Factors Associated with Postoperative Dysphagia Following Cervical Spine Surgery

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ABSTRACT

Factors Associated with Postoperative Dysphagia Following Cervical Spine Surgery

Postoperative dysphagia and dysphonia are well-known complications of cervical spine surgery. However, most research has been retrospective, leaving gaps in understanding acoustic changes in voice and speech following these procedures. Furthermore, factors contributing to postoperative swallowing and voice issues have not been consistently identified. This study aimed to identify the factors associated with postoperative dysphagia and to evaluate pre- and postoperative changes in swallowing, voice, and speech, both within and between groups categorized by these factors.

A total of 33 participants (mean age: 54.09±11.12) undergoing cervical spine surgery were recruited, with 11 receiving anterior, 17 posterior, and 5 combined approaches. Overall swallowing, voice, and speech functions were assessed before and 1 month after surgery, and Bazaz Dysphagia Score was collected three times (before surgery, within 1 week after surgery, and 1 month postoperatively). Out of 33 participants, 23 participants completed BISA15+ and EAT-10 at the same time points as the Bazaz Dysphagia Score and additionally at 2 weeks postoperatively.

Cerebral palsy, higher Neck disability Index (NDI) score, operation approach, and a history of neck surgery were confirmed as the factors associated with swallowing complaints. Logistic regression analysis revealed NDI as a consistent predictor of dysphagia severity, while the posterior approach was associated with a lower likelihood of dysphagia. Significant differences were observed across most variables between the groups. However, recovery trajectory was similar for most variables.

Significant changes in dysphagia severity were observed overall, with postoperative swallowing difficulties peaking within the first week and subsiding in most patients, except for those with cerebral palsy. Regarding voice, a significant change was observed in shimmer normality. Although consistent statistical deterioration in auditory-perceptual variables was not observed, overall severity increased postoperatively, indicating a decline in voice quality.

Following cervical spine surgery, notable changes were observed primarily in swallowing. The severity of swallowing difficulties was generally greater in the groups with the identified risk factors. Change in shimmer normality, and overall deterioration in auditory-perceptual variables suggest that voice-related discomfort may occur after cervical spine surgery.

These findings suggest that patients with specific risk factors, such as high NDI scores or cerebral palsy, are more susceptible to swallowing and voice-related complications following cervical spine surgery. This study highlights the need for preoperative counseling to educate at-risk patients about potential complications.

Key words: cervical spine surgery, dysphagia, dysphonia, Bazaz Dysphagia Score, Neck Disability Index

I. Introduction

1. Background

Cervical spine surgery is commonly conducted to address congenital, degenerative, and traumatic conditions that affect spinal mobility, aiming to restore nerve function and alleviate symptoms such as pain, weakness, tingling, and numbness. The anterior cervical approach is widely used and effective, but may cause difficulties with swallowing and voice as the procedure involves passing through several significant and aerodigestive and neurovascular structures.[1, 2] The reported complaints about voice and swallowing difficulties following this approach vary widely with rates ranging from 0.4% to 71%. This substantial discrepancy in the rates of swallowing complaints following surgery is due to operation approach, number of cervical levels involved, dysphagia criteria, assessment tools, time intervals between evaluations, follow-up period.[3, 4] The factors contributing to postoperative issues with voice and swallowing remain unclear and have not been consistently identified.[2]

Cervical Dysphagia is well-recognized as a complication after anterior cervical spine surgery. The frequency of dysphagia following ACDF has been reported to vary across studies. Reported rates of swallowing difficulties after ACDF include 2[5], 11[6], and 13%.[7] Often anterior approach involves one or two cervical levels, but studies have indicated that the likelihood of complications linked to this procedure rises when three or more levels are involved.[8] Post-operative dysphagia is known as a common complication of ACDF, with evidence suggesting that its occurrence becomes more frequent as the number of treated levels increases.[9]

Dysphagia is often temporary for the majority of patients, indicating that the complications may stem from minor post-operative injuries rather than irreversible neural damage.[4] While this issue may not pose an immediate threat to life, it can significantly diminish patients' quality of life.[10] Aspiration pneumonia is one of the primary causes of mortality in patients with cervical spine injuries highlighting the importance of applying early screening for dysphagia.[11]

Dysphagia in patients undergoing ACDF has been linked to various factors reported in the literature, such as increased age,[12] multiple level surgeries,[13] exposure of more than 3 spinal levels or above level C4,[2] cervical level surgeries particularly C1-4,[4, 14] and gender.[11]

Dysphonia is another potential complication following cervical spine surgery. While most patients recover within a few days, some experience temporary vocal issues. Reported symptoms of dysphonia vary significantly, ranging from subtle voice changes to more severe manifestations like a hoarse or raspy voice, difficulty speaking, voice fluctuations throughout the day, or even complete loss of voice.[15] Complaints related to swallowing persisted for over a year in 9% of patients, while complaints about voice lasted more than a year in 28%.[2]

2. Purpose of study

This study aims to identify factors associated with postoperative swallowing complaints. This study also compares changes in swallowing, voice, and speech related variables between the groups categorized based on affecting factors to postoperative dysphagia and examines the changes in these aspects within each group. Hopefully, the results of this study will contribute to the body of evidence supporting the need for additional preoperative counseling on potential complications for patients who exhibit these risk factors.

3. Hypotheses

The purpose of this study is to identify factors associated with swallowing difficulty, and compare changes in swallowing, voice, and speech functions between the groups categorized based on affecting factors to postoperative dysphagia and examine the changes in these aspects within each group.

Hypotheses of this study are as follows.

First, there will be significant association between Bazaz Dysphagia Scores and risk factors, such as age, BMI, NDI, number of cervical levels operated on, type of surgery, duration of symptoms, underlying diagnoses, and cervical surgery history.

Second, significant differences will be observed in swallowing, voice, and speech related variables between groups categorized based on affecting factors to postoperative dysphagia.

Lastly, there will be significant differences in swallowing, voice, and speech functions within each group before and after surgery.

II. METHODS

1. Participants

Adult patients scheduled for cervical spine surgery at Severance Hospital were considered for inclusion. Exclusion criteria included inability to provide informed consent, insufficient proficiency in spoken or written Korean, or failure to attain normal scores on the Korean Mini-Mental State Examination (K-MMSE).

A total of 33 participants completed the evaluation both preoperatively and postoperatively, and 23 participants completed additional swallowing follow-up questionnaires.

Collected demographic variables included age, gender, body mass index, and duration of symptom, and operative characteristics included operation approach, cervical levels involved (above C4, multilevel≥3), and prior neck surgery history.

The participants (n=33) consisted of 23 males (70%) and 10 females (30%) with mean age of 54 years (±11.12) ranging from 26 to 74. Mean duration of symptom was 2.02 years (±3.16), and mean body mass index was 24.45 kg/m² (±4.93), and mean K-MMSE score was 27.52 (±2.17). Mean Neck Disability Index was 32.70% (±17.95) while 13 (39%) had NDI score of 17 or higher, while the remaining 20 participants (61%) scored below 17.

Of the 33 participants, 11 (33%) underwent an anterior approach, 17 (52%) underwent a posterior approach, and 5 (15%) had a combined approach (Table 2).

Table 1. Baseline participant characteristics

Variable	Cervical spine surgery (n=33)
Age (mean SD, years)	54.09±11.12
Gender (n)	33
Female	10
Male	23
BMI (mean SD)	24.45±4.93
K-MMSE (mean SD, scores)	27.52±2.17
Duration of symptom (mean SD, years)	2.02±3.16
Education (mean SD, years)	13.30±3.38
Prior neck surgery (n)	33
Yes	7
No	26
Medical history (n)	33
Cervical myelopathy	26
Cerebral palsy	9
Operation approach (n)	33
Anterior	11
Posterior	17
Combined anterior and posterior	5
Spinal levels involved (n)	33
Multilevel (≥3 segments)	26
Above C4	18
NDI (mean SD, %)	32.70±17.95
17 or higher	13
Below 17	20

BMI: Body mass index, K-MMSE: Korean Mini-Mental State Examination, NDI: Neck Disability Index

Table 2. Demographic and clinical information

Case	Age/ sex	BMI	Diagnosis	Prior surgery	Myelopathy	Cerebral palsy	Above C4	Surgery
1	54/F	40.58	OPLL C1-2-3	Y	Y	N	Y	PSF C1-2
2	73/M	23.8	Stenosis C7-T1, Spondylolisthesis C7-T1	Y	Y	N	N	PSF C7-T1
3	70/F	21.1	CSM C5-6-7	N	Y	N	N	ACDF C5-6-7
4	39/M	21.45	CSM C3-4-5-6-7	N	Y	Y	Y	ACDF C3-4-5-6-7 PSF C3-4-5-6-7-T1-T2
5	54/M	24.01	CSM O-C1, C7-T1	Y	Y	Y	Y	OCT fusion O-C2-3-4-5-6-7-T1-2-3
6	59/F	23.44	Subluxation C1-2	N	N	N	Y	PSF C1-2
7	74/M	19.82	C1 Assimilation, CSM C2-3-4	N	Y	N	Y	PSF C1-2-3-4-5
8	41/M	28.07	OPLL C5-6	N	N	N	N	ACDF C5-6
9	65/M	26.04	CSM C5-6-7	N	Y	N	N	ACDF C5-6-7
10	69/M	19.87	CSM C4-5-6	N	N	N	N	ACDF C4-5-6
11	47/M	33.87	OPLL C3-4, HCD C4-5	N	Y	N	Y	ACDF C3-4-5
12	46/M	24.02	HCD C5-6-7	N	N	N	N	ACDF C5-6-7
13	62/M	22.41	HCD C4-5-6	N	Y	N	N	ACDF C4-5-6
14	26/M	34.96	IM tumor (Hemangioblastoma) C7	N	N	N	N	Laminotomy C7 and TR
15	56/F	19.11	OPLL C3-4-5-6-7-T1-2-3	N	Y	N	Y	Laminoplasty C3-4-5-6-7, Hemilaminectomy T1-2-3
16	51/F	20.7	OPLL C1-2-3-4-5, T1,2, OLF T1-2	N	Y	N	Y	Laminoplasty C2-3-4-5, TL C1, T1,2, PSF T1-2

17	62/M	18.08	OPLL C1-2	Y	Y	N	Y	TL C1, PSF 1-2
18	60/M	27.66	OPLL C2-3-4-5	N	Y	N	Y	Laminoplasty C2 lower-C3-4-5 upper
19	62/M	22.15	OPLL C4-5-6-7	N	Y	N	N	Laminoplasty C4-5-6-7 upper
20	48/M	25.76	CSM C3-4-5-6-7	N	Y	N	Y	Laminoplasty C3-4-5-6-7 upper
21	66/F	22.72	HCD C6-7-T1 Lt	N	N	N	N	Posterior Keyhole C6/7/T1 Lt
22	58/M	25.1	HCD C4-5-6	N	Y	N	N	ACDF C4-5-6
23	54/M	24.77	CSM C3-4-5-6	N	Y	N	Y	ACDF C3-4-5-6
24	53/F	25.54	CSM C4-5-6-7	N	Y	Y	N	ACDF C4-5-6-7 (Peek Cage alone & DBM), PSF C4-5-6-7, facetectomy C4-5-6 Lt
25	51/F	22.39	CSM C2-3-4	N	Y	Y	Y	PSF C2-3-4
26	38/M	28.02	CSM, OPLL C3-4-5-6-7	N	Y	N	Y	Laminoplasty C3-4-5-6-7 upper
27	56/M	25.45	HCD C5-6 Rt	N	N	N	N	ACDF C5-6
28	57/M	21.56	CSM C4-5-6, OPLL C5-6	N	Y	N	N	ACDF C4-5-6
29	47/M	21.83	CSM C4-5-6-7, Cervical stenosis C2-3-4-5-6-7	Y	Y	Y	Y	ACDF C4-5-6-7, PSF C2-3-4-5-6-7
30	52/F	23.6	CSM C3-4-5-6-7	Y	Y	Y	Y	PSF C3-4-5-6-7
31	41/M	15.5	CSM C3-4-5	N	Y	Y	Y	ACDF C3-4-5, PSF C3-4-5
32	36/M	23.34	CSM C5-6-7	N	Y	Y	N	ACDF C5-6-7, PSF C5-6-7
33	58/F	28.06	CSM C2-3-4	Y	Y	Y	Y	PSF C2-3-4

OPLL: Ossification of posterior longitudinal ligament, CSM: Cervical spondylotic myelopathy, HCD: Herniated cervical disc, PSF: Posterior spinal fusion, ACDF: Anterior cervical discectomy & fusion

2. Methods

A. Data collection

This research received approval from the Institutional Review Board (IRB) of Severance Hospital under protocol number 4-2020-0283. Any adult patient scheduled for cervical spine surgery at Severance Hospital who was able to provide informed consent and understand spoken or written Korean was considered for inclusion. The study's purpose and procedures were explained to participants over the phone, and written consent was later collected from those who agreed to take part in the research. In total, 30 patients participated in swallowing, voice, and speech evaluation both preoperatively and postoperatively. All participants passed the Korean Mini-Mental State Examination (K-MMSE) with normal scores. Among them, twenty participants agreed to answer the follow-up questionnaires to examine swallowing difficulties.

