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Assessment of age-related changes on oral diadochokinesis and masticatory function in healthy old adults

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Assessment of age-related changes on oral diadochokinesis and masticatory function in healthy old adults

Directed by Professor Bock-Young Jung

A Masters Thesis

Submitted to the Department of Dentistry

and the Graduate School of Yonsei University

in partial fulfillment of the requirements for the degree of

Master of Dental Science

Seyeon Min

December 2023

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2023 년 12 월 민세연 올림

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TABLE OF CONTENTS

연세대학교
YONSEI UNIVERSITY

`

연세대학교
YONSEI UNIVERSITY

LIST OF FIGURES

연세대학교
YONSEI UNIVERSITY

LIST OF TABLES

연세대학교
YONSEI UNIVERSITY

APPENDIX

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Abstract

Assessment of age-related changes on oral diadochokinesis and masticatory function in healthy old adults

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(Directed by Professor Bock-Young Jung, D.D.S., M.S.D., Ph.D.)

Purpose

This cross-sectional study aimed to identify the age-related change of oral diadochokinetic function and its association with various orofacial factors in healthy old adults. There is a lack of consensus diagnostic values of tongue-lip motor function and oral dryness to diagnose oral frailty.

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Material and Methods

A total of 385 healthy participants were divided into three different age groups: 20–64 years(Gr1); 65–74 years(Gr2); and ≥75 years(Gr3). To investigate the tongue-lip motor functional ability, oral diadochokinesis(ODK) was assessed as the number of repetitions of the monosyllable /pa/ta/ka/. Both subjective and objective masticatory functional assessments were conducted for masticatory function evaluation. Four questionnaires were used for subjective masticatory ability, cognitive ability, and psychological status. For the dynamic objective masticatory function, masticatory performance(MP), bite force(BF), and occluding area were examined, and for the static objective masticatory function, the number of remaining teeth and functional tooth pairs. Handgrip strength(HG), oral dryness, and tongue pressure(TP) were assessed to identify influencing factors. Intergroup differences were evaluated by the ANOVA and Kruskal-Wallis test, and the correlations between ODK and orofacial factors were evaluated.

Results

This study revealed significant age-related declines in TP, HG, and ODK /pa/ta/ka/, especially after 65 years. PHQ-9 scores and oral dryness showed significant differences between Gr1 and Gr3. Factors affecting MP were Posterior teeth, Eichner index, BF, Occluding area, KMMSE, ODK /pa/ta/ka/. MP is affected by /pa/ta/ at age for Gr2 and /pa/ta/ka/ for Gr3. Each syllable of ODK was associated with different factors but common factors associated with ODK /pa/ta/ka/ were MP, HG, and PHQ-9. For the syllable /pa/ta/,

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Eichner Index, TP, and oral dryness were additionally associated. MP, TP, HG, oral dryness, and KMMSE were associated ODK/ka/ in Gr3.

Conclusions

The cut-off values of each orofacial factor and each association with MP and ODK were investigated for the diagnosis of oral frailty and oral hypofunction, the findings of which could give a practical intuition for recovery of oral functio n in old adults. These findings contribute to a comprehension of age-related variat ions in oral function and the multifactorial nature of masticatory dynamics.

Keywords: Masticatory performance, Oral diadochokinesis, Tongue-lip motor function, Swallowing function, Oral frailty

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Assessment of age-related changes on oral diadochokinesis and masticatory function in healthy old adults

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Ⅰ. INTRODUCTION

The age-related functional deterioration of orofacial structures defined as oral frailty has been focused and various several masticatory parameters have been presented as the important factors to masticatory performance (MP) in geriatrics (1-3). A position paper of the Japanese Society of Gerodontology (JSG) classified the orofacial state into four stages: healthy state, oral frailty, oral hypofunction, and oral dysfunction, and suggested that the stage of oral frailty and oral hypofunction could be restored to the previous stage by performing dental treatment intervention

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before oral dysfunction stage of irreversible condition (4). Therefore, a number of previous studies have focused on establishing a clear diagnostic system and its standardization as well as the interactive association between oral-masticatory factors (3, 4).

Oral function has been investigated by assessing multiple related factors including oral uncleanness, oral dryness, bite force (BF), tongue-lip motor function, tongue pressure (TP), swallowing function, the number of remaining teeth, functional tooth pairs and MP, which could impair the essential activities of daily living and contribute to physical frailty (2-6). In addition, physical, psychological, neurologic, structural factors are associated with “oral frailty” and malnutrition is the most relevant factor in the old adults (7, 8).

Swallowing disorders, or dysphagia, can be caused by aging, swallowing-related muscle degeneration, sarcopenia, physical frailty and comorbidities. Dysphagia is known to be related with malnutrition, dehydration, aspiration pneumonia leading to significant mortality and morbidity (9). Swallowing requires the coordinated activity of many nerves and muscles of mouth, lips, pharynx, and esophagus (10, 11). Especially, oropharyngeal dysphagia encompassing oral cavity of an initial voluntary component and the pharynx of more reflexive component is

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an essential domain (10).

Oral stage could be divided into two stages of oral preparatory phase and propulsive stage (10). The preparatory phase is more complex for solid food than liquid because the food should be transported over the teeth to be chopped down and mixed with saliva, then be positioned and swallowed as like liquid. At the initial stage of swallowing, the bolus is temporarily positioned within the anterior portion of the mouth, in front of the posterior wall of the transient cavity created by the middle portion of the tongue and the soft palate. Then during oral-propulsive stage, the bolus of fluid is positioned on the superior surface of the tongue, and the tongue tip is then placed against the roof of the mouth and through anterior to posterior flexion, forces the bolus toward the pharynx (9). Normal swallowing requires harmonized nerve and muscle coordination such as the superior laryngeal nerve, a branch of the vagus nerve, tongue, and the supra-hyoid muscle. (9, 10)

Tongue-lip motor function as an indicator of orofacial function, is generally assessed using Oral Diodochokinesis(ODK) based on the linguistic background (4, 11). Decreased Tongue-lip motor function can be a result of sensory impairments in brain function or perioral muscle function such as Parkinson’s disease, traumatic injury, head and neck surgery, muscle atrophy, and malnutrition (4). A few recent

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studies reported that the reduced ODK is associated with declined swallowing function (12-15). In the process of swallowing, the initial motion of tongue is related with /ta/, and the latter is similar to /ka/ pronunciation, especially in ODK /pa/, and /ka/ was reported to be significantly related with swallowing function and lips also help to create a tight seal which prevents food and liquids from leaking during the swallowing reflex as well as from food trapping into the buccal or labial sulci (10-12). Meanwhile, some researchers have claimed controversial outcome about ODK parameters, that /pa/ sound for <6.2 times/s is associated with swallowing problems, suggesting the importance of maximum voluntary lip force (4, 11, 12). There is neither sufficient evidence for the association of each component of ODK /pa/, /ta/, and /ka/ with the change of the tongue-lip motor function, especially swallowing function, depending aging, nor enough data to apply to clinical investigations. Even it is clear that the role of lip-tongue motor function is crucial in swallowing and MP in the old population (12, 15-17), however there is a lack of evident findings regarding the association of each oral functions with ODK and MP.

Decreased TP refers to a reduced ability to force the bolus toward the pharynx suggesting impaired swallowing. The cut-off value to diagnose the decreased TP in the old population has been suggested from 26-30 kPa (4, 8).

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Several previous epidemiologic studies reported Oral dryness, manifesting as a prodromal sign of oral frailty, is known to be caused by various factors such as medication, poor general health, aging and female gender (4, 18). However, there are controversial findings about association between chewing function and the salivary flow in vulnerable old individuals (19, 20). Oral dryness could be also a risk factor of declined swallowing function. A cross sectional study on lip-motor function and associated orofacial functions reported that xerostomia was negatively correlated with lip force and reduced number of ODK /ka/, causing a higher chance for subjective swallowing difficulties even more in the older group (11).

By establishing a standard value for tongue-lip motor function according to the age, it will be possible that oral frailty or oral hypofunction can be diagnosed quantitatively and qualitatively in a timely manner in the old population. However, there is currently a lack of researches on the consensus diagnostic values of tongue-lip motor function including ODK values, TP, and Oral dryness. The goal of this study is not only to assess ODK, TP, and oral dryness in old individuals with normal dentition to establish normal data, but also to identify affecting factors and to determine their association with MP. The null hypothesis of this study that there are no significant differences in ODK and other orofacial factors among the age groups

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II. MATERIALS and METHODS

Study participants

Among the patients who visited the Department of Advanced General Dentistry of the Yonsei University Dental Hospital from August 2020 to January 2023, 385 participants (168 males and 217 females) who met the following criteria were included: the patients 1) who were over 20 years old and capable of independent activities of daily living (ADL); 2) who had at least 20 remaining teeth, including fixed dental prostheses without any chewing difficulties. The participants 1) who had a history of surgical intervention or radiation therapy in head and neck area, 2) who had on going dental treatment or removable dental prostheses, and 3) who had the disease causing declined oral function such as stroke, dementia and temporomandibular disease were excluded. Of the 420 participants, 35 individuals with insufficient recordings were also excluded. Sample size was determined based on G *power 3.1 software (Kiel University, Kiel, Germany) with an α of 0.05, power as 0.8, and an effect size of 0.25.

Study design

This study was conducted according to the guidelines of the Declaration of Helsinki and approved by the institutional review board committee of the Yonsei

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School of Dentistry (No. 2-2020-0047). For masticatory function evaluation, both subjective and objective assessments were performed regarding various orofacial factors (Figure 1). The identical methodologies for subjective and objective masticatory assessment, used in our previous researches were applied (21, 22). Two trained researchers conducted both objective and subjective functional examinations based on outpatient protocol for all participants.

Objective assessment

Objective assessments can be categorized into static and dynamic domains. The static assessment encompasses the dental status indicating the current state of oral structures. The number of remaining teeth and Eichner Index of function tooth pairs was determined by counting the teeth that were natural or restored, except third molars and root rests.

The objective dynamic masticatory function was investigated through masticatory performance test and bite force test.

Dental status, Masticatory performance (MP), Tongue pressure (TP), Bite force (BF), Hand grip (HG), Occluding area.

MP was assessed using the glucose concentration derived from chewed gummy jelly (Gurucolum, GC, Tokyo, Japan). The participants were instructed to

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chew a jelly for 20 seconds and subsequently rinsed with distilled water, then, the glucose concentration was then measured using a special device (Glucosensor GS-2, GC, Tokyo, Japan). TP was measured using a balloon-based device (TPM-01, JMS, Hiroshima, Japan). Participants were asked to press the balloon probe against the anterior hard palate, maintaining peak pressure for approximately 7 seconds and the average of three trials was recorded. BF and occluding area were analyze using a pressure-sensitive sheet (97μm). Participants were asked to bite a sensor sheet at maximal force for 3 seconds, ensuring Frankfort's horizontal plane remained parallel to the ground. Analysis utilized a bite force analyzer (Dental Prescale 50H, GC, Tokyo, Japan) and Occluser 709 software (Occluser 709, GC, Tokyo, Japan) (21). HG, reflecting overall bodily strength, was tested using a handheld dynamometer (TKK 5401, Takei Scientific Instruments Co., Ltd., Tokyo, Japan) (22). Participants were asked to stand and grab a dynamometer in their hand with maximum power at attention posture and instructed to squeeze the grip continuously with full force. The HG value is obtained by alternating between the left and right sides in two consecutive repetitions each and then calculating the mean.

