Swallowing Efficacy in Patients Undergoing Maxillomandibular Resection: Impact of Preoperative Tongue and Swallowing-Related Muscle Exercises

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Abstract

Swallowing difficulties potentially impact postoperative functional recovery and quality of life. This pilot study aimed to evaluate the effects of preoperative tongue and swallowing muscle exercises on maximum tongue strength and swallowing function in patients undergoing oral and maxillofacial surgery. Seven patients were randomly assigned to two groups: Group 1 performed tongue and swallowing exercises only after surgery, while Group 2 performed the exercises both preoperatively and postoperatively. Maximum tongue strength (MTS) and swallowing capacity were assessed using the Iowa Oral Performance Instrument (IOPI) and Repetitive Saliva Swallowing Test (RSST), respectively, at five time points: baseline (T0), one day before surgery (T1), and at 1 month (T2), 2 months (T3), and 3 months (T4) postoperatively. Both groups exhibited the lowest MTS at T2, followed by a gradual increase over time, with no significant differences between them. Group 1 reached an equivalent MTS value at T4, whereas Group 2 exceeded its baseline (T0) value, starting from T3. For RSST, no significant differences were observed within each group over time or in the changes between groups. Our preliminary findings indicate that preoperative tongue and swallowing exercises did not lead to significant improvements in maximum tongue strength or swallowing capacity. However, Group 2, which underwent preoperative training, demonstrated a more notable trend of improvement, particularly surpassing baseline values earlier than Group 1. These results suggest a potential benefit of preoperative training; however, further studies with larger sample sizes are required to confirm its efficacy and clinical relevance.

Keywords**:** *tongue, swallowing, exercise, maxillectomy, mandibulectomy*

1. Introduction

Swallowing safely and efficiently is a basic human function that needs complex neuromuscular process. The currently accepted model of swallowing is categorized into three primary phases: the oral, pharyngeal, and esophageal stages. During the oral phase, the tongue plays a critical role by sealing the bolus in the oral cavity against the hard palate and elevating it into the oropharynx to initiating the next phases of swallowing (Matsuo, & Palmer, 2008; Panara et al., 2022).

Surgical resection of oral, or oropharyngeal pathology, can impair tongue function, leading to reduced tongue mobility, diminished strength, and difficulties in bolus manipulation and propulsion into the pharynx, ultimately causing dysphagia during the oral and pharyngeal phases (Lazarus, 2006; Pauloski et al., 1994). Jawbone resections, such as mandibulectomy, further disrupt tongue function due to the attachment of intrinsic and extrinsic tongue muscles, including the genioglossus muscle, which is anchored to the mandible. This muscle plays a vital role in bolus preparation, pressing it against the palate, and moving it through the oral cavity into the pharynx (Kajee et al., 2013; Palmer, 1998). Moreover, patients with maxillary tumors frequently undergo maxillary and palatal resections, which can result in an open communication between the oral and nasal cavities. Without the hard palate, the tongue cannot efficiently transport the bolus to the posterior oral cavity during the oral phase of swallowing (Kamiyanagi et al., 2018). Studies have indicated that swallowing difficulties in maxillectomy patients are influenced by multiple factors, with maximum tongue pressure identified as a crucial determinant of swallowing ability (Ogino et al., 2021).

Research has demonstrated that tongue-strengthening exercises can enhance tongue strength and swallowing function in both healthy individuals and those with swallowing disorders. Tongue strength has been shown to be a reliable predictor of oral phase swallowing challenges, such as bolus manipulation and clearance (Robbins et al., 2007). Resistance training involving pressing the tongue against the palate not only strengthens the tongue but also improves anterior and superior hyoid movements during swallowing (Namiki et al., 2019). Moreover, swallowing exercises are also widely documented to enhance swallowing function during the oropharyngeal stages (Lancaster, 2015; Langmore, & Pisegna, 2015). However, patients may be unable to perform such exercises for several days post-surgery due to pain. In these cases, performing tongue and swallowing-related muscle exercises prior to surgery may be beneficial.

Prophylactic tongue and swallowing-related muscle exercises have been found to improve swallowing outcomes in patients undergoing radiotherapy for head and neck cancer (Roe, & Ashforth, 2011). However, limited research exists on the impact of pre-surgical tongue and swallowing exercises on postoperative swallowing difficulties. This study aims to investigate the effects of preoperative tongue and swallowing-related muscle exercises on maximum tongue strength and swallowing capacity in patients undergoing oral and maxillofacial surgery.