(A) Preoperative Interview

Demographic information and medical history were retrieved from the electronic medical records and confirmed during the preoperative interview. Neck Disability Index was provided by the Department of Neurosurgery.

(B) Cognitive assessment

In order to evaluate cognitive function, the Korean Mini-Mental State Examination (K-MMSE)[16] was performed.

(C) Oral motor skills

Overall oral motor function was evaluated through the following procedures. Participants were asked to hold a wooden tongue depressor with their lips and puff out their cheeks to examine strength, coordination, and tension of lips. Through the assessment of tongue movement, the tension, range, and velocity of tongue motion were examined. Voluntary coughing was observed to confirm the adduction of vocal folds, and velopharyngeal function was assessed by evaluating the extent of soft plate movement and the gag reflex.

(D) Swallowing function

A graduate student in a speech and language pathology program examined participants pre- and post-operatively.

(a) Dry multiple swallow test

Patients were instructed to swallow saliva twice consecutively. During this process, the researcher applied the four-finger method to assess the promptness of the swallowing movement, as well as the extent of hyoid bone and laryngeal movement.

(b) Water swallow test

Participants were instructed to hold water in their mouth until the researcher place their fingers on the participant's neck and signaled them to swallow. The four-finger method was applied same as the dry swallow test. Any signs of penetration or aspiration were observed, the test was immediately stopped.

(c) Bazaz Dysphagia Score

Dysphagia was assessed using Bazaz dysphagia score scale, one of the most frequently utilized questionnaires for assessing dysphagia.[13] It categorizes the severity of swallowing difficulties based on patient-reported challenges with swallowing liquids and solids. The severity is rated on a scale from 0 to 3, with higher scores indicating more significant swallowing difficulty. The questionnaire was completed before the surgery, within one week after the surgery, and every month thereafter.

(d) Brief Inventory of Swallowing Ability (BISA15+)

The Brief Inventory of Swallowing Ability (BISA15+) is a 20-item questionnaire. It is clinically useful for screening older adults with difficulties in swallowing or chewing. The tool uses a 3-point scale ranging from 0 to 2, with a full score of 40. Higher scores indicate a greater severity of dysphagia.[17] BISA15+ was completed as frequently as the Bazaz dysphagia score with an additional assessment two weeks after surgery.

(e) Eating Assessment Tool-10 (EAT-10)

The Eating Assessment Tool is a clinical tool designed to assess dysphagia. It allows patients to self-evaluate their swallowing difficulties, providing an initial estimate of the severity of their condition. It consists of 10 items, each addressing aspects that may pose challenges for individuals experiencing swallowing difficulties.[18] A score of 3 or higher indicates clinically significant dysphagia. The tool is administered to assess the presence of dysphagia before and after surgery.[19] EAT-10 was completed as frequently as the Bazaz dysphagia score with an additional assessment two weeks after surgery.

(E) Voice Data Collection

Voice samples were recorded where surrounding noise is less than 50 dB using the ICD-UX560F (SONY Corp., Tokyo, Japan) voice recorder. The voice recorder was placed 10cm away from the participant's mouth while they sat comfortably in an upright position facing the researcher. Voice data were collected as follows.[20]

(a) Maximum phonation time (MPT)

To assess respiratory and vocal fold functions, which are components of the subsystem for speech production, the maximum phonation time was measured. Participants were instructed to inhale deeply and then produce the vowel sound /a/ for as long as possible. Three trials were conducted for each participant.

(b) Prolonged /a/ phonation

Participants were asked to sustain the vowel sound /a/ for 5 seconds at their natural pitch and comfortable loudness level.

(c) Vowel space area (VSA)

The vowel space area (VSA) is derived from the acoustic analysis of the speaker's voice and is quantified by plotting the first formant (F1) and second formant (F2) values on a two-dimensional coordinate system, based on resonance frequencies and tongue positions. The F1 value reflects tongue height, while the F2 value indicates the anterior-posterior position of the tongue. VSA, associated with speech intelligibility and vowel articulation accuracy provides an indirect assessment of changes in tongue movement within the oral cavity for individuals exhibiting speech

sound issues. Participants were instructed to produce five vowels (/a, æ, i, o, u/) for 3 seconds twice respectively.[21-24]

(d) Diadochokinetic rate (DDK)

DDK includes both the alternating motion rate, which is repeating a single syllable, and the sequential motion rate which is repeating a sequence of three different syllables: /puh/, /tuh/, and /kuh/ as regularly and accurately as possible. This assessment provides an overall measure of the speed and precision of articulatory movements. Participants were instructed to repeat /puh/, /tuh/, and /kuh/ as rapidly and consistently as possible for 5 seconds for the AMR task, and to produce a sequence of three different syllables as quickly and regularly as possible for the SMR task.[25]

(e) Speech intelligibility and speech rate

Participants were instructed to read the Korean standard autumn passage at a comfortable pitch and loudness to assess speech intelligibility and speech rate.

(F) Swallowing-related quality of life

(a) Swallowing-Quality of Life (SWAL-QOL)

Swallowing-Quality of Life is a patient-reported questionnaire developed to evaluate quality of life related to swallowing. Comprising 44 items, it assesses 10 distinct aspects of quality of life and has demonstrated high levels of internal consistency and reliability.[26] Additionally, it has been recognized as an appropriate tool for assessing patient's quality of life related to swallowing, regardless of the underlying causes and severity of dysphagia.[27,28]

(G) Voice-related quality of life

(a) Voice Handicap Index (VHI)

The Voice Handicap Index (VHI) is a widely used, validated self-assessment tool designed for assessing voice-related quality of life. It allows patients to subjectively evaluate the severity of their voice problems in daily life within three domains: physical, functional, and emotional aspects. It consists of thirty questions equally distributed across the three aspects.[29]

(H) Neck disability index (NDI)

As the pain originating from cervical degenerative diseases often extends beyond just the affected area, various means of diagnosis are required to make more accurate differentiation. In addition to assessing anatomical conditions, the overall degree of disability perceived by the patient and the extent of discomfort experienced in daily life due to pain are evaluated using self-report measures.[30] The Neck Disability Index (NDI) is a widely utilized and well-established tool for assessing neck pain. It includes 10 categories that evaluate the effect of neck pain on various aspects of daily life, such as personal care, lifting, reading, concentration, work, driving, sleeping, and recreational activities.[31]

B. Data analysis

(A) Oral motor function

Each parameter was evaluated using a 5-point Likert scale, ranging from 0 to 4, where higher scores represented greater levels of difficulty.

(B) Swallowing function

(a) Dry multiple swallow test

The promptness and range of hyoid excursion and laryngeal elevation during the second swallow were assessed using a 5-point scale (0 = no issues, 1 = some difficulty with the second swallow, 2 = failure of the second swallow, 3 = able to swallow once with difficulty, 4 = unable to swallow at all).[32]

(b) Water swallow test

The performance of hyoid excursion and laryngeal elevation during water swallowing was assessed using the four-finger method. The promptness of elevation was rated on a 5-point scale (0 = normal speed, 1 = slightly slow, 2 = moderately slow, 3 = barely moving, 4 = no movement), while the range of elevation was rated on a 5-point scale (0 = normal range, 1 = normal range, but slightly irregular, 2 = slightly limited, 3 = significantly limited, 4 = no movement).[32]

(c) Dysphagia incidence and severity classification according to Bazaz dysphagia score

The severity of swallowing difficulties during the intake of liquids and solids was scored using a 4-point scale[13] as shown in below (Table 3). Participants were considered to suffer from dysphagia if they rated more than 0 for either liquid or solid.

Table 3. Bazaz Dysphagia Score

Severity	Liquid	Solid
None (0)	None	None
Mild (1)	Rare	Occasionally (only with specific food)
Moderate (2)	Difficulty with large volumes or rapid swallowing	Frequent − unable to swallow certain solids and can swallow other solids with mild to moderate difficulty
Severe (3)	Difficulty with all liquids	Frequent - can swallow only small amount of solid foods

(d) Brief Inventory of Swallowing Ability (BISA15+)

BISA15+ has 20 questions and full score is 40. Each question is rated on a scale of 3 points ranging from 0 to 2, and higher score represents more severe dysphagia.[17]

(e) Eating Assessment Tool-10 (EAT-10)

EAT-10 consists of 10 questions, each rated on a scale of 5 points. Each question ranges from 0 to 4, and full score is 40. Higher scores correspond to greater severity of dysphagia. A score of 3 or higher is strongly associated with clinically significant dysphagia.[19]

(C) Voice and speech function

Collected voice samples were analyzed using Praat software, version 5.2.23.

(a) Maximum phonation time (MPT)

MPT was analyzed using Praat, by retrieving the length in seconds of the total uninterrupted phonation time. Of the two voice samples collected, longer phonation time was analyzed.

(b) Auditory-perceptual evaluation

A certified SLP and a graduate student in speech and language pathology program rated voice quality listening to voice recordings of passage reading and maximum phonation according to the GRBAS scale which evaluates five parameters: Grade (overall voice abnormality), Roughness, Breathiness, Asthenia, and Strain. Each parameter is assessed on a 4-point scale: 0 represents normal, 1 corresponds to mild, 2 indicates moderate, and 3 reflects severe.[33]

(c) Acoustic analysis

Praat software, version 5.2.23. was used to analyze the collected voice samples. To minimize perturbations that typically occur during the onset of phonation, stable three-second-long portion after the initial one second was analyzed.[34] Average values of fundamental frequency, jitter, shimmer, Noise-to-Harmonics ratio were collected as instructed.[35]

(d) Diadochokinetic rate (DDK)

Each speech sample was analyzed using Praat software, and the researcher counted the number of waveforms produced within five seconds. The regularity and accuracy of each attempt were then rated on a scale of 4 points, where 0 corresponds to normal, 1 corresponds to mild, 2 corresponds to moderate, and 3 corresponds to severe.[36]

(e) Vowel space area (VSA)

The vowel space area (VSA) was calculated using Praat software by retrieving the mean F1 and F2 values from the sustained phonation of five vowels (/a, e, i, o, u/). The formant ceiling was set at 5000 Hz for males and 5500 Hz for females. The extracted values were then used to calculate the area according to the formula provided below [21, 24]

VSA= 0.5|[F1/a/(F2/ae/-F2/o/)+F1/ae/(F2/i/-F2/a/)+F1/i/(F2/u/-F2/ae/)+
F1/o/(F2/a/-F2/u/)+F1/u/(F2/o/-F2/i/)

(f) Speech rate

The number of syllables read per second was calculated by dividing the total number of syllables by the total time taken to read the autumn passage.