Oral diadochokinesis (ODK)

ODK was performed by recording the number of repetitions for the

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monosyllables /pa/, /ta/, /ka/ per second to evaluate movement capacity of the lip, the anterior region of the tongue and the posterior region of the tongue, respectively using an automatic measuring device (Kenkou-kun Handy, Takei Scientific Instruments Co., Ltd., Tokyo, Japan). Each syllable is pronounced audibly for a total of 5 seconds, and the evaluation involves determining the number of syllables pronounced per second.

Oral dryness

Oral dryness was measured by using an oral moisture-checking device (Mucus® , Life Co., Ltd., Saitama, Japan). Oral moisture was measured on the center of the lingual mucosa approximately 10 mm from the tip of the tongue with a disposable polyethylene covered sensor. The measurements were made three times and the mean was used. Oral moisture values range from 0 to 99.9, and values of ≥29.6, 28.0–29.5, and ≤27.9 are defined as normal, borderline dry mouth, and dry mouth, respectively (23). The sensitivity and specificity values are close to 80%.

Subjective Assessment

Four questionnaires such as Food Intake Ability (FIA), OHIP-14, KMMSE (Korean-Mini-Mental State Examination), and Patient Health Questionnaire-9 (PHQ-9) were used for subjective masticatory ability, cognitive ability, and

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psychological status.

FIA was evaluated by asking the subjects to complete questionnaires listing 14 kinds of food ranging from soft and easy-to-chew food to hard food (22). A five-point Likert scale was used to score masticatory ability for 1 point (cannot chew at all); 2 points (difficult to chew); 3 points (cannot say either way); 4 points (can chew some); and 5 points (can chew well).

OHIP-14 is one of the commonly used questionnaires for assessing Oral Health-Related Quality of Life (OHRQoL). This questionnaire evaluates seven items, including functional limitation, pain, psychological discomfort, physical disability, psychological disability, social disability, and handicap, using a four-point Likert scale (0 = never, 1 = hardly ever, 2 = occasionally, 3 = fairly often, and 4 = very often). A lower total score indicates better OHRQoL (24).

KMMSE questionnaire, consisted of 30 questions and each question assigned a score of either 0 or 1 point, score ranges from 0 to 30, with lower scores indicating more significant cognitive impairment. To identify individuals with mild cognitive impairment (MCI), a previous study's threshold of 23 points was used as a cut-off score for inclusion in the MCI group (21).

The **PHQ-9** is used for assessing self-reported depression severity, following the scores ranging from "0" (not present at all) to "3" (present nearly every day) for each of the 9 criteria from the DSM-IV. PHQ-9 scores of 5, 10, 15,

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and 20 correspond to classifications of mild, moderate, moderately severe, and severe depression, respectively (25).

Data analysis

All statistical analyses were carried out using SAS 9.4 (SAS Institute, Inc., Cary, NC) and R (version 4.0.0, R Foundation for Statistical Computing, Vienna, Austria) with a significance level of α =0.05. Normality was assessed using the Shapiro-Wilk test. One-way analysis of variance (ANOVA) and the Kruskal-Wallis test were used to compare continuous variables for normally distributed and non-normally distributed data, respectively. The intragroup differences were analyzed by repeated measures ANOVA with Bonferroni post hoc corrections. To determine the statistical correlation between ODK and masticatory function, multiple generalized linear analyses were performed. All of the methodologies were reviewed by an independent statistician.

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III. RESULTS

Demographic information

The participants consisted of 217 women (56.36%) and 168 men (43.64%) and the mean age of 61.30 years. (Table 1)

Subjective and objective masticatory function among age groups

Table 2 showed various statistical differences regarding orofacial factors. Eichner index, TP, HG, and ODK /pa/ta/ka/ showed a significant decline with increasing age. The number of remaining teeth, posterior teeth, Occluding area, and BF showed significant difference between Gr1 and Gr2, Gr1 and Gr3 but didn't show difference between Gr2 and Gr3. There was significant decrease in FIA only between Gr 1 and 2. Significant differences in PHQ-9 and Oral dryness were observed between Gr1 and Gr3. KMMSE, MP, and OHIP-14 presented no significant differences between the age groups.

Multiple linear regression analysis with ODK

Table 3 presents the outcomes of multiple linear regression analysis for factors associated with ODK after adjusting sex, age, and BMI. Significant associations were observed with Eichner index, MP, TP, BF, HG, oral dryness,

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KMMSE, and PHQ-9 for both /pa/ and /ta/, and Occluding area was additionally significant in /ta/. For /ka/, significant associations were present with MP, HG, and PHQ-9.

Table 4 shows the regression analysis for ODK by age groups. In Gr 1, HG, and PHQ-9 were significant factors associated with ODK /pa/, while BF, occluding area, HG, and PHQ-9 were associated with ODK /ta/. For ODK /ka/, BF, HG, and PHQ-9 were associated. In Gr 2, MP was significantly associated with ODK /pa/, while MP and Occluding area for /ta/. No factors were associated with ODK /ka/. In Gr3, Eichner index, MP, TP, HG, and OHIP-14, and KMMSE were significant factors for ODK /pa/, meanwhile, Eichner index, MP, TP, HG, OHIP-14, KMMSE, and PHQ-9 were significant with ODK /ta/. For ODK /ka/, MP, TP, HG, Oral dryness, and KMMSE showed significance with ODK /ka/.

Multiple linear regression analysis with MP

Table 5 presents the results of multiple linear regression analysis on factors affecting MP after adjusting gender, age, and BMI. Significant associations were observed with Posterior teeth, Eichner index, BF, Occluding area, KMMSE, ODK /pa/ta/ka/. Oral dryness did not show a significant association to MP.

The regression analysis of MP by age group indicated as follows (Table 6): 1) In Gr 1, BF and PHQ-9 were significantly associated with MP. 2) In Gr 2, TP,

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BF, occluding area, ODK /pa/ta/, and FIA were significant factors. 3) In Gr 3, Eichner index, BF, ODK /pa/ta/ka/, and KMMSE showed significant associations.

Normal distribution histogram of factors affecting masticatory functions

Figure 2 presents the normal distribution histogram of factors affecting masticatory functions divided by age groups and sex. Supplement assessment of the variables of oral function among age groups is shown in Table A1 and Figure A1.

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IV. DISCUSSION

The study aimed to analyze ODK and MP to establish the normal range of ODK according to age in healthy old individuals with normal dentition, with the goal of early detection and screening for swallowing hypofunction. Additionally, the study explores the correlation between ODK and various orofacial factors.

While most studies on geriatrics or gerontology involve individuals over 60 or 65 years as the elderly, the age was set based on the general trend of classifying individuals as senior citizens at or above the age of 65 in this study. At the initial stage of this study, participants were divided into four age categories; Gr 1(20-44 years), Gr 2(45-64 years), Gr 3(65-74 years), and Gr 4(over 75 years). However, there were no significant differences in orofacial variables between Gr 1 and 2. Therefore, the participants were divided into three groups, Gr 1(<65 years old), Gr 2(65-74 years) and Gr 3(≥75years). Given the cross-sectional nature of the study, a careful attention was noted to participant selection to avoid the confounding effects on the validity and reliability of the research findings. The participants were enough healthy from the perspective of physical and mental condition to manage ADL and IADL (26), in addition, they had 26 ± 4.16 teeth at least which is considered a sufficient number of teeth to support masticatory

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function based on the short arch concept (4, 21, 26).

The muscle-related orofacial factors such as TP, HG, and ODK values turned out to continuously decrease with aging while the dentition-related variables such as the remaining teeth, functional tooth pairs, BF, and Occluding area showed significant changes after 65 years old. In addition, PHQ-9 and oral dryness indicated meaningful differences at 75 years. The continuous decrease of the muscle-related orofacial factors can be supported by the previous studies that human age-related muscle atrophy begins at the age of 25 years and continuously progressed and accelerated after the age of 60 (11, 22, 27). Therefore, the first hypothesis was rejected.

On the other hand, KMMSE, MP, and OHIP-14 showed no significant differences by age groups. It is noteworthy that despite significant differences in both dentition and muscle-related factors, there was no age difference in MP, whereas there was a significant difference in FIA between Gr 1 and Gr 2, These findings can be interpreted that although structural changes begin at the age of 65 and muscle-related factors continue to change after the age of 65, MP and OHIP-14 can be to recovered through adaptation to the oral environment.

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In this study, three syllables /pa/ta/ka/ of ODK showed significant differences among the different age groups and the mean values of each syllable was lower than those of the JSG position paper (4), even all participants were physically healthy with normal masticatory function (Table 2). Schimmel et al observed that a significant difference was shown for only the monosyllable /ta/ depending age groups and each age group represented the different ODK mean score which also was lower than the cut off values described in the previous studies which did not take into consideration the age of the elderly, frailty severity, dental status of the participants (11-13). A need has been suggested to re-evaluate the cut-off values used to diagnose ODK or oral frailty, not only among Japanese populations but also in European society (11). The findings of this study also suggest the age-related ODK thresholds should be redefined and customized based on mother tongue languages, integrated frailty or ethnicity to diagnose tongue-lip functional ability such as swallowing.

Considering the association between ODK and orofacial functional factors, three common factors – MP, HG, and PHQ-9 appeared to have influences on the ODK of /pa/ta/ka/. For the syllable /pa/ and /ta/, the Eichner index, BF, TP, and KMMSE appeared to be significantly associated (Table 3). Several researches have reported the controversial results that the /pa/ for <6.2 times/s among the ODK

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syllables was associated with swallowing difficulties (12) and the /ka/ score was associated with subjective swallowing function (14) or with MP in denture wearer (17).

Why the syllable /ka/ showed different associating factors from the syllable /pa/ta/. The syllable /ka/ did not show a significant correlation with tongue pressure and a comparatively weak association with MP comparing to the syllable /pa/ta/. Considering that tongue pressure measurements primarily focus on the anterior or middle dorsum of the tongue (12), the observed association between the ODK /ka/ and TP can be supported by a previous study reporting that TP was associated with only ODK /ta/ (11). In the transition from the oral to oropharyngeal phases where the food bolus is transferred by the elevation and the contraction of tongue and soft palate, an involuntary swallowing sequential process, is more related with the root of tongue and the syllable /ka/ (10, 11, 14, 28, 29) which might explain the weaker association between the syllable /ka/.

Unlike ODK /ka/, the ODK /pa/ta/ was associated with Eichner Index and occluding area, which were related with the well-functioning occlusion (10, 29-31). Both /pa/ and /ta/ are classified as plosive sounds, but while /pa/ emphasizes the opening and closing of the lips, /ta/ involves more active tongue movement. For the

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syllable /ta/, the positioning and movement of the tongue are crucial and for pronouncing /ta/, the term "hypoglossal resting position" can be used (10). Therefore, it can be assumed that dentition-related factors such as the Eichner Index and occluding area can potentially improve syllable pronunciation by stabilizing the structural tongue position due to well-defined anterior and posterior occluding areas.

ODK values of the Gr 1 was associated with HG and PHQ-9 but in Gr3, the association with TP, HG, MP and KMMSE appeared. (Table 4) Kim et al reported that HG and TP are significantly associated in all age groups (22), therefore ODK can be associated with both factors. However, in the Gr 1 of this study, TP did not show a meaningful influence on ODK. This means that most of the participants in Gr 1 had sufficient TP not to affect ODK.

