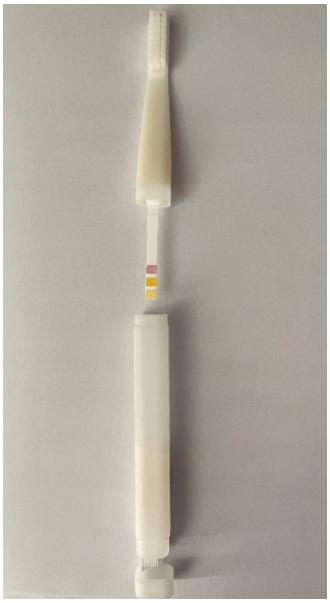

Fig 8. Product sketch model

To simulate user acceptance and use of the product, we used the technology acceptance model (TAM) for further user evaluation of the product. In the past quarter century, the technology acceptance model (TAM), introduced by Fred Davis, has become a widely used model for examining factors affecting the acceptance of new technologies by users (Marangunić & Granić, 2015). Having a solid understanding of the TAM is essential for anyone interested in studying user acceptance (Chuttur, 2009). This model can serve as a useful guide for researchers in order to design different products and thus achieve high levels of user acceptance in various applications (Chen et al., 2011). The logic of the model has now been confirmed by rigorous statistical extrapolation and has important theoretical implications (Bagozzi, 2007). Despite TAM is mostly used in the field of information technology, researchers demonstrate the validity and robustness of the TAM model, which has been widely used, but may also have application to a broader range of situations (King & He, 2006). There are over twenty studies testing TAM in health care, and dozens more empirical and theoretical papers mentioning TAM in health IT, indicating TAM is increasingly considered as a suitable theory for health care (Holden & Karsh, 2010).

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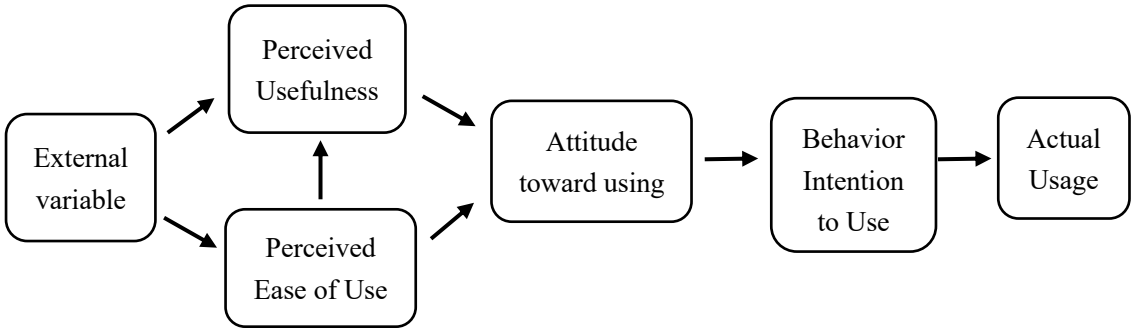

Fig. technology acceptance model

Perceived Usefulness refers to ‘the extent to which a person believes that using a particular technology will enhance her/his job performance’(Davis, 1989). Perceived Ease of Use refers to ‘the degree to which a person believes that using a technology will be free from effort’ (Davis, 1989). It is hypothesized that perceived ease of use can also affect perceived usefulness and attitude towards using technology, however these factors are considered distinct factors influencing the user's attitude (Masrom, 2007). Furthermore, such attitudes towards using the technology determine the actual behavior to utilize that system (Masrom, 2007).

We perform product analysis on products based on several core factors in TAM to understand users’ view and predict actual usage of the product. The methodology used here is a combination of interviews and questionnaires. Firstly, a total of 14 participants were interviewed for an average of 35-40 minutes. Interviews were conducted with dentists to explain the composition, using process, and intended using effect of the product. Following the explanation, their opinion and suggestions for improvement were recorded. At the end of the interview, participants were asked to fill in a questionnaire with questions based on several dimensions of TAM that echoed the interview questions to verify their consistency.