(g) Speech intelligibility

The autumn passage reading task was evaluated on a scale of 5 points, in which 0 corresponds to normal, 1 corresponds to mild, 2 corresponds to moderate, 3 corresponds to severe, and 4 represents profound. The score was determined based on whether the researcher had difficulty understanding the participant's speech, with higher scores indicating greater difficulty.[37]

(D) Additional patient-reported questionnaires

(a) Swallowing-Quality of Life (SWAL-QOL)

The SWAL-QOL consists of 44 items, each rated on a scale of 5 points ranging from 1 to 5. Full score is 220, and the minimum is 44 with higher scores reflecting a better quality of life.[28]

(b) Voice Handicap Index (VHI)

The VHI consists of 30 items, each rated on a scale of 5 points that ranges from 0 to 4. Full score is 120, and the minimum is 0. High score suggests that individual’s voice related quality of life is low.[38]

(c) Neck Disability Index

Each item is rated on a scale of 6 points ranging from 0 to 5. Higher scores suggest that an individual is experiencing greater disability. The total score is out of 50, with the severity of disability categorized as the following: range from 0 to 4 corresponds to no disability, range from 5 to 14 corresponds to mild disability, range from 15 to 24 corresponds to moderate disability, range from 25 to 34 corresponds to severe disability, and scores of 35 or above means complete disability.[39] In this study, the Neck Disability Index (NDI) scores were analyzed as a percentage, as the total score of participants who do not drive is five less than the maximum score.[40] The prognosis of cervical spine surgery tends to be unfavorable when the pre-operative NDI score is 17 or higher.[41] Therefore, the subjects were divided into two groups based on the NDI score, with a cutoff score of 17.

C. Statistical analysis

Statistical analysis was conducted using the IBM SPSS (Statistical Package for the Social Sciences, version 25.0) for Windows.

Linear regression analysis, logistic regression analysis, and Fisher's exact test were conducted to identify the factors associated with post-operative dysphagia.

Two-way repeated-measure ANOVA was conducted to compare changes in overall variables between groups.

Wilcoxon signed-rank test was used to examine the changes in swallowing, voice, and speech functions before and after cervical surgery along with the self-reported quality of life related to swallowing and voice.

Friedman test was used to determine whether there were statistically significant differences in swallowing function across three different time points. Wilcoxon signed-rank tests were conducted to identify in which specific period significant change was observed.

III. RESULTS

1. Factors associated with dysphagia

A. The factors associated with swallowing complaints based on Bazaz Dysphagia Score

Fisher's exact test was conducted to identify factors associated with swallowing complaints before surgery, 1 week after surgery, and 1 month after surgery. Significant associations were observed for cerebral palsy, Neck Disability Index (NDI), prior neck surgery, and surgical approach in relation to pre-operative swallowing difficulties. Patients with cerebral palsy had a significantly higher likelihood of pre-operative dysphagia (p=.002). Similarly, those with an NDI score of 17 or higher showed a significantly increased prevalence of pre-operative dysphagia (p=.009). A history of prior neck surgery was also associated with higher rates of pre-operative dysphagia (p=.027) (Table 4).

At 1 week post-operation, cerebral palsy and NDI remained significant factors. Patients with cerebral palsy were more likely to report dysphagia (p=.039), while those with an NDI score of 17 or higher demonstrated a significantly higher prevalence of dysphagia (p=.005) (Table 5).

At 1 month post-operation, the analysis identified significant associations for cerebral palsy, NDI, prior neck surgery, and surgical approach. All patients with cerebral palsy experienced dysphagia at this time point (p=.001). Patients with an NDI score of 17 or higher were also more likely to have dysphagia (p=.000). A history of prior neck surgery was linked to an increased likelihood of dysphagia (p=.007) (Table 6).

Table 4. Factors associated with pre-operative dysphagia (n=33)

Variables		No dysphagia	Dysphagia	χ^2	p
Gender	Male	15 (65.2%)	8 (34.8%)	.072	1.000
	Female	7 (70%)	3 (30%)		
Age	20~49	4 (44.4%)	5 (55.6%)	2.943	.240
	50~59	11 (78.6%)	3 (21.4%)		
	60~	7 (70%)	3 (30%)		
Cerebral palsy	Yes	2 (22.2%)	7 (77.8%)	11	.002*
	No	20 (83.3%)	4 (16.7%)		
Myelopathy	Yes	17 (65.4%)	9 (34.6%)	.091	1.000
	No	5 (71.4%)	2 (28.6%)		
DoS[1]	<6months	11 (84.6%)	2 (15.4%)	3.635	.216
	6~11months	4 (66.7%)	2 (33.3%)		
	≥12months	7 (50%)	7 (50%)		
NDI[2]	<17	17 (85%)	3 (15%)	7.679	.009*
	≥17	5 (38.5%)	8 (61.5%)		
Prior neck surgery	Yes	2 (28.6%)	5 (71.4%)	5.802	.027*
	No	20 (76.9%)	6 (23.1%)		
Above C4	Yes	11 (61.1%)	7 (38.9%)	.550	.712
	No	11 (73.3%)	4 (26.7%)		
Multilevel ≥ 3	Yes	19 (73.1%)	7 (26.9%)	2.266	.186
	No	3 (42.9%)	4 (57.1%)		
Operation approach	Anterior	10 (90.9%)	1 (9.1%)	7.839	.019*
	Posterior	11 (64.7%)	6 (35.3%)		
	Combined	1 (20%)	4 (80%)		

*p<.05

Fisher's exact test

[1]DoS: Duration of symptom

[2]NDI: Neck Disability Index

Table 5. Factors associated with dysphagia at 1 week post-op[1] (n=33)

Variables		No dysphagia	Dysphagia	χ^2	p
Gender	Male	7 (30.4%)	16 (69.6%)	0.383	.686
	Female	2 (20%)	8 (80%)		
Age	20~49	3 (33.3%)	6 (66.7%)	.445	.888
	50~59	4 (28.6%)	10 (71.4%)		
	60~	2 (20%)	8 (80%)		
Cerebral palsy	Yes	0 (0%)	9 (100%)	4.641	.039*
	No	9 (37.5%)	15 (62.5%)		
Myelopathy	Yes	7 (26.9%)	19 (73.1%)	0.008	1.000
	No	2 (28.6%)	5 (71.4%)		
DoS[2]	<6months	5 (38.5%)	8 (61.5%)	2.122	.399
	6~11months	2 (33.3%)	4 (66.7%)		
	≥12months	2 (14.3%)	12 (85.7%)		
NDI[3]	<17	9 (45%)	11 (55%)	8.044	.005*
	≥17	0 (0%)	13 (100%)		
Prior neck surgery	Yes	0 (0%)	7 (100%)	3.332	.149
	No	9 (34.6%)	17 (65.4%)		
Above C4	Yes	6 (33.3%)	12 (66.7%)	0.733	.458
	No	3 (20%)	12 (80%)		
Multilevel ≥ 3	Yes	7 (26.9%)	19 (73.1%)	0.008	1.000
	No	2 (28.6%)	5 (71.4%)		
Operation approach	Anterior	2 (18.2%)	9 (81.8%)	3.990	.156
	Posterior	7 (41.2%)	10 (58.8%)		
	Combined	0 (0%)	5 (100%)		

*p<.05

Fisher's exact test

[1]OP: Operation

[2]DoS: Duration of symptom

[3]NDI: Neck Disability Index

Table 6. Factors associated with dysphagia at 1 month post-op[1] (n=33)

Variables		No dysphagia	Dysphagia	χ^2	p
Gender	Male	14 (60.9%)	9 (39.1%)	4.661	.057
	Female	2 (20%)	8 (80%)		
Age	20~49	5 (55.6%)	4 (44.4%)	.481	.825
	50~59	7 (50%)	7 (50%)		
	60~	4 (40%)	6 (60%)		
Cerebral palsy	Yes	0 (0%)	9 (100%)	11.647	.001*
	No	16 (66.7%)	8 (33.33%)		
Myelopathy	Yes	12 (46.2%)	14 (53.8%)	.267	.688
	No	4 (57.1%)	3 (42.9%)		
DoS[2]	<6months	8 (61.5%)	5 (38.5%)	3.904	.133
	6~11months	4 (66.7%)	2 (33.3%)		
	≥12months	4 (28.6%)	10 (71.4%)		
NDI[3]	<17	15 (75%)	5 (25%)	14.291	.000*
	≥17	1 (7.7%)	12 (92.3%)		
Prior neck surgery	Yes	0 (0%)	7 (100%)	8.362	.007*
	No	16 (61.5%)	10 (38.5)		
Above C4	Yes	7 (38.9%)	11 (61.1%)	1.460	.303
	No	9 (60%)	6 (40%)		
Multilevel ≥ 3	Yes	13 (50%)	13 (50%)	.113	1.000
	No	3 (42.9%)	4 (57.1%)		
Operation approach	Anterior	9 (81.8%)	2 (18.2%)	9.963	.005*
	Posterior	7 (41.2%)	10 (58.8%)		
	Combined	0 (0%)	5 (100%)		

*p<.05

Fisher's exact test

[1]OP: Operation

[2]DoS: Duration of symptom

[3]NDI: Neck Disability Index

B. Risk factors for post-operative dysphagia following cervical spine surgeries

Logistic regression and linear regression analyses were conducted to identify factors predicting swallowing difficulty and Bazaz Dysphagia Scores at different postoperative time points.

At 1 week post-operation, logistic regression analysis revealed that the Neck Disability Index (NDI) was a significant predictor of swallowing difficulty in both univariate (OR=1.16, p=.012) and multivariate analyses (OR=1.17, p=.014), indicating that higher NDI scores were associated with an increased likelihood of swallowing difficulty. Additionally, the surgical approach was a significant factor in the multivariate analysis, with patients undergoing a posterior approach showing reduced odds of swallowing difficulty compared to those who did not undergo the posterior approach (OR=0.10, p=.049) (Table 7). At 1 month post-operation, NDI remained a significant predictor of swallowing difficulty in both univariate (OR=1.14, p=.004) and multivariate analyses (OR=1.19, p=.004) (Table 8).

Linear regression analysis for Bazaz Dysphagia Score for liquid consistency at 1 week post-operation did not identify significant predictors in either univariate or multivariate analyses, although NDI approached significance in the univariate analysis (Coefficient=0.02, p=.067) (Table 9). At 1 month post-operation, NDI emerged as a significant predictor of Bazaz Dysphagia Score for liquid in both univariate and multivariate analyses (Coefficient=0.02, p=.032). The combined surgical approach was also significantly associated with higher Bazaz scores for liquid compared to the anterior approach (Coefficient=1.16, p=.033) (Table 10).

For solid consistency at 1 week post-operation, NDI was a significant predictor in both univariate (Coefficient=0.03, p=.001) and multivariate analyses (Coefficient=0.02, p=.004). Cerebral palsy also emerged as a significant predictor in the univariate analysis (Coefficient=0.88, p=.012). Furthermore, the combined surgical approach was associated with significantly higher Bazaz scores in both univariate (Coefficient=1.14, p=.008) and multivariate analyses (Coefficient=1.23, p=.002) (Table 11). At 1 month post-operation, NDI remained a significant predictor for solid consistency in both univariate (Coefficient=0.03, p=.001) and multivariate analyses (Coefficient=0.02, p=.004). Additionally, cerebral palsy and prior neck surgery were significant predictors of higher Bazaz Dysphagia Scores in the multivariate analysis (Coefficients=1.03, p=.001; and 0.66, p=.019, respectively). The combined surgical approach was also a significant predictor of increased Bazaz scores (Coefficient=0.88, p=.005) (Table 12).

These findings underscore the consistent role of NDI as a predictor of postoperative swallowing difficulty and its association with Bazaz Dysphagia Scores across time points and consistencies. Additional risk factors, including cerebral palsy, prior neck surgery, and the combined surgical approach, were also significant predictors of increased dysphagia severity.

