ORIGINAL RESEARCH

Zero Waste: Consumers' Perception of the Use of Eco-friendly Toothpaste Tablets—A Quasi-experimental Study

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Abstract

Aims: The purpose of the study was to evaluate consumers' perception of the use of eco-friendly toothpaste tablets and evaluate whether there would be a perception difference by consumer demographics: Gender and age.

Materials and methods: Participants ($N = 152$) received one packet of toothpaste tablets (Denttabs GmbH, Berlin, Germany). Participants were instructed to brush using toothpaste tablets twice daily. At the end of the 1-week period, participants completed a 10-item questionnaire on their satisfaction of the use of toothpaste tablets. Pearson's Chi-squared test was used to test the distribution of positive and negative responses by gender and by age. Tests of hypotheses were two-sided with $\alpha = 0.05$.

Results: The majority responded favorably to cleanliness after usage, flavor, ease of use, importance of eco-friendliness of toothpaste products, intention to switch to tablets, and overall satisfaction with the texture. However, 59.9% of participants disliked the texture of tablets. Based on Pearson's Chi-squared test, there were no statistically significant differences in the distribution of positive and negative responses by gender except for flavor ($p = 0.013$), where more males responded negatively (27.4 vs 11.5%). Participants were further categorized by age and respective generation ($n = 38$/age generation type). There were no significant differences in the distribution of positive and negative responses by age generation except for flavor ($p = 0.023$) and potential switch to toothpaste tablets ($p = 0.030$). For both items, millennials showed a greater proportion of negative responses than the other generations.

Conclusions: Toothpaste tablets offer an effective and eco-friendly alternative to traditional toothpaste. While patients generally view them positively, texture remains a major factor influencing acceptance.

Clinical significance: Consumer responses indicate a positive perception of toothpaste tablets, supporting their potential as a sustainable alternative to conventional dentifrices. Clinicians should highlight both the environmental benefits and the sensory differences when recommending toothpaste tablets to support patient adoption and align with growing sustainability trends.

Keywords: Dentifrice, Environmental sustainability, Patient perception, Toothpaste tablets.

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Introduction

Traditional toothpaste, widely regarded as essential for maintaining oral hygiene and preventing dental diseases such as dental caries and periodontal disease, typically comes packaged in tubes composed of plastics, aluminum, steel, and nylon. While effective for oral health, these tubes pose substantial environmental challenges. Globally, it is estimated that approximately 1.5 billion toothpaste tubes are discarded annually, leading to significant accumulation in landfills and contributing heavily to environmental degradation.[1–3] A critical factor compounding this environmental concern is that the plastic components of these tubes may require up to 700 years to begin the process of decomposition.[4] Consequently, toothpaste tubes have been classified as environmentally hazardous waste, significantly contributing to persistent plastic pollution. This issue highlights the necessity of integrating sustainable practices within dentistry, fostering a growing demand for environmentally friendly alternatives and heightening environmental awareness within both professional communities and consumer markets.[5–8]

In response to the growing ecological concerns associated with conventional toothpaste packaging, manufacturers have developed biodegradable toothpaste tubes as a novel solution. However, a more revolutionary and sustainable alternative is the formulation and adoption of toothpaste tablets.[9–12] These toothpaste tablets represent an innovative solution, being composed of waterless toothpaste formulas compressed into pill-like structures. Their application is straightforward yet distinctly different from traditional methods: a tablet is placed in the oral cavity, chewed thoroughly to facilitate dissolution aided by natural saliva, converting it into a paste-like substance suitable for cleaning teeth and gum. Subsequently, brushing is performed with a damp

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toothbrush. By eliminating conventional plastic packaging, these tablets enable the use of eco-friendly packaging materials, such as glass jars, aluminum tins, or other biodegradable and reusable materials, substantially mitigating environmental waste.

