# Association of Mixing Ability with Oral Status among Thai Elderly

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## Abstract

The association of mixing ability with oral status is still limited in Thailand. This study aimed to investigate whether the mixing ability of older participant was associated with oral status, including the varying degree of occlusal support, periodontal status, and salivary flow rate. The cross-sectional study was conducted with 120 independently living older people aged 60 and over in Khon Kaen, Thailand. Dentate participants without denture replacement were recruited. Mixing ability was firstly measured by a two-color chewing gum mixing ability test with 20 chewing cycles and secondly determined the variance of hue (VOH) with the ViewGum software; inadequate mixing presents with a larger VOH. A calibrated dentist recorded the oral status and class of occlusal support according to the Eichner index. A structured questionnaire was used to obtain information on demographics, medical history, and oral health behaviors. Multiple linear regression analysis was used to evaluate the association between mixing ability and occlusal support while controlling for possible confounders. The result indicated that mixing ability was associated with occlusal support according to the Eichner index classification. (Beta: 1.041, 95% CI: 1.022 – 1.06), percentage of CAL ≥ 5 (Beta: 1.003, 95% CI, 1.002 – 1.004) but was not related to salivary flow rate after controlling for all possible confounders. This study suggested that mixing ability was associated with occlusal support according to Eichner index classification and periodontitis in the elderly.

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## Introduction

Thailand is experiencing a demographic transition due to the aging population. By 2040, Thailand's population of older people is expected to increase to 25 % of the population.[1] Deleteriousness of the physical in the elderly leads to a variety of health problems, including oral health problems. Moreover, a national oral health survey revealed high levels of tooth loss and a high prevalence of periodontal disease, indicating poor oral health among Thai older people.[2] The World Dental Federation Organization (FDI World Dental Federation) has redefined the word "oral health" as an important part of general health both physically and mentally. Chewing and swallowing are included in the ability of oral function[3], which may be different from other aging changes because of a remarkable change in tooth loss.

The goal of the masticatory function is to break food down into discrete portions by chewing and mixing the aliment with saliva in order to form a bolus that is safe to swallow.[4] Besides these functional aspects; mastication plays an important role which is considered the first link in the chain for proper digestion and absorption of nutrients. It is reported that the number of cycles needed to chew a standard piece of food increases progressively with age, with increased particle size reduction and longer chewing sequence duration.[5] Several factors might compromise the masticatory function. Most commonly, the lack of teeth or saliva, as well as reduced muscular forces which seem to accelerate dysfunction with aging, are associated with an impaired chewing function.[6] Two-colored chewing gum[7] has been used to asses the degree of bolus formation and color-mixing and to quantify masticatory performance. The mixing ability test with the two-colored chewing gum is a good method to determine masticatory function in participants with a compromised masticatory performance.[8]

Therefore, it is necessary to study factors that may be linked masticatory function to the aging process. However, there is no epidemiologic study of the relationship between oral status and masticatory performance among Thai older people. Therefore, we conducted a study that aimed to investigate the relationship between oral status and mastication performance characterized by mixing ability of older people in Khon Kaen, Thailand.

## Materials and Methods

This cross-sectional study was carried out among older people in the Muang District of Khon Kaen province during April-August 2017. The study protocol was approved by Khon Kaen University Ethics Committee for Human Research (HE602048). Eligibility criteria of participants included being 60 years of age or older at the time of the interview, and the ability to communicate. Exclusion criteria were: (1) having dementia or schizophrenia; (2) having a visual impairment, hearing impairment, or deafness; and (3) complete edentulousness; (4) wearing a denture. Stratified random sampling was employed to identify participants. Five sub-districts were randomly chosen to represent the central area of Muang district as well as the surrounding areas in each direction. Eligible participants in each sub-district were then randomly selected and invited to meet the investigators at a sub-district health center. All participants provided written informed consent before taking part in the study.