Table 7. Logistic regression analysis for predicting swallowing difficulty at 1 week post-op[1] from clinical variables

Model	Univariate analysis		Multivariate analysis	
Variables (reference)	Odds ratio	p	Odds ratio	p
Age	1.06 (.04)	.142		
DoS[2]	1.20 (.18)	.317		
BMI[3]	.90 (.08)	.179		
NDI[4]	1.16 (.06)	.012*	1.17 (.06)	.014**
Myelopathy	1.09 (.95)	.931		
Cerebral palsy	-	.999		
Prior neck surgery	-	.999		
Operation approach (Anterior)				
Posterior	.20 (.90)	.078	.10 (1.19)	.049*
Combined	-	.999		
Multilevel >3	1.09 (.95)	.931		
Above C4	.50 (.82)	.396		

*p< .05, ** p<.01

[1]OP: Operation

[2]DoS: Duration of symptom in year

[3]BMI: Body mass index

[4]NDI: Neck Disability Index

Table 8. Logistic regression analysis for predicting swallowing difficulty at 1 month post-op[1] from clinical variables

Model	Univariate analysis		Multivariate analysis	
Variables (reference)	Odds ratio	p	Odds ratio	p
Age	1.04 (.03)	.231		
DoS[2]	1.12 (.12)	.350		
BMI[3]	.90 (.08)	.206		
NDI[4]	1.14 (.05)	.004**	1.19 (.05)	.004**
Myelopathy	1.56 (.86)	.607		
Cerebral palsy	-	.999		
Prior neck surgery	-	.999		
Operation approach (Anterior)				
Posterior	1.84 (.70)	.388		
Combined	-	.999		
Multilevel >3	.75 (.86)	.738		
Above C4	2.36 (.72)	.231		

*p< .05, ** p<.01

[1]OP: Operation

[2]DoS: Duration of symptom in year

[3]BMI: Body mass index

[4]NDI: Neck Disability Index

Table 9. Linear regression analysis for predicting Bazaz Dysphagia Score for liquid at 1 week post-op[1]

Model	Univariate analysis		Multivariate analysis	
Variables (reference)	Coefficient (SE)	p	Coefficient (SE)	p
Age	.02 (.02)	.261		
DoS[2]	.03 (.06)	.698		
BMI[3]	-.03 (.04)	.503		
NDI[4]	.02 (.01)	.067		
Myelopathy	-.34 (.49)	.488		
Cerebral palsy	.50 (.44)	.265		
Prior neck surgery	.16 (.49)	.747		
Operation approach (Anterior)				
Posterior	-.63 (.38)	.114		
Combined	.82 (.54)	.137		
Multilevel >3	.02 (.49)	.964		
Above C4	-.30 (.40)	.457		

*p< .05, ** p<.01

[1]OP: Operation

[2]DoS: Duration of symptom in year

[3]BMI: Body mass index

[4]NDI: Neck Disability Index

Table 10. Linear regression analysis for predicting Bazaz Dysphagia Score for liquid at 1 month post-op[1]

Model	Univariate analysis		Multivariate analysis	
Variables (reference)	Coefficient (SE)	p	Coefficient (SE)	p
Age	.02 (.02)	.295		
DoS[2]	-.01 (.06)	.921		
BMI[3]	-.03 (.04)	.508		
NDI[4]	.02 (.01)	.032*	.02 (.01)	.032*
Myelopathy	-.05 (.49)	.920		
Cerebral palsy	.86 (.42)	.050		
Prior neck surgery	.41 (.48)	.401		
Operation approach (Anterior)				
Posterior	.13 (.40)	.743		
Combined	1.16 (.52)	.033*		
Multilevel >3	.31 (.49)	.524		
Above C4	.16 (.40)	.700		

*p< .05, ** p<.01

[1]OP: Operation

[2]DoS: Duration of symptom in year

[3]BMI: Body mass index

[4]NDI: Neck Disability Index

Table 11. Linear regression analysis for predicting Bazaz Dysphagia Score for solid at 1 week post-op[1]

Model	Univariate analysis		Multivariate analysis	
Variables (reference)	Coefficient (SE)	p	Coefficient (SE)	p
Age	.01 (.01)	.368	.03 (.01)	.027*
DoS[2]	.09 (.05)	.076		
BMI[3]	-.04 (.03)	.271		
NDI[4]	.03 (.01)	.001**	.02 (.01)	.004**
Myelopathy	.58 (.38)	.139		
Cerebral palsy	.88 (.33)	.012*		
Prior neck surgery	.69 (.38)	.079		
Operation approach (Anterior)				
Posterior	-.31 (.32)	.348		
Combined	1.14 (.40	.008*	1.23 (.36)	.002**
Multilevel >3	.22 (.40)	.582		
Above C4	.18 (.32)	.588		

*p< .05, ** p<.01

[1]OP: Operation

[2]DoS: Duration of symptom in year

[3]BMI: Body mass index

[4]NDI: Neck Disability Index

Table 12. Linear regression analysis for predicting Bazaz Dysphagia Score for solid at 1 month post-op[1]

Model	Univariate analysis		Multivariate analysis	
Variables (reference)	Coefficient (SE)	p	Coefficient (SE)	p
Age	.01 (.01)	.521		
DoS[2]	.05 (.05)	.285		
BMI[3]	-.01 (.03)	.646		
NDI[4]	.03 (.01)	.001**	.03 (.01)	.004**
Myelopathy	.52 (.35)	.151		
Cerebral palsy	1.03 (.28)	.001**		
Prior neck surgery	.93 (.33)	.008**	.66 (.26)	.019*
Operation approach (Anterior)				
Posterior	.02 (.30)	.952		
Combined	1.06 (.37)	.007**	.88 (.29)	.005*
Multilevel >3	.34 (.36)	.353		
Above C4	.06 (.30)	.855		

*p< .05, ** p<.01

[1]OP: Operation

[2]DoS: Duration of symptom in year

[3]BMI: Body mass index

[4]NDI: Neck Disability Index

2. Non-cerebral palsy and Cerebral palsy

A. Comparison between groups

(A) Swallowing-related questionnaires

Two-way repeated-measure ANOVA was conducted to compare changes in Bazaz Dysphagia Scores, BISA15+, and EAT-10 between the groups with cerebral palsy and without cerebral palsy. First, with in Bazaz Dysphagia Score, average scores of both groups were significantly different before and after surgery for both liquid ($p < .001$) and solid consistency ($p < .001$), meaning that swallowing difficulties worsened in both groups. The group effect was significant for both liquid ($p = .038$) and solid ($p < .001$) consistency, with higher dysphagia severity consistently observed in the cerebral palsy group. However, the time and group interaction effect was not significant for either liquid or solid consistency ($p = .527$), suggesting similar patterns of change in both groups (Table 13).

Similarly with EAT-10 ($p = .021$) and BISA15+ ($p = .044$), statistically significant differences were observed between average scores of both groups before and after surgeries. Both scores peaked at 1 week postoperatively and gradually decreased over time in both groups, indicating a temporary exacerbation of swallowing difficulties immediately after surgery, followed by gradual improvement. The group effect was also significant for both BISA15+ ($p < .001$) and EAT-10 scores ($p = .003$), showing that the cerebral palsy group consistently exhibited higher scores across all time points, reflecting more severe swallowing difficulties compared to the non-cerebral palsy group. However, the time and group interaction effect was not significant for either BISA15+ or EAT-10, indicating that both groups followed a similar trajectory of score changes over time (Table 14).

Table 13. Comparison of changes in Bazaz Dysphagia Scores in non-cerebral palsy and cerebral palsy groups

Measures	Non-CP (n=24)			Cerebral palsy (n=9)			Time		Group		Time*Group	
	Pre-op	Post-op[1]	Post-op[2]	Pre-op	Post-op[1]	Post-op[2]	F	P	F	P	F	P
Liquid	0.08±0.28	1.17±1.20	0.58±1.10	0.89±0.78	1.67±0.87	1.44±1.01	12.778	.000*	4.710	0.038*	0.555	.563
Solid	0.08±0.28	0.79±0.88	0.42±0.72	0.78±0.67	1.67±0.71	1.44±0.73	15.143	.000*	17.582	0.000*	0.647	.527

*p< .05

[1]Post-op: within 1 week after surgery

[2]Post-op: about 1month after surgery

Table 14. Comparison of EAT-10 and BISA15+ between non-cerebral palsy and cerebral palsy groups

Variables	Non-cerebral palsy (n=16)				Cerebral palsy (n=7)				Time		Group		Time*Group	
	Pre-op	Post-op 1 week	Post-op 2 weeks	Post-op 4weeks	Pre-op	Post-op 1 week	Post-op 2 weeks	Post-op 4weeks	F	P	F	P	F	P
BISA15+[1]	1.56 ±2.19	4.31 ±4.81	1.81 ±2.48	1.50 ±2.19	8.29 ±7.52	11.14 ±4.60	10.00 ±5.42	9.00 ±3.74	3.725	.021*	27.55	.000*	0.273	.815
EAT-10[2]	0.75 ±1.29	6.38 ±6.96	1.56 ±2.83	1.25 ±2.38	7.29 ±4.07	12.71 ±9.91	10.00 ±11.46	10.00 ±10.95	3.273	.044*	11.366	.003*	.427	.736

*p< .05

[1]BISA15+: Brief Inventory of Swallowing Ability

[2]EAT-10: Eating Assessment Tool

(B) Swallowing, voice, speech related variables

Two-way repeated measure ANOVA showed that average scores of overall variables before and after surgery were significantly different between the two groups, except for shimmer and vowel space area (VSA). For swallowing function, significant main effects of time and group were observed for Dry Swallow Test (DST) excursion ($p=.004$ for time; $p<.001$ for group) and DST promptness ($p=.007$ for time; $p<.001$ for group), with the CP group consistently showing higher scores. Water Swallow Test (WST) also revealed significant time and group effects for excursion ($p<.001$ for time; $p<.001$ for group) and promptness ($p=.007$ for time; $p<.001$ for group). However, the time and group interaction effects for these measures were not significant, indicating similar patterns of change over time for both groups. Additional variables including lip closure ($p=.018$ for time; $p<.001$ for group) and buccal strength ($p=.023$ for time; $p<.001$ for group), showed similar results, with no significant interaction effects. Tongue strength also demonstrated significant effects of time ($p=.031$) and group ($p<.001$).

For voice function, Maximum Phonation Time (MPT) did not show a significant time effect ($p=.950$), but the group effect was significant ($p<.001$), with the CP group exhibiting shorter phonation times. Fundamental frequency (F0) showed a significant group effect ($p=.003$) and a time and group interaction effect ($p=.012$), indicating differing patterns of change between the groups. Jitter and shimmer revealed significant group effects ($p=.038$ for jitter; $p=.011$ for shimmer), though time and interaction effects were not significant.

For speech function, /puhtuhkuh/ diadochokinesis (DDK) regularity demonstrated significant effects of time ($p=.001$) and group ($p<.001$) but no significant interaction effects. Speech rate showed no significant time effect ($p=.763$), though a significant group effect ($p<.001$) indicated slower rates in the CP group. Speech intelligibility did not show significant effects for time, group, or interaction.

Regarding quality of life, SWAL-QoL did not show significant time ($p=.106$) or interaction effects ($p=.852$), although the CP group reported significantly poorer swallowing-related quality of life ($p<.001$). Similarly, the Voice Handicap Index showed a significant group effect ($p<.001$), with the CP group reporting greater voice handicaps, while time and interaction effects were not significant (Table 15).