6.5.1 Participants

All of the dentists interviewed have extensive clinical experience, specializing in a wide range of dental treatments such as restorative dentistry, dental implants, pediatric dentistry and orthodontics. The youngest doctor has eight years of experience in dental treatment. Since they work in different departments, the patients they receive vary in age, but the majority are between 30 and 60 years old. To exclude the influence of the dentist's English proficiency level on the accuracy of the interview results, the entire conversation was conducted in Chinese and the results were output in English.

Interviewee	Gender	Working years	Departments	Patient group
1	Female	15 years	Prosthodontics	Mostly 30-60 years old
2	Female	9 years	Pediatric dentistry	Mostly 4-12 years old
3	Male	13 years	Endo & restorative dentistry	Various age groups
4	Female	9 years	Orthodontics	Mostly teenagers
5	Male	12 years	Oral and maxillofacial surgery	Mostly 30-60 years old
6	Female	17 years	Dental Implantology	Mostly 40-70 years old
7	Male	15 years	Orthodontics	Mostly teenagers
8	Male	11 years	Endo & restorative dentistry	Various age groups
9	Female	21 years	Prosthodontics	Various age groups
10	Male	15 years	Dental Implantology	Mostly 40-60 years old
11	Female	12 years	Endo & restorative dentistry	Mostly 12-40 years old
12	Male	10 years	Oral and maxillofacial surgery	Mostly 30-60 years old
13	Female	8 years	Prosthodontics	Mostly 30-60 years old
14	Female	19 years	Endo & restorative dentistry	Mostly 40-60 years old

Table 15. Interviewee information

In accordance with the Technology Acceptance Model theory, the questions we addressed in the questionnaire and interviews are presented in the table 16, along with their theoretical support.

Construct	Measurement dimensions of construct	Reference
Perceived usefulness	1. The product is useful for home oral testing (PU1)	(Hu et al., 1999) (Chismar & Wiley-Patton, 2002) (Mun et al., 2006)
	2. The product allows oral testing to be accomplished more quickly (PU2)	(Hu et al., 1999) (Liang et al., 2003), (Liu & Ma, 2006)
	3. The product can increase quality of Home Oral Care (PU3)	(Chismar & Wiley-Patton, 2002) (Liang et al., 2003)
	4. The product makes it easier to identify oral problems (PU4)	(Chismar & Wiley-Patton, 2002) (Han et al., 2005)
	5. The job performance of the product is great (PU5)	(Mun et al., 2006) (Tung et al., 2008)
	6. The product can make dentist-patient communication effective (PU6)	(Tung et al., 2008) (Van Schaik et al., 2002)
Perceived ease of use	1. It is easy to learn to operate the testing process (PEOU 1)	(Hu et al., 1999) (Van Schaik et al., 2002) (Liu & Ma, 2006)
	2. The using process is clear and understandable (PEOU 2)	(Hu et al., 1999) (DJ et al., 2003)
	3. The product is easy to use (PEOU 3)	(Tung et al., 2008)
	4. It is easy to remember how to use this product (PEOU 4)	(Mun et al., 2006)
	5. It is easy to become skillful with this product (PEOU 5)	(Hu et al., 1999) (Wu et al., 2007)
	6. The product is controllable and flexible (PEOU 6)	(Hu et al., 1999) (Liang et al., 2003)
Attitude toward using	1. I think the product is well worth using (AT1)	(Hu et al., 1999) (Bagozzi et al., 1992) (Davis, 1989)
	2. I like the design of this product (AT2)	
	3. I rate this product highly (AT3)	
	4. I think the product is better than regular toothbrushes (AT4)	
Intention to use	1. I would like to use this product to help with oral care (BI 1)	(Bagozzi et al., 1992) (Hu et al., 1999) (Davis, 1989)
	2. I look forward to using this product (BI 2)	
	3. I am likely to use this product in the future (BI 3)	
	4. I will use this product regularly in the future (BI 4)	

Table 16. Interview& Questionnaire questions

All variables are measured in multiple question items, with between 4 and 6 questions. The questions were worded as follows: "The product is useful for home oral testing." Responses were on a Likert-type scale, ranging from 1 = "Totally disagree", 2 = "Disagree", 3 = "Not sure", 4 = "Agree", 5 = "Totally agree".