The primary hypothesis is that these pre-surgical tongue and swallowing-related muscle exercises can enhance maximum tongue strength and swallowing capacity compared to a control group.

2. Objectives

To investigate the effects of pre-operative tongue and swallowing-related muscle exercises on maximum tongue strength and swallowing capacity in patients undergoing oral and maxillofacial surgery.

3. Materials and Methods

3.1 Participants

This prospective pilot study involved participants scheduled for oral and maxillofacial surgeries between February 2023 and November 2024 at the Oral and Maxillofacial Surgery Department, Faculty of Dentistry, Chulalongkorn University, and Rajavithi Hospital, Bangkok, Thailand. All participants received detailed information about the study and provided written informed consent prior to enrollment.

The study adhered to the ethical standards outlined in the Declaration of Helsinki and was reviewed and approved by the ethics committees of the Faculty of Dentistry, Chulalongkorn University (HREC-DCU 2023-050), Rajavithi Hospital (66148), and the Thai Clinical Trials Registry (TCTR20231110001) https://www.thaiclinicaltrials.org/show/TCTR20231110001

Participants were included in the study if they met the following criteria: (1) classified as ASA I or II (healthy or with mild systemic disease), (2) undergoing resection in the maxillomandibular area affecting swallowing, such as mandibulectomy, maxillectomy, and glossectomy, (3) capable of performing tongue and swallowing-related muscle exercises, and (4) able to understand the Thai language through reading or listening. Exclusion criteria included: (1) a history of swallowing deficits, (2) prior experience with swallowing or tongue exercises, (3) a history of chemotherapy, (4) a history of radiotherapy to the head and neck area, (5) muscular disorders, (6) mental retardation or psychiatric issues, and (7) hypoglossal nerve injury or neurological impairments.

3.2 Study Protocol

Participants were randomly divided into two groups, with randomization conducted using blocks of four via an online randomization tool (www.sealedenvelope.com). The surgeons performing the procedures were blinded to the group assignments.

Group 1: Participants in this group started tongue and swallowing-related muscle exercises 4 weeks after surgery, following a recovery period. The exercises were then performed for 8 weeks.

Group 2: Participants in this group started the exercises 2 weeks prior to surgery, paused for 4 weeks after surgery to allow for recovery, and then resumed the exercises for an additional 8 weeks.

The participants were instructed by the assessor on how to perform the exercises, which included:

1. Tongue-in-Cheek (Hajdú et al., 2022): Push the tongue against the inside of the cheek, from side to side (Figure 1)**.** Hold for 5 seconds on each side: perform 5 repetitions.

2. Head-Tilt (Kim et al., 2015): Stand or sit with the back straight, then tilt the head from side to side as if trying to touch the ear to the shoulder (Figure 2)**.** Hold for 5 seconds on each side: perform 5 repetitions.

3. Effortful Swallowing (Balou et al., 2019): Push the tongue up to the roof of the mouth then swallow "hard" with effort (pretend to swallow a golf ball) (Figure 3): perform 10 repetitions

Participants performed the exercises at home three times daily (morning, noon, and evening), 7 days a week. To support adherence, they were provided with an instructional booklet, a daily checklist, video tutorials, and multimedia animations for reference.

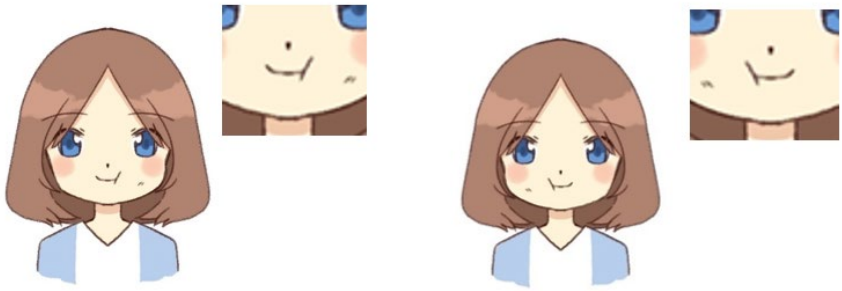

Figure 1 Demonstrated tongue-in-cheek exercise. A) Push the tongue against the inside of the right cheek, holding for 5 seconds. B) Push the tongue against the inside of the left cheek, holding for 5 seconds.

Figure 2 Demonstrated Head-tilt exercise. A) Tilt the head to the right side, holding for 5 seconds. B) Tilt the head to the left side, holding for 5 seconds.

