

Non-Contact Saliva Secretion Enhancement: Acoustic Radiation Pressure at the Submandibular Region

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I. INTRODUCTION

Dry mouth (xerostomia) is an increasingly recognized health issue, particularly among the elderly [1]. Reduced saliva secretion leads to discomfort and increases the risk of dysphagia, oral infections, and aspiration pneumonia, affecting about 30 % of those aged 65 and older, with higher prevalence over age 75 [2].

While manual salivary gland massage can promote secretion, its effectiveness varies by technique and is difficult for individuals to perform independently [3]. To overcome these issues, we propose a non-contact stimulation method using an Airborne Ultrasound Tactile Display (AUTD) [4], which applies focused ultrasound to the submandibular region via acoustic radiation pressure.

Effectiveness was evaluated using the spitting method [5]. Participants rested for two minutes, provided a baseline saliva sample, received AUTD stimulation with a 50 Hz square wave for two minutes, and then provided a second sample. Changes in saliva volume were analyzed to assess the stimulation effect.

II. EXPERIMENTAL METHODS

A. Experimental Setup

The experimental setup is shown in Fig. 1(a). As illustrated, four AUTD units were arranged to form an upward-facing phased array with dimensions of 384 mm × 303 mm. Participants positioned their jaws slightly above the array to receive ultrasound stimulation from below. (Fig.1(b))

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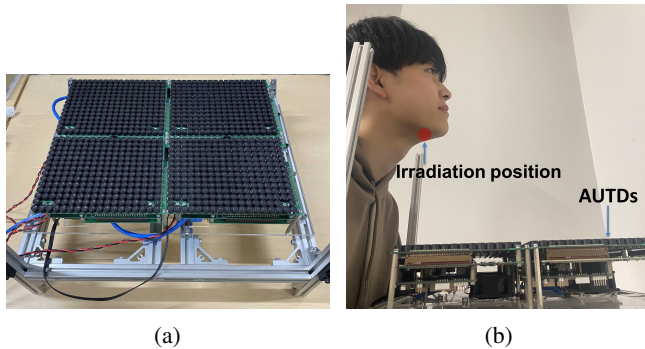


Fig. 1: The left figure shows four AUTDs that used for the experimental setup. The right figure shows the experimental scene

A focal point was set at 150 mm height. Ultrasound stimulation was applied to the submandibular region for two minutes using a 40 kHz carrier modulated by a 50 Hz square wave. The focal size was about 1 cm, matching the wavelength.

Sinusoidal modulation was also tested but provided smoother intensity transitions, which likely weakened the tactile sensation. As a result, saliva secretion was lower than with square wave modulation. Therefore, square wave modulation was adopted due to its stronger tactile effect.

B. Stimulation Site

In this study, we aimed to enhance saliva secretion through non-contact stimulation using acoustic radiation pressure, targeting the region typically stimulated in conventional submandibular gland massage [3]. The submandibular gland lies along the inner surface of the mandible, extending from below the ear to beneath the chin [6]. Gentle pressure on this area has been shown to increase saliva secretion; therefore, we applied ultrasonic stimulation to the same region to evaluate its effectiveness.

C. Experimental Procedure

In this study, we conducted a saliva collection experiment with participants to evaluate the effect of acoustic radiation pressure-based salivary gland stimulation on saliva secretion. The detailed procedure is described below.

1) Pre-experiment Preparation

- a) Participants were instructed to refrain from eating, drinking, or brushing their teeth for 1 hour before the experiment.
- b) To ensure a consistent environment, participants were instructed to sit in a relaxed state in a quiet laboratory.

2) Measurement of Baseline Saliva Secretion

- a) Participants remained still without swallowing saliva for 2 minutes (however, they were allowed to swallow saliva that accumulated in the throat).
- b) After 2 minutes, saliva was collected using the spitting method [5]. Specifically, participants spat saliva into a measuring cup, and the weight was measured using an electronic balance (precision: 0.001 g).

3) Presentation of Ultrasonic Tactile Stimulation

- a) A tactile stimulus modulated with a 50 Hz square wave was irradiated to the submandibular region for 2 minutes using the AUTD.