It is noteworthy that toothpaste tablets were initially conceived not solely due to environmental considerations but because of their pharmacological advantages. Specifically, their rapid dissolution properties in saliva significantly enhance the immediate bioavailability of fluoride, optimizing its protective efficacy against dental caries. Several scientific investigations have substantiated the effectiveness of toothpaste tablets, particularly their capacity to remineralize early-stage carious lesions and maintain a lower degree of abrasivity, thereby safeguarding tooth enamel integrity.[13–15] Despite their scientifically supported benefits and growing popularity driven by eco-friendly consumer trends, toothpaste tablets are not yet widely available through traditional retail channels. Currently, they remain predominantly marketed and distributed through online platforms, indicating potential avenues for broader accessibility and increased adoption in the future.[16]

Consumer satisfaction and the main attributes contributing to the selection of one toothpaste over another are influenced by many factors, such as consumer demographics, costs, availability, product quality, packaging, brand value, and others.[17] Specific toothpaste attributes include the cleaning ability, flavor, texture, and additional disease-preventing properties, such as antiplaque, anticavity, antistaining, and antisensitivity properties. There is a wealth of literature on consumers' satisfaction with toothpaste that demonstrates the claimed disease-preventing properties.[18–23] However, there is scarce information on the cleaning efficacy of toothpaste tablets and consumer perception and satisfaction with their usage. Therefore, the purpose of this study was to evaluate consumers' perception on the use of toothpaste tablets and evaluate whether there would be a perception difference by consumer demographics: gender and age. This is novel as there is limited information on the perception of toothpaste tablets. We hypothesized that there would be no difference in consumer perception of the use of toothpaste tablets by gender and age.

Materials and Methods

Research Compliance

This study used a quasi-experimental study design through the recruitment of subjects to use toothpaste tablets twice daily and completing a survey at the end of the trial. The research study was approved as a minimal risk study by the Institutional Review Board at Loma Linda University in Loma Linda, California, United States of America (IRB # 5240492).

Pilot Survey

The survey questions were developed by the authors based on key topics related to toothpaste perceptions. To ensure the survey's validity and reliability, it was initially distributed among dental students. This preliminary testing helped refine the questions, ensuring they accurately captured patient perceptions of cleanliness, flavor, ease of use, eco-friendliness, texture, satisfaction, and willingness to switch to toothpaste tablets. Additionally, inter-rater reliability was assessed using Cohen's kappa coefficient, achieving a kappa score above 0.8, indicating excellent agreement among respondents. Piloting the survey with dental students allowed us to validate the consistency and clarity of responses, further enhancing the study's overall reliability and readiness for administration to a broader audience.

Sample Size Calculation

G*Power 3.1.9.4 (Heinrich-Heine Dusseldorf University, Germany) was used to determine the sample size based on the following parameters: 95% power, 0.62 effect size, and two experimental groups (female vs male). A minimum sample size of 70 participants per group was assessed to be appropriate. Considering the 8% attrition of participants, a total of 152 participants were enrolled.

Inclusion and Exclusion Criteria

Participants were eligible for inclusion in the study if they were male or female, aged 18 years or older, in good general health, and available for the 1-week duration of the clinical research study. Eligible participants were required to be current users of conventional toothpaste, able to fully understand and comply with all written and verbal instructions, physically capable of performing all study procedures, and willing to sign an informed consent form. Individuals were excluded from participation if they had taken part in another clinical study within 1 month prior to enrollment, were edentulous, had a history of allergies to oral care or personal care products or their ingredients, had any condition that, in the opinion of the investigator, could interfere with the conduct of the study, or were pregnant or lactating.

Study Procedures

The experimental study design is illustrated as a flow diagram in Figure 1. On enrollment, participants received one packet of toothpaste that contains 125 tablets (Denttabs GmbH, Berlin, DE). Participants were instructed to switch from using their current toothpaste to using toothpaste tablets twice daily. However, they were asked to keep their brushing technique, toothbrush type, and additional use of oral hygiene care products the same as before the initiation of the study. At the end of the 1-week period, participants completed a 10-item questionnaire (Fig. 2).[24] The survey titled "User friendliness and perception of toothpaste tablets as observed by consumers" was designed to assess participants' experiences and attitudes toward using Denttabs, a toothpaste tablet. It began with demographic questions regarding gender, age, and a self-reported compliance question whether participants used Denttabs as instructed. The main body of the survey consisted of a series of