Fig 9. Interview process

To sort and arrange information gained from the interviews, we used qualitative software tool Nvivo to further analyze and discover insights from unstructured or qualitative data. First, we counted the frequency of the words that appeared in the interviews and combined synonyms (e.g., promote, improve, enhance) and removed some invalid words (e.g., one, very). A sentimental analysis of the interview results was then performed, and the main parameters extracted from the TAM were manually coded. The results are shown in the following section.

6.5.2 Findings:

A separate analysis of the questionnaire and interview results was conducted to determine the overall level of acceptance of the design. We analyzed the results obtained from the questionnaire using descriptive statistics to analyze the overall acceptance with the product among the participants based on two dimensions: mean and standard deviation.

PU1	4.43	PE1	4.71	AT1	4.71	BI1	4.14
PU2	4.36	PE2	4.64	AT2	4.07	BI2	4.50
PU3	4.57	PE3	4.86	AT3	4.57	BI3	4.21
PU4	4.36	PE4	4.36	AT4	4.29	BI4	4.07
PU5	3.64	PE5	4.43	**AT**	**4.41**	**BI**	**4.23**
PU6	3.86	PE6	4.14				
PU	**4.20**	**PE**	**4.52**				

Table 17. Mean value of the variables

PU1	0.51	PE1	0.47	AT1	0.47	BI1	0.77
PU2	0.74	PE2	0.50	AT2	0.73	BI2	0.65
PU3	0.65	PE3	0.36	AT3	0.65	BI3	0.70
PU4	0.50	PE4	0.74	AT4	0.61	BI4	0.73
PU5	0.84	PE5	0.65				
PU6	0.86	PE6	0.77				

Table 18. Standard deviation tof the variables

According to the results, perceived usefulness, perceived ease of use, attitude toward using, and intention to use all receive satisfactory mean scores, reaching 4.20. The highest mean score for ease of use reaches 4.52, indicating that the design is unanimously accepted by the respondents as being easy to use. Only two questions, PU5, PU6, received a mean score of less than 4 and showed a standard deviation of greater than 0.8. These results suggest the PU5, PU6 questions still

have some doubts and people's opinions vary regarding them.

Based on the extracted data from the interview, NVivo 11 was used to analyze the data and identify a number of parameters.

Word	Counting	Weighted percentage (%)	Similar words
Promote	45	3.39	Promote, improve, boost
Like	28	2.21	Hope, would like, favorite, appreciate
Comfortable	25	1.88	Pleasant
Effect	23	1.73	Impact, influence
Recommend	20	1.50	Advocate
Easy	23	1.73	Simple, accessible, convenient
Clear	10	0.75	Understandable, explicit
Flexible	9	0.68	Controllable
Cost effectiveness	8	0.60	Cost performance, affordable, cheap
Ingenious	7	0.53	Clever
Accuracy	7	0.53	Precision
Practical	5	0.38	Useful, functional

Table 19. Word frequency statistics

According to the word frequency statistics, we can get an initial idea of the user's thoughts about the product. The statistic results show that the words ‘Promote’, ‘improve’, ‘boost’ appeared frequently during the interviews, reaching 45 times. Some adjectives describing product features or operational steps also are mentioned by the interviewees frequently, such as ‘simple’, ‘convenient’, ‘flexible’. Respondents also generally expressed positive attitudes toward the product, words indicating attitudes such as ‘like’, ‘appreciate’ and ‘approve’ also appeared frequently during the interviews. Additionally, the interviewees commented on the product's cost-effectiveness during the interviews, reflecting that the product enabled the oral health test to be accomplished at a reduced cost, thereby enabling the general public to afford it.