*Assessment of mixing ability*

The mixing ability test measures how well a participant mixes a two-colored chewing gum, which consists of the ''Hubba-Bubba Tape Gum'' (The Wrigley Company Ltd., England) used for testing. The test piece measured 30 mm x 18 mm x 3 mm and was made from the strips of the 'Sour Berry' (azure color) and 'Fancy Fruit' (pink color) gum. Strips of two-colored chewing gum were cut from both colors and manually stuck together.[9]

All the participant were examined and instructed by one operator. They were asked to sit upright with their heads in a natural position. Each participant was told to

chew one sample of gum on their preferred chewing side for 20 cycles and to terminate the act of chewing with their mouths closed. After that, the instructor had the participant open their mouths and remove the gum bolus with an explorer. Both the participant and the instructor counted the number of chewing strokes. The gums were then spat into transparent plastic bags and flattened to a wafer of 1 mm thickness and labeled with numbers.

The scanning took place within 24 hours, as the color of the chewing gum might degrade (saliva enzymes). Both sides of the samples were scanned using a flatbed scanner (resolution 300 dpi, Epson Perfection V750 Pro, Seiko Epson Corp., Japan) and subsequently copied into one image. The compound images were then assessed with a purpose-built program, which is freely available (ViewGum# software, dHAL Software, Greece, www.dhal.com). The variance of the hue (VOH) with no measurement unit is considered as the measure of mixing; inadequate mixing presents larger variance on the hue axis than complete mixing. The method used was originally described by Halezonetis et al.[10]

### Oral Examinations

Examinations of periodontal status dental caries and posterior occlusal contact were performed in the sub-district health center using mouth mirror and a periodontal probe. The participants were examined on a mobile dental chair under portable halogen light. Periodontal probing depth (PD) and clinical attachment levels (CAL) were examined using the random half-mouth six-sites per tooth protocol.[11] The examiner was well-calibrated with a periodontist. The duplicate examination was carried out in 10 percent of the samples. Intra-examiner and inter-examiner reliability of periodontal examination were good with an ICC>0.8 for each. Dental caries was evaluated using the World Health Organization (WHO) criteria, and decayed, missing, and filled teeth (DMFT) index was calculated. Posterior occlusal contact was recorded according to the Eichner Index[12], based upon existing contact points of natural teeth between the maxilla and mandible in the bilateral premolar and molar regions. According to the Eichner Index, the molar and premolar occlusal contacts of the residual teeth defined the classification. Group A had contact in four support zones; group B had one to three zones of contact or contact in the anterior region only; and group C had no occlusal contact at all, although a few teeth could remain.

### Stimulated salivary flow rate

Before oral examination and mixing ability test stimulated whole saliva was collected by the mastication method. The subjects were asked to swallow all the saliva in their mouths, chew a measured amount of paraffin wax (Orion Diagnostica, Finland) for 5 minutes at their own pace and then spit into a graduated tube. After collection, flow rates of the whole saliva were expressed as mL/min. Subjects were classified into two groups according to their salivary flow rates. Subjects whose stimulated salivary flow rate was less than 0.5 mL/min were placed in the hyposalivation group, and the remaining subjects were designated as the normal salivary flow group.[13]

### Statistical Analysis

Data are expressed as means and standard deviations (SDs) for continuous variables and as frequencies and percentages for categorical variables. Data was analyzed using IBM SPSS software version 19.0 (SPSS, Chicago, IL, USA). The periodontal status was assessed in the extent of periodontitis based on the percentage of sites with CAL ≥ 5mm which was obtained from (the total site of periodontal pockets with CAL ≥5mm / total number of probed pockets) x 100. Pearson correlations were used to test the association of percent of CAL ≥ 5 and salivary flow rate with mixing ability. The independent T-test was used to test for differences in mixing ability among socioeconomic status and health behavior, and One-Way ANOVA was performed to test for differences in mixing ability among subgroups A, B, C according to the Eichner Index. A multiple linear regression analysis was carried out to test the relationship of each explanatory variable with the outcome variable (mixing ability: The

variance of the hue (VOH)) after controlling for the other factors. With the explanatory variable, the salivary flow rate and periodontal status based on the percentage of sites with CAL≥5 mm were used as continuous variables. Gender had only two categories and was scored as female = 0, male = 1. Posterior occlusal contact had three categories, from which dummy variables were created.