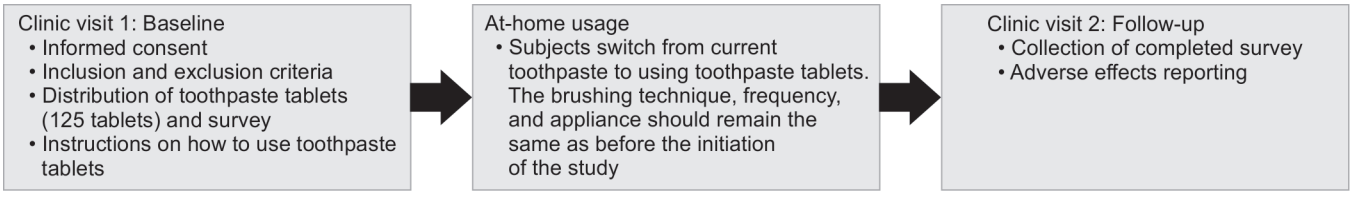
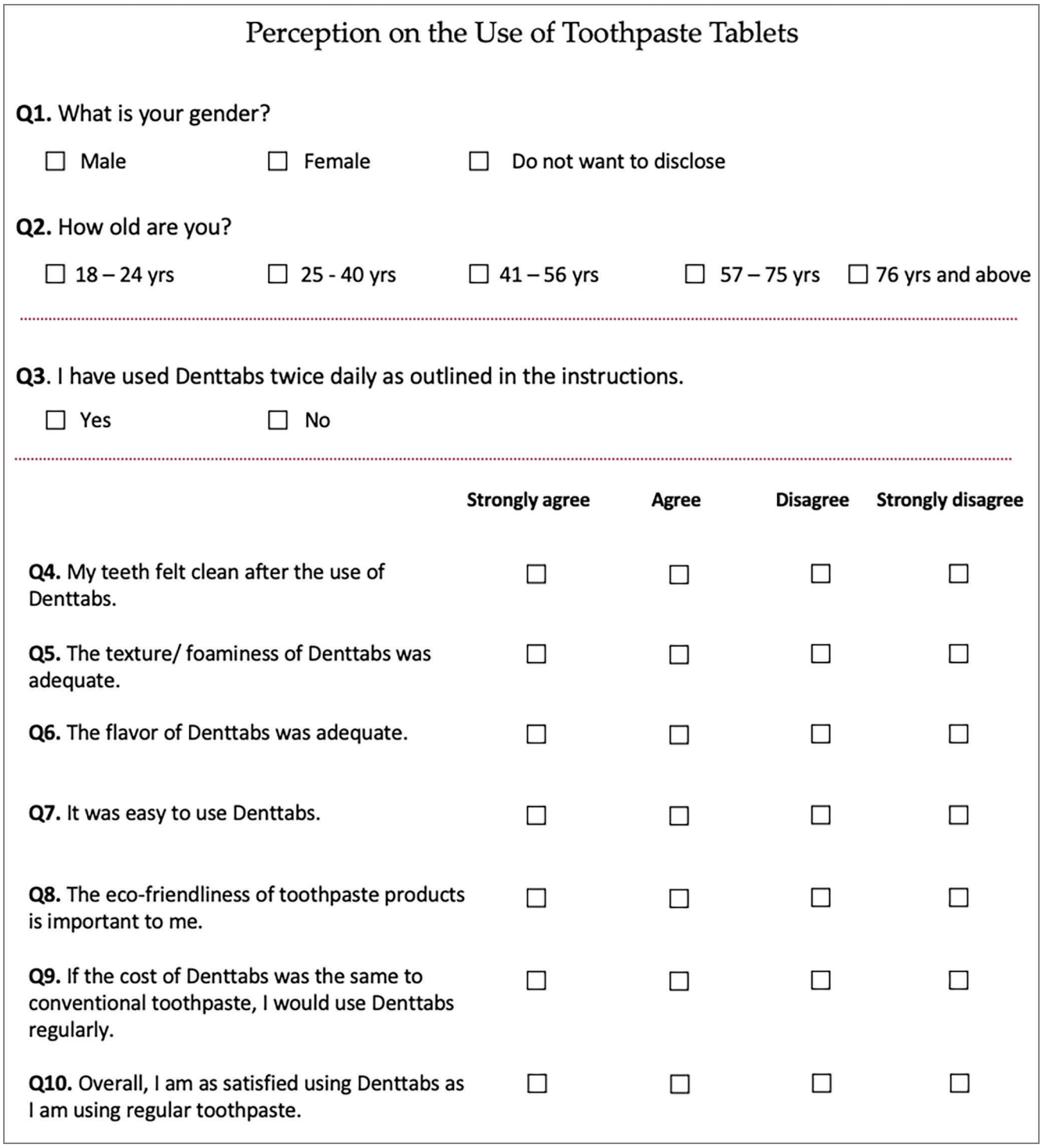


Fig. 1: Flow diagram of experimental study design



Perception on the Use of Toothpaste Tablets

Q1. What is your gender?

