Patient Preference and Adherence

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ORIGINAL RESEARCH

Effect of Nurse-Led Swallowing Rehabilitation on Swallowing Function, Quality of Life, and Adherence in Patients with Oral Cancer: A Single Center Randomized Controlled Trial

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Objective: Oral cancer patients frequently experience high rates of dysphagia, multiple complications, and poor rehabilitation compliance post-surgery. This study aims to evaluate the effectiveness of specialized nurse-led dysphagia rehabilitation program in improving patients' swallowing function, quality of life, adherence, and nutritional status.

Methods: A single center randomized controlled trial design was employed. 89 patients admitted to the Department of Oral and Maxillofacial Surgery at Zhejiang Cancer Hospital between July 17, 2025, and October 20, 2025, were randomly assigned to an intervention group (n=45) or a usual care group (n=44). The intervention group received a comprehensive rehabilitation program (diagnostic phase, perioperative phase, pre-discharge preparation phase, adjustment and adaptation phase) implemented by a multidisciplinary team led by specialized nurses, supported by a WeChat mini-program. The usual care group received a standard rehabilitation program. Outcome measures included functional oral intake scale, swallowing-related quality of life scale, swallowing function exercise compliance scale, and body mass index. Assessments were conducted at baseline (T0), 1 week post-surgery (T1), 2 weeks (T2), and 4 weeks (T3). Generalized estimating equations were used to analyze changes in outcomes over time.

Results: Post-intervention, the intervention group demonstrated significantly superior scores compared to the usual care group in swallowing function (at T2 and T3), quality of life (at T1, T2, and T3), and adherence (at T1, T2, and T3). Nutritional status was also significantly better in the intervention group at T1 and T2. Generalized estimating equations analysis revealed statistically significant group-by-time interaction effects for swallowing function, quality of life, adherence, and nutritional status.

Conclusion: Compared with conventional rehabilitation protocols, a swallowing rehabilitation program led by specialized nurses effectively improves swallowing function, quality of life, adherence, and early nutritional status in patients after oral cancer surgery.

Keywords: oral cancer, dysphagia, rehabilitation nursing, specialist nurse, swallowing function

Introduction

Oral cancer is the most common malignant tumor in the head and neck region, and includes cancers of the lip, tongue, gum, and floor of mouth, with over 90% of cases being classified as squamous cell carcinoma.[1] According to global cancer statistics from 2020, approximately 378,000 new cases are diagnosed annually, ranking sixth globally in terms of incidence.[2] The disease burden in China continues to rise. Currently, a comprehensive treatment model centered on surgical resection combined with radiotherapy and chemotherapy has increased the five-year overall survival rate to around 60%.[3] Against this backdrop, the focus of treatment has expanded beyond merely improving survival rates to encompass long-term patient quality of life. One of the major long-term concerns is treatment-induced functional sequelae.

Dysphagia, which is highly prevalent and has severe clinical consequences, has emerged as a core issue affecting rehabilitation quality.[4] Swallowing is a highly intricate neuromuscular coordination process that relies on the integrity of

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the anatomical structures of the mouth and throat and the integration of sensory and motor functions.[5] While radical oral cancer surgery achieves complete tumor resection, it often inevitably damages critical structures and nerves, such as the tongue, mandible and soft palate, thereby impairing the physiological mechanisms of swallowing.[6] Clinical studies report an extremely high incidence of postoperative dysphagia, ranging from 66% to 88%, with some studies indicating an initial incidence as high as 98% in the postoperative period.[7–9] This complication directly causes physiological hazards such as aspiration, aspiration pneumonia, malnutrition and dehydration, and also exacerbates psychological distress such as anxiety and depression,[2,10] creating a vicious cycle. Ultimately, these factors lead to adverse clinical outcomes, including prolonged hospital stays, increased medical costs and poor functional recovery.[11]

Research indicates that standardized swallowing rehabilitation training can effectively reduce the incidence and severity of dysphagia.[12] Currently, commonly used clinical rehabilitation methods include chin tuck against resistance exercise, respiratory muscle training, and oropharyngeal muscle training.[13–15] However, these approaches face limitations such as monotonous training patterns, transportation difficulties, and shortages of specialized personnel, which affect patient compliance and consequently lead to suboptimal rehabilitation outcomes.[16,17] Therefore, effectively enhancing patient compliance and accelerating the rehabilitation process has become an urgent issue.

Baudelet M et al compared the effects of diary support, app support, and therapist support on patient compliance. They found that during a 4-week training period, the therapist support group demonstrated the highest compliance rate, while the app support group had the lowest.[18] This result highlights the critical role of professionals in the rehabilitation process. However, as of 2024, China has only approximately 50,000 rehabilitation therapists, equating to roughly 3.57 therapists per 100,000 population—far below the international standard of 50 per 100,000.[19] This shortage struggles to meet the growing demand for rehabilitation services.

Since 2002, China has advanced its specialized nurse training system. By the end of 2023, the nation had trained over 44,000 specialized nurses, with the scope of specialized nursing continuously expanding. Research indicates that specialized nurses not only effectively improve patients' health status, functional capacity, and quality of life while shortening hospital stays and reducing readmission rates, but also enhance patients' self-efficacy and satisfaction. They partially compensate for the shortage of rehabilitation therapists.[20] Despite specialized nurses playing a pivotal role in dysphagia management, research on nurse-led rehabilitation models remains significantly constrained. Existing studies predominantly focus on short-term, fragmented technical interventions, lacking standardized protocols and professional access criteria. This results in insufficient replicability and rigor within intervention program. More critically, there is a severe shortage of evidence regarding long-term outcomes and quality of life, hindering the effective transition of this model from clinical exploration to systematic, evidence-based nursing practice.[21,22]

Against this backdrop, this study aims to evaluate the impact of a swallowing rehabilitation strategy led by specialized nurses on post-oral cancer surgery patients' swallowing function, quality of life, adherence, and nutritional status. The goal is to provide more effective rehabilitation support for oral cancer survivors.

