Project Title: To explore the correlation between chewing and swallowing difficulties during oral preparation in the elderly through non-contact imaging analysis of mandibular movement trajectory and oral movement rate

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Duration of the Experiment: 20220420-20230217

INTRODUCTION:

Current Status of Older Adults in Taiwan:

According to a 2001 survey of elderly residents in Taipei communities, approximately 20% of older adults reported a subjective perception of swallowing problems, and around 12% exhibited significant chewing and swallowing difficulties (dysphagia) (Wang Ting-Kuei et al., 2001). In a 2021 survey conducted in Kaohsiung across different age groups, 63.10% of older adults were found to have chewing and swallowing difficulties, with variations observed across age brackets (Liu et al., 2021). Similarly, a Japanese study revealed that the prevalence of chewing and swallowing difficulties in community-dwelling older adults aged 65 and above was 19.5% for those aged 65–74, 26.6% for those aged 75–84, and 45% for those aged 85 and above—indicating a significant increase in prevalence with age (Appendix 1-2) (Igarashi et al., 2019).

Chewing and Swallowing Process and Associated Issues:

Chewing and swallowing difficulties can lead to malnutrition and, in severe cases, aspiration pneumonia, which may result in death (Shieh et al., 2015). Importantly, many older adults are not aware that they have such impairments (Baijens et al., 2016).

The chewing and swallowing process consists of four phases: the oral preparatory phase, oral propulsive phase, pharyngeal phase, and esophageal phase (Ho Yi-Hui et al., 2014). During the overall process, the purpose of chewing is to evenly break down food and moisten it with saliva to form a bolus for swallowing (Slavicek, 2020). The hyoid bone plays a crucial role in the swallowing

motion (Lin et al., 2021). Literature has also shown through videofluoroscopic studies that during normal eating, the movements of the mandible and hyoid bone exhibit significant rhythmic and synchronized motion (Hiiemae & Palmer, 2003).

Regarding the definition of chewing and swallowing difficulties, the term can be broadly interpreted as choking. In a narrower sense, choking refers to food residue (residual), penetration, or aspiration into the trachea and lungs. If choking or aspiration occurs during the cognitive or preparatory phase, it is considered a chewing disorder; if it occurs during the oral, pharyngeal, or esophageal phases, it is classified as a swallowing disorder (Huang Chun-Te et al., 2019).

The symptoms of chewing and swallowing difficulties vary depending on the phase:

(1) Oral preparatory phase: Difficulty closing lips, reduced chewing ability, and impaired tongue movement control.

(2) Oral phase: Poor tongue movement and lip closure, food residue in the buccal cavity, drooling, and pre-swallow choking.

(3) Pharyngeal phase: Abnormal vocal quality during swallowing, nasal regurgitation, coughing during swallowing, and food sticking in the throat after swallowing.

(4) Esophageal phase: Issues include esophageal reflux, hiccups or indigestion, and post-swallow coughing.(Logemann, 1984; Palmer et al., 2000; Ho Yi-Hui et al., 2014; Logemann)

Gold Standards and Limitations of Chewing and Swallowing Assessments:

(1) Videofluoroscopic Swallowing Study (VFSS): First proposed by Dr. Logemann in 1983, this method uses barium-laced food of varying consistencies to identify chewing and swallowing difficulties during the oral preparatory, oral, and pharyngeal phases (Logemann, 1984). Despite being considered the gold standard for assessing dysphagia, VFSS has several drawbacks: barium-laced food may be rejected by cognitively impaired patients, exposure to radiation is a concern, and the examination must be conducted in a radiology room with dynamic imaging capabilities—

limiting its accessibility (Chiu Yi-Hsiang et al., 2020).

(2) Fiberoptic Endoscopic Evaluation of Swallowing (FEES): Introduced by Dr. Susan Langmore in 1988, this method involves using an endoscope to observe the structure and function of the pharynx and larynx, and dyed food is used to assess swallowing (Langmore, 2017; Langmore et al., 1988). The main limitation of FEES is that it does not capture the complete swallowing process; it only allows inference based on pre- and post-swallow states to identify the cause of dysphagia or the timing of aspiration (Chiu Yi-Hsiang et al., 2020).