- b) Participants were allowed to swallow saliva freely during the ultrasound tactile stimulation.
- 4) Measurement of Saliva Secretion after Stimulation
 - a) After the ultrasonic stimulation ended, participants rested for 2 minutes as in step 2-(a).
 - b) After 2 minutes, saliva was collected again using the spitting method and evaluated based on its weight.

D. Analysis

The following procedure was used to analyze the experimental results:

- 1) The amount of saliva secreted during the resting period and after ultrasonic tactile stimulation was measured and compared.
- 2) The rate of increase in saliva secretion was calculated to assess the effect of acoustic radiation pressure stimulation.
- 3) A paired two-tailed t-test was performed to determine whether the increase in secretion was statistically significant.

III. EXPERIMENTAL RESULTS

In this study, the effect of non-contact stimulation using acoustic radiation pressure on saliva secretion was evaluated in six participants using the spitting method [5]. The mean salivary secretion (\pm SEM) was 0.677 ± 0.153 g at rest and 0.857 ± 0.154 g with irradiation (Fig.2(b)). A paired t-test revealed a statistically significant increase in secretion under ultrasound stimulation ($p = 0.021$) (Fig.2(b)). The rate of increase varied among participants, with a maximum increase of 256.41% observed in one case (Fig.2(a)).

IV. DISCUSSION

This study investigated whether ultrasound stimulation promotes saliva secretion. Unmodulated ultrasound had no significant effect, suggesting that tactile perception may contribute to salivation. Moderate stimulation proved effective, though individual differences in jaw positioning influenced results.

V. CONCLUSION

This study proposed a non-contact method for salivary gland stimulation using acoustic radiation pressure generated by a phased-array ultrasound device (AUTD). A 50 Hz square wave was applied to the submandibular region, resulting in increased saliva secretion, suggesting the method's potential for managing dry mouth in elderly or care-dependent individuals.

Although users currently perceive vibration during stimulation, future work aims to eliminate this sensation to improve comfort. Further research will focus on increasing the number of participants, optimizing stimulation parameters, and evaluating saliva quality and user experience. This approach could contribute to non-contact oral care solutions in medical and caregiving settings.

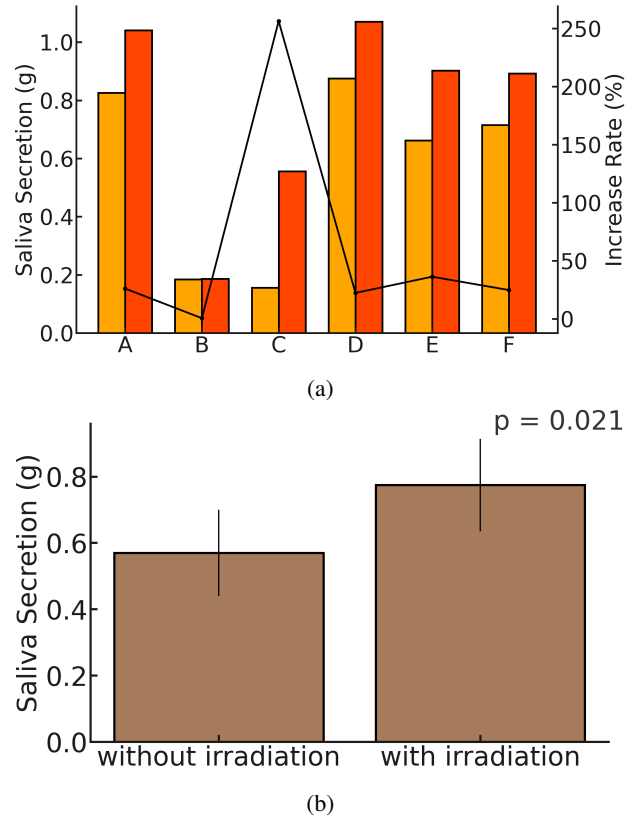


Fig. 2: The top figure shows Saliva Secretion With and Without Irradiation. The orange bars represent values measured without irradiation, while the red bars indicate values measured with irradiation. The brown line with circular markers shows the percentage increase in secretion for each participant.

The bottom figure shows Comparison of Saliva Secretion.

VI. ACKNOWLEDGEMENT

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