Sentiments	counting
Positive	46
Neutral	10
Mixed	15
Negative	6

Table 20. Sentiment analysis

Sentiment analysis allows us to gain a more intuitive understanding of user attitudes and approval of the product. Most of the interviewees hold positive perceptions of the product followed by mixed. It is clearly visible that only a few interviewees have negative view. Through further analysis of the negative comments, it was noted that most of these points were related to the accuracy of the test strips and the dryness of the environment in which they were stored. These two issues are discussed in detail in the subsequent paragraphs. It is visible that in general the oral testing toothbrush is viewed positively by dentists.

Node	Reference point
Perceived usefulness	51
The product can increase quality of Home Oral Care	9
The product can make dentist-patient communication effective	6
The job performance of the product is great	4
The product allows oral testing to be accomplished more quickly	8
The product makes it easier to identify oral problems	11
The product is useful for oral health	13
Perceived ease of use	49
The using process is clear and understandable	10
It is easy to become skillful with this product	8
It is easy to remember how to use this product	6
The product is controllable and flexible	5
The product is easy to use	9
It is easy to learn to operate the testing process	11
Attitude toward using	38
The product is well worth using	9
I like the design of this product	11
The product is better than regular toothbrushes	9
I rate this product highly	9
Intention to use	29
I would like to use this product to help with oral care	8
I will use this product regularly in the future	5
I am likely to use this product in the future	9
I look forward to this product	7

Table 21. Manual coding node map

Further, several core variables from the TAM model were used as nodes and the interview recording were manually coded using Nvivo software to clearly categorize the interview information. Overall, the doctors generally agreed that the design would achieve the desired effect. In terms of the usefulness of the products, almost all the doctors indicated that the products could help to some extent in improving oral health. Eleven doctors and nine doctors respectively mentioned that the product makes it easier to detect oral problems and improves the quality of oral care at home.

The ease of use of the product was also generally recognized by the respondents. The vast majority of respondents said that the steps were clear and easy to understand and that it was easy to learn how to use the product. During the interviews, we explained how to use the product and asked the respondents to complete the steps independently. 11 out of 14 respondents were able to use the product accurately, while 3 respondents were able to complete the operation basically, with missing steps. In terms of altitude towards using and intention to use, 11 of the doctors expressed their preference for the product, describing it as practical and cleverly designed. Most doctors consider the product to be superior to ordinary toothbrushes and worth using. Eight doctors indicated that they would consider using this product for oral care purposes, while the rest indicated that they would be more likely to suggest it to their patients, as it is more appropriate for

those who may not be able to receive frequent and regular professional oral examinations.

Other perspectives from respondents which are not addressed in table 21 are worth noting. Several dentists mentioned that "the significance of this design is not only its original function, but also serves as a reminder, a warning, so that people will make regular oral check-ups a habit, which in turn will influence their attitude and the importance they place on oral health." Dentists hope that by popularizing at-home oral care products, people will be encouraged to become more aware of oral hygiene and develop good oral hygiene habits.
We have also summarized several concerns and suggestions in relation to the product raised by dentists and have proposed solutions accordingly.

1. How to ensure the product is moisture resistant?
As the product involves the storage of test strips, several dentists have expressed concerns about the moisture resistance of the toothbrush bar. Firstly, the test strips are stored at the end of the toothbrush bar, where there is relatively little contact with water. Secondly, we will add a moisture-proof desiccant to the storage area of the toothbrush bar to prevent moisture from contaminating the test strips. We can also increase the roughness of the contact surface between the cap and the toothbrush bar or take a leaf from the rotating seal of the water bottle spout, both of which are effective in improving the reliability of the seal.

2. How to ensure the accuracy of the testing results?
In terms of the accuracy of the results, the accuracy of the test strips is not comparable to that of precision dental instrument, and there may be deviations in the results due to improper handling by the user. However, the test strips are mainly used as an aid to diagnosis and as a warning for oral problems, reminding the user to seek timely medical care. From this point of view, the accuracy of the test results can meet the requirements. This product is a modification of an existing oral test product, and the main purpose of the design is to provide users with an affordable and easy-to-operate oral test product, so that the process of oral testing is no longer confined to hospitals but can be integrated into the daily oral care process at home. Improving the accuracy of the test strips is therefore not a design priority for this product but can be one of the targets for the further study.