Given the invasive nature and radiation exposure concerns associated with these gold-standard tests, and the fact that most studies emphasize abnormalities in the pharyngeal phase (as these can lead to life-threatening aspiration), the oral preparatory phase is equally critical. Food must be adequately chewed and mixed with saliva to form a bolus before swallowing. Furthermore, oral function deteriorates with age (Frederick et al., 1996; Wang Ting-Kuei et al., 2001). A literature review on measuring mandibular movement in the oral phase noted that existing techniques—such as mechanical linkage systems, magnetic tracking, video motion analysis, and radiographic tracking—mostly require laboratory environments and professional intervention (Woodford et al., 2020). Thus, a non-invasive and accessible method is becoming a future trend (Shieh et al., 2015).

Limitations in Existing Literature on Mandibular Movement, Chewing/Swallowing, and Video Analysis:

Studies investigating the relationship between mandibular function and chewing/swallowing difficulties during the oral phase have mostly compared invasive methods such as VFSS (Yamamoto et al., 2020); quantified physiological parameters of the mandible (Wänman & Staversjö, 2018; Ketel et al., 2020; Shupe et al., 2019); or involved the use of external materials such as chewing gelatin or food (Wilson et al., 2013; Motoi et al., 2013), or sensors (Hashimoto et al., 2018; Kinuta et al., 2005; Wilson et al., 2016). However, relatively few studies have discussed the correlation between these methods and actual chewing/swallowing disorders.

Research Motivation:

This study aims to develop a non-contact method that uses video analysis to track mandibular movement trajectories (distance, angle, velocity) and tongue movement speed during the oral preparatory phase in older adults. By correlating these physiological parameters with the presence or absence of chewing and swallowing difficulties—as determined by the Repetitive Saliva Swallowing Test (RSST)—this research hopes to establish a low-cost, accurate, and non-invasive screening tool for early-stage assessment of dysphagia in older adults.

Plan Content:

The project is scheduled to commence from the date of approval by the Institutional Review Board (IRB) and will continue until January 28, 2024, with a planned execution period of one year and ten months. The study will be carried out at Kaohsiung Municipal Siaogang Hospital, as well as various community locations across Kaohsiung City. These include district-level Community Development Associations, community-based long-term care stations, adult day care centers, and residential long-term care institutions (nursing-type facilities).

Participants will be enrolled and categorized into two groups: a normal swallowing group and a swallowing difficulty group. Group allocation will be determined based on the results of the Repetitive Saliva Swallowing Test (RSST), using a cutoff of ≥3 swallows as indicative of normal swallowing function and <3 as indicative of chewing or swallowing difficulties. In addition, some participants may be assessed using fiberoptic endoscopic evaluation of swallowing (FEES) and videofluoroscopic swallowing study (VFSS) conducted by the Center for Mastication and Swallowing Function Rehabilitation at Kaohsiung Municipal Siaogang Hospital.

The normal swallowing group will include 25 participants aged 65 to 74 years, 15 participants aged 75 to 84 years, and 10 participants aged 85 to 95 years. The swallowing difficulty group will consist of 30 participants aged 65 to 74 years, 20 participants aged 75 to 84 years, and 15 participants aged 85 to 95 years. In total, 115 older adults will be recruited for the study.

Execution Procedures and Methods:

Inclusion Criteria:

1.Older adults aged between 65 and 95 years.

2.Capable of performing the tasks correctly after training.

3.No significant impairments in lip function, dentition (including the use of dentures), or the ability to open and close the mouth.

4.Willingness to participate and compliance with the study protocol.

Exclusion Criteria (participants who meet the following conditions are not eligible for the study):

Presence of temporomandibular joint disorders or other factors that may affect mandibular movement.

All participants must voluntarily agree to participate after receiving a full explanation of the study content and are required to sign an informed consent form. After screening by the research staff according to the inclusion and exclusion criteria, basic demographic data (such as sex and age) will be collected. The assessments of mandibular movement, diadochokinesis (DDK), and the Repetitive Saliva Swallowing Test (RSST) will be conducted by licensed occupational therapists and physical therapists involved in the study.

Study Design:

(1) Basic Information Collection:** Including gender and age.

(2) Experimental Procedures

1. Recruitment of Eligible Participants

The first step involves screening participants and identifying exclusion criteria.

The second step involves processing basic participant information, which will be handled confidentially by the principal investigator.