Participants and Methods

Study Design

A parallel, double-armed, single-center, randomized controlled trial was conducted at the Zhejiang Cancer Hospital between July 17 and October 20, 2025. The study was registered on the Chinese Clinical Trial Registry (www.chictr.org.cn) under the registration number ChiCTR2500106129. Eligible participants were randomly assigned to the usual care group and intervention group in a ratio of 1:1.

Participants

The inclusion criteria were as follows: (1) Pathologically confirmed diagnosis of oral cancer; (2) Undergone radical surgical treatment; (3) Provided informed consent and signed relevant documentation. The exclusion criteria were as follows: (1) Presence of psychiatric disorders or cognitive impairment; (2) Swallowing disorders caused by irreversible laryngeal nerve transection during surgery or other factors; (3) Concurrent malignant tumors in other sites or severe systemic diseases.

This study was approved by the Institutional Review Board of the Zhejiang Cancer Hospital (Approval no. 2025–79) on January 22, 2025. Written informed consent and signature were obtained from each participant before the beginning of the study. All protected healthcare information was exclusively used for research purposes and safeguarded throughout the study.

Research Methods

All patients meeting inclusion criteria were randomly assigned to either the intervention group or the usual care group. Assessment was conducted using the Functional Oral Intake Scale, Swallowing-related Quality of Life, Swallowing Function Exercise Compliance Scale, Body Mass Index. Assessment timepoints included preoperative (T0), 1 week postoperative (T1), 2 weeks postoperative (T2), and 4 weeks postoperative (T3). Data collection interviews averaged 20 minutes in duration. All data were collected by two uniformly trained rehabilitation specialist nurses holding master's degrees during scheduled follow-up periods to ensure consistency and accuracy. The specific measures were as follows.

Intervention Group

Recruit one physician with five or more years of experience, one rehabilitation therapist, and four specialized rehabilitation nurses. The physician and rehabilitation therapist are responsible for the patient's final diagnosis, developing and reviewing personalized swallowing rehabilitation plans and treatment protocols. Nurses serve as the primary implementers of these plans, handling the execution of rehabilitation exercises, patient education, regular follow-ups, and data collection and documentation.

Prior to intervention, all team members will undergo 10 hours of standardized training covering: the theoretical foundation of this rehabilitation program (timing theory), specific implementation methods for each stage, standardized communication techniques, and key points for swallowing function assessment and training. This ensures consistent and professional team operations.

This program follows the disease progression trajectory, seamlessly integrating rehabilitation interventions into four critical periods to ensure comprehensive, continuous management from diagnosis through postoperative recovery. See Table 1 for specific details.

Usual Care Group

Implement standard rehabilitation care protocols, including Dry swallowing exercises and supraglottic elevation training: 5–8 repetitions per set, 2 sets daily. Oral motor exercises (jaw, lips, cheeks, tongue movements): 10–20 repetitions per exercise, 2 sets daily. Coughing training: 10–20 repetitions per set, 2 sets daily. Routine care: Includes oral care, psychological support, pain management, wound care, and dietary guidance. Post-discharge follow-up: Weekly visits primarily assess swallowing function and adjust protocols as needed. Distribute printed health education materials.

Observation Indicators

Demographic Data Collection

At enrollment, demographic and baseline clinical characteristics were collected for all participants, including age, gender, tumor subtype, smoking history, alcohol consumption history, underlying medical conditions and Body Mass Index (BMI).

Evaluation of Swallowing Function

Functional Oral Intake Scale (FOIS), ranging from 1 to 7 levels, with 1 = Nothing by mouth, 2 = Tube-dependent with minimal attempts of intake of food or liquids, 3 = Tube-dependent with consistent oral intake of food or liquids, 4 = Total oral diet of a single consistency, 5 = Total oral diet with multiple consistencies but requiring special preparations or compensations; 6 = Total oral diet with multiple consistencies without special preparation but with specific food limitations; and 7 = Total oral diet with no restrictions.[23]

Evaluation of Quality of Life

The Swallowing-related Quality of Life (SWAL-QOL) scale designed by McHorney et al was adopted. This 44-item scale comprises 11 dimensions, assessing swallowing-related quality of life from social interaction, emotional,

Table 1 Swallowing Rehabilitation Program Content

Stage	Time	Contents
Diagnosis Phase	From diagnosis to admission to the pre-hospital preparation center	(1) Educate on disease knowledge, treatment plans, and the importance of oral preparation; guide selection of mouthwash and oral hygiene strategies. (2) Establish a friendly nurse-patient relationship, introduce the medical team, calm emotions, and enhance confidence in treatment. (3) Assist with preoperative examinations, conduct baseline swallowing function assessments, and implement breath-swallow coordination training. Delivered via a WeChat mini-program (Kangtu Guardian—Easy Swallow) combined with printed materials.
Perioperative Phase	From ward admission to 2 weeks post-surgery	(1) Provide systematic instruction on managing postoperative complications, nutrition, skin grafts, pain, and airway management. (2) Divide rehabilitation into three phases: continuous tube feeding, intermittent tube feeding, and oral feeding. Guide patients in effective coughing, sputum clearance, swallowing muscle training, tongue exercises, Mendelssohn maneuvers, eating environment, feeding position, eating techniques, meal timing, portion sizing, and hydration training. (3) Promptly address concerns and alleviate negative emotions. Rehabilitation plans are dynamically adjusted by specialized rehabilitation nurses based on ongoing assessments.
Pre-Discharge Preparation Phase	2 Days Before Discharge	(1) Thoroughly explain discharge precautions, complication monitoring, and emergency medical pathways. (2) Reinforce swallowing exercise techniques, aspiration prevention and management, articulation training, dietary preparation, and nutritional calculations. Train patients and caregivers to use the "Kangtu Guardian" mini-program for self-assessment and documentation. (3) Affirm the patient's positive progress during hospitalization to reinforce their rehabilitation confidence and the family caregiver's trust.
Adjustment and Adaptation Phase	4 weeks post-surgery	(1) Conduct follow-ups via phone, WeChat, or "Kangtu Guardian" mini-program, providing offline outpatient appointment information. (2) Guide current dietary management, oral hygiene, and functional exercises; document issues, analyze causes, and adjust the rehabilitation plan. (3) Encourage patient expression and address negative emotions; provide additional emotional support for those with poor recovery and recommend in-person follow-up visits. Conduct weekly summaries and adjustments.

