ORIGINAL ARTICLE

Comparison of formant scores between complete denture users and subjects with complete dentition: a preliminary study

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Received: 20 November 2024
Revised: 10 February 2025
Accepted: 20 March 2025
Published: 31 March 2025
DOI: 10.24198/pjd.vol37no1.59201

p-ISSN 1979-0201
e-ISSN 2549-6212

Citation:
Andryas I, Syarfina T, Tanti I, Kusdhany LS. Comparison of formant score between complete denture user and complete dentition subject: A preliminary study. Padj J Dent, March 2025; 37(1): 78-86

ABSTRACT

Introduction: Edentulism impairs the ability to chew, eat, and speak properly. Dentures, which aim to address this issue, are also believed to contribute to a decrease in the peak intensity value and spectral width of sound formants. Formants refer to the air within the vocal tract that is set in vibration by the vocal fold's action. This study aims to observe changes in formant values between complete denture users and participants with complete dentition. **Methods:** This preliminary study recruited six voluntary participants, divided into two groups. The first group consisted of subjects with complete dentition, while the second group comprised individuals wearing complete dentures on both arches. All participants introduced themselves, and their speech was recorded using PRAAT® software. For the second group, recordings were made both with and without dentures. Statistical analysis was performed using one-way ANOVA. **Results:** Significant differences in formant scores were observed across all groups. Post hoc tests revealed a significant difference in formant scores between completely edentulous subjects without dentures and the complete dentition group; **Conclusion:** Correcting speech defects is the third main objective in fabricating denture prostheses. Enhancing the phonetically beneficial construction of denture quality improves psychosocial parameters, including quality of life and socialization abilities, and accelerates successful Prosthodontic treatment. The findings indicate that the format score of a person with a complete denture is not substantially different from that of an individual with complete dentition. Conversely, individuals who have lost their complete dentures and not using complete denture may exhibit significant differences in formant score.

KEYWORDS

Complete denture, formant, intelligibility, sound, speech

INTRODUCTION

There are a number of consequences associated with the edentulous condition (Zarb, 2014, as cited in Angela M. C. Martins et al., 2021). These include a reduction in the size of the lower third of the face, a decrease in vertical dimension, a reduction or loss of masticatory movement, poor aesthetics, and phonetic problems.[1] Thus, the loss of teeth and supporting tissues is known to significantly affect speech, as it results in major changes to the oral cavity. Missing teeth and supporting tissues must be replaced with dentures to address these issues.[2]

After receiving complete dentures, post-insertion adjustments should be consistently made by clinicians to ensure proper rehabilitation. At this stage, patient satisfaction is a critical factor in the success or failure of complete denture therapy.[3] To ensure the success of dentures, it is necessary to perform an evaluation based on a comprehensive assessment of both mechanical and functional aspects, as well as phonetic considerations.[2]

Phonetic changes have long been a concern in dentistry, especially in the field of Prosthodontics.[4–12] It has been observed that complete edentulism and its prosthetic rehabilitation significantly impact speech intelligibility and quality of life. Studies have shown that the new maxillary dentures can improve speech intelligibility to the level of healthy dentition within 6 months of adaptation.[11,13] Various denture designs, including those with metallic frameworks or resilient acrylic resin for palatal rugae[6,14–16], can affect speech production differently.[17] Overall, prosthetic rehabilitation of edentulous patients can significantly enhance speech intelligibility and contribute to improved Oral Health-Related Quality of life (OHRQoL).[18]

Disturbances in voice intelligibility due to denture use can be observed through changes in formant values.[2] The shape of the consonant spectrum results from the interaction between the spectrum of the primary sound source and the frequency characteristics of the sound channel, which functions as a filter and emphasizes certain frequencies. It is important to note that pronunciation refers to the way a word is pronounced, not the act of pronouncing it, making it possible to compare or to analyze the formants of specific speech sounds.