Although most of participants in this study were psychologically and physically considered normal but KMMSE was turned out to influence on ODK /pa/ta/ except the syllable /ka/. (table 3) Lee et al reported the significant associations between MP and KMMSE in the old population (21), therefore, there could be expected the significant multilateral association among KMMSE, MP and ODK/pa/ka/. In real, in the age group of over 75 years, both KMMSE and ODK

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/ka/ emerged the significant associating factors to MP and ODK /pa/ appeared more significantly compared that in the Gr 2 where ODK /pa/ta/ was distinctively associated with MP (Table 6). This means that the muscle related with ODK /ka/ gets weaker after weakness of voluntary muscles related with /pa/ta/, which could be a serial event in the old population (17, 32). For the younger group below 65, PHQ-9 exerted a discernible influence on MP, but not any syllables of ODK. This result is in line with the study that self-assessed masticatory evaluation was significantly important factor to MP in the younger age group (22, 33).

In a multiple linear regression analysis to detect the associating factors with MP, posterior teeth, occluding area and Eichner index, BF and ODK, and KMMSE exhibited significant associations with MP (Table 5). Eichner Index indicating the locations and numbers of the functional tooth pairs showed a significant association with MP regardless of age (Table 5), however, in the intragroup analyses it showed no significance except the age group over 75 years (Table 6). This result can be interpreted that the Eichner index appeared more pronounced as a determinant of MP due to the significantly fewer remaining teeth of Gr3. (Table 2,6). An earlier review and a longitudinal study indicated the positive association between the number/ functional tooth pairs and MP (3, 34). This study represented that the functional tooth pairs is more crucial factor to MP (Table 5,6)

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It is noteworthy that TP consistently decreases across age groups and no direct correlation between TP and MP was found. There seem controversial results on the association between MP and TP: positive association (3, 17) or no association (22). This discrepancy in the association between TP and MP might be due to the heterogeneity of the related studies in the selection of comparison groups, latency, ascertainment of diagnosis, and age distribution of the study population.

Oral dryness could be a risk factor to swallowing and MP. Some studies have shown that the stimulated salivary flow rate is positively associated with MP (19, 35), meanwhile, other studies reported that excessive saliva may not improve MP but sufficient saliva is mandatory for chewing and swallowing (3, 6). This study did not show any association between MP and oral dryness because most participants in this study were in relatively healthy condition. As for the association with swallowing function, oral dryness was not only significantly associated with ODK/pa/ta/ for all ages, but also with ODK /ka/ in Gr 3, which means that oral dryness may affect swallowing function based on previous studies (11, 12, 14, 17).

This study has revealed the new cut off values in the various orofacial criteria in the healthy old individuals to identify oral hypofunction, however some

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limitations should be addressed. The ultimate goals of these researches is to identify the relevant factors to enhance masticatory performance and swallowing to prevent or delay the onset of oral frailty which could lead to low quality of life, comorbidities, and the increased mortality in old individuals. Although this study has performed on the basis that tongue-lip motor function assessed by using ODK is the key in swallowing (11, 12, 15, 24, 36), a crucial method is to be designed for assessment of actual swallowing instead of RSST or Eat-10 (11, 13, 14). In addition, further studies should be designed to reveal the mutual causal relationship among various influencing factors through various modifications of the subject criteria and population size depending the investigating factors.

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V. CONCLUSION

Under the limited condition of this study, this study revealed that the mean values of the tested oro- facial parameters showed significant differences depending on the age groups. The values of ODK /pa/ta/ka/ were significantly correlated with masticatory function regardless of age groups. For older individuals of above 75 years old, Eichner Index indicating the functional tooth pairs and cognitive ability appeared significant to ODK and MP.

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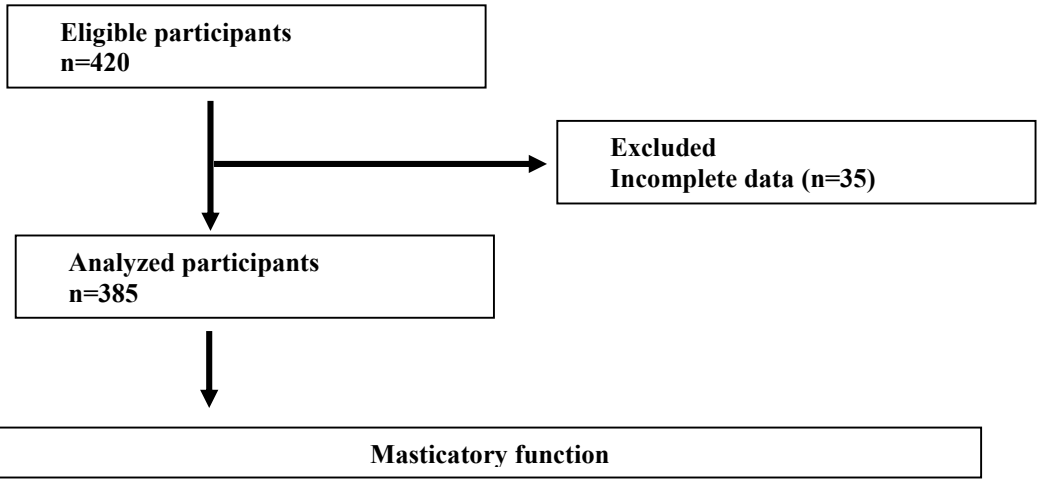
Figures

Figure. 1 Flowchart of study participants and study design



Objective assessment	Subjective assessment
- Dental status assessment - Masticatory Performance - Tongue Pressure - Bite Force and Occluding Bite Area - Handgrip Strength - Oral Diadochokinesis - Oral Dryness	- Food Intake Ability Questionnaire - OHIP - KMMSE - PHQ-9

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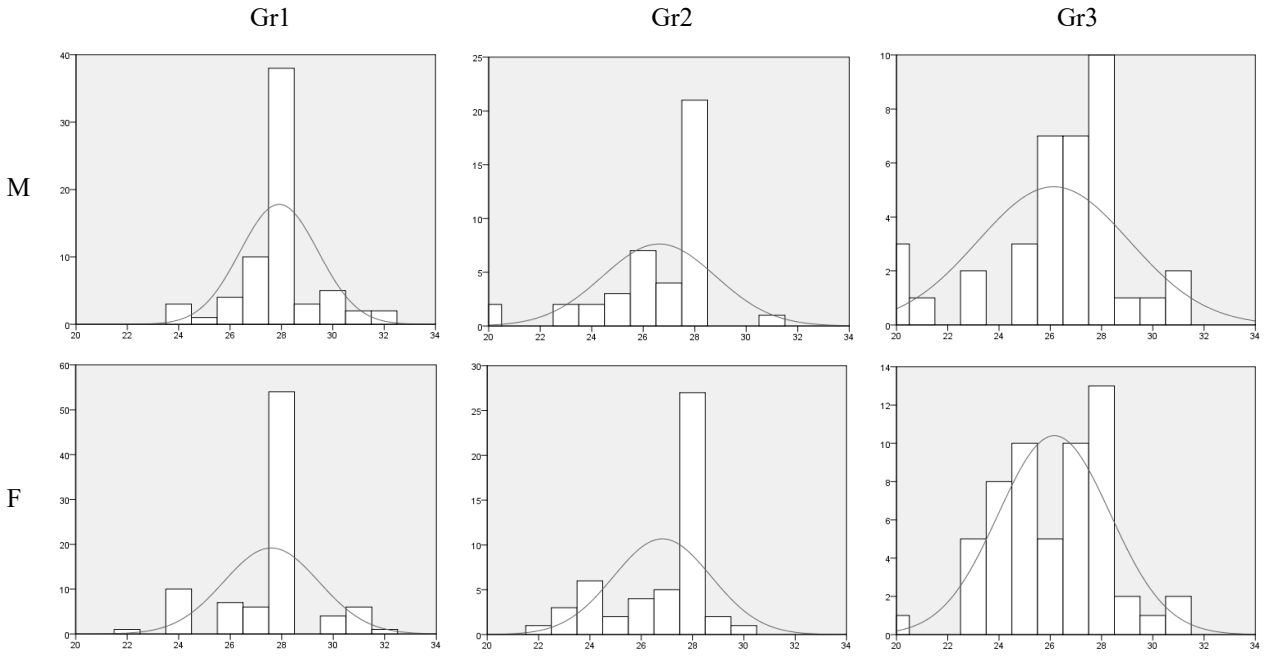
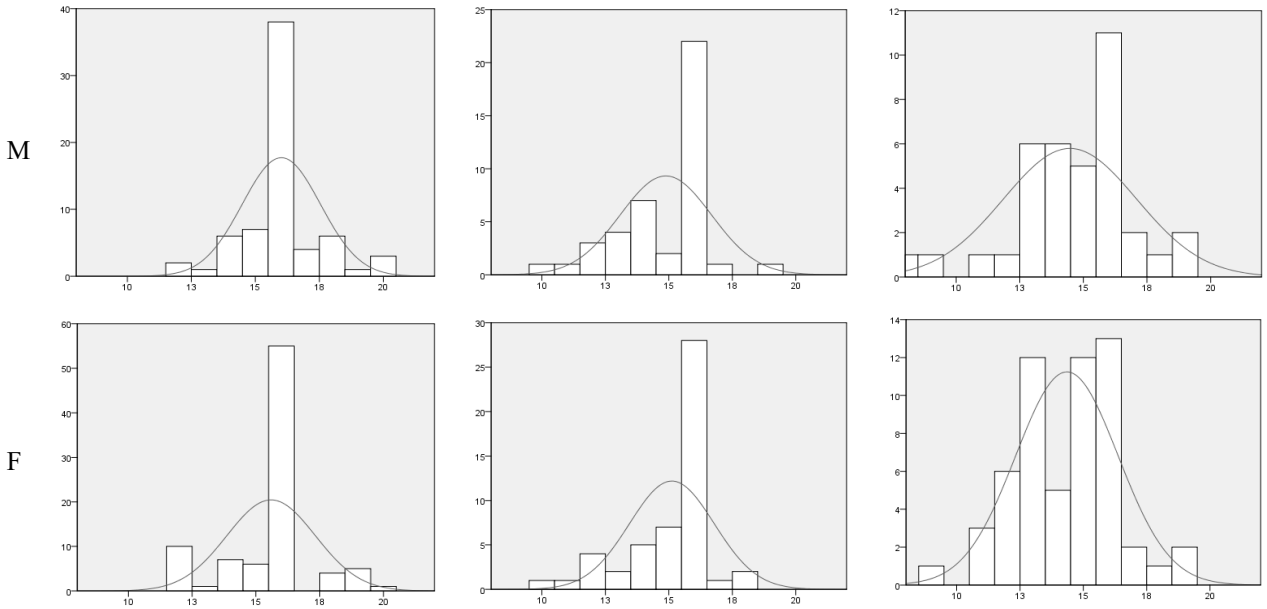
Figure 2. Normal distribution histogram of factors affecting masticatory functions