psychological, and physical perspectives. Lai et al adapted and revised the Chinese version, achieving reliability coefficients ranging from 0.847 to 0.906 and validity coefficients from 0.870 to 1.000. Scoring employs a 5-point Likert scale, yielding scores between 44 and 220 points. The higher the score, the better the patient's quality of life.[24]

Evaluation of Adherence

The Swallowing Function Exercise Compliance Scale developed by Qin et al comprises three dimensions: rehabilitation exercise compliance (items 1–8), exercise effect monitoring compliance (items 9–11), and proactive advice-seeking compliance (items 12–14). Each item uses a 4-point Likert scale ranging from "Not at all" to "Completely," scored as 1 to 4 points respectively. The total score ranges from 14 to 56 points, with higher scores indicating greater compliance with functional exercises.

Randomization, Allocation Concealment and Blinding

Patients were randomly assigned to the intervention group and the usual care group via a computer-generated randomization program. Eligible patients were sequentially numbered according to their admission order and allocated to groups based on corresponding numbers in the randomization table A total of 89 patients were enrolled in this study, comprising 45 in the intervention group and 44 in the usual care group. Due to significant differences in intervention formats, blinding of patients and intervention-implementing researchers was not feasible. However, to ensure impartiality in data analysis, an independent researcher coded the study data using SPSS, designating the intervention group as "A" and the

usual care group as "B". The data analysts thus remained blind to the group assignments. Following completion of the research report, the investigator disclosed the coding meanings: the letter "A" corresponded to the intervention group, and "B" to the usual care group.

Statistical Processing

The required sample size was determined using G*Power 3.1 software. Calculations indicated that at an α level of 0.05 and an effect size (w) of 0.4, a minimum sample size of 61 cases was required to achieve 80.0% test power. Accounting for a 20% attrition rate, the study initially planned to enroll 74 participants. The final total number of participants enrolled was 89 (Figure 1).

Statistical analyses were performed using IBM SPSS (version 20.0), with intention-to-treat analysis. Data normality was tested using normal Q-Q plots and Shapiro–Wilk tests. Normal continuous data were reported as the mean (SD) and analyzed using independent sample *t*-test. The median (interquartile range, IQR) and Mann–Whitney *U*-tests were used for non-normal data. Categorical variables were compared using $\chi 2$ test with frequencies and percentages. Generalized estimating equation (GEE) analysis was used to assess changes in the differences in outcomes at T1, T2 and T3 compared with those in T0 between the two groups and compare changes in outcomes over time. Sensitivity analysis reassesses the efficacy of interventions following multiple interpolations to determine the robustness and reliability of conclusions. Furthermore, subgroup analysis and interaction analysis are employed to investigate whether factors such as disease type, underlying medical conditions, age, and gender influence the impact of interventions on swallowing function. All statistical analyses were two-sided, and the significance level was set at 0.05.