The final peak spectrum of sound includes regions known as the formants (F1, F2, F3, and so on). The first resonance occurs at the lowest frequency, while the second and third resonances occur at the jaw and lips/teeth, respectively.[19] Formant refers to the air within the vocal tract that is set in vibration by the vocal fold's action. The use of dentures is believed to cause a decrease in the peak intensity value and spectral width of formants, whether dentures are worn or not.[20]

While numerous studies have examined the relationship between complete dentures and speech disorders, few have attempted to employ formant and other acoustic data as investigative resources to examine the linguistic alterations associated with the use of complete dentures.

The present study aims to provide objective analysis of speech systems in complete denture users. Specifically, it seeks to observe changes in formant values that occur in complete denture users compared to participants with complete dentition. The formant score can be used as a new diagnostic tool to identify acoustic problems in complete denture user.

This preliminary study is necessary to further understand and improve the phonetic aspects of complete dentures following prosthodontic treatment. The null hypothesis of this study is that there are no significant differences in formant values between completely edentulous participants with and without dentures compared to participants with complete dentition.

METHODS

This observational pilot study employed non-probability sampling and included randomly six volunteers. The study aimed to investigate whether pre-measure analysis could differentiate between two groups. As this is a preliminary study, no specific target and formula applied for the number of participants. Participants were selected based on inclusion and exclusion criteria to minimize bias in the collected data.

Participants in the study were required to complete dentures on both arches, manufactured by the Faculty of Dentistry, Universitas Sumatera Utara. Exclusion criteria included individuals with voice distortion due to congenital conditions or trauma, elderly individuals with Parkinson's disease, and those with tongue or hearing anomalies. Participants with complete dentition and no history of orthodontic treatment were included as controls. A potential confounding factor was the participants' living environment, which could affect the sound color of the participants in this study. To mitigate sound bias data, recordings were conducted in a soundproof room, and strict adherence to the inclusion and exclusion criteria was maintained. Figure 1 provides a detailed flow diagram of the participant recruitment process.