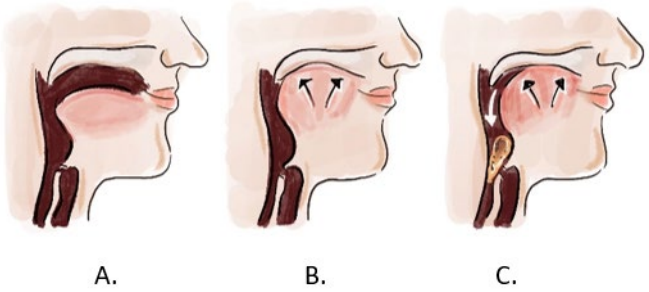

Figure 3 Demonstrated Effortful-swallow exercise. A) Start with tongue at rest. B) Press the tongue against the roof of mouth as hard as you can. C) Swallow as hard as you can.

3.3 Outcomes Measurement

3.3.1 Maximum Tongue Strength

Maximum tongue strength was measured using the Iowa Oral Performance Instrument (IOPI) (IOPI Medical LLC, Carnation, Washington) and recorded in kilopascals (kPa).

Maximum Tongue Strength (MTS) was measured by placing the bulb against the midline of the hard palate, just behind the upper teeth (Figure 4). Participants were instructed to press the tongue bulb against the palate with maximum effort, sustaining the pressure for 3 seconds. To ensure consistent placement during each trial, a permanent mark was made on the connecting tube at the level of the incisors. Each measurement was performed three times, and the average pressure was calculated and recorded.

3.3.2 Swallowing Capacity

Swallowing capacity was evaluated using the Repetitive Saliva Swallowing Test (RSST) (Oguchi et al., 2000). Participants were instructed to swallow their saliva as often as possible within a 30-second timeframe, while the assessor counted the number of swallows by palpating the larynx.

The evaluations were conducted at the following time points: 2 weeks before the surgery as a baseline (T0), 1 day prior to the mandibulectomy as the 2nd evaluation (T1), and at 4, 8, and 12 weeks after the mandibulectomy as the 3rd (T2), 4th (T3), and 5th (T4) evaluations, respectively. A summary of the evaluation schedule is presented in Figure 5.

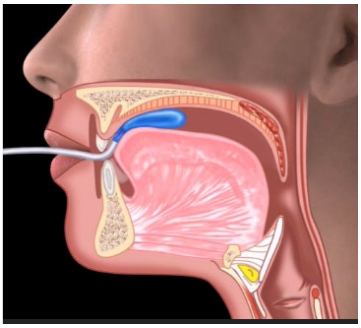

Figure 4 Maximum tongue strength (MTS) measurement

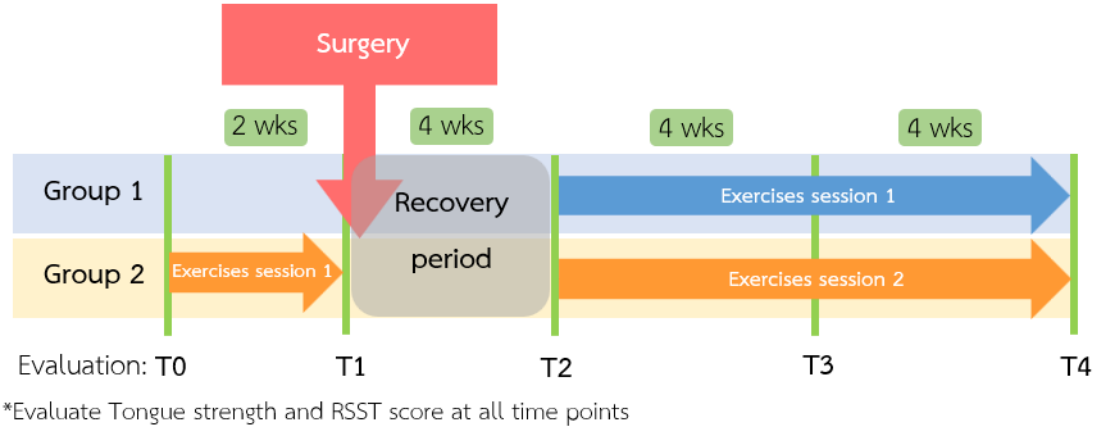

Figure 5 Timeline of evaluation

3.4 Statistical Analysis

Descriptive statistics were presented as frequencies and percentages. The Shapiro–Wilk test was used to evaluate the normality of data distribution. The Wilcoxon signed-rank test was applied to compare

maximum tongue strength and RSST across the evaluation time points (T0, T1, T2, T3, and T4) within each group. Inter-group comparisons at the same time points were performed using the Mann-Whitney U test. Statistical significance was set at a p value of less than 0.05, and all analyses were conducted using SPSS Statistics for Windows, version 29 (SPSS, Chicago, IL, USA).