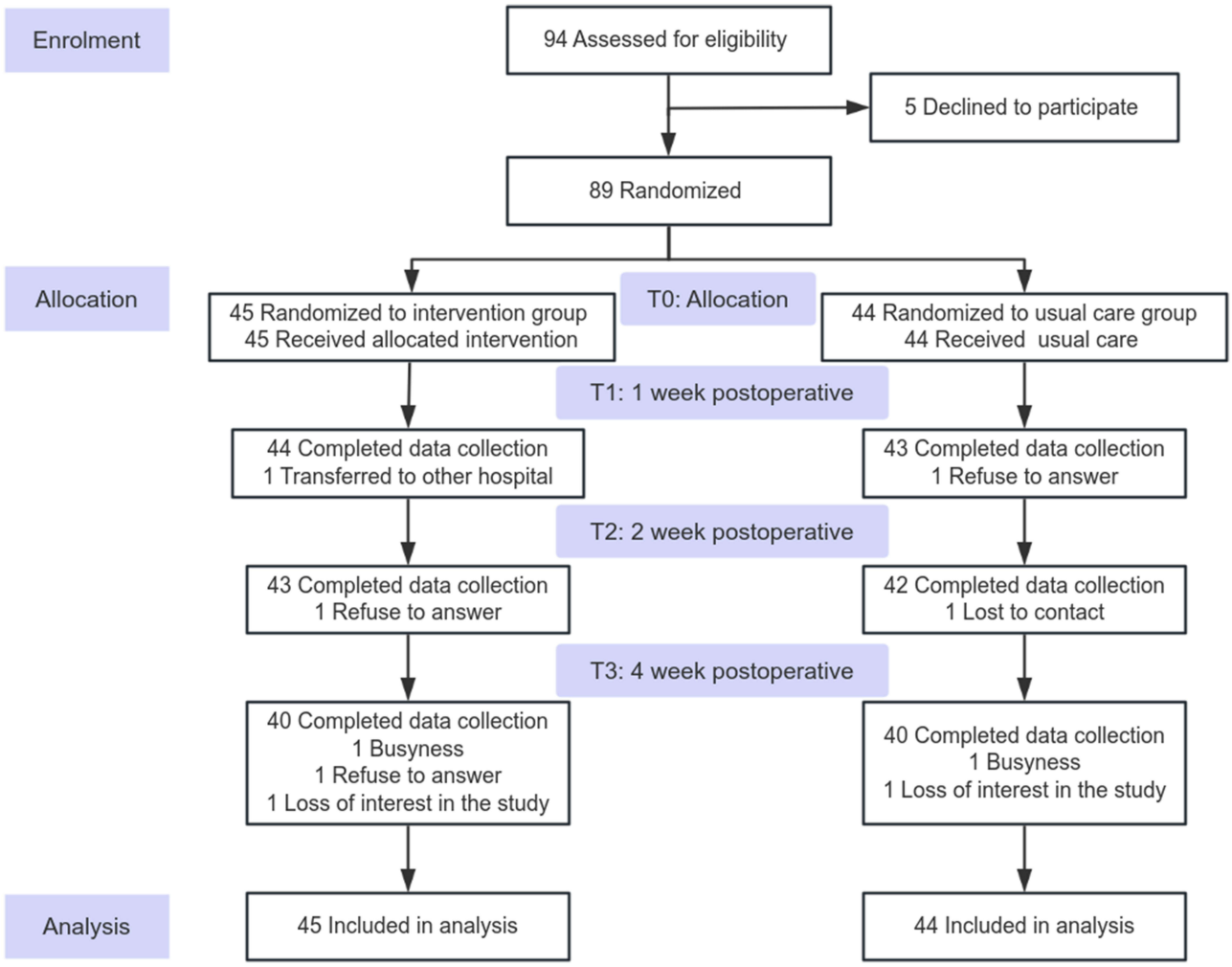

Figure 1 Flowchart illustrating the recruitment and allocation of participants in the study.

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Results

Participant Flow

A total of 94 oral cancer patients were screened prior to commencement, with 89 eligible participants randomly allocated to either the intervention group (n=45) or the usual care group (n=44). The CONSORT flow diagram is presented in Figure 1. Data collection was completed by 87 participants at T1, 85 participants at T2, and 80 participants at T3. Reasons for withdrawal in the intervention group included transfer to another hospital, refusal to respond, and loss of interest in the study. The primary reasons for withdrawal in the usual care group were refusal to respond and loss of contact. The overall attrition rate was 10.1%. No significant differences were observed between participants who completed the study and those who withdrew in terms of baseline characteristics for sociodemographic features and outcome variables (as shown in Supplementary Material Table 1).

Comparison of General Data

A total of 89 patients were included. There were no significant differences between the two groups in terms of age, underlying diseases, baseline swallowing function, or BMI ($P > 0.05$), indicating comparability, as shown in Table 2.

Table 2 Baseline Demographic and Clinical Characteristics of Study Participants (n = 89)

Parameter	Observation Group	Usual Care Group	t/χ2 /Z	P value*
Gender, n (%)			0.105*	0.746
Male	22(48.9%)	20(45.5%)		
Female	23(51.1%)	24(54.5%)		
Age, M ± SD	63.30±14.58	63.08±14.60	0.069#	0.945
Smoking History, n (%)				
Yes	25(55.6%)	23(52.3%)	0.096*	0.756
No	20(44.4%)	21(47.7%)		
Drinking history, n (%)				
Yes	23(51.1%)	23(52.3%)	0.012*	0.913
No	22(48.9%)	21(47.7%)		
Disease Type, n (%)			0.846&	0.838
Tongue cancer	17(37.8%)	17(38.6%)		
Oral floor cancer	2(4.4%)	4(9.1%)		
Cheek mucosa Cancer	15(33.3%)	13(29.5%)		
Other types	11(24.4%)	10(22.7%)		
Underlying medical conditions, n (%)			1.710&	0.425
0	4(8.9%)	2(4.5%)		
1	26(57.8%)	31(70.5%)		
2 or more	15(33.3%)	11(25.0%)		
Eat-10	2.76±0.802	2.68±0.771	0.442#	0.660
BMI	21.64±1.351	21.65±1.371	0.043#	0.966

Notes: #independent sample *t*-test was used for comparison between the two groups; &nonparametric test was used for comparison between the two groups; *chi-square test was used for comparison between the two groups.

Comparison of Swallowing Function Between the Two Groups Before and After Intervention

There was no significant difference in swallowing function scores between the two groups at baseline and 1 week post-intervention (P > 0.05). However, at 2 and 4 weeks post-intervention, the intervention group demonstrated higher swallowing function scores than the usual care group, indicating that nurse-led swallowing rehabilitation measures promote recovery of swallowing function in oral cancer patients (P<0.05). The GEE modeling showed significant interaction terms (group*time) at T2 (β= 1.124, 95% CI = from 0.564 to 1.684, p<0.001) and T3 (β= 0.871, 95% CI = from 0.311 to 1.431, p=0.002), but no statistically significant interaction effects were detected at T1, as shown in Tables 3, 4 and Figure 2.

Comparison of Quality of Life Between the Two Groups Before and After Intervention

Prior to intervention, no significant difference existed in quality of life scores between the two groups (P > 0.05). At 1 week, 2 weeks, and 4 weeks post-intervention, the quality of life scores in the intervention group were higher than those in the usual care group, indicating that nurse-led swallowing rehabilitation measures effectively enhances quality of life (P<0.05). The GEE modeling showed significant interaction terms (group*time) at T1 (β= 9.101, 95% CI = from 1.414 to 16.788, p=0.020), T2 (β= 15.066, 95% CI = from 7.380 to 22.753, p<0.001) and T3 (β= 10.971, 95% CI = from 3.825 to 18.658, p=0.005), as shown in Tables 3, 4 and Figure 3.