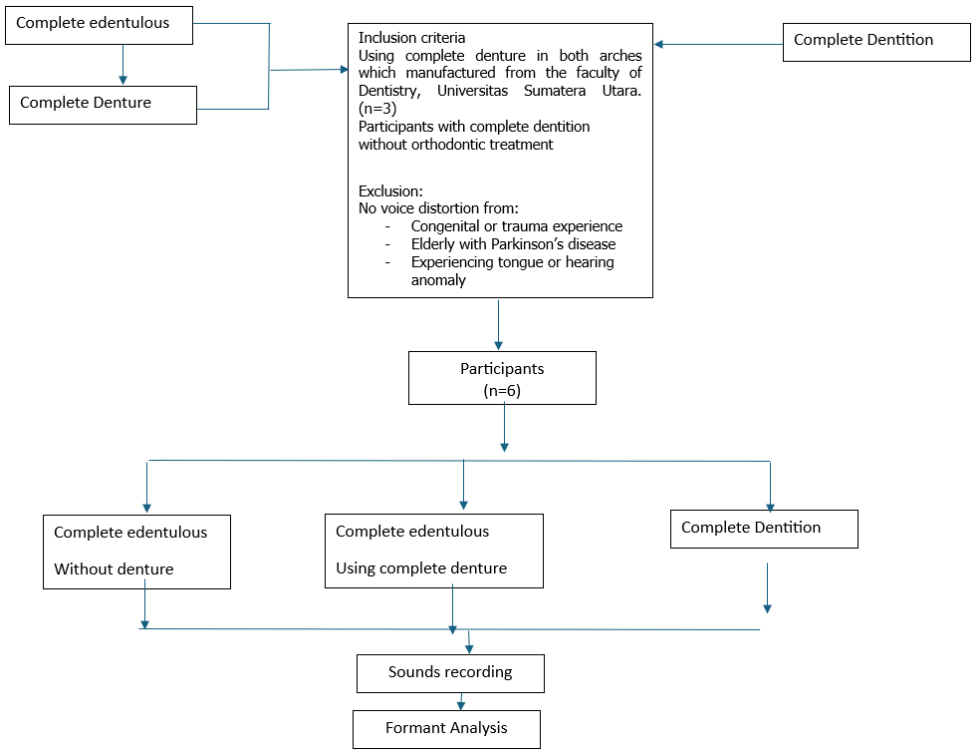

Figure 1. Participants Recruitment Flow Diagram

Participants were divided into two groups: the first group consisted of three individuals with complete dentition, and the second group consisted of three complete denture users. All voice recordings were collected in December 2022. All participants met the eligible criteria, and none were excluded. Participants were asked to introduce themselves in front of a microphone, and their voices were recorded using PRAAT® software (Boersma and Weenink, version 6.2.10, 2022, Amsterdam).[21] For complete denture users, recordings were made both with and without dentures.

For grouping purposes, participants without dentures were labeled as Group I, while the same participants with dentures were labeled as Group II. Complete dentition participants were labeled as Group III. During the self-introduction, participants were asked to say "my name," "occupation," and "age" in Bahasa Indonesia. These phrases were chosen to ensure participants used their natural voices in a comfortable state to avoid voice suppression bias. Voice recordings were saved in WAV format and processed to obtain formant values (F). All formants' mean and deviation values recorded on the PRAAT® software were tabulated as the first three formant values (Formant 1, Formant 2, and Formant 3). The comparison of formant values between participants with complete dentition and two other groups was tested using one-way ANOVA analysis. Post hoc tests, including Tukey and Tamhane tests, were conducted using IBM SPSS Statistics (version 29).

RESULTS

The sociodemographic characteristics of participants and the differences in formant values in this study are summarized in table 1 and table 2. The first group comprised three individuals with complete dentition (mean age: 33 ± 2.65 years), while the second group consisted of three individuals (mean age: 62.33 ± 2.52 years), with 33.33% male and 66.66% female participants. The results of this study show that participants with complete dentition (Group III) served as controls and exhibited mean formant values that increased progressively from Formant 1 to Formant 3.

A similar trend was observed in the edentulous group without dentures (Group I) and the edentulous group using dentures (Group II). In all groups, the F1 value was the lowest, and the F3 value was the highest. However, the formant values in the

edentulous with dentures (Group II) were closer to those in the control group (Group III), except for F3, where the mean formant value in Group I was closer to Group III. Notably, the mean formant values in Group I (F1 and F2) were nearly twice those of the control group. Figure 1 illustrates the differences in sound wave forms analyzed using PRAAT software for the pronunciation of "my name" in Bahasa Indonesia across the three groups: edentulous without dentures (A), edentulous with dentures (B), and complete dentition (C).

Table 1. Participants' Sociodemographic Characteristics

Participant Characteristic	Frequency	Percentage ((%)
(Dental status: Age range (average ± SD))		
Complete Edentulous: 62-65 (62,33 ± 2,52)	3	50
Complete Dentition: 30-36 (33±2,65)	3	50
Total	**6**	**100**
Gender		
Male	2	33,33
Female	4	66,66
Total	**6**	**100**

Saphiro-Wilk's normality test showed a p-value > 0.05 for all groups, indicating normal data distribution. Differences in mean formant values across groups were analyzed using a one-way ANOVA test. The statistical test results revealed significant differences among all tested groups. Post hoc tests indicated a significant difference in mean formant values for F1 (p = 0.02) between the edentulous group without dentures (Group I) and the complete dentition group (Group III). For F2, significant differences were observed between Group I and Group II (p = 0.03) and between Group I and Group III (p = 0.01). In F3, significant differences were found between Group I and Group II (p = 0.02) and between Group II and Group III ((p = 0.01) table 3)). Figure 1 illustrates the sound wave analysis using PRAAT software.