2. Chewing and Swallowing Difficulty Assessment (RSST)

Participants are seated naturally in a chair, looking forward, with minimal movement of the head and body. The examiner places their index finger gently on the subject's laryngeal prominence (Adam’s apple), with the remaining fingers resting lightly on the neck. After ensuring the participant's mouth is moist, they are instructed to continuously swallow saliva for 30 seconds. The number of times the laryngeal prominence moves past the examiner's middle finger is recorded. A result of three or more swallows is considered normal; fewer than three indicates a chewing and swallowing difficulty.

Instructional script: "Swallow your saliva—keep swallowing—as many times as you can!"

Duration: Approximately 15 minutes (including explanation, recording, and on-site analysis).

3. Mandibular Movement (Maximum opening and closing of the mouth 10 times)

Participants are seated naturally in a chair, looking straight ahead, minimizing movement of the head and body. Five round stickers will be placed on the face to serve as reference points for measuring mouth-opening movements. The first point (Point A) is placed by palpation in the depression in front of the ear and serves as the axis. The second point is placed at the center above the upper lip, and the third at the center below the lower lip (Point C). The fourth point is placed parallel to Point A at a 5 cm distance (Point D), and the fifth point is placed on the tip of the nose (Point E), which serves as a reference for the BE distance. Participants are asked to perform maximum mouth opening and closing movements 10 times. During the process, a mobile phone is fixed on a tripod at a distance of 50 cm from the participant, aligned to face Point A. A laser level on the right side of the tripod is aimed horizontally at Point D, and an auxiliary light is mounted

above the phone for proper lighting. The video will be uploaded to a computer after the experiment for movement analysis. The following parameters will be extracted from the video:

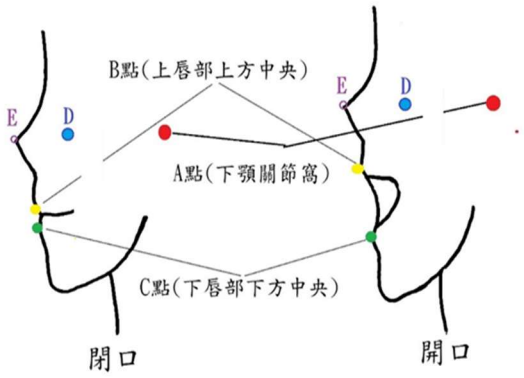
(1) Angle and distance between Points A, B, and C when the mouth is closed normally.

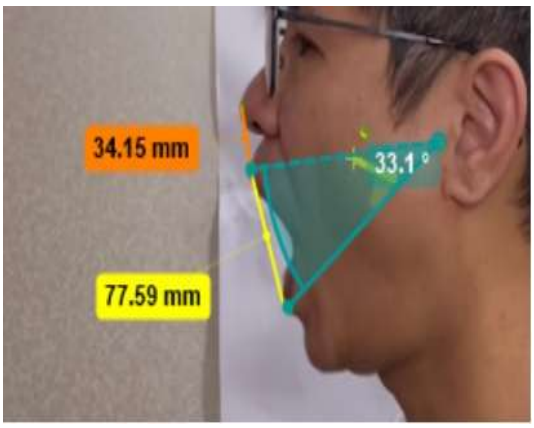
(2) Angle and distance between Points A, B, and C when the mouth is maximally open.

(3) Speed of opening and closing movements.

Instructional script:

"Now take a deep breath, then open your mouth as wide as you can and close it—repeat this movement 10 times."





Duration: Approximately 20 minutes (including explanation and recording).

4. Diadochokinesis (DDK)

The experiment is conducted one-on-one in a quiet room. The participant is seated, and a microphone is placed about 10 cm from the mouth. A timer is used, and the recording is done through the microphone. Participants are asked to pronounce /pa/, /ta/, and /ka/ (Mandarin: as in shǒu**pà**, tà**bù**, kā**fēi**; Taiwanese: **phah** gín-á, **that** kha-kiû, **khà** tiān-uē) as fast and as clearly as possible, repeating each syllable at least 15 times. Each syllable is tested three times, and practice is allowed before testing.

Instructional script:

"Now take a deep breath, then say /papapa/ as clearly and quickly as possible."

"Now take a deep breath, then say /tatata/ as clearly and quickly as possible."