(a) Remaining teeth



(b) Posterior teeth

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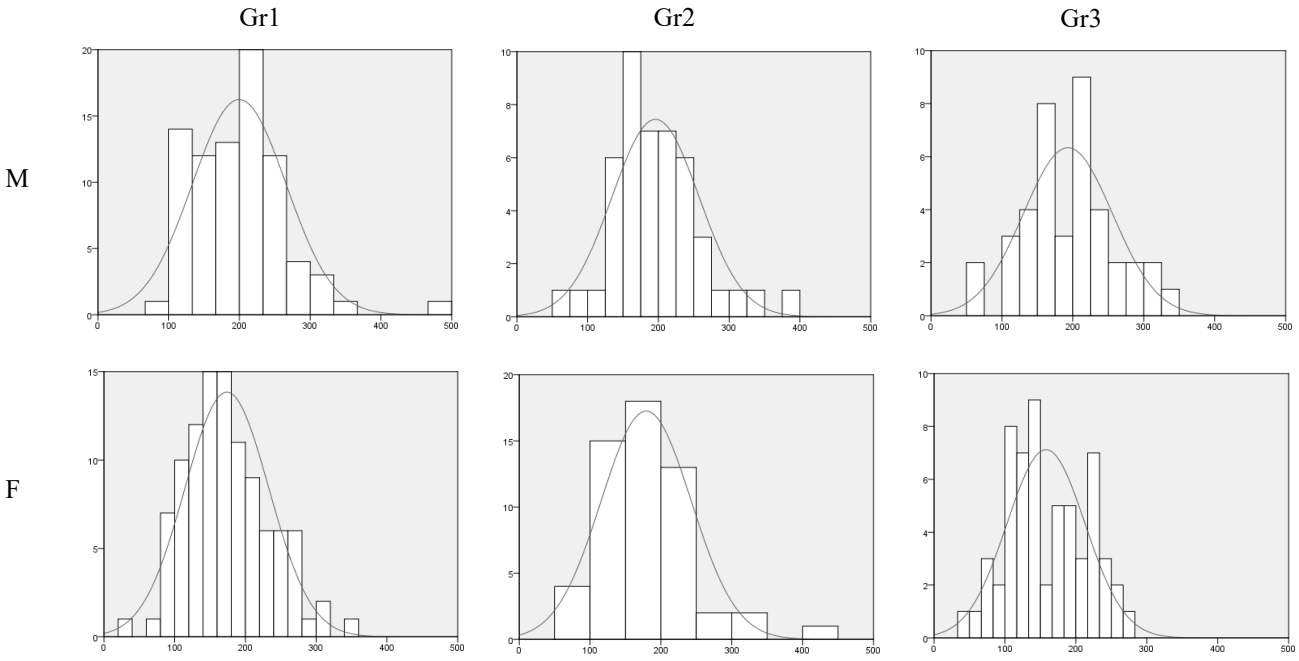
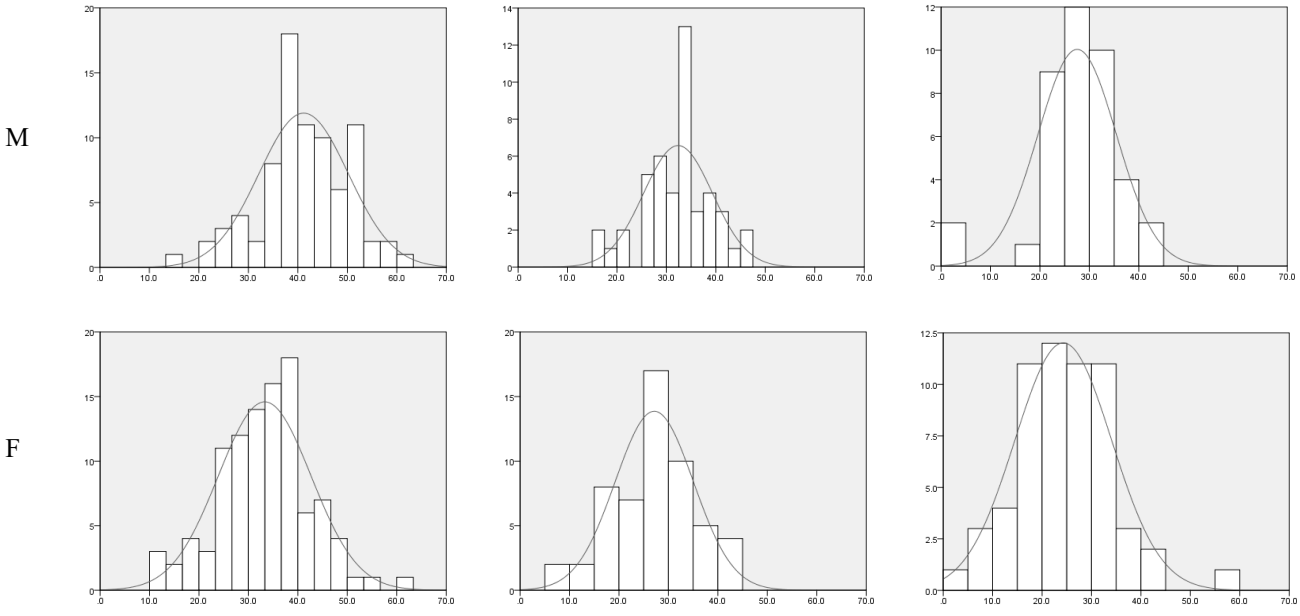


(c) MP



(d) TP

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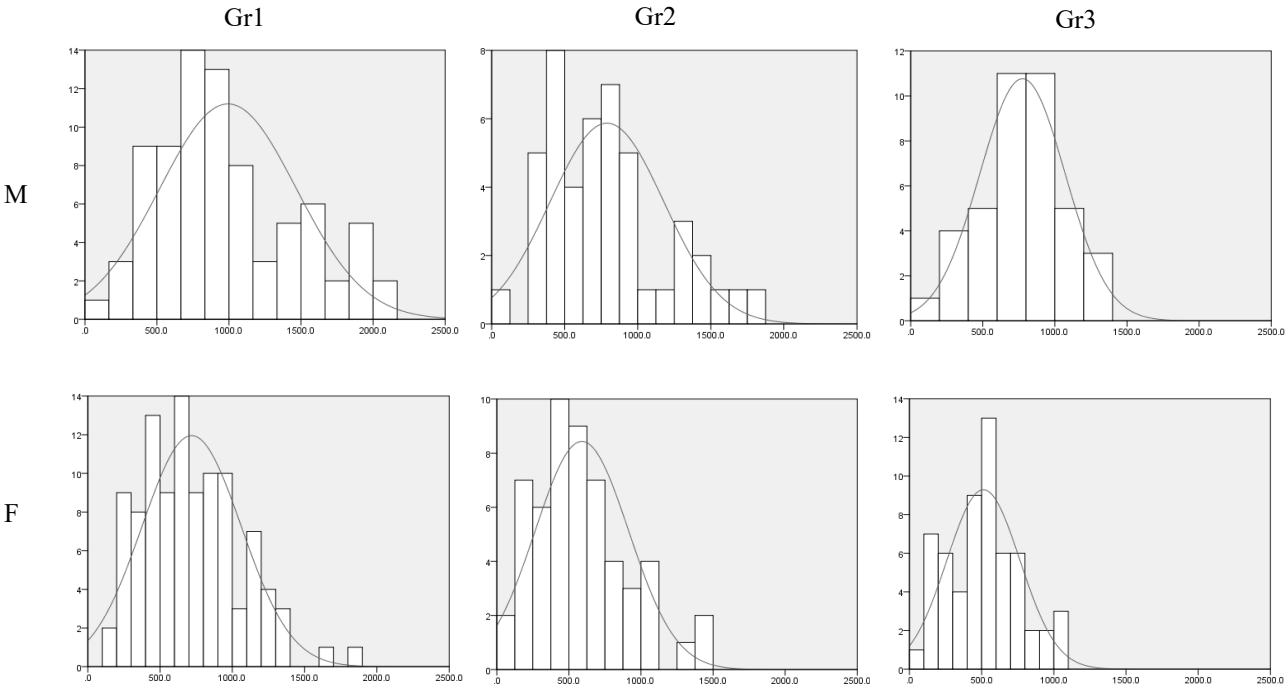
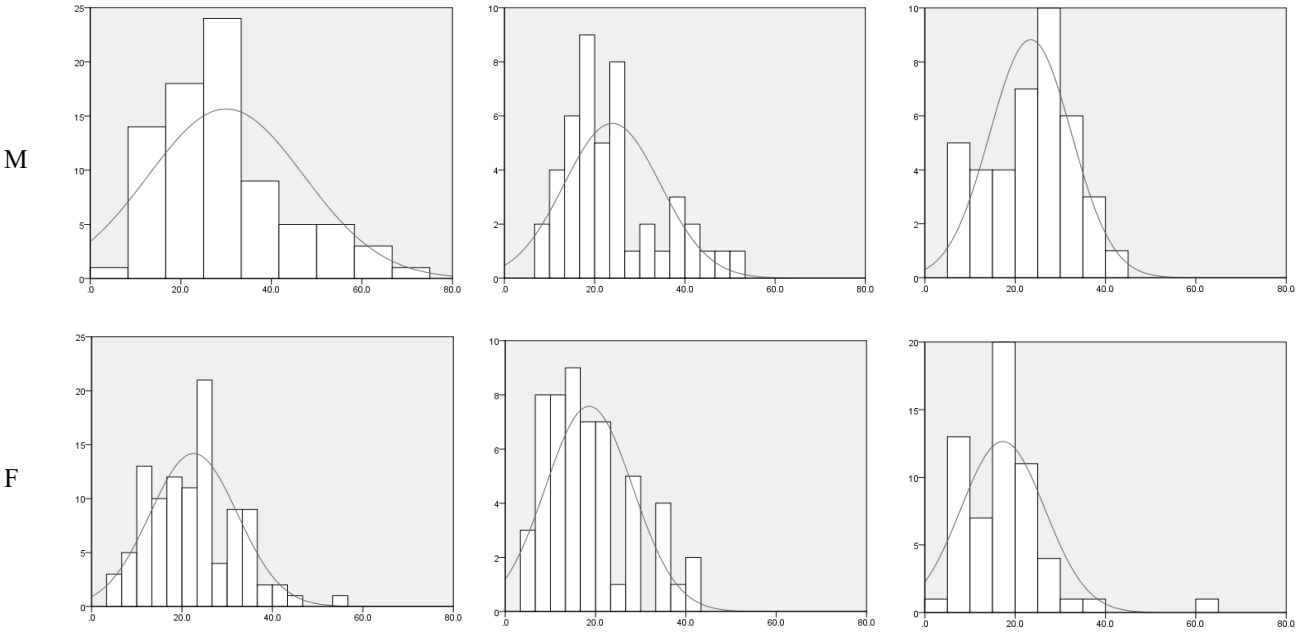