Table 2. Mean Formants Values Across Test Groups

Respondent Group	F1 (Hertz) mean (p Value)	F2 (Hertz) mean (p Value)	F3 (Hertz) mean (p Value)
Edentulous without dentures (I)	1.507,11 ± 301,4*	2.972,52 ± 148,4*,†	3.077,19 ± 87,6*
Edentulous with dentures (II)	909.87 ± 25,1	1.215,69 ± 285*	2.123,63 ± 296,5*,†
Complete dentition (III)	520,29 ± 115,6*	1.671,73 ± 97,7†	3.107,78 ± 33,4†

The same symbol (*,†) indicate significant value at 0.05 level between compared groups

Table 3. Normality test, one way ANOVA and Post Hoc value across test groups

Formant	Normality test Respondent Group			Anova Test	Post Hoc Test (p value) Respondent Group		
	Edentulous without dentures (I)	Edentulous with dentures (II)	Complete dentition (III)	(p value)	Edentulous without dentures (I)	Edentulous with dentures (II)	Complete dentition (III)
F1	.281	.885	.110	0.026	(0.02)	(0.45)	(0.02)
F2	.617	.221	.426	0.002	(0.03) and (0.01)	(0.03)	(0.01)
F3	.113	.864	.814	0.013	(0.02)	(0.02) and (0.01)	(0.01)