Table 15. Comparison of pre-to post-op changes in swallowing, voice, speech related variables in non-cerebral palsy and cerebral palsy groups

Variables	Normal (n=24)		Cerebral palsy (n=9)		Time		Group		Time*Group	
	Pre-op	Post-op[1]	Pre-op	Post-op[1]	F	P	F	P	F	P
DST_Excursion	0.40±0.61	1.00±0.92	2.28±1.09	2.67±0.50	9.584	.004*	43.894	.000*	0.450	.507
DST_Promptness	0.29±0.46	0.90±0.88	2.00±1.09	2.44±0.73	8.199	.007*	46.661	.000*	0.190	.666
WST_Excursion	0.31±0.59	0.83±0.70	1.78±1.09	2.56±0.58	23.128	.000*	42.736	.000*	0.905	.349
WST_Promptness	0.04±0.20	0.44±0.77	1.56±1.13	2.06±1.07	8.355	.007*	40.930	.000*	0.113	.739
Lip closure	0.25±0.44	0.38±0.65	2.22±1.79	2.61±1.41	6.294	.018*	35.016	.000*	1.660	.207
Buccal strength	0.19±0.44	0.35±0.52	2.33±1.73	2.56±1.51	5.694	.023*	38.214	.000*	0.116	.735
Tongue strength	0.13±0.34	0.19±0.48	2.11±1.43	2.50±1.22	5.139	.031*	57.865	.000*	2.687	.111
Tongue ROM	0.19±0.41	0.17±0.35	2.61±1.58	3.00±1.50	3.382	.076	69.119	.000*	4.191	.049*
Tongue tip velocity	0.19±0.44	0.19±0.38	2.67±1.32	2.94±1.24	1.557	.221	95.893	.000*	1.557	.221
Soft palate movement	0.00±0.00	0.25±0.53	1.56±1.42	1.78±1.39	5.617	.024*	28.161	.000*	0.019	.890
Coughing	0.13±0.45	0.38±0.58	2.56±1.42	2.83±1.37	9.334	.005*	59.956	.000*	0.026	.873
MPT	16.53±6.89	15.64±5.30	5.82±3.92	6.82±3.68	0.004	.950	22.570	.000*	1.411	.244
F0	140.83±36.73	145.31±36.84	199.71±50.92	175.94±28.32	3.282	.080	10.433	.003*	7.038	.012*
Jitter	0.53±0.48	0.55±0.39	4.06±8.52	1.10±0.93	3.719	.063	4.677	.038*	3.826	.060
Shimmer	3.90±2.10	4.82±2.67	7.94±6.21	6.73±3.41	0.047	.829	7.243	.011*	2.657	.113

*p< .05

[1]Post-op: 1 month after surgery

DST: Dry swallow test, WST: water swallow test, MPT: maximum phonation time, VSA: Vowel space area, SWAL-QOL: Swallowing quality of life, VHI: Voice Handicap Index

Table 15. Comparison of pre-to post-op changes in swallowing, voice, speech related variables in non-cerebral palsy and cerebral palsy groups (continued)

Variables	Normal (n=24)		Cerebral palsy (n=9)		Time		Group		Time*Group	
	Pre-op	Post-op[1]	Pre-op	Post-op[1]	F	P	F	P	F	P
NHR	0.06±0.06	0.07±0.06	0.18±0.28	0.13±0.16	2.316	.138	3.916	.057	3.394	.075
Grade	0.77±0.94	0.96±1.05	2.28±0.97	2.44±1.04	2.858	.101	15.732	.000*	0.010	.921
Roughness	0.75±0.91	1.02±1.09	1.39±1.27	2.00±1.15	9.940	.004*	4.306	.046*	1.480	.233
Breathiness	0.375±0.65	0.65±0.91	1.39±1.27	1.33±1.30	0.878	.356	5.886	.021*	2.018	.165
Asthenia	0.04±0.20	0.146±0.45	0.67±1.00	1.00±1.00	2.286	.141	16.812	.000*	0.627	.434
Strain	0.13±0.45	0.29±0.53	1.50±1.27	2.06±1.47	12.371	.001*	26.996	.000*	3.587	.068
/puh/ regularity	0.00±0.00	0.17±0.50	1.78±1.56	1.78±1.48	0.476	.495	31.467	.000*	0.4766	.495
/tuh/ regularity	0.00±0.00	0.13±0.37	1.94±1.55	2.17±1.37	3.958	.056	47.057	.000*	0.310	.581
/kuh/ regularity	0.08±0.28	0.19±0.57	1.89±1.43	2.17±1.50	2.680	.112	38.137	.000*	0.554	.462
/puhtuhkuh/ regularity	0.04±0.14	0.21±0.44	1.44±1.42	1.83±1.27	9.316	.005*	30.219	.000*	1.491	.231
/puh/ accuracy	0.04±0.20	0.04±0.20	1.89±1.69	1.89±1.54	0.000	1.000	34.028	.000*	0.000	1.000
/tuh/ accuracy	0.00±0.00	0.04±0.20	1.83±1.50	2.06±1.38	2.818	.103	47.41	.000*	1.319	.260
/kuh/ accuracy	0.00±0.00	0.04±0.20	1.89±1.52	1.83±1.54	0.009	.924	37.906	.000*	0.459	.503
/puhtuhkuh/ accuracy	0.02±0.10	0.08±0.41	1.50±1.41	2.11±1.54	13.0699	.001*	35.208	.000*	8.668	.006*

*p< .05

[1]Post-op: 1 month after surgery

DST: Dry swallow test, WST: water swallow test, MPT: maximum phonation time, VSA: Vowel space area, SWAL-QOL: Swallowing quality of life, VHI: Voice Handicap Index

Table 15. Comparison of pre-to post-op changes in swallowing, voice, speech related variables in non-cerebral palsy and cerebral palsy groups (continued)

Variables	Normal (n=24)		Cerebral palsy (n=9)		Time		Group		Time*Group	
	Pre-op	Post-op[1]	Pre-op	Post-op[1]	F	P	F	P	F	P
Speech rate	4.51±0.76	4.66±0.95	2.27±1.43	2.20±1.49	0.093	.763	37.07	.000*	0.727	.400
Speech intelligibility	0.04±0.20	0.10±0.36	2.11±1.14	2.28±1.35	2.067	.161	69.41	.000*	0.427	.518
VSA	248370.31 ±125192.77	259724.34 ±115001.86	195821.05 ±153182.39	198659.05 ±145954.95	0.121	.730	1.533	.225	0.044	.836
SWAL-QOL	206.88±8.44	199.87±21.88	172.56±26.00	163.78±43.68	2.775	.106	20.770	.000*	0.035	.852
VHI	3.54±7.69	4.54±7.96	61.11±29.53	48.44±38.30	2.804	.104	62.922	.000*	3.848	.059

*p< .05

[1]Post-op: 1 month after surgery

DST: Dry swallow test, WST: water swallow test, MPT: maximum phonation time, VSA: Vowel space area, SWAL-QOL: Swallowing quality of life, VHI: Voice Handicap Index

B. Within-group changes from pre-to post-op 1 month

(A) Swallowing-related questionnaires

Friedman test was conducted to analyze changes in Bazaz Dysphagia Scores for liquid and solid consistencies across three time points (before surgery, 1 week after surgery, and 1 month after surgery) in groups with and without cerebral palsy.

For liquid consistency, significant changes were observed in both groups. In the non-CP group, Bazaz Dysphagia Scores increased significantly from 0.08±0.28 pre-operatively to 1.17±1.20 at 1 week post-op, followed by a decrease to 0.58±1.10 at 1 month post-op ($p<.001$). In the CP group, scores increased from 0.89±0.78 pre-op to 1.56±0.88 at 1 week post-op and remained unchanged at 1 month post-op ($p=.016$).

For solid consistency, significant changes were also noted. In the non-CP group, scores increased from 0.08±0.28 pre-operatively to 0.79±0.88 at 1 week post-op, then decreased to 0.42±0.72 at 1 month post-op ($p<.001$). In the CP group, scores increased from 0.78±0.67 pre-op to 1.67±0.71 at 1 week post-op and slightly decreased to 1.44±0.73 at 1 month post-op ($p=.003$) (Table 16).

Wilcoxon signed-rank test was conducted to examine in which period the changes in Bazaz Dysphagia Scores for liquid and solid consistency in both groups. Within non-CP group, a significant increase in Bazaz Dysphagia Scores was observed from pre-op to 1 week post-op ($p=.001$) and from pre-op to 1 month post-op ($p=.033$) for liquid consistency, indicating a worsening in swallowing difficulties. For solid consistency, score changes observed from pre-op to 1 week post-op ($p=.004$) and from pre-op to 1 month post-op ($p=.038$) were significant as well (Table 17).

Similarly, Friedman test and Wilcoxon signed-rank test were conducted to evaluate changes in EAT-10 and BISA15+ scores across four time points (pre-op, 1 week post-op, 2 weeks post-op, and 4 weeks post-op) in both groups.

Significant change was confirmed in the group without cerebral palsy for both questionnaires across the four time points, while no statistically significant change was noted in cerebral palsy group (Table 18).

In the group with no cerebral palsy, significant changes were observed in both BISA15+ ($p=.036$) and EAT-10 ($p=.010$) scores across time points. For BISA15+, a significant increase was observed from pre-op to 1 week post-op ($p=.033$), with no significant changes between subsequent time points. Similarly, EAT-10 scores increased significantly by 1 week after surgery ($p=.007$),

followed by non-significant decreases at 2 weeks and 4 weeks post-op. In contrast, the CP group showed no significant changes in BISA15+ or EAT-10 scores across time points, indicating consistently higher scores and more persistent swallowing difficulties over time since pre-op (Table 19).

Table 16. Changes in Bazaz Dysphagia score in non-cerebral palsy and cerebral palsy groups

Measures	Non-cerebral palsy (n=24)					Cerebral palsy (n=9)				
	Pre-op	Post-op[1]	Post-op[2]	X^2	p	Pre-op	Post-op[1]	Post-op[2]	X^2	p
Liquid	0.08±0.28	1.17±1.20	0.58±1.10	20.591	.000*	0.89±0.78	1.56±0.88	1.56±0.88	8.333	.016*
Solid	0.08±0.28	0.79±0.88	0.42±0.72	14.176	.000*	0.78±0.67	1.67±0.71	1.44±0.73	11.143	.003*

*p<.05

Friedman test

[1]Post-op: 1 week after surgery

[2]Post-op: 1 month after surgery

Table 17. Changes in Bazaz Dysphagia Score between time points in non-cerebral palsy and cerebral palsy groups

Measures		Non-cerebral palsy (n=16)			Cerebral palsy (n=7)		
		Pre-op	Post-op[1]	Post-op[2]	Pre-op	Post-op[1]	Post-op[2]
Liquid	Mean±SD	0.08±0.28	1.17±1.20	0.58±1.10	0.89±0.78	1.56±0.88	1.56±0.88
	p	-	.001*	.033*	-	.096	.096
Solid	Mean±SD	0.08±0.28	0.79±0.88	0.42±0.72	0.78±0.67	1.67±0.71	1.44±0.73
	p	-	.004*	.038*	-	.011*	.034*

*p<.05

Wilcoxon signed-rank test

[1]Post-op: 1 week after surgery

[2]Post-op: 1 month after surgery

Table 18. Changes in EAT-10 and BISA15+ scores in non-cerebral palsy and cerebral palsy groups

Variables	Non-cerebral palsy group (n=16)						Cerebral palsy group (n=7)					
	Pre-op	Post-op 1 week	Post-op 2 weeks	Post-op 4weeks	X^2	p	Pre-op	Post-op 1 week	Post-op 2 weeks	Post-op 4weeks	X^2	p
BISA15+[1]	1.56 ±2.19	4.31 ±4.81	1.81 ±2.48	1.50 ±2.19	8.265	.036*	9.00 ±7.62	11.43 ±4.50	10.86 ±4.95	10.00 ±3.42	1.473	.723
EAT-10[2]	0.75 ±1.29	6.38 ±2.83	1.56 ±2.83	1.25 ±2.38	10.705	.010*	8.14 ±4.81	12.86 ±9.84	11.14 ±10.79	11.00 ±10.30	2.492	.502

*p<.05

Friedman test

[1]BISA15+: Brief Inventory of Swallowing Ability

[2]EAT-10: Eating Assessment Tool

Table 19. Changes in EAT-10 and BISA15+ scores between time points in non-cerebral palsy and cerebral palsy groups

Variables		Non-cerebral palsy (n=16)				Cerebral palsy (n=7)			
		Pre-op	Post-op 1 week	Post-op 2 weeks	Post-op 4weeks	Pre-op	Post-op 1 week	Post-op 2 weeks	Post-op 4weeks
BISA15+[1]	Mean±SD	1.56 ±2.19	4.31 ±4.81	1.81 ±2.48	1.50 ±2.19	9.00 ±7.62	11.43 ±4.50	10.86 ±4.95	10.00 ±3.42
	p	-	.033*	.833	.666	-	.207	.600	.500
EAT-10[2]	Mean±SD	0.75 ±1.29	6.38 ±6.96	1.56 ±2.83	1.25 ±2.38	8.14 ±4.81	12.86 ±9.84	11.14 ±10.79	11.00 ±10.30
	p	-	.007*	.201	.776	-	.345	.866	.752

*p<.05

Wilcoxon signed-rank test

[1]BISA15+: Brief Inventory of Swallowing Ability

[2]EAT-10: Eating Assessment Tool

(B) Swallowing, voice, speech related variables

Wilcoxon signed-rank test was conducted to evaluate pre- to post-operative changes (pre-op to 1 month post-op) in swallowing, voice, and speech-related variables within each group.