(e) BF



(f) Occluding area

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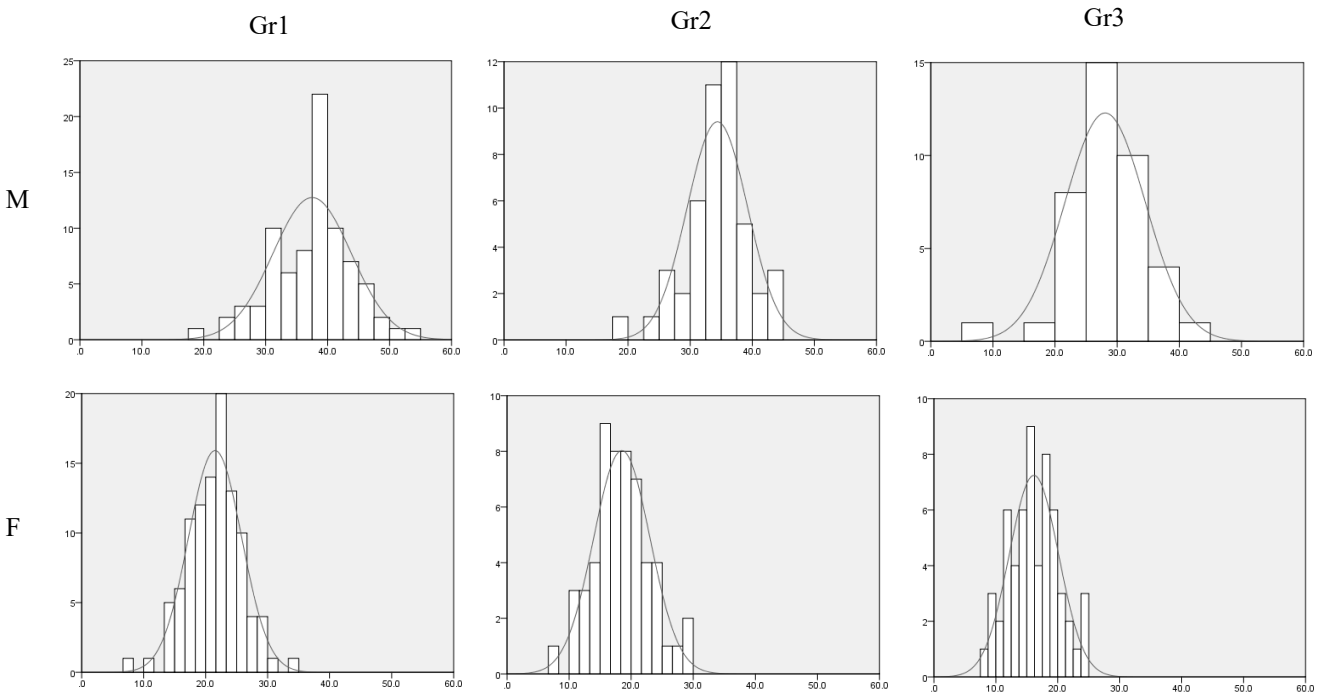
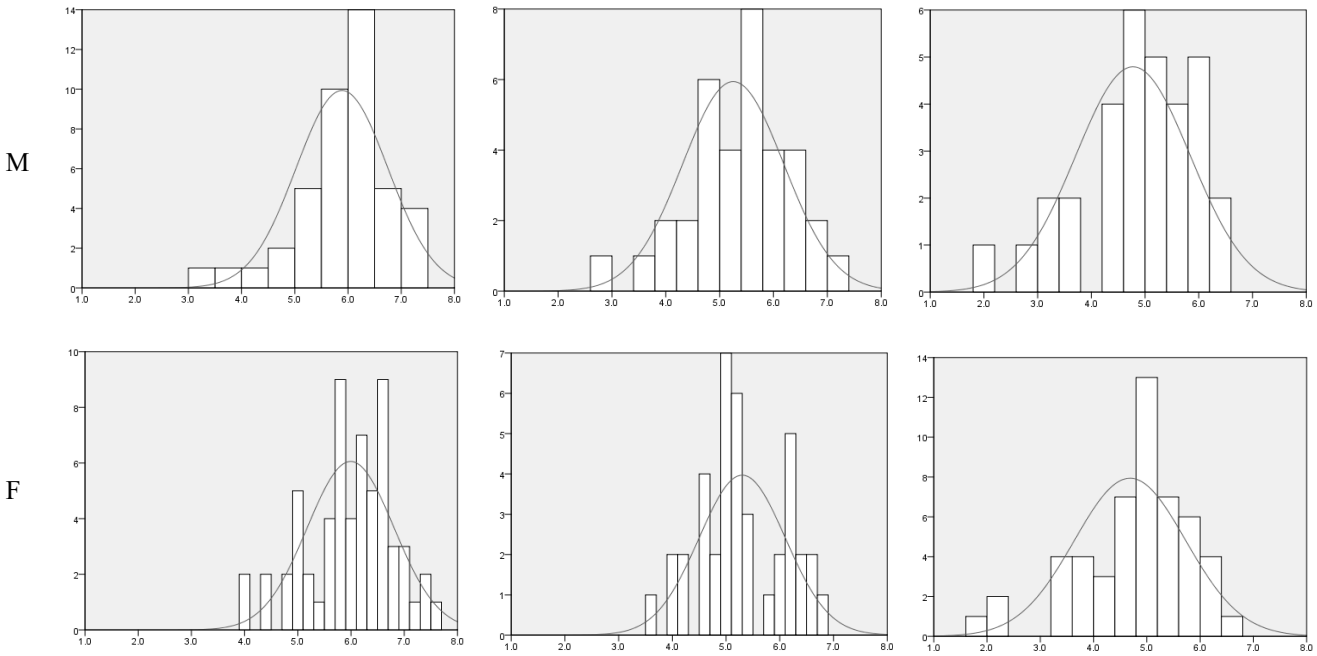


(g) HG



(h) /pa/

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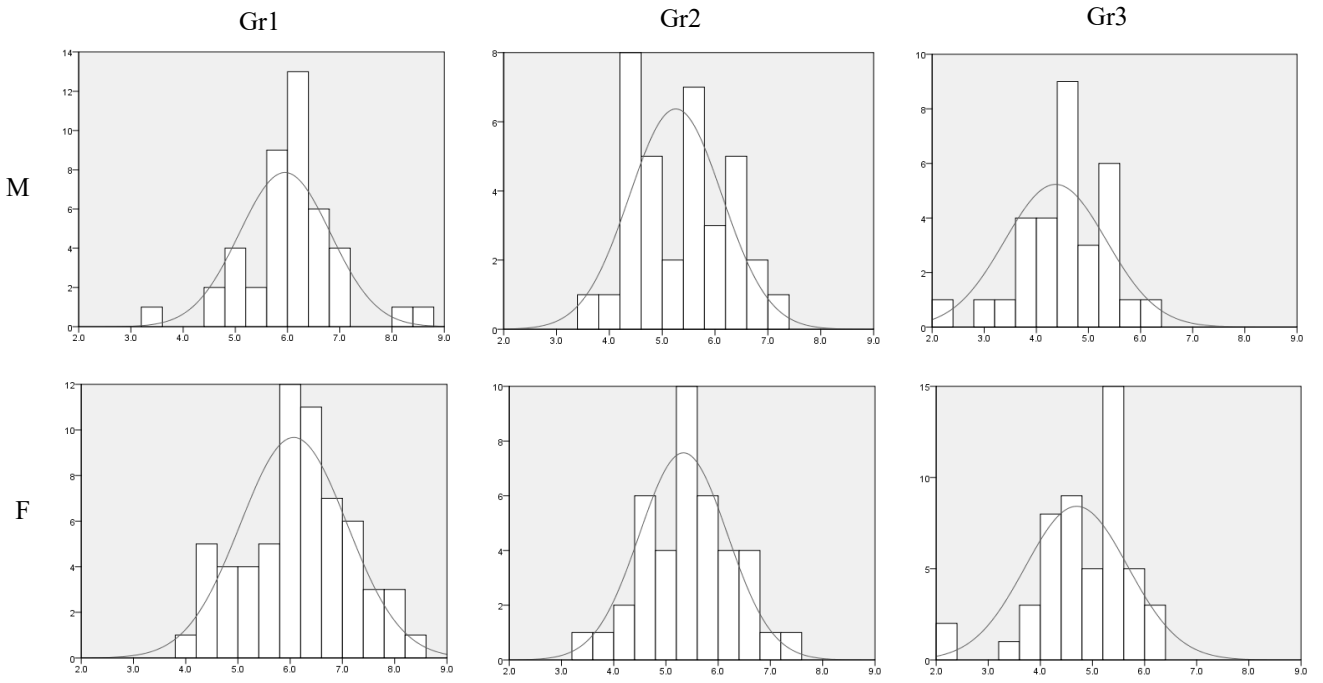
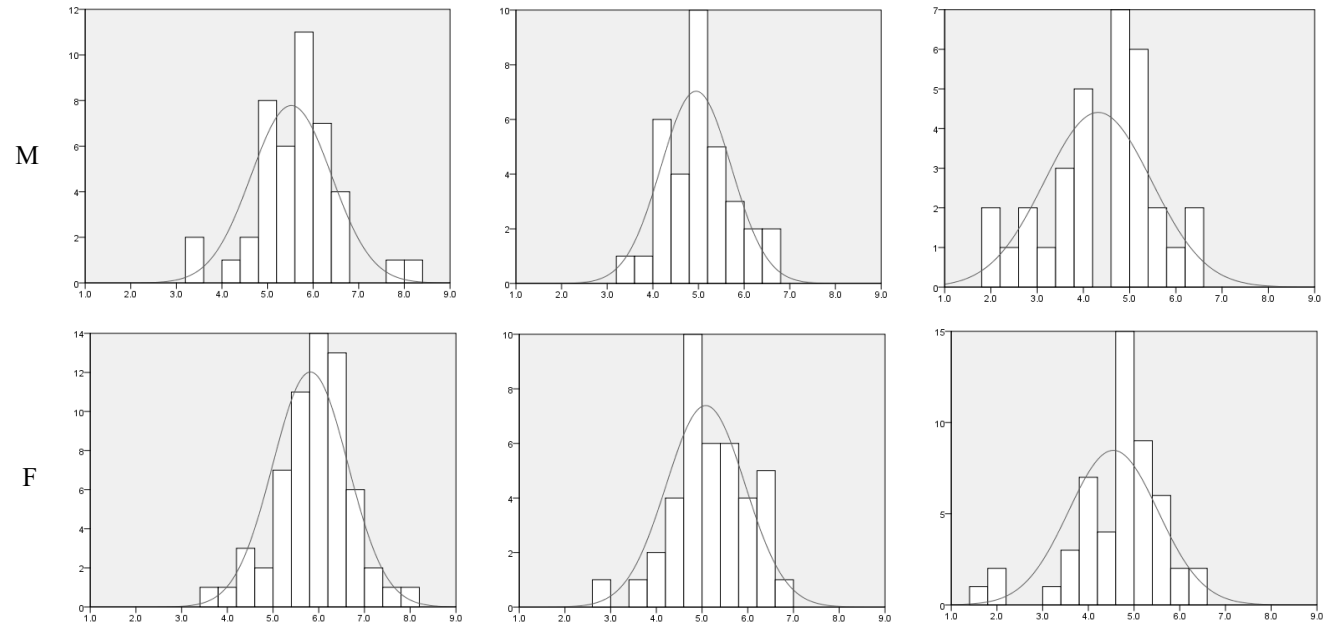