☐ Male ☐ Female ☐ Do not want to disclose

Q2. How old are you?

☐ 18 – 24 yrs ☐ 25 - 40 yrs ☐ 41 – 56 yrs ☐ 57 – 75 yrs ☐ 76 yrs and above

Q3. I have used Denttabs twice daily as outlined in the instructions.

☐ Yes ☐ No

	Strongly agree	Agree	Disagree	Strongly disagree
Q4. My teeth felt clean after the use of Denttabs.	☐	☐	☐	☐
Q5. The texture/ foaminess of Denttabs was adequate.	☐	☐	☐	☐
Q6. The flavor of Denttabs was adequate.	☐	☐	☐	☐
Q7. It was easy to use Denttabs.	☐	☐	☐	☐
Q8. The eco-friendliness of toothpaste products is important to me.	☐	☐	☐	☐
Q9. If the cost of Denttabs was the same to conventional toothpaste, I would use Denttabs regularly.	☐	☐	☐	☐
Q10. Overall, I am as satisfied using Denttabs as I am using regular toothpaste.	☐	☐	☐	☐

Fig. 2: Survey on user friendliness and perception of toothpaste tablets as observed by consumers

statements evaluating key aspects of the Denttabs experience, including perceptions of cleanliness, texture, flavor, ease of use, eco-friendliness, cost considerations, and overall satisfaction compared with regular toothpaste. Responses were collected using a four-point Likert scale ranging from "strongly agree (1)" to "strongly disagree (4)," allowing for detailed insight into user perceptions.

Data Analysis

Pearson's Chi-squared test was utilized to determine if there were significant differences in the distribution of consumer perceptions (categorized as positive or negative responses) based on demographic characteristics, such as gender and age-groups. This test assesses whether any observed differences in response

Table 1: Perception of the use of toothpaste tablets by generation (% positive/negative responses)

Perception	*Gen Z: 18–24 yrs*	*Millennials: 25–40 yrs*	*Gen X: 41–56 yrs*	*Boomers/Postwar: ≥57 yrs*	*p-value*
Cleanliness	86.8/13.2	84.2/15.8	94.7/5.3	92.1/7.9	0.424
Texture	39.5/60.5	42.1/57.9	28.9/71.1	50/50	0.31
Flavor	86.5/13.5	65.8/34.2	92.1/7.9	78.9/21.1	0.023
Ease of use	89.5/10.5	81.6/18.4	92.1/7.9	92.1/7.9	0.416
Eco-friendliness	86.8/13.2	78.9/21.1	97.4/2.6	92.1/7.9	0.069
Switch	71.1/28.9	50/50	65.8/34.2	81.6/18.4	0.03
Satisfaction	73/27	71.1/28.9	84.2/15.8	76.3/23.7	0.55