Table 3 Comparison of Outcome Measures Between the Two Groups Before and After the Intervention (n = 89)

Scale	Group	n	T0	T1	T2	T3
FOIS	Usual care group	44	5.11±0.81	2.25±0.44	4.55±1.23	5.91±0.89
	Intervention group	45	4.96±0.80	2.38±0.65	5.51±1.65	6.62±0.72
	F		0.927	1.085	3.131	4.185
	P		0.357	0.281	0.002	<0.001
	Cohen' d		0.19	−0.23	−0.66	−0.88
SWAL-QOL	Usual care group	44	105.16±12.75	116.61±13.55	131.18±14.25	150.45±15.52
	Intervention group	45	105.40±11.86	125.96±13.32	146.49±13.46	161.67±10.63
	F		0.092	3.280	5.212	3.984
	P		0.927	<0.001	<0.001	<0.001
	Cohen' d		−0.20	−0.69	−1.10	−0.84
BMI	Usual care group	44	21.65±1.37	18.52±0.84	20.29±1.11	21.29±1.79
	Intervention group	45	21.64±1.35	19.94±1.23	21.01±1.18	21.39±1.85
	F		0.043	6.359	2.952	0.266
	P		0.966	<0.001	0.004	0.791
	Cohen' d		−0.01	−1.34	−0.62	−0.56
Swallowing Function Exercise Compliance Scale	Usual care group	44	23.52±1.53	38.34±2.52	33.95±2.33	26.57±1.76
	Intervention group	45	23.24±1.37	44.87±1.54	40.36±1.40	34.84±2.50
	F		0.904	14.745	15.737	18.055
	P		0.368	<0.001	<0.001	<0.001
	Cohen' d		0.19	−3.12	−3.33	−3.82

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Table 4 Changes in Outcomes at T1, T2 and T3 in Two Groups Compared to T0 Based on GEE Models

	β	95% CI		p
		Lower Limits	Upper Limits	
FOIS				
Group (Usual care group vs Intervention group)	−0.158	−0.554	0.238	0.434
Time				
Baseline	Reference			
1th W	−2.864	−3.262	−2.465	<0.001
2th W	−0.568	−0.967	0.170	0.005
4th W	0.795	0.397	1.194	<0.001
Group * time				
Group * T0	Reference			
Group * T1	0.286	−0.274	0.846	0.317
Group * T2	1.124	0.564	1.684	<0.001
Group * T3	0.871	0.311	1.431	0.002
SWAL-QOL				
Group (Usual care group vs Intervention group)	0.241	−5.194	5.676	0.931
Time				
Baseline	Reference			
1th W	11.455	5.989	16.920	<0.001
2th W	26.023	20.557	31.488	<0.001
4th W	45.295	39.830	50.761	<0.001
Group * time				
Group * T0	Reference			
Group * T1	9.101	1.414	16.788	0.020
Group * T2	15.066	7.380	22.753	<0.001
Group * T3	10.971	3.285	18.658	0.005
BMI				
Group (Usual care group vs Intervention group)	−0.012	−0.580	0.555	0.966
Time				
Baseline	Reference			
1th W	−3.130	−3.700	−2.559	<0.001
2th W	−1.405	−1.975	−0.834	<0.001
4th W	−0.361	−0.932	0.209	0.215
Group * time				

(*Continued*)

Table 4 (Continued).

	β	95% CI		p
		Lower Limits	Upper Limits	
Group * T0	Reference			
Group * T1	1.432	0.629	2.234	<0.001
Group * T2	0.818	0.015	1.620	0.046
Group * T3	0.115	−0.688	0.917	0.779
Swallowing Function Exercise Compliance Scale				
Group (Usual care group vs Intervention group)	−0.278	−1.069	0.513	0.490
Time				
Baseline	Reference			
1th W	14.818	14.023	15.613	<0.001
2th W	10.432	9.637	11.227	<0.001
4th W	3.045	2.250	3.841	<0.001
Group * time				
Group * T0	Reference			
Group * T1	6.804	5.686	7.922	<0.001
Group * T2	6.679	5.561	7.798	<0.001
Group * T3	8.555	7.436	9.673	<0.001

Comparison of Adherence Between the Two Groups Before and After Intervention

Prior to intervention, adherence scores differed insignificantly between groups (P > 0.05). At 1 week, 2 weeks, and 4 weeks post-intervention, the intervention group exhibited higher adherence scores than the usual care group, indicating