In the non-CP group, significant worsening in swallowing function was observed, including increases in Dry Swallow Test (DST) excursion ($p=.003$) and promptness ($p=.010$), Water Swallow Test (WST) excursion ($p=.002$) and promptness ($p=.028$), soft palate movement ($p=.034$), and coughing ($p=.014$). Regarding voice, a significant increase in breathiness ($p=.040$) was noted. For speech function, /puhtuhkuh/ regularity showed a significant increase in scores, indicating decreased regularity ($p=.038$).

In the CP group, statistically significant change was identified in WST excursion ($p=.026$) and voice-related parameters, including roughness ($p=.026$) and strain ($p=.039$), while a significant improvement in Maximum Phonation Time ($p=.017$) was noted. These results may reflect differential recovery patterns between the groups (Table 20).

Table 20. Pre- to post-op changes in non-cerebral palsy and cerebral palsy groups

Variables	Non-cerebral palsy group (n=24)			Cerebral palsy group (n=9)		
	Pre-op	Post-op[1]	p	Pre-op	Post-op[1]	p
DST_excursion	0.40±0.61	1.00±0.92	.003*	2.28±1.09	2.67±0.50	.141
DST_promptness	0.29±0.46	0.90±0.88	.010*	2.00±1.09	2.44±0.73	.066
WST_excursion	0.31±0.59	0.83±0.70	.002*	1.78±1.09	2.56±0.58	.026*
WST_promptness	0.04±0.20	0.44±0.77	.028*	1.56±1.13	2.06±1.07	.066
Lip closure	0.25±0.44	0.38±0.65	.180	2.22±1.79	2.61±1.41	.109
Buccal strength	0.19±0.44	0.35±0.52	.052	2.33±1.73	2.56±1.51	.157
Tongue strength	0.13±0.34	0.19±0.48	.450	2.11±1.43	2.50±1.22	.180
Tongue ROM	0.19±0.41	0.17±0.35	.705	2.61±1.58	3.00±1.50	.102
Tongue tip velocity	0.19±0.44	0.19±0.38	.861	2.67±1.32	2.94±1.24	.180
Soft palate movement	0.00±0.00	0.25±0.53	.034*	1.56±1.42	1.78±1.39	.157
Coughing	0.13±0.45	0.38±0.58	.014*	2.56±1.42	2.83±1.37	.102
MPT	16.53± 6.89	15.64±5.30	.391	5.82±3.92	6.82±3.68	.017*
F0	140.83±36.73	145.31±36.84	.153	199.71±50.92	175.94±28.32	.214
Jitter	0.53±0.48	0.55±0.39	.484	4.06±8.52	1.10±0.93	.441
Shimmer	3.90±2.10	4.82±2.67	.052	7.94±6.21	6.73±3.41	.441
NHR	0.06±0.06	0.07±0.06	.297	0.18±0.28	0.13±0.16	.441

*p<.05

Wilcoxon signed-rank test

[1]Post-op: 1 month after surgery

DST: Dry swallow test, WST: water swallow test, MPT: maximum phonation time, VSA: Vowel space area, SWAL-QOL: Swallowing quality of life, VHI: Voice Handicap Index

Table 20. Pre- to post-op changes in non-cerebral palsy and cerebral palsy groups (continued)

Variables	Non-cerebral palsy group (n=24)			Cerebral palsy group (n=9)		
	Pre-op	Post-op[1]	p	Pre-op	Post-op[1]	p
Grade	0.77±0.94	0.96±1.05	.135	2.28±0.97	2.44±1.04	.180
Roughness	0.75±0.91	1.02±1.09	.077	1.39±1.27	2.00±1.15	.026*
Breathiness	0.38±0.65	0.65± 0.91	.040*	1.39±1.27	1.33±1.30	.655
Asthenia	0.04±0.20	0.15±0.45	.285	0.67±1.00	1.00±1.00	.480
Strain	0.13±0.45	0.29±0.53	.131	1.50±1.27	2.06±1.47	.039*
/puh/ regularity	0.00±0.00	0.17±0.50	.109	1.78±1.56	1.78±1.48	1.000
/tuh/ regularity	0.00±0.00	0.13±0.37	.109	1.94±1.55	2.17±1.37	.214
/kuh/ regularity	0.08±0.28	0.19±0.57	.357	1.89±1.43	2.17±1.50	.248
/puhtuhkuh/ regularity	0.04±0.14	0.21±0.44	.038*	1.44±1.42	1.83±1.27	.149
/puh/ accuracy	0.04±0.20	0.04±0.20	1.000	1.89±1.69	1.89±1.54	1.000
/tuh/ accuracy	0.00±0.00	0.04±0.20	.317	1.83±1.50	2.06±1.38	.330
/kuh/ accuracy	0.00±0.00	0.04±0.20	.317	1.89±1.52	1.83±1.54	.705
/puhtuhkuh/ accuracy	0.02±0.10	0.08±0.41	.317	1.50±1.41	2.11±1.54	.149

*p<.05

Wilcoxon signed-rank test

[1]Post-op: 1 month after surgery

DST: Dry swallow test, WST: water swallow test, MPT: maximum phonation time, VSA: Vowel space area, SWAL-QOL: Swallowing quality of life, VHI: Voice Handicap Index

Table 20. Pre- to post-op changes in non-cerebral palsy and cerebral palsy groups (continued)

Variables	Non-cerebral palsy group (n=24)			Cerebral palsy group (n=9)		
	Pre-op	Post-op[1]	p	Pre-op	Post-op[1]	p
Speech rate	4.51±0.76	4.66±0.95	.057	2.27±1.43	2.20±1.49	.441
Speech intelligibility	0.04±0.20	0.10±0.36	.317	2.11±1.14	2.28±1.35	.450
VSA	248370.31 ±125192.77	259724.34 ±115001.86	.648	195821.05 ±153182.39	198659.05 ±145954.95	.859
SWAL-QoL	206.88±8.44	199.87±21.882	.338	172.56±26.00	163.78±43.68	.514
VHI	3.54±7.70	4.54±7.96	.362	61.11±29.53	48.44±38.30	.260

*p<.05

Wilcoxon signed-rank test

[1]Post-op: 1 month after surgery

DST: Dry swallow test, WST: water swallow test, MPT: maximum phonation time, VSA: Vowel space area, SWAL-QOL: Swallowing quality of life, VHI: Voice Handicap Index

3. Groups with Neck Disability Index below 17, and 17 or higher

A. Comparison between groups

(A) Swallowing-related questionnaires

A repeated measures ANOVA was conducted to compare changes in Bazaz Dysphagia Scores for liquid and solid consistency across three time points (pre-op, 1 week post-op, and 1 month post-op) between groups with Neck Disability Index (NDI) scores below 17 and 17 or higher.

For liquid consistency, a significant main effect of time was observed ($p<.001$), indicating that dysphagia severity changed significantly across the three time points in both groups. The group effect was not statistically significant ($p=.097$), suggesting no substantial difference in overall scores between the two NDI groups. The time and group interaction was also not significant ($p=.878$), indicating similar patterns of score changes over time for both groups. Specifically, scores increased immediately after surgery (pre-op to 1 week post-op) and partially recovered by 1 month post-op in both groups (Table 21).

For solid consistency, significant main effects of time ($p<.001$) and group ($p<.001$) were identified. This indicates that dysphagia severity changed significantly over time and was consistently worse in the group with NDI scores of 17 or higher compared to those with scores below 17. The time and group interaction was not significant ($p=.443$), suggesting that while the higher NDI group had worse dysphagia, the pattern of changes over time was similar for both groups. In both groups, scores increased significantly at 1 week post-op and partially improved by 1 month post-op (Table 21).

These results highlight that while both groups experienced significant postoperative increases in dysphagia severity, the group with NDI scores of 17 or higher consistently exhibited more severe dysphagia for solid consistency, emphasizing the impact of higher NDI scores on postoperative swallowing outcomes.

The EAT-10 and BISA15+ scores were compared between groups over four time points: preoperatively, 1 week postoperatively, 2 weeks postoperatively, and 4 weeks postoperatively.

For BISA15+ scores, participants with NDI scores of 17 or higher showed significantly higher scores compared to those with scores below 17 ($p=.021$). Additionally, significant changes were observed over time across both groups ($p=.031$), indicating variations in swallowing-related complaints at different time points (Table 22).

For EAT-10 scores, a significant change over time was observed (p=.046), suggesting temporal variations in swallowing difficulties across the study period (Table 22).

Table 21. Comparison of changes in Bazaz Dysphagia Score in groups with NDI Scores Below and 17 or higher

Measures	Below 17 (n=20)			17 or higher (n=13)			Time		Group		Time*Group	
	Pre-op	Post-op[1]	Post-op[2]	Pre-op	Post-op[1]	Post-op[2]	F	P	F	P	F	P
Liquid	0.10±0.31	1.15±1.23	0.60±1.14	0.69±0.75	1.46±0.97	1.23±1.01	16.969	0.000*	2.927	0.097	0.130	0.878
Solid	0.05±0.22	0.70±0.92	0.35±0.67	0.62±0.65	1.54±0.66	1.23±0.83	17.567	0.000*	15.762	0.000*	0.825	0.443

*p< .05

[1]Post-op: within 1 week after surgery

[2]Post-op: 1 month after surgery

Table 22. Comparison of EAT-10 and BISA15+ between groups with NDI Scores Below and 17 or higher

Variables	Below 17 (n=15)				17 or higher (n=8)				Time		Group		Time*Group	
	Pre-op	Post-op 1 week	Post-op 2 weeks	Post-op 4weeks	Pre-op	Post-op 1 week	Post-op 2 weeks	Post-op 4weeks	F	P	F	P	F	P
BISA15+[1]	1.67 ±2.55	5.27 ±5.30	3.00 ±4.71	1.93 ±2.55	7.25 ±7.34	8.50 ±6.02	6.75 ±5.50	7.25 ±5.23	3.367	.031*	6.181	.021*	0.873	.447
EAT-10[2]	1.27 ±2.34	8.07 ±8.69	2.73 ±6.66	2.40 ±6.06	5.50 ±2.34	8.75 ±8.03	6.75 ±8.86	6.75 ±8.99	3.227	.046*	1.665	.211	0.590	.629

*p< .05

[1]BISA15+: Brief Inventory of Swallowing Ability

[2]EAT-10: Eating Assessment Tool

(B) Swallowing, voice, speech related variables

A two-way repeated measures ANOVA was conducted to compare pre- to post-operative changes (pre-op to 1 month post-op) between groups with Neck Disability Index (NDI) scores below 17 and 17 or higher. Significant findings revealed that the NDI ≥17 group consistently demonstrated worse swallowing, voice, and speech functions compared to the NDI <17 group. In swallowing function, significant main effects of time and group were observed for the Dry Swallow Test (DST) excursion (time: p=.001; group: p=.022) and promptness (time: p=.002; group: p=.003), with the NDI ≥17 group showing greater impairment across both measures. Similar results were found for the Water Swallow Test (WST), where significant main effects of time and group were observed for excursion (time: p<.001; group: p=.018) and promptness (time: p=.002; group: p=.007). Additionally, a significant time and group interaction was found for WST excursion (p=.047), indicating that the NDI ≥17 group experienced less recovery over time compared to the NDI <17 group. Other swallowing-related measures, including lip closure (time: p=.013; group: p=.004), buccal strength (time: p=.011; group: p=.013), tongue strength (time: p=.027; group: p<.001), and soft palate movement (time: p=.005; group: p=.007), also showed significant main effects, with the NDI ≥17 group consistently showing greater impairments.