Total participants $N = 152$, $n = 38$ per generation type

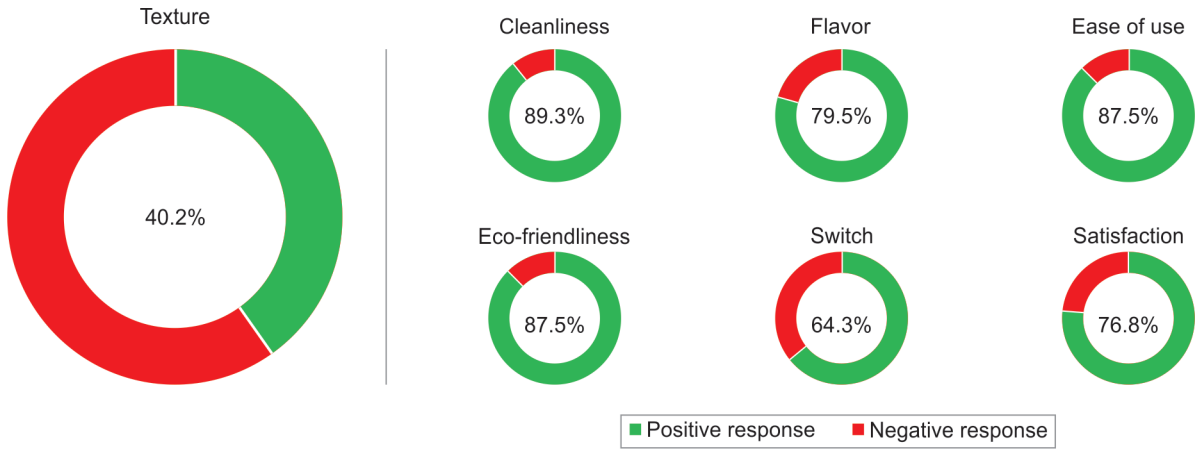


Fig. 3: Perception on the use of toothpaste tablets by question item. Description in circle denotes the % positive responses

distributions across these demographic categories occurred by chance or represent genuine differences in perceptions among these groups. All statistical analyses were two-sided, meaning they tested for deviations in both directions (positive or negative differences) without assuming a specific direction. Statistical significance was established at an alpha level of 0.05; thus, *p*-values below this threshold indicated statistically significant differences between groups. Analyses were conducted using R statistical software version 4.3 and the Jamovi statistical package (version 1.1.9.0).

Results

A total of 152 subjects participated in the study. The female and male ratio was 51.2% vs 48.7%. All participants reported compliance with the use of toothpaste tablets as instructed.

Table 1 presents the perceptions of toothpaste tablet use across different generations, expressed as the percentage of positive and negative responses. A total of 152 participants were included, with 38 individuals representing each generational group (Gen Z: 18–24 years, Millennials: 25–40 years, Gen X: 41–56 years, and Boomers/postwar: ≥57 years). Perception responses were on a four-point Likert scale but for analysis purposes, strongly agree and agree were merged as positive, and strongly disagree and disagree as negative. The overall perception of the use of toothpaste tablets is illustrated in Figure 3.

Regarding perceptions of cleanliness, positive responses were high across all generations, ranging from 84.2% among Millennials to 94.7% among Gen X participants ($p = 0.424$). Texture received comparatively lower positive ratings, with Gen X reporting the lowest positive perception (28.9%) and Boomers/postwar participants reporting a balanced 50% positive response ($p = 0.31$).

Significant generational differences were observed for flavor ($p = 0.023$), with Gen X demonstrating the highest positive response rate (92.1%), while Millennials reported a lower positive perception (65.8%). Ease of use was consistently rated highly among all groups, with positive responses exceeding 81% across generations ($p = 0.416$). Eco-friendliness was also rated positively by most participants, particularly among Gen X (97.4%), although the difference across generations approached but did not reach statistical significance ($p = 0.069$). Willingness to switch from conventional toothpaste to toothpaste tablets showed a significant difference among generations ($p = 0.03$), with Boomers/postwar participants indicating the highest willingness to switch (81.6%), whereas Millennials showed the least (50%). Finally, overall satisfaction with the toothpaste tablets was generally high, with Gen X again reporting the highest positive satisfaction (84.2%) and Millennials the lowest (71.1%); however, no significant difference was observed between groups ($p = 0.55$). There were no statistically significant differences based on gender for all items reported ($p > 0.05$, in all instances). No adverse effects were reported with the usage of toothpaste tablets.

The results suggest that toothpaste tablets are generally well-received across age-groups, with high marks for cleanliness, ease of use, and eco-friendliness. Texture and flavor were more

variable, with flavor showing a statistically significant difference favoring Gen X. Generational differences in willingness to switch from traditional toothpaste were also significant, with older adults more open to change.