"Now take a deep breath, then say /kakaka/ as clearly and quickly as possible."

If the participant cannot produce at least 15 repeated syllables or shows interruptions or errors, the number of correctly completed repetitions will be recorded. If errors occur in all attempts, the best performance will be used for analysis.

Duration: Approximately 15 minutes (including explanation, recording, and real-time analysis).

5. The total estimated time for the above experiments is 50 minutes. Including rest time, the full participant procedure will be completed within 60 minutes.

Study Design and Statistical Methods:

Statistical Methods:

Data will be analyzed using the Statistical Package for the Social Sciences (SPSS, IBM SPSS, Chicago, IL). Descriptive statistics will be used to analyze basic demographic data. Multivariate analysis of variance (MANOVA) will be applied to compare differences in mandibular movement trajectories (angle, distance, and velocity) and tongue movement speed among different groups, including gender, and between the normal swallowing group—comprising young-old adults (65–74 years), middle-old adults (75–84 years), and old-old adults (85–95 years)—and the swallowing difficulty group, categorized in the same age brackets. The moving average method will be used to analyze and predict trends (smoothness) in mandibular movement. Pearson correlation analysis will be conducted to examine the degree of correlation between mandibular movement trajectories (angle, distance, velocity), tongue movement speed, and the presence of chewing and swallowing difficulties.

Sample/Data Collection Methods, Frequency, Quantitative Data (e.g., dosage), and Storage Procedures, as well as Concurrent Treatments:

All collected data and signed consent forms will be securely stored at the Sports Biomechanics Laboratory on the 7th floor of the International Academic Research Building at Kaohsiung Medical University. Digital data will be saved on encrypted computers, while physical documents will be kept in locked drawers. Throughout the experimental period and until the end of the project, all materials will be managed by the principal investigator, with no access granted to unauthorized personnel.

Expected Outcomes and Benefits of the Study:

This study does not offer immediate benefits to the participants. The primary aim is to investigate and analyze the differences in mandibular movement trajectories (distance, angle, and velocity) and tongue movement speed among older adults in the Kaohsiung area. It is anticipated that the findings will contribute to the future development of early screening tools for detecting chewing and swallowing disorders in this population.

Possible Side Effects, Risks, and Handling Procedures:

1. During the testing process, a potential side effect may be pain or discomfort in the temporomandibular joint (TMJ). Since the experiment involves mandibular movement, participants will receive thorough safety education before the intervention and will be instructed to perform the movements correctly and appropriately. In the event of discomfort in the TMJ area, participants will be advised to apply a cold compress (15 minutes per session with a 5–10 minute break).

2. Appropriate rest periods will be provided between the two experimental sessions, during which participants will be asked if they are experiencing any discomfort, such as TMJ pain or discomfort. If any signs of discomfort or adverse reactions occur, the experiment will be immediately terminated.

3. All experimental equipment used is non-invasive and does not pose any harm to the human body. However, a very small number of participants may experience skin discomfort due to the use of adhesive stickers or pigment applied to the skin. In such cases, the experiment will be terminated

immediately to ensure participant safety.

4. All participants must voluntarily sign an informed consent form after receiving a full explanation of the study. They will be screened by research staff according to the inclusion and exclusion criteria before the collection of basic demographic data (such as sex and age). Assessments of mandibular movement, DDK, and RSST will be conducted by licensed occupational and physical therapists.

Laboratory Equipment:

Recording Equipment:

Model: ICD-PX470

Manufacturer: SONY

(https://helpguide.sony.net/icd/p47/v1/zh-tw/contents/TP0001156289.html)

Microphone:

Model: BY-MM1

Manufacturer: BOYA

(https://www.boya-mic.com.tw/product/boya-vdmcbymm1000/)

Video Recording Device:

Model: iPhone 13

Manufacturer: Apple Inc.

(https://support.apple.com/kb/SP851?locale=zh_TW)

Lighting Equipment:

Model: VL49 (see Figure 3-10)

Manufacturer: ULANZI

(https://www.ulanzi.com/products/mini-led-video-light-ulanzi-vl49?_pos=2&_sid=91f6bf26e&_ss=r)

Motion Analysis Software:

Kinovea 0.9.4: Chamant, (2021) Kinovea (Version 0.9.4), Computer software.

Available at: https://www.kinovea.org/