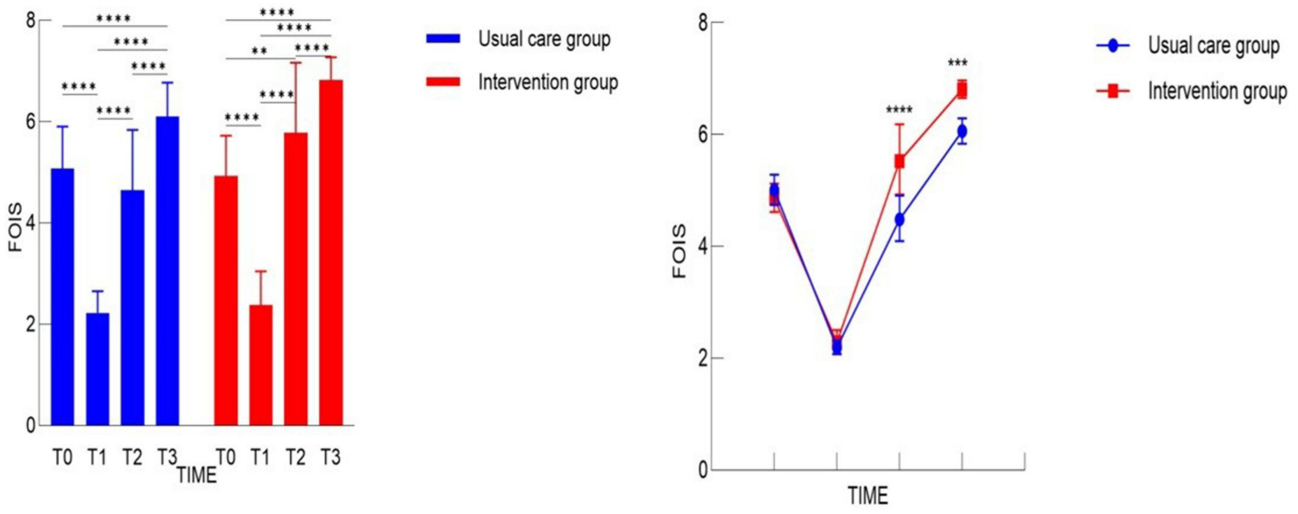

Figure 2 Changes in Swallowing Function Over Time.
Notes: **: p<0.01; ***: p<0.001; ****: p<0.0001.

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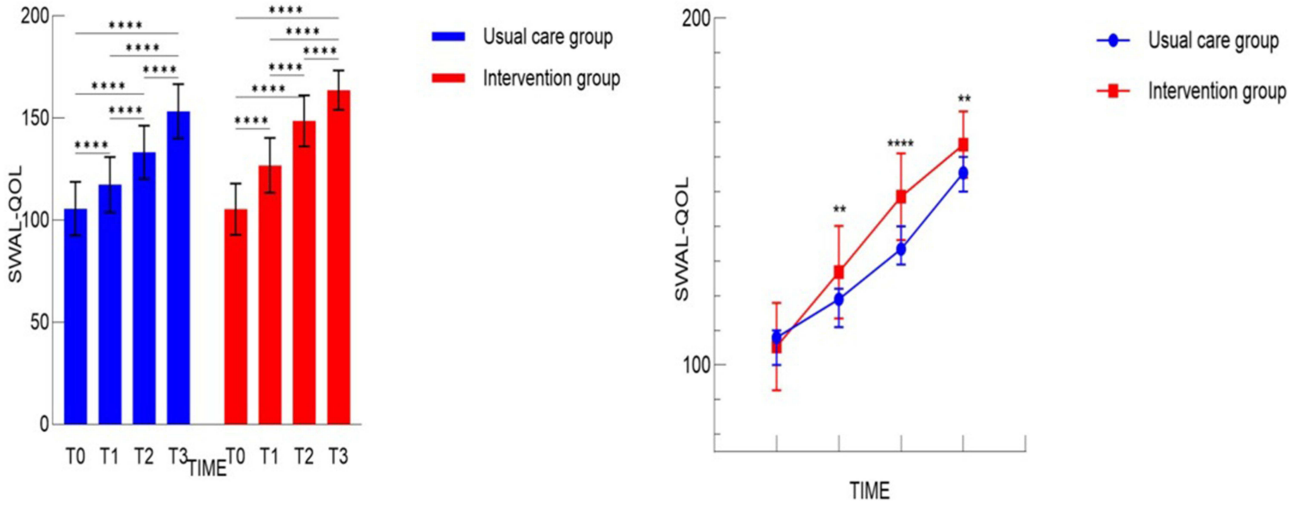

Figure 3 Changes in Quality of Life Over Time.
Notes: **: p<0.01; ****: p<0.0001.

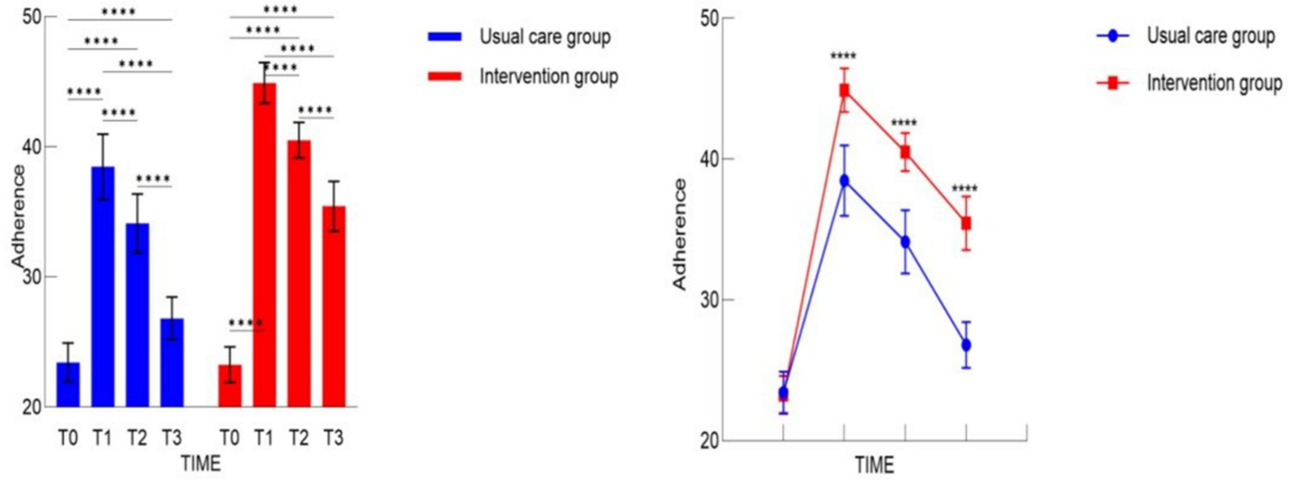

Figure 4 Changes in Adherence Over Time.
Notes: ****: p<0.0001.

that nurse-led swallowing rehabilitation measures can improve adherence (P < 0.05). The GEE modeling showed significant interaction terms (group*time) at T1 (β= 6.804, 95% CI = from 5.686 to 7.922, p<0.001), T2 (β= 6.679, 95% CI = from 5.561 to 7.798, p<0.001) and T3 (β= 8.555, 95% CI = from 7.436 to 9.673, p<0.001), as shown in Tables 3, 4 and Figure 4.