Discussion

The development and promotion of toothpaste tablets are novel and offer an innovative solution to preserving the environment. As such, assessing consumer perceptions of novel toothpaste tablets is essential for evaluating their potential acceptance and integration into daily oral hygiene practices. This study, using a quasi-experimental design and survey distribution following 1 week of toothpaste tablet use, provided valuable real-world insights into consumer experiences. By capturing perceptions related to cleanliness, flavor, texture, ease of use, eco-friendliness, and satisfaction, the study highlights critical factors influencing consumer willingness to adopt new oral healthcare products. These findings are significant for guiding future product development, improving patient compliance, and promoting sustainable alternatives in oral health care. Our study provides important insights into consumer perceptions regarding the use of toothpaste tablets. Although the grainy texture of the tablets was not favorably received, overall satisfaction with their use remained positive. These findings are consistent with those reported by Martinez et al., who similarly observed high levels of satisfaction across both conventional toothpaste and toothpaste tablets, despite more negative perceptions related to "texture/foaminess" for the tablet formulation.[25] Our study results are significant as they bring awareness to the need for an environmentally friendly alternative to conventional toothpaste as well as how manufacturers can improve their tablets' formula and design to further promote consumers' willingness to switch.

It is well known that there is a difference in the perception of eco-friendly alternatives among gender and age. Studies suggest that females are more likely to engage in "green" behavior and buy more environmentally friendly products when compared with their male counterparts.[26] Age also plays a role, with older individuals paying more attention to the growing environmental needs. When looking at interest in "taking action to help the environment," the biggest decline seen occurred between Gen X and Millennials.[27,28] Despite the reported differences in perception of eco-friendliness, our study indicated that regardless of gender or generation type, eco-friendliness of toothpaste products was important to most participants. Based on the results, we accepted our null hypothesis that there would be no difference in the distribution of positive and negative responses based on gender and age. There was only a difference in the distribution of positive and negative responses by age category for flavor and switch. Interestingly, consumers reported a positive response to Denttabs, with 76.2% satisfaction; however, only 67.1% of subjects reported positively to willingness to switch. This discrepancy can be attributed to the texture, which had the highest level of negative responses. This suggests that texture, and the related mouthfeel of toothpaste, plays an essential role in how consumers evaluate a product. The conventional paste texture might have been ingrained in many consumers, making it very challenging for tablets to compete with the paste formula.

This strong consumer focus on texture is further supported by findings in recent literature evaluating the clinical performance and material effects of toothpaste tablets.[25] While consumer acceptance heavily relies on sensory factors like mouthfeel, it is also important to consider how toothpaste tablets perform in terms of clinical outcomes and material preservation when compared with traditional toothpastes. Three recent studies have evaluated various aspects of toothpaste tablets compared with conventional toothpaste formulations. Martinez et al. conducted a 2-week randomized controlled clinical trial and found that toothpaste tablets provided plaque and gingivitis control equivalent to conventional dentifrice.[25] Padilla et al. explored the impact of toothpaste tablets on resin-based composites and found that tablets preserved surface gloss and minimized roughness significantly better than traditional toothpastes.[29] Similarly, Ko et al. assessed different types of toothpaste tablets and reported that while all products led to some loss of gloss and increase in roughness, Chewtab tablets caused the least deterioration, whereas charcoal-based tablets had the most detrimental effects.[30] Collectively, these findings suggest that toothpaste tablets offer clinical efficacy comparable to conventional products, with potential advantages in material compatibility, though sensory attributes, such as texture, remaining areas for improvement.

A major strength of this study was its real-world design, allowing participants to incorporate toothpaste tablets into their daily oral hygiene routines under typical use conditions, thereby providing practical insights into consumer experiences and perceptions. The inclusion of a broad age range and the use of a validated survey instrument further enhanced the generalizability and reliability of the findings. Additionally, the high compliance rate among participants minimized potential bias related to nonadherence. However, several limitations must be acknowledged. The short study duration of 1 week may not have been sufficient for participants to fully adapt to the novel texture and mouthfeel of toothpaste tablets, potentially influencing their perceptions negatively. Furthermore, the study relied on self-reported measures, which are inherently subject to response bias. The sample was also geographically limited, potentially affecting the external validity of the results. Future research with a longer evaluation period, a larger and more diverse population, and objective clinical outcomes would be valuable to confirm and extend these findings.

Conclusions

Within the limitations of the study, it is concluded that toothpaste tablets offer an effective and eco-friendly alternative to traditional toothpaste. While patients generally view them positively, texture remains a major factor influencing acceptance. Clinicians should highlight both the environmental benefits and the sensory differences when recommending toothpaste tablets to support patient adoption and align with growing sustainability trends.

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