## Results

### Characteristics of the older participants

There were 120 older participants in this study, with an average age (SD) of 70.2 (6.7) years old. The oldest was 89 years old. The majority of participants were female (59.6 %), married (55.1 %), having a primary school education (60.5 %), and living with family (93.8 %). More than half (65.0 %) were not working, 17.5 % worked in agriculture, and the rest either had their own business or were employed (Table 1). Most participants were non-smokers and non-alcohol drinkers. Only 29.2 % were free of systemic diseases. Regarding oral health behaviors, 94.2 % of the participants brushed their teeth daily, and 75.8 % used fluoride toothpaste. More than 80 % had previous dental treatment, but only 43.3 % had an annual dental visit (Table 2).

*Table 1*  *Characteristics of Study Participants (n = 120)*

| Characteristic | N (%) |
| --- | --- |
| Gender | |
| – Male | 49 (40.8) |
| – Female | 71 (59.2) |
| Age in years | |
| – 60-69 | 59 (49.2) |
| – 70-79 | 46 (38.3) |
| – ≥80 | 15 (12.5) |
| Marital status | |
| – Not married | 56 (46.7) |
| – Married | 64 (53.3) |
| Education | |
| – No formal education | 8 (6.7) |
| – Primary school | 70 (58.3) |
| – Secondary school or higher | 42 (35.0) |
| Occupation | |
| – Not working | 78 (65.0) |
| – Employed | 8 (6.7) |
| – Agriculture | 21 (17.5) |
| – Business | 13 (10.8) |
| Living arrangement | |
| – Alone | 10 (8.3) |
| – With children | 39 (32.5) |
| – With spouse | 57 (47.5) |
| – With relatives | 14 (11.7) |

**Table 2** *Health Behavior Information (n = 120)*

| Characteristic | N (%) |
|---|---|
| **Current smoking** | |
| – Yes | 21 (17.5) |
| – No | 99 (82.5) |
| **Alcohol drinking** | |
| – Yes | 46 (38.3) |
| – No | 74 (61.7) |
| **Presence of systemic disease** | |
| – Absent | 35 (29.2) |
| – Present | 85 (70.8) |
| **History of dental treatment** | |
| – No previous treatment | 24 (20.0) |
| – Had previous treatments | 96 (80.0) |
| **Annual dental visits** | |
| – No | 68 (56.7) |
| – Yes | 52 (43.3) |
| **Frequency of tooth brushing** | |
| – Less than once daily | 7 (5.8) |
| – At least once daily | 113 (94.2) |
| **Type of toothpaste** | |
| – Fluoride toothpaste | 83 (75.8) |
| – Non-fluoride toothpaste | 29 (24.2) |

The average mixing ability was 0.14 (SD = 0.12, min = 0.016, max = 0.659). The prevalence of caries experience (DMFT>0) among older people was 81.3 %, with the average DMFT of 15.8 (SD = 7.1). The average number of remaining teeth was 21.6 (SD = 2.9). Regarding periodontal status, the participants had an average CAL of 4.3 (SD = 1.7) mm. Most participants (88 %) had at least one site with CAL≥5 mm. The average percentage of the site with CAL ≥5 mm was 35.8 (SD = 30.1). The average stimulated salivary flow rate was 0.78 (0.32) ml/min. When the participants were classified based on the posterior occluding teeth according to Eichner's index, the majority was subtype B (55.8 %) followed by subtype A (32.5 %) and subtype C (11.7 %) respectively.

Tables 3 and 4 show the bivariate analysis of factors related to mixing ability with Variance of Hue as the outcome. Mixing ability was significantly associated with gender, marital status, posterior occluding teeth according to Eichner's index, percentage of CAL ≥ 5, and salivary flow rate.

*Table 3* Factors Associated with Mixing ability among older people in Khon Kaen Province

| Characteristic | Mixing ability (Variance of Hue) Mean (SD) | P-value |
|---|---|---|
| **Gender** | | |
| – Male | 0.11 (0.09) | **0.004** |
| – Female | 0.17 (0.12) | |
| **Marital status** | | |
| – Not married | 0.18 (0.14) | **0.004** |
| – Married | 0.11 (0.09) | |
| **Dental caries** | | |
| – No | 0.16 (0.12) | 0.43 |
| – Yes | 0.14 (0.12) | |
| **Eichner 's index** | | |
| – Eicher A | 0.082 (0.066) | **< 0.001*** |
| – Eicher B | 0.161 (0.123) | |
| – Eicher C | 0.266 (0.138) | |
| **Annual dental visits** | | |
| – No | 0.16 (0.12) | 0.29 |
| – Yes | 0.13 (0.12) | |
| **Presence of systemic disease** | | |
| – Absent | 0.14 (0.12) | 0.99 |
| – Present | 0.14 (0.12) | |
| **Frequency of tooth brushing** | | |
| – Less than once daily | 0.15 (0.14) | 0.49 |
| – At least once daily | 0.13 (0.10) | |