4. Results and Discussion

4.1 Results

From February 2023 to November 2024, seven patients (4 males and 3 females) were randomly assigned to either Group 1 (3 participants) or Group 2 (4 participants). The mean age was 31.57 ± 9.64 years (range: 19–46 years). Diagnoses in Group 1 included one case each of verrucous carcinoma, adenoid cystic carcinoma, and odontogenic keratocyst. Group 2 diagnoses consisted of three cases of ameloblastoma and one case of osteoblastoma. Detailed baseline information is presented in Table 1. and no participants were excluded.

Table 1 Baseline characteristics

		Group 1 (n)	**Group 2 (n)**	**p-value**
Age (years)	Mean±SD	39±8.19	26±6.68	0.08[a]
	Range	30-46	19-35	
Gender	Male	1 (33.33%)	3 (75%)	0.27[b]
	Female	2 (66.67%)	1 (25%)	
MTS (kPa)	Mean±SD	51.44±13.49	41.5±12.57	0.29[a]
RSST (score)	Mean±SD	6±1	5.75±1.5	0.85[a]
Disease	No	2 (66.67%)	4 (100%)	0.21[b]
	Yes	1 (33.33%) (Dyslipidemia)	0 (0%)	
Medication	No	2 (66.67%)	4 (100%)	0.21[b]
	Yes	1 (33.33%)	0 (0%)	
Diagnosis	Benign	1 (33.33%)	4 (100%)	0.05[b]
	Malignant	2 (66.67%)	0 (0%)	
Treatment area	Tongue	1 (33.33%)	0 (0%)	0.16[b]
	Posterior of Mandible	1 (33.33%)	4 (100%)	
	Maxilla	1 (33.33%)	0 (0%)	
Reconstruction	No	1 (33.33%)	0 (0%)	0.18[b]
	FFF	0 (0%)	3 (75%)	
	ICBG	1 (33.33%)	1 (25%)	
	Obturator	1 (33.33%)	0 (0%)	
Complication	No	2 (66.67%)	2 (50%)	0.66[b]
	Yes	1 (33.33%) (Graft infection)	2 (50%) (Graft infection)	

SD=Standard Deviation, n=Number, MTS =Maximum tongue strength, RSST=Repetitive Saliva Swallowing Test, kPa=kilopascal, ICBG=Iliac Crest Bone Graft, FFF=Fibular Free flap

Statistical analysis using; [a] Mann-Whitney test, [b] Chi-square

For MTS, both groups showed a decrease one month after the surgery (T2). There was no statistically significant difference in the degree of reduction within the group at T2 (Table 2). After they performed the exercises, Group 2 showed a greater increase in MTS during T3 and T4 compared to Group 1(Table 3). Similarly, the RSST scores did not show any significant differences within or between the groups at any evaluation point (Table 1 and 2). Notably, none of the participants met the criteria for dysphagia, as all successfully completed at least three swallows within 30 seconds. There was no statistically significant difference in the changes in MTS and RSST compared to baseline at each time point (Table 3).

Table 2 Maximum tongue strength and repetitive saliva swallowing test values at different time points compared to baseline in each group

Evaluation visit			T0	T1	T2	T3	T4
MTS	Group 1	Mean ± SD	51.44±13.50	50.33±9.50	35.33±6.98	45.45±7.60	51.33±4.67
		p-value	N/A	1.00[a]	0.285[a]	0.285[a]	0.655[a]
	Group 2	Mean ± SD	41.5±12.57	45.33±13.49	34.17±11.39	47±6.53	43.5±8.21
		p-value	N/A	0.465[a]	0.144[a]	0.273[a]	0.715[a]
RSST	Group 1	Mean ± SD	6.00±1.00	5.67±0.58	5.33±2.31	5.00±1.00	5.00±1.00
		p-value	N/A	0.317[a]	0.414[a]	0.276[a]	0.276[a]
	Group 2	Mean ± SD	5.75±1.5	6.25±0.96	5.0±1.41	6±0.82	6.25±1.71
		p-value	N/A	0.317[a]	0.581[a]	0.564[a]	0.414[a]

MTS =Maximum tongue strength, kPa=kilopascal, RSST= Repetitive saliva swallowing test

[a] p-value compared with baseline (T0), Statistical analysis using Wilcoxon signed-rank test.