In terms of voice function, the NDI ≥17 group exhibited significantly worse fundamental frequency (F0) values, as indicated by a significant group effect (p=.001) and a time and group interaction (p=.033), suggesting differing patterns of change between the groups. Voice quality, as measured by grade (time: p=.046; group: p=.016) and strain (time: p<.001; group: p=.002), also showed significant main effects, with the NDI ≥17 group experiencing greater impairments post-operatively.

For speech function, significant differences were observed in diadochokinesis (DDK) regularity for /tuh/ (time: p=.012; group: p=.003), /kuh/ (group: p=.041), and /puhtuhkuh/ (time: p=.010; group: p=.042), with the NDI ≥17 group exhibiting greater impairment across these measures.

In terms of quality of life, SWAL-QoL scores showed a significant main effect of group (p=.005), while VHI scores revealed a significant group effect (p=.009), indicating that swallowing- and voice- related quality of life were lower in the NDI ≥17 group (Table 23).

Table 23. Comparison between groups with NDI score below 17 and 17 or higher

Variables	Below 17 (n=20)		17 or higher (n=13)		Time		Group		Time*Group	
	Pre-op	Post-op[1]	Pre-op	Post-op[1]	F	P	F	P	F	P
DST_excursion	0.60±0.88	1.10±1.06	1.39±1.34	2.00±1.00	14.417	0.001*	5.860	0.022*	0.154	0.697
DST_promptness	0.40±0.75	0.93±1.05	1.31±1.16	1.92±0.86	11.629	0.002*	10.203	0.003*	0.073	0.789
WST_excursion	0.50±0.83	0.90±0.85	1.04±1.16	1.92±0.98	30.131	0.000*	6.234	0.018*	4.288	0.047*
WST_promptness	0.20±0.52	0.45±0.63	0.85±1.21	1.54±1.39	12.036	0.002*	8.246	0.007*	2.652	0.114
Lip closure	0.35±0.75	0.40±0.82	1.46±1.71	1.89±1.53	6.294	0.013*	9.950	0.004*	4.318	0.046*
Buccal strength	0.35±0.93	0.48±0.97	1.42±1.66	1.69±1.49	7.237	0.011*	7.012	0.013*	0.969	0.333
Tongue strength	0.18±0.59	0.15±0.56	1.42±1.47	1.85±1.41	5.405	0.027*	57.865	0.000*	6.848	0.014*
Tongue ROM	0.30±0.91	0.30±0.91	1.69±1.61	1.92±1.75	1.477	0.233	11.655	0.002*	1.477	0.233
Tongue tip velocity	0.25±0.72	0.23±0.70	1.81±1.58	2.04±1.59	1.029	0.318	18.764	0.000*	1.591	0.217
Soft palate movement	0.00±0.00	0.25±0.53	1.56±1.42	1.78±1.39	9.153	0.005*	8.400	0.007*	1.763	0.194
Coughing	0.13±0.45	0.38±0.58	2.56±1.42	2.83±1.37	9.334	0.005*	59.956	0.000*	0.026	0.873
MPT	17.31±7.10	16.34±5.14	7.92±5.13	8.45±4.76	.091	.765	20.371	.000*	1.057	.312
F0	134.48±35.14	140.03±36.39	191.36±46.11	174.64±27.65	1.254	.271	14.364	.001*	4.982	.033*
Jitter	0.43±0.19	0.51±0.32	3.13±7.13	1.00±0.85	2.095	.158	3.298	.079	2.424	.130
Shimmer	4.21±2.23	4.60±1.70	6.22±5.70	6.49±4.06	.283	.599	3.379	.076	.008	.929
NHR	0.05±0.05	0.06±0.05	0.16±0.23	0.13±0.13	.967	.333	4.224	.048*	1.439	.239

*p< .05

[1]Post-op: 1 month after surgery

DST: Dry swallow test, WST: water swallow test, MPT: maximum phonation time, VSA: Vowel space area, SWAL-QOL: Swallowing quality of life, VHI: Voice Handicap Index

Table 23. Comparison between groups with NDI score below 17 and 17 or higher (continued)

Variables	Below 17 (n=20)		17 or higher (n=13)		Time		Group		Time*Group	
	Pre-op	Post-op[1]	Pre-op	Post-op[1]	F	P	F	P	F	P
Grade	0.83±1.03	0.95±1.16	1.73±1.17	2.00±1.10	4.341	.046*	6.486	.016*	.581	.452
Roughness	0.78±1.01	0.98±1.21	1.15±1.09	1.77±0.97	10.629	.003*	2.592	.118	2.759	.107
Breathiness	0.38±0.67	0.68±0.96	1.08±1.19	1.08±1.19	2.054	.162	2.727	.109	2.054	.162
Asthenia	0.15±0.49	0.23±0.62	0.31±0.75	0.62±0.87	2.116	.156	1.913	.177	.782	.383
Strain	0.20±0.62	0.20±0.52	0.96±1.23	1.65±1.36	20.291	.000*	12.002	.002*	20.291	.000*
/puh/ regularity	0.10±0.45	0.18±0.49	1.08±1.55	1.27±1.48	1.466	.235	9.077	.005*	0.282	.599
/tuh/ regularity	0.15±0.67	0.15±0.56	1.12±1.53	1.50±1.44	7.117	.012*	10.051	.003*	7.117	.012*
/kuh/ regularity	0.25±0.72	0.40±0.95	1.08±1.43	1.23±1.54	2.006	.167	4.525	.041*	0.000	.986
/puhtuhkuh/ regularity	0.15±0.46	0.38±0.78	0.85±1.34	1.08±1.27	7.201	.012*	4.497	.042*	0.001	.973
/puh/ accuracy	0.20±0.70	0.15±0.49	1.08±1.61	1.15±1.58	0.030	.863	6.048	.020*	0.670	.419
/tuh/ accuracy	0.13±0.56	0.20±0.70	1.08±1.50	1.19±1.47	1.698	.202	7.078	.012*	0.076	.784
/kuh/ accuracy	0.15±0.67	0.20±0.70	1.08±1.48	1.04±1.48	0.008	.930	5.571	.025*	0.457	.504
/puhtuhkuh/ accuracy	0.13±0.46	0.20±0.62	0.89±1.36	1.31±1.65	7.517	.010*	6.873	.013*	3.671	.065

*p< .05

[1]Post-op: 1 month after surgery

DST: Dry swallow test, WST: water swallow test, MPT: maximum phonation time, VSA: Vowel space area, SWAL-QOL: Swallowing quality of life, VHI: Voice Handicap Index

Table 23. Comparison between groups with NDI score below 17 and 17 or higher (continued)

Variables	Below 17 (n=20)		17 or higher (n=13)		Time		Group		Time*Group	
	Pre-op	Post-op[1]	Pre-op	Post-op[1]	F	P	F	P	F	P
Speech rate	4.38±1.09	4.56±1.18	3.16±1.52	3.11±1.71	.319	.577	8.284	.007*	.857	.362
Speech intelligibility	0.30±0.92	0.30±0.92	1.08±1.24	1.31±1.42	2.705	.110	5.351	.028*	2.705	.110
VSA	237711.51 ±122341.66	221700.86 ±93152.51	228388.21 ±153082.44	275946.05 ±160976.55	.795	.379	.277	.602	3.230	.082
SWAL-QOL	205.40±11.10	201.15±20.94	185.38±27.78	172.92±41.02	3.855	.059	9.086	.005*	.931	.342
VHI	8.40±19.42	7.50±13.90	35.92±37.52	30.38±38.74	.929	.343	7.702	.009*	.482	.493

*p< .05

[1]Post-op: 1 month after surgery

DST: Dry swallow test, WST: water swallow test, MPT: maximum phonation time, VSA: Vowel space area, SWAL-QOL: Swallowing quality of life, VHI: Voice Handicap Index

B. Within-group changes from pre-to post-op 1 month

(A) Swallowing-related questionnaires

Changes in Bazaz Dysphagia Scores for liquid and solid consistencies were analyzed within groups divided by Neck Disability Index (NDI) scores below 17 and 17 or higher. For the NDI <17 group, significant changes were observed over time for both liquid ($p<.001$) and solid ($p=.002$) consistencies (Table 24). Pairwise comparisons revealed a significant increase in liquid scores from pre-op to 1 week post-op ($p=.003$) only. Similarly, solid scores significantly increased from pre-op to 1 week post-op ($p=.009$) but showed no significant improvement from 1 week to 1 month post-op (Table 25).

For the NDI ≥17 group, significant changes were also observed over time for both liquid ($p=.011$) and solid ($p<.001$) consistencies (Table 24). Pairwise comparisons indicated a significant increase in liquid scores from pre-op to 1 week post-op ($p=.021$). Solid scores also significantly increased from pre-op to 1 week post-op ($p=.006$) (Table 25).

Changes in EAT-10 and BISA15+ scores were analyzed within groups divided by Neck Disability Index (NDI) scores below 17 and 17 or higher. For the NDI <17 group, significant changes were observed over time for both BISA15+ ($p=.010$) and EAT-10 ($p=.004$) scores (Table 26). Pairwise comparisons revealed a significant increase in BISA15+ scores from pre-op to 1 week post-op ($p=.011$). Similarly, EAT-10 scores significantly increased from pre-op to 1 week post-op ($p=.011$), both reflecting decline in swallowing function in early-postoperative period (Table 27).

In the NDI ≥17 group, no statistically significant changes were observed over time for either BISA15+ or EAT-10 scores (Table 26). Pairwise comparisons also indicated no significant changes across time points for BISA15+ or EAT-10, suggesting persistently elevated scores and ongoing swallowing difficulties in this group (Table 27).

Table 24. Changes in Bazaz Dysphagia score in groups with NDI Scores Below and 17 or higher

Measures	NDI below 17 (n=20)					NDI 17 or higher (n=13)				
	Pre-op	Post-op[1]	Post-op[2]	X^2	p	Pre-op	Post-op[1]	Post-op[2]	X^2	p
Liquid	0.10±0.31	1.15±1.23	0.60±1.14	15.235	.000*	0.69±0.75	1.46±0.97	1.23±1.01	8.857	.011*
Solid	0.05±0.22	0.70±0.92	0.35±0.67	11.214	.002*	0.62±0.65	1.54±0.66	1.23±0.83	14.000	.000*

*p<.05

Friedman test

[1]Post-op: 1 week after surgery

[2]Post-op: 1 month after surgery

Table 25. Changes in Bazaz Dysphagia Score between time points in groups with NDI Scores Below and 17 or higher

Measures		NDI below 17 (n=20)			NDI 17 or higher (n=13)		
		Pre-op	Post-op[1]	Post-op[2]	Pre-op	Post-op[1]	Post-op[2]
Liquid	M±SD	0.10±0.31	1.15±1.23	0.60±1.14	0.69±0.75	1.46±0.97	1.23±1.01
	p	-	.003*	.057	-	.021*	.053
Solid	M±SD	0.05±0.22	0.70±0.92	0.35±0.67	0.62±0.65	1.54±0.66	1.23±0.83
	p	-	.009*	.063	-	.006*	.023*

*p<.05

Wilcoxon signed-rank test

[1]Post-op: 1 week after surgery

[2]Post-op: 1 month after surgery

Table 26. Changes in EAT-10 and BISA15+ scores in groups with NDI Scores below and 17 or higher

Variables	NDI below 17 (n=15)						NDI 17 or higher (n=8)					
	Pre-op	Post-op 1 week	Post-op 2 weeks	Post-op 4weeks	X^2	p	Pre-op	Post-op 1 week	Post-op 2 weeks	Post-op 4weeks	X^2	p
BISA15+[1]	1.67 ±2.55	5.27 ±5.30	3.00 ±4.71	1.93 ±2.55	10.677	.010*	7.25 ±7.34	8.50 ±6.02	6.75 ±5.50	7.25 ±5.23	2.400	.516
EAT-10[2]	1.27 ±2.34	8.07 ±8.69	2.73 ±6.66	2.40 ±6.06	12.239	.004*	5.50 ±4.81	8.75 ±8.03	6.75 ±8.86	6.75 ±8.99	2.538	.492

*p<.05

Friedman test

[1]BISA15+: Brief Inventory of Swallowing Ability

[2]EAT-10: Eating Assessment Tool

Table 27. Changes in EAT-10 and BISA15+ scores between time points in groups with NDI Scores below and 17 or higher

Variables		NDI below 17 (n=15)				NDI 17 or higher (n=8)			
		Pre-op	Post-op 1 week	Post-op 2 weeks	Post-op 4weeks	Pre-op	Post-op 1 week	Post-op 2 weeks	Post-op 4weeks
BISA15+[1]	M±SD	1.67 ±2.55	5.27 ±5.30	3.00 ±4.71	1.93 ±2.55	7.25 ±7.34	8.50 ±6.02	6.75 ±5.50	7.25 ±5.23
	p	-	.011*	.248	.596	-	.396	.752	.734
EAT-10[2]	M±SD	1.27 ±2.34	8.07 ±8.69	2.73 ±6.66	2.40 ±6.06	5.50 ±4.81	8.75 ±8.03	6.75 ±8.86	6.75 ±8.99
	p	-	.011*	.610	.888	-	.078	.735	.832

*p<.05

Wilcoxon signed-rank test

[1]BISA15+: Brief Inventory of Swallowing Ability

[2]EAT-10: Eating Assessment Tool

(B) Swallowing, voice, speech related variables

Wilcoxon signed-rank test was conducted to analyze pre- to post-operative changes in swallowing, voice, and speech-related variables within each group.