*Boldface indicates statistical significance.*

*\*Statistically significant differences were found at each comparison of Eichner subgroup, One way ANOVA test*

*Table 4* Factors Associated with Mixing ability among Elderly in Khon Kaen Province in Pearson's correlation

| Factors | Mixing ability | Percent of CAL ≥ 5 | Salivary flow rate |
|---|---|---|---|
| **Mixing ability** | | | |
| R | | | |
| *P*-value | | | |
| **Percent of CAL ≥ 5** | | | |
| R | 0.305 | | |
| *P*-value | **0.001** | | |
| **Salivary flow rate** | | | |
| R | - 0.303 | - 0.090 | |
| *P*-value | **0.002** | 0.368 | |

*R signifies a Pearson correlation coefficient, Boldface indicates statistical significance*

Table 5 presents the multivariate linear regression analyses of the associations of mixing ability with other factors. The results showed that mixing ability was significantly associated with the posterior occluding teeth according to Eichner's index (beta: 1.041, 95% CI: 1.022 – 1.06), percentage of CAL ≥ 5 (beta: 1.003, 95% CI: 1.002 – 1.004) and gender (beta: 1.173, 95% CI: 1.104 – 1.242) but, salivary flow rate lost the significant association with mixing after controlling for other factors.

**Table 5** *Associations between mixing ability and factors among older people in Khon Kaen province in multivariate multiple linear regression analysis for mixing ability*

| Factors | Beta (95% Confidence Interval) | *P*-value |
|---|---|---|
| Eichner 's index | 1.041 (1.022 – 1.06) | **0.035** |
| Percent of CAL ≥ 5 mm. | 1.003 (1.002 – 1.004) | **0.029** |
| Salivary flow rate | 0.896 (0.836 – 0.956) | 0.073 |
| Female | 1.173 (1.104 – 1.242) | **0.022** |

*Boldface indicates statistical significance.*

*Dependent variable: mixing ability.*

*Beta signifies a standardized partial regression coefficient, which indicates the relative importance of each variable.*

*Percent of CAL ≥ 5 mm, Salivary flow rate were used as continuous variables.*

*Gender: female = 1, male = 0 (male was the reference group)*

*Eichner's index: subtype A = 0, subtype B = 1, subtype C = 2 (subtype A was the reference group)*

## Discussion

Studies reported that factors that affect masticatory performance are associated with a decline of oral health condition[14-17], which seem to accelerate dysfunction with aging. To our knowledge, this was the first epidemiologic study investigating the association between mixing ability and oral status among Thai older people. Our results support the hypothesis that mixing ability dysfunction associated with a decreased condition of oral status. The present study found that persons subjected to low mixing ability have severe attachment loss and less occlusal supporting zone than those with high mixing ability in which potential confounders such as gender and salivary flow rate could be controlled.

The major strength of this study is that the main outcome variable was determined by measuring the mixing ability, which is now widely used, and to evaluate the ability to mix and knead a food bolus. Two-color chewing gum[8,9,18-20] has been used for testing for the quantification of masticatory performance among older people. Validity and reliability studies have shown that mixing ability tests are a reliable alternative to comminution tests.[21,22] CAL used for evaluating periodontitis, which is a disease that can newly develop, regress, or progress over time. As an attachment loss requires long periods to develop[23], the CAL measurement can support the validity of periodontitis case ascertainment. A full-mouth periodontal examination (FMPE) is time-consuming in periodontal surveys then the random half-mouth six-sites per tooth protocol was used. This method produces the smallest bias and provides the best agreement with FMPE in estimating periodontitis severity as determined by CAL, PD, and BOP.[11] The Eichner's index was used to classify the occlusal supporting zones that consist of a pair of permanent teeth in the molar and premolar areas.[12] These areas are very important to support for chewing food. Having no occluding support area will directly affect the efficiency of chewing ability. Posterior occlusal contacts of the remaining teeth have been

confirmed as key predictors of the reduction of masticatory performance in an earlier study.[24] The previous study has demonstrated that replacing missing teeth with a removable prosthesis cannot approach the efficiency of a complete natural dentition.[25] These reveal that the preservation of posterior functional teeth may be of primary importance for masticatory performance. Several studies provided evidence that masticatory performance was associated with tooth loss.[26] The present study also showed that the number of remaining teeth according to Eichner's index is associated with mixing ability and more strongly in Eichner group A than in groups B and C. These results suggest that the preservation of posterior functional teeth may be of primary importance for masticatory performance.