Comparison of Nutrition Between the Two Groups Before and After Intervention

Prior to intervention and at 4 weeks post-intervention, no significant difference existed in nutritional status between the two groups (P > 0.05). At 1 week and 2 weeks post-intervention, the intervention group exhibited superior nutritional outcomes compared to the usual care group, indicating that nurse-led swallowing rehabilitation accelerates nutritional recovery (P<0.05). The GEE modeling showed significant interaction terms (group*time) at T1 (β= 1.432, 95% CI = from 0.629 to 2.234, p<0.001) and T2 (β= 0.818, 95% CI = from 0.015 to 1.620, p=0.046), but no statistically significant interaction effects were detected at T3, as shown in Tables 3, 4 and Figure 5.

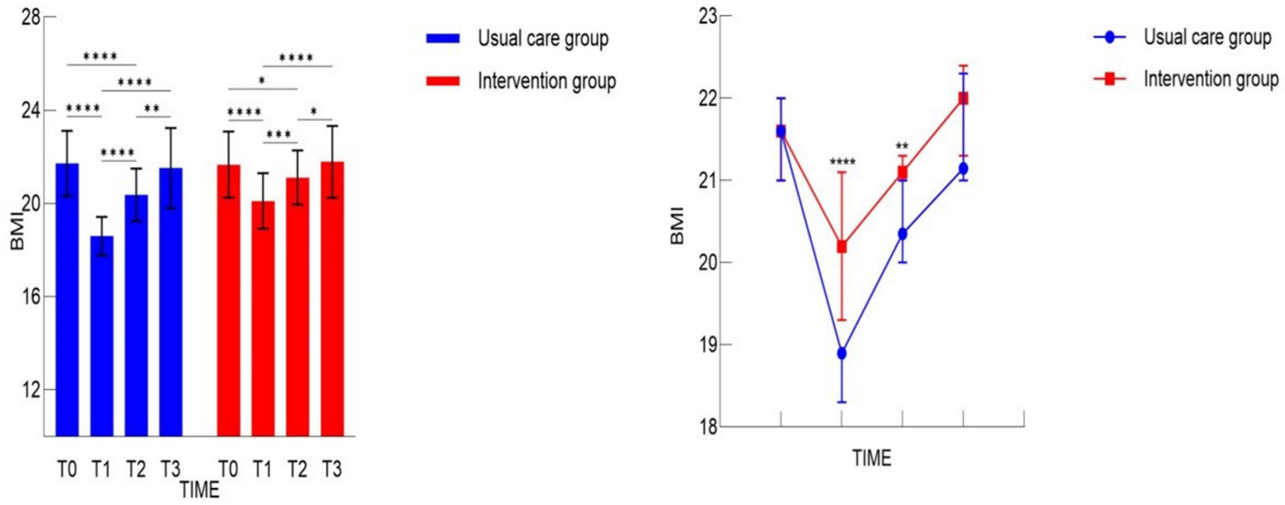

Figure 5 Changes in nutritional status over time.
Notes: *: p<0.05; **: p<0.01; ***: p<0.001; ****: p<0.0001.

Sensitivity Analysis and Subgroup Analyses

Sensitivity analysis is essential for evaluating the robustness of research findings derived from the original data. The sensitivity analysis performed using the per-protocol (PP) approach demonstrated that outcome indicators yielded results comparable to those obtained from the main analysis based on ITT. This confirms the reliability of the study findings and conclusions regarding the initial efficacy of nurse-led swallowing rehabilitation interventions (Supplementary Table 2). Furthermore, no statistically significant interactions were observed between any of the characteristics and the intervention outcomes ($P > 0.05$). Consequently, factors such as disease type, underlying medical conditions, age, and gender did not influence the efficacy of the swallowing intervention (Supplementary Table 3).

Discussion

This study marks the first domestic development and validation of a comprehensive swallowing rehabilitation management model for oral cancer patients, led by rehabilitation nurse specialists and grounded in the "timing theory." Results demonstrate that this model significantly outperforms routine care in improving patients' swallowing function, quality of life, adherence, and early nutritional status. It provides an effective new pathway to address swallowing rehabilitation challenges amid China's shortage of rehabilitation therapists.

Results indicate that at weeks 2 and 4 post-intervention, the intervention group demonstrated significantly higher FOIS scores than the usual care group, reflecting superior recovery of oral feeding capacity. Concurrently, the intervention group demonstrated superior SWAL-QOL scores compared to the usual care group at 1, 2, and 4 weeks post-surgery. This finding aligns with the conclusions of Bulto LN's[25] research and concurs with reports by L X et al[26] and W Y et al[27] regarding the efficacy of nurse-led swallowing interventions in oral cancer patients. Collectively, these studies validate the advantages and therapeutic efficacy of a comprehensive management model led by specialist nurses. While traditional rehabilitation care models incorporate foundational training, they lack systematic, individualized, and continuous management. The model established in this study fully considers the characteristics of oral cancer patients and the importance of lifelong swallowing training. Intervention begins at the diagnostic phase, laying the knowledge and functional foundation through "pre-rehabilitation." During the perioperative and pre-discharge preparation phases, dynamic and intensive assessments and guidance by specialized nurses ensure precise implementation and timely adjustment of rehabilitation measures. During the adjustment and adaptation phase, digital tools and regular follow-ups achieve "seamless continuity" of rehabilitation support, effectively addressing the critical issue of insufficient post-discharge support. This comprehensive, multidimensional, and personalized intervention not only directly promotes

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functional recovery of swallowing-related muscle groups but also enhances overall quality of life through comprehensive health education, complication management, and psychological support.