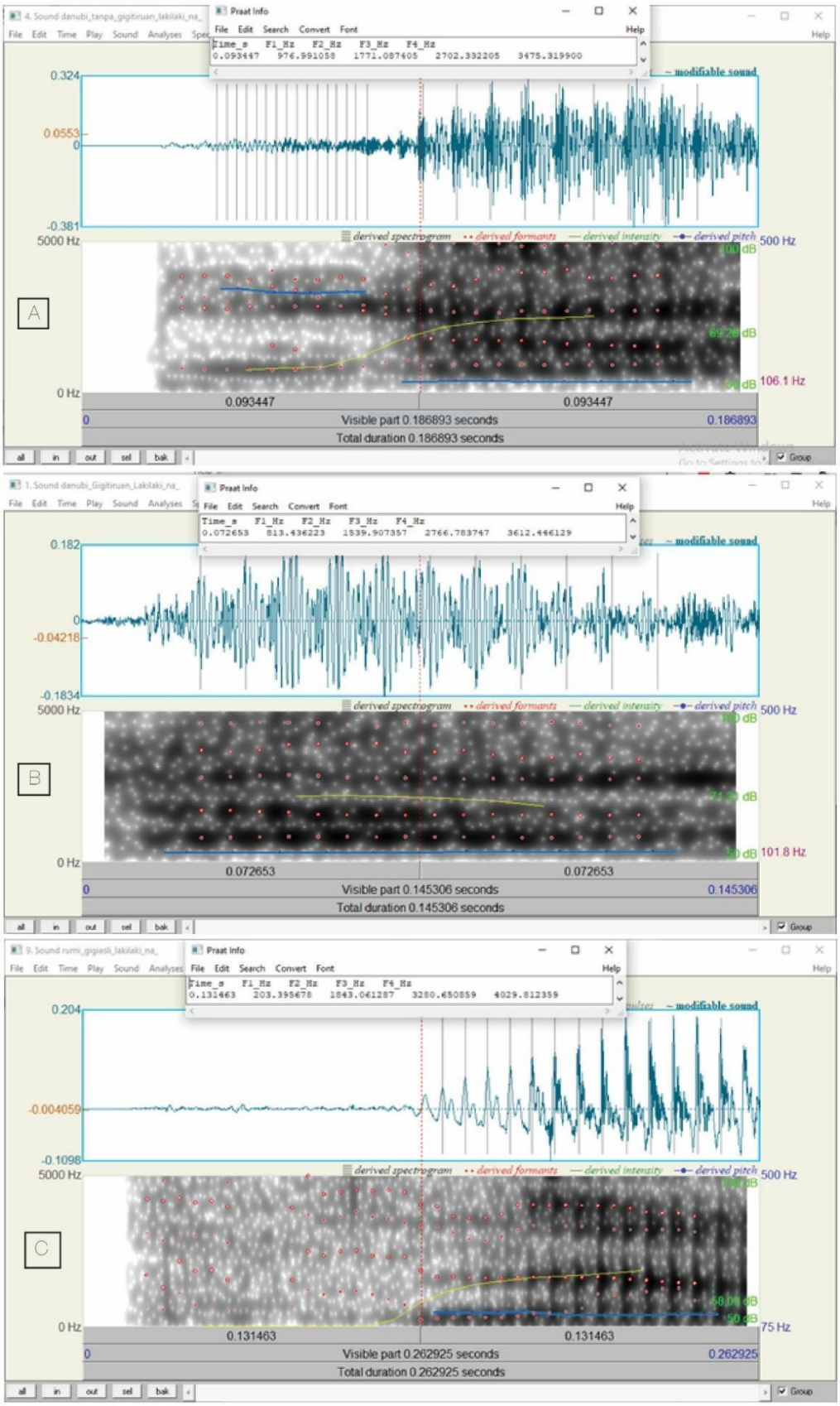

Figure 1. Sound wave analysis using PRAAT software: (A) Edentulous respondent sound wave without complete dentures, (B) Edentulous respondent sound wave with complete dentures, and (C) Complete dentition respondent sound wave.

DISCUSSION

Tooth loss is believed to impair articulation, eventually leading to impaired pronunciation. Tooth loss and denture use can also cause articulation disorders, as complete dentures cover the entire palate area and replace the teeth in the anterior region. These two factors enhance impaired articulation and affect speech.[11] The results of this study align with this understanding, showing that tooth loss and denture use result in different formant values compared to those in participants with complete dentition. Although dentures aim to improve articulation, their quality significantly affects speech intelligibility. The results of this study in table 2 support the claim made by Knipfer et al. that stated the use of complete dentures will significantly improve speech intelligibility.[18] The difference in formant values in this study indicates that there is a difference in acoustic parameter scores of edentulous participants and complete dentition participants. This shows that tooth loss can cause articulation disorders.

This can be observed from the results of the above study, where the formant values of denture wearers differ from those of the complete dentition group. The results of this study (table 2) also demonstrate that tooth loss without dentures causes the highest speech impairment compared to participants who wear dentures and participants with complete dentition. Hassel and Holste (as cited in Dewita et al.) stated that speech disorders in complete denture wearers are believed to occur because denture elements and bases limit tongue space and alter the location of tongue articulation contact with the palate and mucosa of the alveolus.[22]

Formants are concentrated regions of sound signals that the auditory system, including the cochlea and brain, uses to decipher the complex frequency signals involved in producing speech sounds. In the production, perception, and description of speech sounds, the first three formants (F1, F2, and F3) are the most important sound frequency values.[23] In this study, the F1, F2, and F3 values show a pattern of similarity between participants without tooth loss and those wearing dentures. However, the F1 sound frequency demonstrates a significant difference when comparing individuals who have lost teeth and do not use dentures to those without tooth loss. This finding suggests that voice production is disrupted when a person has lost all their teeth. Changes in sound frequency due to the use of dentures can be observed in the formant values.[20] The F2 and F3 values reveal significant differences in voice intelligibility between denture wearers and non-wearers, supporting the study's hypothesis (table3). As Hussein et al, stated that there was a significant difference in sound level between individuals without dentures and immediately after using complete denture.[24]

The differences in formant values observed in this study are attributed to changes in the palatal contour of the dental arch area. Another factor contributing to impaired voice intelligibility is errors in the arrangement of denture elements.[24] Previous studies stated that if a denture maintains the natural contour of the palate and has an appropriate thickness, it will facilitate articulation by allowing normal tongue movement, resulting in no significant difference between the sounds produced with a denture and those produced by individuals with natural teeth. Additionally, changes in the voice of the denture wearers have been linked to the thickness of the denture base. If the denture base is too thick, it can cause difficulty in pronouncing the letters "s," "t," "d," and "n" due to premature contact between the tongue and the denture base.[2,25]

Even though the present study did not examine the thickness of the base or numerous other objective criteria shown to affect sound intelligibility, all respondents who had used dentures were gathered from one dental teaching hospital which has great concern on complete denture production standard practice. The result in table 3, demonstrate that the formant value (F1) in complete denture users is not significantly different from that of the group with complete dentition. The finding confirms that contributed factors mentioned above were controlled.