Table 3 Changes in maximum tongue strength and repetitive saliva swallowing test scores from baseline at each time point, compared between groups

Evaluation visit		T1-T0	T2-T0	T3-T0	T4-T0
MTS	Group 1	-1.11±4.55	-16.11±15.76	-6±8.82	-0.11±9.50
	Group 2	3.83±9.53	-7.33±8.04	5.58±10.44	9.56±15.29
	p-value	0.48	0.289	0.157	0.48
RSST	Group 1	-0.33±0.58	-0.67±1.53	-1±1.73	-1±1.74
	Group 2	0.5±1	-0.75±2.63	0.25±0.96	0.5±1.29
	p-value	0.186	0.719	0.266	0.208

MTS =Maximum tongue strength, kPa=kilopascal, RSST= Repetitive saliva swallowing test
Statistical analysis using Mann-Whitney U test

4.2 Discussion

Surgical removal of oral and oropharyngeal lesions can lead to reduced tongue functionality, difficulties in tongue mobility, diminished tongue strength, impaired bolus control, and challenges in propelling the bolus into the pharynx. These issues often result in dysphagia during the oral and pharyngeal phases of swallowing (Lazarus, 2006; Pauloski et al., 1994). Research has demonstrated that tongue-strengthening and swallowing exercises can enhance tongue strength and improve swallowing function in both healthy individuals and those with pathological conditions. Tongue strength has been identified as a reliable indicator of oral phase swallowing difficulties, such as bolus manipulation and clearance (Robbins et al., 2007). Additionally, several tools can be used to assess swallowing capacity, including the Modified Barium Swallow Study (MBS) and Fibre-Optic Endoscopic Evaluation of Swallowing (FEES) (Hintze, 2013). However, in general practice or when these instruments are unavailable, a clinical measurement method can serve as a useful screening tool for swallowing difficulties. The Repetitive Saliva Swallowing

Test (RSST) is a simple, non-invasive screening tool for dysphagia, demonstrating high sensitivity and a strong correlation with aspiration risk compared to video fluorographic assessment (Oguchi et al., 2000; Persson et al., 2019). Combining these two screening evaluation methods, which evaluate swallowing capacity in both the oral and pharyngeal phases, may yield more reliable outcomes in this study.

This study found that the maximum tongue strength (MTS) in Group 2 increased from the baseline evaluation after completing two weeks of exercises (T1-T0) compared to Group 1, though the difference was not statistically significant. This result aligns with findings from other studies in a systematic review, which reported a progressive increase in tongue strength from baseline up to eight weeks of exercises compared to control group (Nurfatul Jannah et al., 2022). However, MTS declined one month after surgery (T2) in both groups, consistent with previous research by Pauloski et al., (1995); (1994), which reported a temporary decline in speech and swallowing function within one to three months after surgical intervention. However, Robbins et al., (2007) observed improvements in tongue and swallowing pressures, Penetration-Aspiration Scale scores, and swallowing-related quality of life in stroke patients following an eight-week tongue-strengthening program.

Notably, Group 2 exhibited a smaller reduction in MTS from baseline (T2-T0) compared to Group 1, though the difference was not statistically significant. By two months post-surgery (T3), Group 2's MTS values exceeded baseline levels, whereas Group 1's remained below baseline. While Group 1 showed gradual improvement, it did not surpass baseline until T4. These findings align with Carroll et al., (2008), who demonstrated that patients undergoing two weeks of pre-treatment swallowing exercises before chemoradiotherapy exhibited improved tongue base-to-posterior pharyngeal wall positioning during swallowing. These results suggest that preoperative tongue-strengthening exercises may help preserve tongue muscle strength following oral and maxillofacial surgery.

At baseline (T0), none of the participants met the diagnostic criteria for dysphagia according to the Repetitive Saliva Swallowing Test (RSST) (<3 swallows per 30 seconds). Throughout the study period (T1–T4), no significant changes in RSST scores were observed in either group. These findings contrast with previous studies that have reported postoperative swallowing impairments (Nakayama et al., 2022; Pauloski et al., 1995; Pauloski et al., 1994; Zacharia, 2013). However, this discrepancy may be due to differences in patient populations, as previous research has primarily focused on individuals with oropharyngeal cancer who often undergo additional treatments, such as neck dissection or chemoradiotherapy-factors known to exacerbate swallowing dysfunction.