(i) /ta/



(j) /ka/

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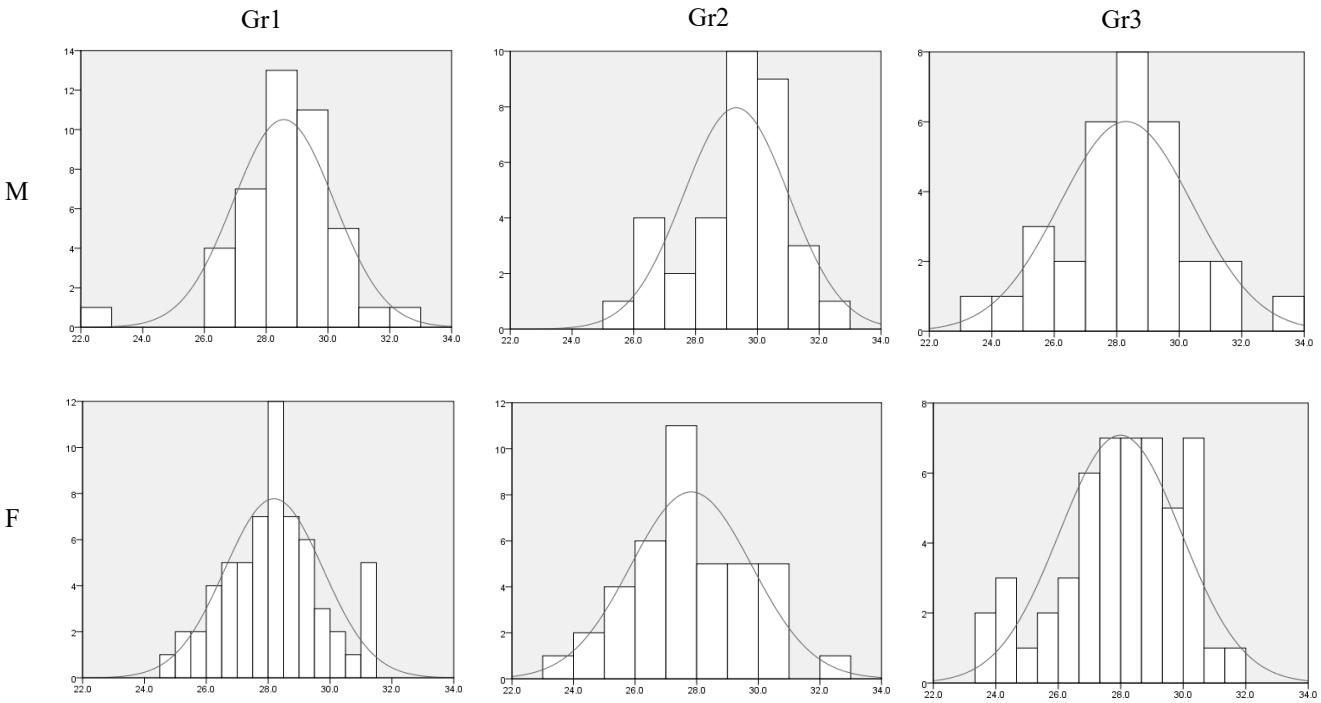
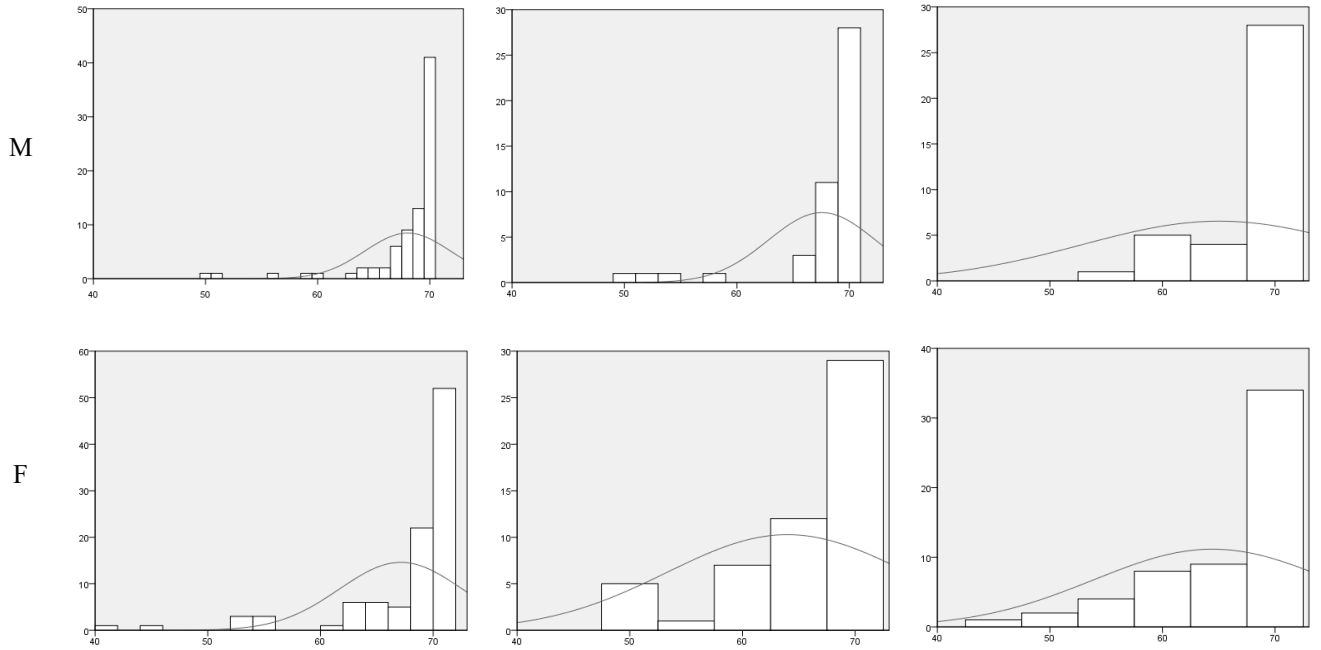


(k) Oral dryness



(l) FIA

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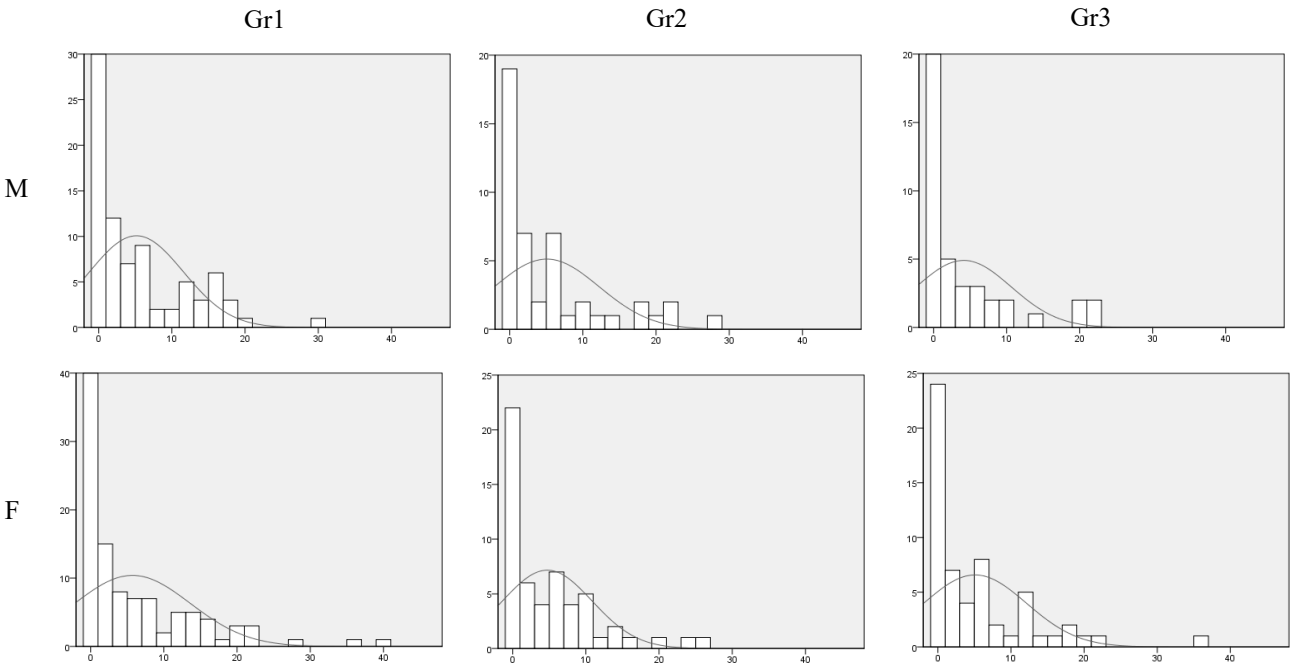
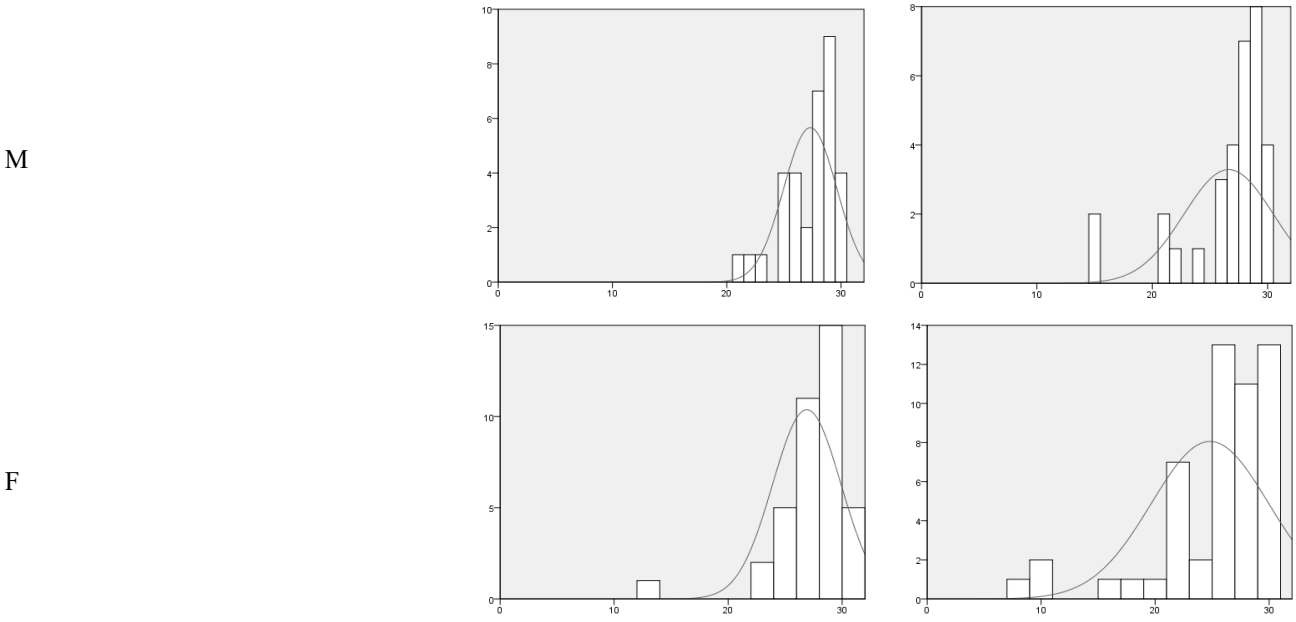


(m) OHIP-14



(n) KMMSE

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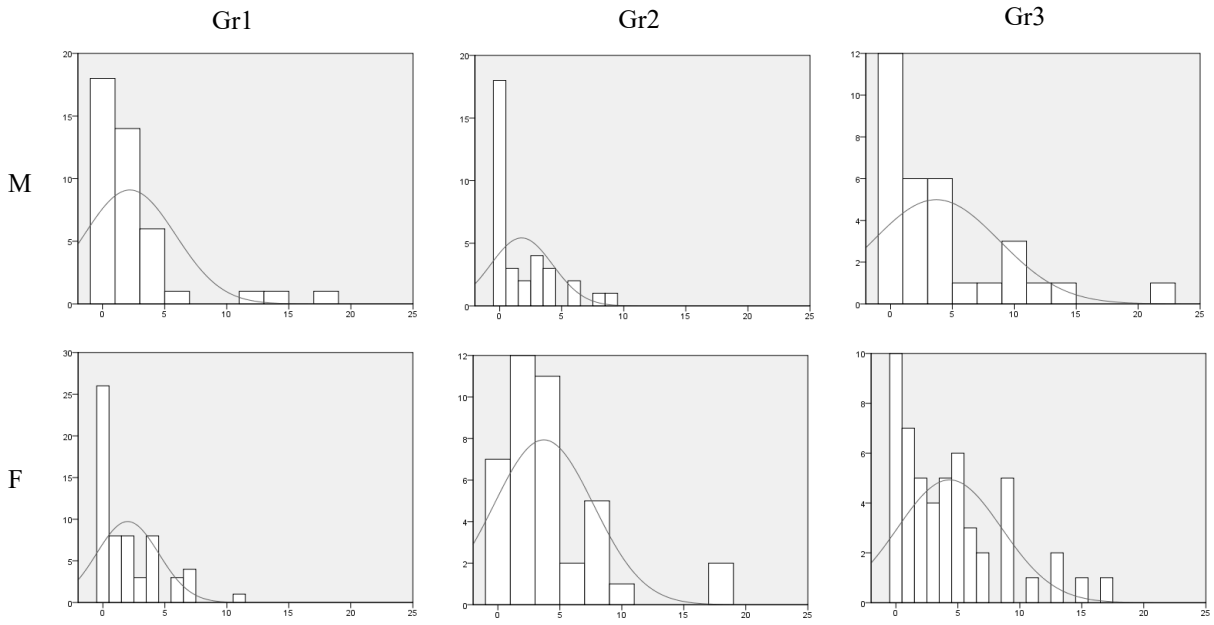