The results of our study showed the deficient mixing ability among those who have severe periodontitis, which is similar to the study in patients with various periodontal conditions. The periodontal status ranging from healthy to generalized disease categorized by the alveolar bone height–to–tooth length evaluated the effect of periodontitis on masticatory performance revealed that the masticatory performance had a significant correlation with the alveolar bone height. Therefore, the loss of periodontal supporting structures has negative effects on masticatory performance.[27] Natural teeth are equipped with extremely sensitive tactile sensors – periodontal mechanoreceptors situated in the periodontal ligament provide detailed information about intensive and spatial aspects of tooth loads, which support the neural control of masticatory forces.[28-30] Reduced periodontal tissue support accompanies impaired regulation of masticatory forces. Faulty mechanoreceptive innervation of the periodontal ligament and a change in biting strategy due to the weakened support of the teeth may account for the more defensive food‑splitting behavior.[31]

Mouth dryness is a common complaint amongst older people and is often associated with diseases and therapeutic medication[32], which suggests hyposalivation is not a physiological, but rather a pathological, age-related characteristic. The association showed that the stimulated salivary flow rate was significant with masticatory performance in the bivariate analysis by lost significance in linear regression analysis after controlling for other factors. Additional analysis was done, and there was a low prevalence of low stimulated saliva flow with 30 % of the study population, which could affect the power of test when adjusted in the final model. The results implied that xerostomia and other dysfunctions related to salivary supply might negatively influence the masticatory process by making it impossible for participants to gather food into a bolus before swallowing.[33] An experimental study showed that the masticatory ability of 15 nondysphagic volunteers aged 22–31 years with natural dentitions was not influenced by experimental oral dryness. The study of 328 independently living people over the age of 60 years also suggested that salivary flow rate is not linearly associated with masticatory performance.[6]

As in other investigations showed inconsistent results, some studies found that gender did not affect masticatory performance[34] but, the study in Japan revealed that the occlusal force in females was significantly lower than in males.[26] Results of this study indicate that the mixing ability in females was significantly lower than in males. Additional analysis was conducted to assure the confounding effect of age, and there is no statistically significant difference between male and female with an average age of 70.8 years and 69.7 years old, respectively. This finding is consistent with mastication; females might compensate for their low muscle strength by increased coordination of other motor and sensory functions.

The findings reported in our study does not establish causality. The cross-sectional study would be difficult to infer the temporal association between a risk factor and an outcome. Therefore, only an association can be inferred. The measurement results of mixing ability test with two-colored chewing gum will tell the effect of the ability to mix the colors of the gum in term of "variance of hue." The result with inadequate mixing ability presents with larger variance on the hue than

complete mixing. However, there is still no cut off point that indicates the level of sufficient mixing ability. As there are many factors related to mixing ability and answering such questions requires further study or additional measurement. Our study was limited to the younger side of the old – middle old (60 to 79) group; the mean age of this study population is 70.2 ± 6.7 years. Most people in their 60s and early 70s are still fit, active, and able to take care of themselves and may consent to take part in the study differently from the oldest side of the old group (85+).[35] These may be prone to non-response bias; therefore, the results cannot be automatically applied to the oldest side of the old groups. Suggestions for future research are to increase the number of participants and collect more information which would allow for analysis of possible confounding factors. In the future, longitudinal studies are needed to confirm the causal relationship between oral conditions and mixing ability.

## Conclusions

This study provides some evidence of an association between mixing ability and oral status in terms of periodontitis and posterior occlusal contact in older adults when potential confounders, including gender and salivary flow rate, were controlled. Although our results cannot prove a causal relationship, these findings might have valuable implications for the prevention of oral disease and declining of mixing ability in older people.

## Acknowledgment

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