VII. DISCUSSION

With the increasing emphasis on oral health, worldwide oral health-related organizations and individuals are taking steps to improve oral health. Despite considerable progress in global oral health, much work remains to be done. As mentioned in the available literature, research in oral health is the systematic process of acquiring new knowledge through systematic study. However, the advancement of knowledge has not yet reached a broad spectrum of developing countries. It will be urgently needed to map the changing patterns of oral diseases to analyze their underlying causes (Petersen, 2004).

In this study, the initial factors were enumerated, questionnaires were designed, and the data were

further analyzed to examine the associations between the factors and the actual effects of the factors on oral health to develop a more scientifically sound theoretical model. The data analysis results of the questionnaires collected from general population subjects around China indicated that the oral health influencing factor could be characterized by six correlated dimensions including intake, economic factor, social support, awareness factor, physical/mental status, and oral care habit. A total of 21 specific influencing factors were included, and the theoretical model was presented in the previous section.

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This six-factor theoretical model's cause-effect relationships with latent variables were further estimated by partial least squares path modeling (PLS-SEM). Results suggest that the six independent variable factors listed were all associated with oral health to varying degrees. Among these factors, oral health care habits factors (path COEF=0.304, p=0.000) and intake factors (path COEF=0.214, p=0.001) showed the strongest correlation with oral health. The result is not surprising, since it has been demonstrated in numerous studies that people's oral care needs and oral hygiene practices have a direct correlation with their periodontal and dental health (Norris & Lecavalier, 2010) (Hill et al., 2013). The intake factors, including poor dietary habits, smoking, and alcohol consumption have also been repeatedly evaluated to adversely affect oral health supporting by extensive experimental data (Warnakulasuriya et al., 2010) (Wickholm et al., 2003) (Wu, 2012). Social support factors (path COEF=0.167, p=0.002) and economic factors (path COEF=0.135, p=0.010) ranked third or fourth in this study as factors influencing oral health.

Specifically, among the 21 subdivided influencing factors, there is little available research on the element "Habit of self-assessment of oral status" and "delayed treatment" (Armfield et al., 2007) . "Self-assessment" and "delayed treatment" are two issues that doctors generally consider having a negative impact on oral health, but which are often neglected. The term "habit of self-assessment" refers to routine oral self-examination, people can also have difficulty examining the entire dental surface because of obstructed view, and an inability to recognize the early signs and symptoms of various oral conditions. Increasingly, self-assessed health status (SAHS) is used as a measure of health. The 'treatment delay' refers to the time between when individual first notices a symptom or confirms mental or physical health problem until the time when treatment initiates (Organization, 2006). The issue has attracted considerable attention in other medical fields, such as diabetes, tuberculosis, cancer, and other conditions (Storla et al., 2008) (Hanna et al., 2020) (Paul et al., 2015), but it has received little attention when dealing with oral health. The issue of treatment delay is of critical importance in health care, as it may lead to deteriorated oral health and problem-oriented treatment (Armfield, 2013).

The study results have led to several implications for both researchers and policy makers. Firstly, existing studies are mainly presented on a specific area of oral health influencing factors, nevertheless the absence of an overview makes it difficult for the reader to extract information effectively. To fill this gap in this research area, a comprehensive review of the literature is proposed, which can assist in understanding how other researchers have categorized oral health impacting factors and have elaborated the link between them. Meanwhile, the theoretical model constructed helps researchers to interpret information intuitively, making it much easier and more efficient to study the oral health related problems. Policy makers can benefit from the results of

the study by understanding the actual needs of the populations and developing more effective ways to address oral health problems, as well as provide with social and economic support.