(o) PHQ-9

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Tables

Table 1. Demographic characteristics of the participants

		Total	Gr 1	Gr 2	Gr 3	p-value
Subjects N (%)		385 (100)	184 (47.79%)	101 (26.23%)	100 (25.97%)	
Age		61.30 ± 18.07	45.89 ± 13.39	70.01 ± 2.70	80.85 ± 4.83	
Sex(%) †	male	168	81	46	41	0.8012
	female	217	103	55	59	

†Chi-square test

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Table 2. Assessment of the variables of oral function among age groups

					Bonferroni correction		
	Gr 1	**Gr 2**	**Gr 3**	**P ††**	**1 vs 2**	**1 vs 3**	**2 vs 3**
Remaining teeth	27.60 ± 1.80	26.40 ± 2.60	26.00 ± 4.16	<.0001 *	0.0012 *	<.0001 *	0.0984
Posterior teeth	15.68 ± 1.78	14.92 ± 1.80	14.38 ± 2.08	<.0001 *	0.0054 *	<.0001 *	0.0522
Eichner index(A:B) †	180:4	95:6	88:12	0.0051 *			
MP	188.14 ± 65.93	186.07 ± 60.86	183.09 ± 54.04	0.2750	.	.	.
TP †††	36.29 ± 10.40	30.41 ± 8.45	25.39 ± 8.48	<.0001 *	<.0001 *	<.0001 *	0.0064 *
BF	855.83 ± 434.55	662.73 ± 358.16	671.58 ± 291.25	<.0001 *	0.0039 *	<.0001 *	1.0000
Occluding area	26.26 ± 14.05	20.74 ± 10.44	20.36 ± 8.47	0.0001 *	0.0045 *	0.0006 *	1.0000
HG	28.83 ± 9.49	25.78 ± 9.12	21.89 ± 7.89	<.0001 *	0.0363 *	<.0001 *	0.0009 *
ODK /pa/	5.86 ± 0.83	5.17 ± 0.80	4.74 ± 0.83	<.0001 *	<.0001 *	<.0001 *	0.0042 *
/ta/	5.95 ± 0.96	5.17 ± 0.80	4.57 ± 0.74	<.0001 *	<.0001 *	<.0001 *	<.0001 *
/ka/	5.65 ± 0.81	4.93 ± 0.87	4.49 ± 0.84	<.0001 *	<.0001 *	<.0001 *	0.0030 *
Oral dryness	28.32 ± 1.66	28.59 ± 2.19	27.78 ± 3.88	0.0083 *	.0.1887	0.0075 *	.1.0000
FIA	67.24± 10.37	65.70 ± 9.18	62.71 ± 12.81	0.0217 *	0.0450 *	0.1062	1.0000
OHIP-14	5.31 ± 7.10	4.88 ± 6.93	4.76 ± 6.63	0.5258	.	.	.
KMMSE	27.87 ± 1.91	27.04 ± 3.09	25.58 ± 5.10	0.0914	.	.	.
PHQ-9	2.01 ± 2.97	2.87 ± 3.45	4.43 ± 5.50	0.0039 *	0.2865	0.0039 *	0.3258

Mean±SD

† Chi-square test

†† Kruskal wallis test

††† ANOVA test

p * < 0.05

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Table 3. Multiple linear regression analysis of factors associated with ODK

	Dependent variable	Multiple model†			
		B	CI		p
/pa	Remaining teeth	0.0211	-0.0326	0.0748	0.4394
	Posterior teeth	0.0207	-0.0392	0.0806	0.4969
	Eichner index	-0.6392	-1.0973	-0.1811	0.0065 *
	MP	0.0032	0.0014	0.0051	0.0007 *
	TP	0.0159	0.0028	0.0290	0.0177 *
	BF	0.0004	0.0000	0.0007	0.0299 *
	Occluding area	0.0096	-0.0002	0.0193	0.0545
	HG	0.0480	0.0250	0.0711	< 0.0001 *
	Oral dryness	0.0721	0.0105	0.1337	0.0219 *
	FIA	0.0066	-0.0032	0.0165	0.1863
	OHIP-14	-0.0032	-0.0197	0.0133	0.7016
	KMMSE	0.0409	0.0015	0.0803	0.0419 *
	PHQ-9	-0.3424	-0.6401	-0.0447	0.0243 *
/ta/	Remaining teeth	0.0224	-0.0311	0.0759	0.4108
	Posterior teeth	0.0284	-0.0313	0.088	0.3501
	Eichner index	-0.4944	-0.9593	-0.0296	0.0372 *
	MP	0.0035	0.0016	0.0054	0.0003 *
	TP	0.0137	0.0002	0.0272	0.0467 *
	BF	0.0005	0.0002	0.0009	0.0024 *
	Occluding area	0.0125	0.0025	0.0224	0.014 *
	HG	0.0521	0.0286	0.0756	<.0001 *
	Oral dryness	0.0655	0.0023	0.1287	0.0424 *
	FIA	0.007	-0.0031	0.0171	0.1751
	OHIP-14	-0.0154	-0.0321	0.0014	0.0728
	KMMSE	0.0464	0.01	0.0827	0.0128 *
	PHQ-9	-0.5519	-0.8517	-0.2522	0.0003 *
/ka/	Remaining teeth	0.0248	-0.0336	0.0831	0.4036
	Posterior teeth	0.0262	-0.0388	0.0913	0.4278
	Eichner index	-0.4113	-0.915	0.0925	0.1090
	MP	0.0021	0	0.0041	0.0492 *
	TP	0.0112	-0.0032	0.0256	0.1262
	BF	0.0003	-0.0001	0.0007	0.1172
	Occluding area	0.0066	-0.004	0.0173	0.2215
	HG	0.0623	0.0375	0.087	<.0001 *
	Oral dryness	0.0652	-0.0021	0.1325	0.0576
	FIA	0.0003	-0.0104	0.0111	0.9515
	OHIP-14	-0.0057	-0.0237	0.0122	0.5301
	KMMSE	0.0318	-0.0137	0.0774	0.1693
	PHQ-9	-0.4227	-0.7463	-0.0991	0.0107 *

†adjusted by sex, age, BMI

p * < 0.05

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Table 4. Multiple linear regression analysis of factors associated with ODK according to age

	Dependent variable	Gr 1				Gr 2				Gr 3			
		B	CI		p	B	CI		p	B	CI		p
/pa/	Remaining teeth												
	Posterior teeth												
	Eichner index									-0.7666	-1.4339	-0.0992	0.0249
	MP					0.0033	0.0002	0.0063	0.0345	0.0052	0.0014	0.009	0.0079
	TP†									1.4090	0.3373	2.4807	0.0106
	BF												
	Occluding area												
	HG	0.047	0.0156	0.0785	0.0038					0.0723	0.0242	0.1204	0.0037
	Oral dryness												
	FIA												
	OHIP-14									-0.0382	-0.0757	-0.0008	0.0453
	KMMSE									0.0562	0.0090	0.1034	0.0202
	PHQ-9	-0.5732	-1.0954	-0.0511	0.0318								
/ta/	Remaining teeth												
	Posterior teeth												
	Eichner index									-0.6904	-1.3453	-0.0356	0.0391
	MP					0.0038	0.0008	0.0067	0.0140	0.0047	0.0011	0.0084	0.0118
	TP†									1.0289	-0.0174	2.0751	0.0538
	BF	0.0007	0.0002	0.0012	0.0052								
	Occluding area	0.0152	0.0020	0.0283	0.0244	0.0199	0.0001	0.0397	0.0491				
	HG	0.0489	0.0124	0.0854	0.0092					0.0738	0.0283	0.1194	0.0018
	Oral dryness												
	FIA												
	OHIP-14									-0.0568	-0.0911	-0.0225	0.0015
	KMMSE									0.0731	0.0292	0.1170	0.0014
	PHQ-9	-0.6774	-1.2784	-0.0765	0.0276					-0.508	-0.9806	-0.0354	0.0355
/ka/	Remaining teeth												
	Posterior teeth												
	Eichner index												
	MP									0.0050	0.0012	0.0088	0.0097
	TP†									1.3736	0.3068	2.4403	0.0123
	BF	0.0005	0.0001	0.0010	0.0160								
	Occluding area												
	HG	0.0485	0.0165	0.0805	0.0033					0.0974	0.0520	0.1428	<.0001
	Oral dryness									0.1152	0.0031	0.2274	0.0441
	FIA												
	OHIP-14												
	KMMSE									0.8596	0.3369	1.3824	0.0016
	PHQ-9	-0.5419	-1.0744	-0.0095	0.0461								

*adjusted by sex, age, BMI

†Log-transformed variable adjusted by sex, BMI

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Table 5. Multiple linear regression analysis of factors associated with MP

Dependent variable	Multiple model†			
	B	CI		p*
Remaining teeth	2.5180	-0.5467	5.5828	0.1070
Posterior teeth	4.3815	0.9373	7.8257	0.0128 *
Eichner index	-47.7829	-77.0938	-18.4721	0.0015 *
TP	0.7139	-0.0069	1.4346	0.0522
BF	0.0454	0.0283	0.0625	<.0001 *
Occluding area	1.0641	0.5307	1.5976	0.0001 *
HG	0.9333	-0.3139	2.1804	0.1420
/pa/	13.7767	5.9157	21.6378	0.0007 *
/ta/	14.1787	6.5285	21.8289	0.0003 *
/ka/	7.3549	0.0269	14.6829	0.0492 *
Oral dryness	0.4872	-0.2839	1.2582	0.2145
FIA	0.1309	-0.5078	0.7695	0.6872
OHIP-14	-0.5130	-1.4114	0.3855	0.2623
KMMSE	3.3718	0.7648	5.9788	0.0116 *
PHQ-9	-6.7177	-26.4373	13.0018	0.5029

†adjusted by sex, age, BMI

p * < 0.05

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Table 6. Multiple linear regression analysis of factors associated with MP according to age

Dependent variable	Gr 1				Gr 2				Gr 3			
	B	CI		p	B	CI		p	B	CI		p
Remaining teeth												
Posterior teeth												
Eichner index									-42.5013	-78.9876	-6.0150	0.0229
TP					1.8973	0.2065	3.5880	0.0283				
BF	0.0238	0.0011	0.0465	0.0397	0.0742	0.0416	0.1069	<.0001	0.0523	0.0090	0.0957	0.0185
Occluding area					2.5139	1.3615	3.6662	<.0001				
HG												
/pa/					19.2554	1.4430	37.0677	0.0345	16.5585	4.4724	28.6445	0.0079
/ta/					22.4188	4.6846	40.1531	0.0140	16.3964	3.7346	29.0582	0.0118
/ka/									16.2255	4.0337	28.4173	0.0097
Oral dryness												
FIA					1.5369	0.0751	2.9988	0.0395				
OHIP-14												
KMMSE									3.0643	0.3933	5.7352	0.0251
PHQ-9	-47.2094	-81.2865	-13.1322	0.0071								

*adjusted by sex, age, BMI

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Appendix A

Table A1. Supplement assessment of the variables of oral function among age groups