The tongue and swallowing-related muscle exercises in this study aimed to stretch and strengthen the tongue and related musculature, potentially reducing scar fibrosis and enhancing swallowing efficiency. This may contribute to improved swallowing comfort and effectiveness. The tongue-in-cheek exercise, an orofacial muscle exercise, involves pushing the tongue against resistance with maximum force, which strengthens tongue muscles, improves range of motion, and enhances oral muscle coordination (Choy et al., 2023). Similarly, the head-tilt exercise increases pharyngeal pressure and facilitates bolus movement through the pharynx, particularly benefiting patients with unilateral tongue or pharyngeal weakness by directing the bolus along the unaffected pharyngeal wall (Kim et al., 2015). Effortful swallowing exercises, which are task-specific, enhance posterior tongue base movement, tongue base retraction, and pharyngeal pressure (Archer et al., 2021).

Variations in surgical sites may have influenced the study outcomes, as different resections impact swallowing function to varying degrees. Group 1 included two patients with distinct surgical interventions: one underwent a maxillectomy followed by adjunctive radiotherapy (RT) and prosthetic rehabilitation with an obturator for adenoid cystic carcinoma, while the other underwent a wide tongue excision for verrucous carcinoma. In contrast, Group 2 comprised only mandibulectomy cases. Borggreven et al., (2007) reported that oral tongue resection resulted in the least swallowing difficulties, whereas resection involving the base of the tongue and the soft palate led to the most severe swallowing impairments, particularly affecting the contact between the tongue base and the posterior pharyngeal wall. Although evidence on the effects of tongue and swallowing-related muscle exercises across different surgical sites remains limited, other studies involving various surgically treated oropharyngeal sites have still reported significant improvements in

swallowing function following rehabilitation exercises, consistent with the findings of this study (Balbinot et al., 2022; Hsiang et al., 2019; Zhang et al., 2022).

The findings of this study should be interpreted with caution due to several limitations. First, the small sample size of patients undergoing oral and maxillofacial surgery makes it difficult to conclusively determine the benefits of prophylactic tongue and swallowing-related muscle exercises. Second, the unequal distribution of surgical procedures may have influenced the outcomes. Third, the study design restricted the ability to establish clear correlations between study outcomes and potential influencing factors. While RT-related complications such as mucositis, dysphagia, and xerostomia were not significant concerns in this study. Fourth, the short data collection period prevented an assessment of long-term detraining effects after discontinuing the exercises. Fourth, this study employed a screening method to assess patients' swallowing capacity rather than a detailed evaluation of the actual swallowing mechanism. While screening tools are valuable in clinical practice due to their safety, ease of use, and ability to detect swallowing difficulties at an early stage, they may lack the precision needed for a comprehensive analysis. To obtain more detailed insights into swallowing function, future studies should incorporate gold-standard swallowing assessment methods, such as the Modified Barium Swallow Study or Fiber-Optic Endoscopic Evaluation, which provide objective and in-depth evaluations of swallowing physiology. Finally, ethical constraints precluded the inclusion of a non-exercise control group, limiting the ability to compare intervention outcomes against patients who did not perform the exercises. Consequently, this study cannot definitively determine the necessity of these exercises as part of a standardized swallowing rehabilitation program.

5. Conclusion

Although MTS declined at one month postoperatively in both groups, a gradual recovery was observed over time. Notably, the group that underwent preoperative exercises exhibited a smaller initial reduction in MTS and surpassed baseline levels earlier than the non-exercise group, though the differences were not statistically significant. Swallowing function, as assessed by the Repetitive Saliva Swallowing Test (RSST), remained stable throughout the study period, with no significant deterioration. These findings suggest that preoperative exercises may facilitate postoperative tongue strength recovery, although their effect on swallowing function remains inconclusive. Further research with larger, more balanced cohorts is needed to confirm these preliminary findings and better understand the role of tongue-strengthening exercises in postoperative rehabilitation.

6. Acknowledgements

This research project was supported by the Oral and Maxillofacial Surgery and Digital Implant Surgery Research Unit, Faculty of Dentistry, Chulalongkorn University. The authors extend their gratitude to Dr. Kitipong Kaewpichai for his cooperation during data collection at Rajavithi Hospital.

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