This study also has implications for practice and design, as it can provide insight into aspects necessary to improve the oral health of individuals. ‘Habit of self-assessment of oral status" and "delayed treatment" are research gaps identified in the study. Once gaps are identified, designers can design to address factors that are closely related to oral health based on this user-centered study. In this study, a toothbrush combined with test strips designed for people to detect oral problems at home and seek for medical service in time in response to the fact that people often overestimate their oral health. Further design could be directed at exploring domestic or community-based dental electronics, giving the user a more accurate diagnosis. Meanwhile, reducing the cost of the electronic product and making it available to a wider public is also a technical and design issue that needs to be addressed.

Several limitations have been identified in this study. Firstly, lack of diversity in the sample source can be a barrier. Participants in this study are primarily young and middle-aged, with a concentration of those aged 18-39. Due to the chronic and cumulative nature of many oral problems, the severity of oral problems in younger participants may be less severe, which may affect the strength of the correlation between influencing factors and oral issues. An additional limitation of the sample is the small sample size from deprived areas. The data are not deliberately sourced to cover people from poor area, although the participants come from different provinces and regions. Extensive literature indicates that factors associated with quality of life, such as water quality, transport, and access to oral healthcare, have a more substantial adverse effect on disadvantaged areas. Thus, the fact that most participants' households have a high level of financial income may adversely affect the accuracy of the model results. Increasing our sample's heterogeneity may be a further step as it could allow us to generalize the current findings across several settings and geographic locations.

In addition, the participants' self-assessed oral health status may have deviated from the actual status, which is mainly manifested by an overestimation of their oral condition. This may affect the accuracy of the questions in the questionnaire regarding the individual's oral status. A professional assessment by a dental professional would be able to mitigate the impact of this issue. Similarly, we do not have a suitable method for accurately measuring the factor ' infection transmission ', which is excluded from factor analysis and may have been influenced by the limitation, and this direction could also be investigated further. Furthermore, there are limits to the information that can be obtained from the questionnaire. For example, information on the impact of genetic structure or the national and local policy support on oral health may exceed the respondents' perceptions to some extent, and more authoritative scientific data or official documents are needed to support the theory.

In future research, it is possible to focus on the diversification of research methods and the continued exploration of research areas. Firstly, a more diverse data source is necessary to address the above limitations. Oral problems are particularly prominent among vulnerable groups in both developed and developing countries, which means that more targeted research may be a top

priority in addressing the problem. Collecting data from more disadvantaged groups may make the research more socially relevant. The diversity of research methods can be reflected in the variety of information collection methods used by the researcher. Observation, experimentation, and other methods can be used extensively to obtain visual and scientific data. It is recommended to combine theoretical data with practice and to strengthen cooperation with dentists and oral health organizations, broadening the sources of data. By utilizing dental technology products to assist in obtaining experimental data, it would be more accurate than relieving only subjective information from participants via questionnaires. Furthermore, it is also a future endeavor to further validate and explore the two research gaps 'Habit of self-assessment of oral status' and 'delayed treatment' with accurate and rigorous research approach. More research, design attempts and efforts could be put into the area of oral health influencing factors, laying the foundation for improving the oral health status of the entire population.

VIII. CONCLUSION

To summarize, the objective of this research is to identify potential factors that can have an impact on oral health. A conceptual model is proposed with the assistance of factor analysis, and the robustness of it is further estimated by PLS-SEM. Based on the conducted analysis, it can be concluded that there are various causal factors for oral health problems, which are summarized in this paper into six main categories. After identifying research gaps relating to oral health problems, A product design was developed to enhance the quality and efficiency of oral care at home by combining a toothbrush with an oral test strip. 14 dentists from different departments tested the product and the overall acceptance of the product, guided by TAM theory, showed satisfactory results. This research study significantly contributes to the existing body of knowledge in that it provides an overview in terms of factors influencing oral health, based on a user-centred research approach. Meanwhile, the study is significant to researchers, policy makers and designers, since the research gaps identified in this paper could provide them with a way forward to further strengthen the theoretical foundation and enrich the practical work in the field of oral health.

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