		Median (IQR)		
		Gr 1	**Gr 2**	**Gr 3**
Remaining teeth		28 (27.5-28.5)	28 (27-29)	27 (25.5-28.5)
Posterior teeth		16 (15.5-16.5)	16 (15-17)	15 (13.5-16.5)
MP		179.0 (134.5-223.5)	181.0 (144.5-217.5)	169.5 (122.5-292.0)
TP		37.40 (30.84-43.96)	29.73 (25.265-34.195)	26.10 (20.86-31.34)
BF		799.15 (528.20-1070.10)	622.10 (396.30-1018.40)	600.05 (403.525-796.575)
Occluding area		24.60 (17.175-32.025)	18.90 (12.80-25.00)	19.40 (13.025-25.775)
HG		25.85 (17.45-34.25)	24.10 (15.90-32.30)	19.80 (14.05-25.55)
ODK	/pa/	6.0 (5.5-6.5)	5.2 (4.6-5.8)	4.8 (4.2-5.4)
	/ta/	6.0 (5.5-6.5)	5.4 (4.7-6.1)	4.6 (4.1-5.1)
	/ka/	5.8 (5.3-6.3)	5.0 (4.5-5.5)	4.6 (4.0-5.2)
Oral dryness		28.33 (27.415-29.245)	28.63 (27.08-30.18)	28.37 (27.135-29.605)
FIA		70 (3)	68 (4)	69 (6.5)
OHIP-14		2 (8.5)	2 (7)	2 (6)
KMMSE			28 (3)	27 (4)
PHQ-9		1 (3)	2 (4)	3 (6)

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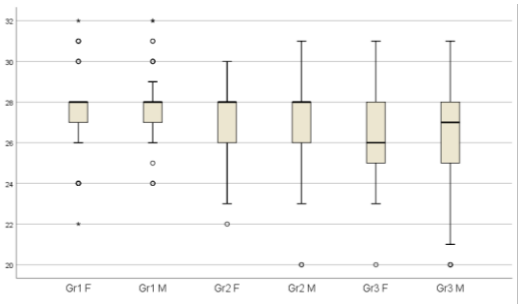
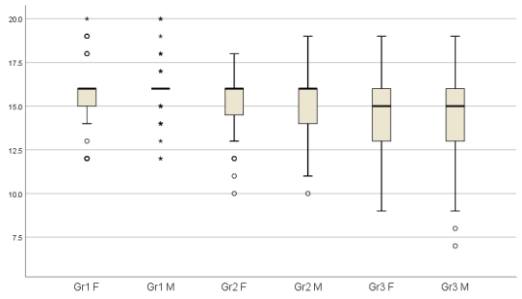
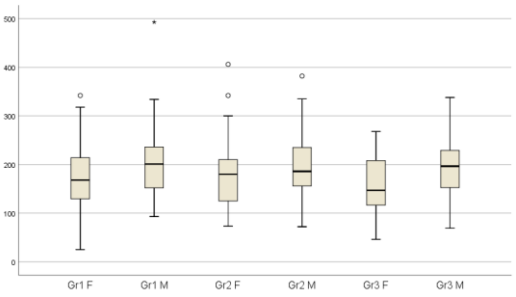
Figure A1. Box plots of factors affecting masticatory functions



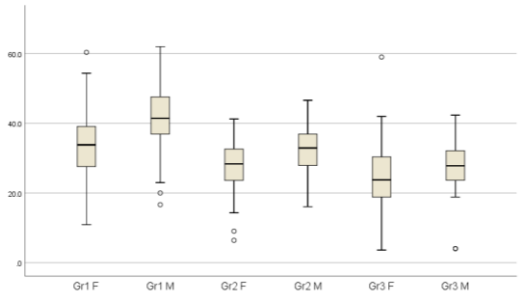
(a) Remaining teeth



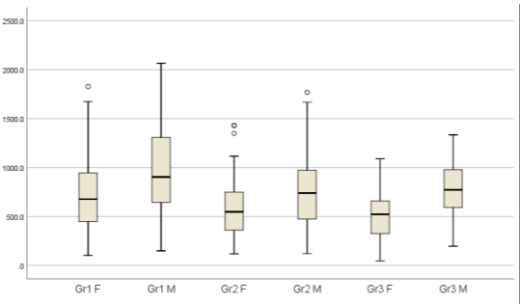
(b) Posterior teeth



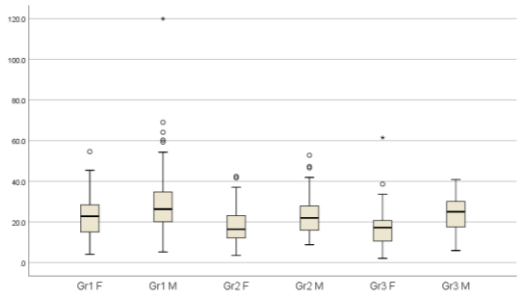
(c) MP



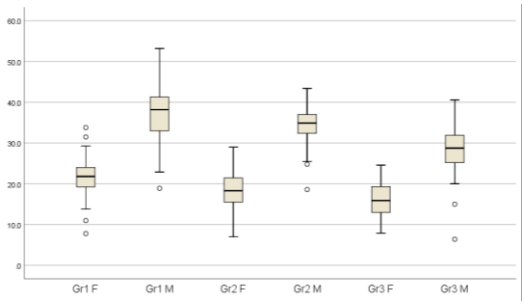
(d) TP



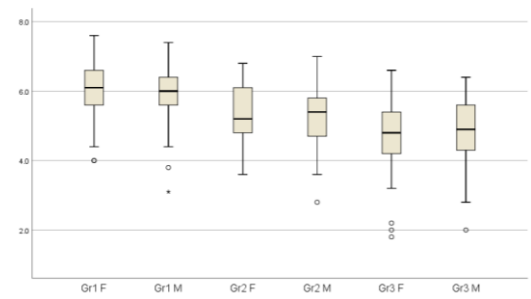
(e) BF



(f) Occluding area



(g) HG



(h) /pa/

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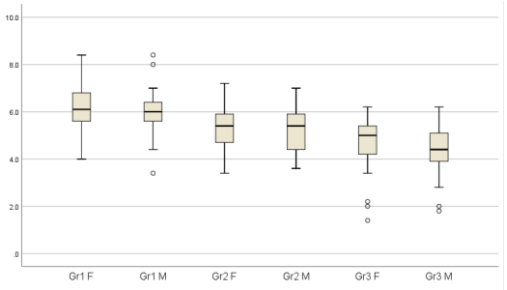
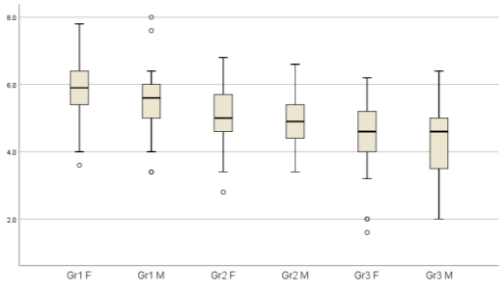
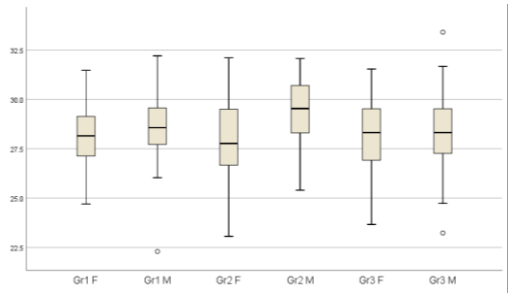


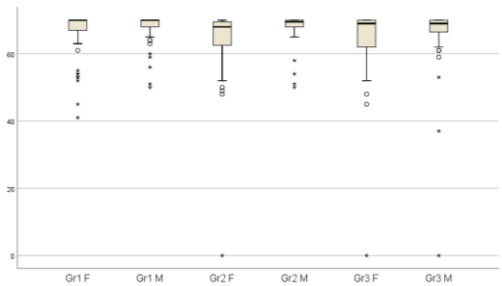
(i) /ta/



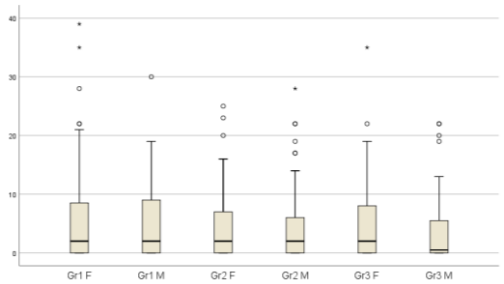
(j) /ka/



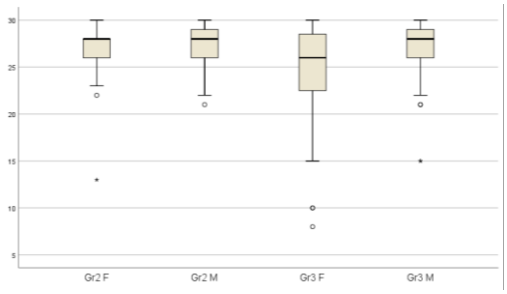
(k) Oral dryness



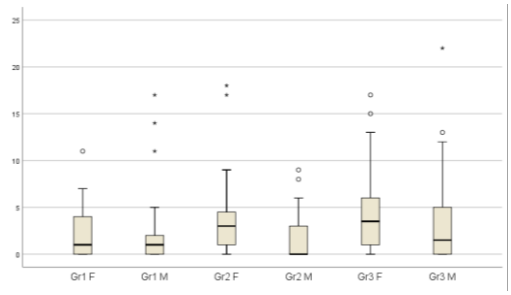
(l) FIA



(m) OHIP-14



(n) KMMSE



(o) PHQ-9

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국문 요약

건강한 노인 인구에서 연령에 따른 구강운동과 저작기능 평가

민세연

연세대학교 치과대학 치의학과

목적

본 연구는 건강한 노인을 대상으로 연령에 따른 구강운동과 저작기능을 평가하는 것을 목적으로 하였다.

방법

2020년 8월 1일부터 2023년 1월 31일까지 연세대학교 치과대학병원 통합치의학과에 내원한 총 385명의 건강한 참가자를 20-64세(그룹 1), 65-74세(그룹 2), ≥75세(그룹 3)의 세 가지 연령대로 나누었다. 구강운동 기능을

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조사하기 위해 Oral diadochokinesis(ODK)를 단음절 /pa/ta/ka/의 반복 횟수로 평가하였다. 저작기능 평가를 위해 주관적 및 객관적 저작 기능 평가가 모두 실시되었다. 주관적 저작 능력, 인지 능력, 심리적 상태 평가를 위해 4개의 설문지가 사용되었다. 동적 객관적 저작 기능의 경우 저작 효율, 교합력, 교합 면적을 조사하였고, 정적 객관적 저작 기능의 경우 남아 있는 치아 수와 기능적 치아 쌍을 평가하였다. 영향 요인을 파악하기 위해 악력, 구강 건조도, 설압을 평가하였다. 그룹 간 차이는 ANOVA 및 Kruskal-Wallis 검정으로 평가하였고, ODK와 구강 기능 인자들의 상관관계를 평가하였다.

결론

구강 노쇠와 구강 기능 저하 진단을 위하여 연령대별 구강 기능 인자들의 평가값과 ODK와 저작 효율과의 연관성을 조사하였으며, 이러한 결과는 연령대별 구강 기능의 변화와 저작 기능의 다요인적 특성을 이해하여 노

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인의 구강 기능 회복을 이해하는데 기여했다.

핵심되는 말: 저작 효율; Oral diadochokinesis; 혀-입술 운동 기능; 삼킴 기능; 구강 노쇠