Adherence is pivotal to rehabilitation outcomes.[4] Our findings indicate that the intervention group demonstrated significantly higher adherence scores at all post-intervention time points compared to the usual care group. This aligns with the research conducted by Yang C[28] and Govender R,[29] and fully validates the effectiveness of nursing interventions in enhancing adherence. Analysis of the reasons primarily attributes this to the following factors: (1) As primary intervention implementers, specialized nurses provided face-to-face supervision and immediate feedback within the hospital setting. Outside the hospital, they conducted follow-ups through multiple channels. This "high-contact" support model effectively replicated the high compliance outcomes associated with "therapist support" in the study, compensating for the limitations of relying solely on diaries or applications (Apps) in maintaining patient motivation.[18] (2) Through phased, multi-format health education, this study deepened patients' understanding of each exercise's purpose and importance, enhancing their cognition and self-efficacy. This transformed passive execution into active participation, thereby improving adherence.[30] (3) Emotional state significantly influences adherence. Specialized nurses bolstered patients' confidence and intrinsic motivation for recovery by fostering positive nurse-patient relationships, promptly acknowledging progress, and addressing negative emotions, thereby improving adherence.[31]

Regarding nutritional indicators, the intervention group demonstrated superior BMI at 1 and 2 weeks post-surgery compared to the usual care group, though the difference was not statistically significant at 4 weeks. The usual care group exhibited markedly lower BMI at 1 and 2 weeks post-surgery, indicating excessive nutritional depletion during oral cancer radical resection and rehabilitation. Conventional care failed to rapidly improve patients' nutritional status, resulting in overall metabolic function unable to meet postoperative recovery demands. This led to significant and persistently low BMI.[32] Conventional care predominantly relied on nasogastric tubes while neglecting the importance of oral feeding. Prolonged nasogastric tube use hindered recovery of respiratory-swallowing coordination and extended tube retention time. This protocol, however, employs systematic assessment to determine the optimal timing for oral feeding initiation. By carefully selecting the type and consistency of foods for oral intake and promoting early oral feeding, it simultaneously exercises respiratory-swallowing coordination. Moreover, direct sensory experience of food flavors through oral feeding enhances appetite, strengthens commitment to recovery, and accelerates nutritional restoration. Previous studies also indicate that timely and appropriate oral feeding, under professional assessment and care, is both safe and effective.[33,34] It promotes the recovery of swallowing functions such as chewing and propulsion, enhances gastrointestinal digestion and absorption, improves the patient's rehabilitation experience, and accelerates the recovery process.[35] By week 4 post-surgery, patients in the control group may have gradually caught up in nutritional status through self-compensation or natural recovery. This suggests the intervention model's advantages are primarily manifested in accelerating the rehabilitation process and improving early clinical outcomes.

Advantages

The innovation of this study lies in integrating the "timing theory" with the role advantages of specialized nurses to establish a standardized, scalable comprehensive swallowing rehabilitation management protocol, providing evidence-based support for optimizing limited healthcare human resource allocation.

Limitations

Despite the positive findings of this study, its limitations must be viewed with caution. Firstly, this single-center design with a limited sample size may restrict the representativeness and generalizability of the results. While single-center implementation facilitates quality control, it fails to adequately reflect how variations in institutional resources, team composition, and patient populations across different healthcare settings may influence intervention outcomes. Secondly, the assessment of intervention efficacy concluded at four weeks post-surgery, constituting a short-term follow-up. While early outcomes demonstrated significant improvement, the long-term maintenance of swallowing function, sustained enhancement of quality of life, and long-term stability of nutritional status require extended observation. Swallowing rehabilitation in oral cancer patients constitutes an ongoing process, and whether short-term advantages translate into long-term benefits remains to be verified. Furthermore, the sample size estimation was based on a pre-trial effect size

hypothesis. In practical implementation, the effect size may vary across specific contexts, necessitating future validation of the observed effect strength through larger-scale studies. Finally, while preliminary pathways for intervention efficacy were explored, the precise mechanisms underpinning the measures remain incompletely elucidated. Future research may employ mixed-methods or multilevel models for deeper investigation.

Conclusion

Overall, this study provides preliminary evidence that a specialist nurse-led swallowing rehabilitation program grounded in timing theory exerts a positive effect on improving short-term swallowing function, quality of life, adherence, and early nutritional status in patients with oral cancer. However, given the limitations, there is an urgent need for future multicenter, large sample randomized controlled trials with extended follow-up periods to validate the long-term efficacy, generalizability, and cost-effectiveness of this model. Concurrently, it is recommended to further investigate the relative contributions of different intervention components (such as pre-rehabilitation, digital follow-up, psychological support, etc). And their differential effects across patient subgroups. This would provide a more robust evidence base for the precise optimization of personalized rehabilitation program.

Clinical Trial Registration

https://www.chictr.org.cn/index.html, ChiCTR2500106129.

Abbreviations

FOIS, Functional Oral Intake Scale; SWAL-QOL, Swallowing-related Quality of Life; BMI, body mass index; GEE, Generalized estimating equation.

Data Sharing Statement

The data used to support the findings of this study are available from the corresponding author upon request.

Ethical Approval

The study was conducted in accordance with the Declaration of Helsinki (as was revised in 2013). The study was approved by Ethics Committee of the Zhejiang Cancer Hospital (Approval no. 2025-79). Written informed consent was obtained from all participants.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

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