The loss of teeth or the presence of dentures leads to inappropriate movement and dispersion of articulation patterns as part of the acoustic energy. This causes a decrease in formant intensity and an increase in the range of formant values.[20] A coherence previous study stated that prosthodontics treatment improves phonation. During the initial pre-intervention assessment, 21 (54%), 3 (7.7%) and 15 (38.5%) patients in the experimental group demonstrated inadequate phonation of the 'S,' 'V,' and 'F' sounds, respectively. One week after-treatment, the number of patients experiencing acoustic disturbances (experimental group) decreased to 17 (43%), 1(2.6%) and 9(23%), respectively. Within one month of prosthodontic treatment, sound production clarity and intelligibility improved in 95% of cases. The improvement of phonation clarity in denture wearers can be seen in Table 2, where in this study it is proven that the formant values in denture wearers are quite close to the formant values in participants with natural teeth compared to edentulous participants.

This suggests that of spectral analysis of disordered phonation may be useful for the objective, qualitative, and quantitative assessment of pronunciation and the evaluation of treatment efficacy.[7] The current study's findings align with those of Godbole et al., who determined that individuals without dental prostheses exhibited significantly diminished speech intelligibility compared to those with dentures.[2] In contrast, Chaturvedi et al. examined speech intelligibility based on sound frequency and intensity rather than formant values. The study also revealed that speech intelligibility was significantly lower in the absence of dental prostheses than when dentures were present.[26] The same phenomenon can be observed in tables 2 and 3 of this study, where individuals without dentures have significantly higher formant values compared to individuals using dentures, particularly for F1 and F2 values.

This study has several limitations. First, the study only included six participants, as it is a preliminary study aimed at understanding and refining future research on phonetic changes after using complete dentures. A larger sample size with balanced gender representation would be ideal to enhance the generalizability of the findings. As a preliminary study, the results may not fully represent the broader population of interest. However, this study successfully assessed the sensitivity of the formant score using PRAAT software, laying the groundwork for future research with a larger population. Second, it would be ideal to follow up and compare the voice changes in the same participants from complete dentition to edentulism.

However, such long-term follow-up was not feasible due to the extended duration required and the multiple factors influencing voice changes, including the natural aging process. These constraints make it challenging to observe longitudinal voice alterations from complete dentition to an edentulous state. Lastly, comparing participants of similar ages is difficult, as complete dentition is more common in younger individuals, while edentulism is more prevalent in older populations. Further research should meticulously investigate the sources of speech intelligibility disturbances. Future research should include larger samples, adaptation periods, subjective feedback from denture users, and objective measurements on qualified complete dentures.

CONCLUSION

Tooth loss can lead to impaired voice clarity. This study found that using complete denture can help a person minimize sound distortion in formant value. The findings indicate that the formant score of a person with a complete denture is not substantially different from that of an individual with complete dentition. Conversely, individuals who have lost their complete dentures and not using complete denture may exhibit significant differences in voice quality. The implication of the study is that using complete dentures may help to improve phonetic impairment, and in analyzing complete denture users, it is imperative to consider not only mastication and aesthetic factors but also phonetic aspects. Formant values can serve as a clinical indicator for voice intelligibility disorders in individuals who use complete dentures.

Acknowledgement
We also would like to express our gratitude to Hibah Riset Kompetitif PUTI 2023 Universitas Indonesia for its financial support in publishing this paper.
Author Contributions: Conceptualization, AI and ST.; methodology, AI and K LS.; software, AI and TS.; writing original draft preparation, AI; writing review and editing, AI, TI, ST,K LS and HG, supervision, ST, TI, K LS
Funding: This research was funded by Hibah Riset Kompetitif PUTI 2023 Universitas Indonesia
Institutional Review Board Statement: Ethical approval for the study was obtained from the Faculty of Dentistry, University of Indonesia (protocol number: 070970922)
Informed Consent Statement: informed consent was obtained from all subjects involved in the study
Data Availability Statement:
The availability of research data will be given with permission from all researchers via email correspondence by paying attention to ethics in research.
Conflicts of Interest: The authors declare no conflict of interest

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