In the NDI <17 group, significant declines in swallowing function were observed, with increases in Dry Swallow Test (DST) excursion (p=.017) and promptness (p=.028), and Water Swallow Test (WST) excursion (p=.011). Significant changes were also noted in coughing (p=.046), indicating weakened voluntary coughing. /puhtuhkuh/ regularity scores increased significantly (p=.034), reflecting worsened coordination. Speech rate showed a slight improvement post-operatively (p=.020). With respect to voice, a significant increase in breathiness was observed, indicating that the breathy quality of the voice became more pronounced (p=.031).

In the NDI ≥17 group, significant increases were observed in DST excursion (p=.019) and promptness (p=.026), WST excursion (p=.005) and promptness (p=.041), /tuh/ regularity (p=.040), and /puhtuhkuh/ accuracy (p=.040), indicating declines in swallowing and speech coordination. Voice function showed further declines, with increases in grade (p=.038), roughness (p=.007), and strain (p=.007), reflecting greater voice dysfunction (Table 28).

Table 28. Pre- to post-op changes in groups with NDI below 17 and 17 or higher

Variables	NDI below 17 (n=20)			NDI 17 or higher (n=13)		
	Pre-op	Post-op[1]	p	Pre-op	Post-op[1]	p
DST_excursion	0.60±0.88	1.10±1.06	.017*	1.39±1.34	2.00±1.00	.019*
DST_promptness	0.40±0.75	0.93±1.05	.028*	1.31±1.16	1.92±0.86	.026*
WST_excursion	0.50±0.83	0.90±0.85	.011*	1.04±1.16	1.92±0.98	.005*
WST_promptness	0.20±0.52	0.45±0.63	.067	0.85±1.21	1.54±1.39	.041*
Lip closure	0.35±0.75	0.40±0.82	.317	1.46±1.71	1.89±1.53	.066
Buccal strength	0.35±0.93	0.48±0.97	.102	1.42±1.66	1.69±1.49	.066
Tongue strength	0.18±0.59	0.15±0.56	.655	1.42±1.47	1.85±1.41	.066
Tongue ROM	0.30±0.91	0.30±0.91	1.000	1.69±1.61	1.92±1.75	.408
Tongue tip velocity	0.25±0.72	0.23±0.70	.705	1.81±1.58	2.04±1.59	.408
Soft palate movement	0.10±0.45	0.25±0.55	.083	0.92±1.38	1.31±1.38	.059
Coughing	0.20±0.89	0.40±0.94	.046*	1.69±1.49	2.04±1.42	.034*
MPT	17.31±7.10	16.34±5.14	.370	7.92±5.13	8.45±4.76	.289
F0	134.48±35.14	140.03±36.39	.126	191.36±46.11	174.64±27.65	.152
Jitter	0.43±0.19	0.51±0.32	.171	3.13±7.13	1.00±0.85	.249
Shimmer	4.21±2.23	4.60±1.70	.086	6.22±5.70	6.49±4.06	.861
NHR	0.05±0.05	0.06±0.05	.695	0.16±0.23	0.13±0.13	.972

*p<.05

Wilcoxon signed-rank test

[1]Post-op: 1 month after surgery

DST: Dry swallow test, WST: water swallow test, MPT: maximum phonation time, VSA: Vowel space area, SWAL-QOL: Swallowing quality of life, VHI: Voice Handicap Index

Table 28. Pre- to post-op changes in groups with NDI below 17 and 17 or higher (continued)

Variables	NDI below 17 (n=20)			NDI 17 or higher (n=13)		
	Pre-op	Post-op[1]	p	Pre-op	Post-op[1]	p
Grade	0.83±1.03	0.95±1.16	.336	1.73±1.17	2.00±1.10	.038*
Roughness	0.78±1.01	0.98±1.21	.301	1.15±1.09	1.77±0.97	.007*
Breathiness	0.38±0.67	0.68±0.96	.031*	1.08±1.19	1.08±1.19	1.000
Asthenia	0.15±0.49	0.23±0.62	.655	0.31±0.75	0.62±0.87	.317
Strain	0.20±0.62	0.20±0.52	1.000	0.96±1.23	1.65±1.36	.007*
/puh/ regularity	0.10±0.45	0.18±0.49	.593	1.08±1.55	1.27±1.48	.317
/tuh/ regularity	0.15±0.67	0.15±0.56	1.000	1.12±1.53	1.50±1.44	.040*
/kuh/ regularity	0.25±0.72	0.40±0.95	.276	1.08±1.43	1.23±1.54	.292
/puhtuhkuh/ regularity	0.15±0.46	0.38±0.78	.034*	0.85±1.34	1.08±1.27	.194
/puh/ accuracy	0.20±0.70	0.15±0.49	.564	1.08±1.61	1.15±1.57	.564
/tuh/ accuracy	0.13±0.56	0.20±0.70	.180	1.08±1.50	1.19±1.47	.396
/kuh/ accuracy	0.15±0.67	0.20±0.70	.317	1.08±1.48	1.04±1.48	.705
/puhtuhkuh/ accuracy	0.13±0.46	0.13±0.46	.317	0.89±1.36	1.31±1.65	.040*

*p<.05

Wilcoxon signed-rank test

[1]Post-op: 1 month after surgery

DST: Dry swallow test, WST: water swallow test, MPT: maximum phonation time, VSA: Vowel space area, SWAL-QOL: Swallowing quality of life, VHI: Voice Handicap Index

Table 28. Pre- to post-op changes in groups with NDI below 17 and 17 or higher (continued)

Variables	NDI below 17 (n=20)			NDI 17 or higher (n=13)		
	Pre-op	Post-op[1]	p	Pre-op	Post-op[1]	p
Speech rate	4.38±1.09	4.56±1.18	.020*	3.16±1.52	3.11±1.71	.650
Speech intelligibility	0.30±0.92	0.30±0.92	1.000	1.08±1.24	1.31±1.42	.216
VSA	237711.51±122341.66	221700.86±93152.51	.391	228388.21±153082.44	275946.05±160976.55	.116
SWAL-QoL	205.40±11.10	201.15±20.94	.481	185.38±27.78	172.92±41.02	.345
VHI	8.40±19.42	7.50±13.90	.893	35.92±37.52	30.38±38.74	.675

*p<.05

Wilcoxon signed-rank test

[1]Post-op: 1 month after surgery

DST: Dry swallow test, WST: water swallow test, MPT: maximum phonation time, VSA: Vowel space area, SWAL-QOL: Swallowing quality of life, VHI: Voice Handicap Index

4. Anterior and posterior approach groups

A. Comparison between groups

(A) Swallowing-related questionnaires

Pre- to post-operative changes in Bazaz Dysphagia Scores were analyzed between anterior and posterior surgical approach groups for both liquid and solid consistencies.

For liquid consistency, a significant main effect of time was confirmed suggesting that average liquid scores of both groups increased significantly before and after surgery and swallowing difficulties with liquid worsened over time (p=.000). Time and group interaction effect (p=.046) was significant, suggesting that the recovery trajectory differed between the anterior and posterior approach groups. Dysphagia scores increased more markedly in the anterior group at by 1 week after the surgery and decreased significantly by 1 month post-op, whereas the posterior group exhibited smaller overall changes.

Main effect for time for solid consistency was significant (p=.002), representing significant changes in dysphagia severity across time points. However, there were no significant group or time and group interaction effects (p=.605 and p=.446, respectively), suggesting that changes in dysphagia scores were similar between the anterior and posterior groups (Table 29).

Pre- to post-operative changes in BISA15+ and EAT-10 were analyzed between the two groups over four time points: preoperatively, 1 week postoperatively, 2 weeks postoperatively, and 4 weeks postoperatively.

For BISA15+ scores, the anterior group demonstrated an increase from 1.29±2.36 before surgery to 4.14±3.98 at 1 week after surgery, followed by a decrease to 2.14±2.67 at 2 weeks and 0.71±1.25 at 4 weeks. Similarly, the posterior group showed an increase from 1.63±2.26 preoperatively to 4.75±5.92 at 1 week postoperatively, with subsequent reductions to 1.62±2.62 at 2 weeks and 2.25±2.76 at 4 weeks. However, no statistically significant differences were observed in the changes over time, between groups, or in the interaction between time and group.

For EAT-10 scores, the anterior group showed an increase from 0.43±0.79 preoperatively to 7.00±8.47 at 1 week after surgery, followed by decreases to 1.29±3.40 at 2 weeks and 1.14±3.02 at 4 weeks. In the posterior group, scores rose from 0.75±1.49 preoperatively to 6.25±6.34 at 1 week after surgery and remained stable at 1.25±2.05 at both 2 and 4 weeks postoperatively. While the

changes over time approached statistical significance, there were no significant differences between groups or in the interaction between time and group (Table 30).

Table 29. Comparison of changes in Bazaz Dysphagia Score in anterior and posterior approach groups

Measures	Anterior (n=11)			Posterior (n=10)			Time		Group		Time*Group	
	Pre-op	Post-op[1]	Post-op[2]	Pre-op	Post-op[1]	Post-op[2]	F	P	F	P	F	P
Liquid	0.09 ±0.37	1.45 ±1.04	0.27 ±0.91	0.00 ±0.00	0.70 ±1.25	0.60 ±1.08	12.180	.000*	.469	.335	.569	.046*
Solid	0.00 ±0.00	0.82 ±0.27	0.27 ±0.65	0.10 ±0.32	0.50 ±0.85	0.20 ±0.42	7.283	.002*	0.276	.605	0.825	.446

*p< .05

[1]Post-op: within 1 week after surgery

[2]Post-op: 1 month after surgery

Table 30. Comparison of EAT-10 and BISA15+ in anterior and posterior approach groups

Variables	Anterior (n=7)				Posterior (n=8)				Time		Group		Time*Group	
	Pre-op	Post-op 1 week	Post-op 2 weeks	Post-op 4weeks	Pre-op	Post-op 1 week	Post-op 2 weeks	Post-op 4weeks	F	P	F	P	F	P
BISA15+[1]	1.29 ±2.36	4.14 ±3.98	2.14 ±2.67	0.71 ±1.25	1.63 ±2.26	4.75 ±5.92	1.62 ±2.62	2.25 ±2.76	1.922	.185	.150	.704	1.510	.266
EAT-10[2]	0.43 ±0.79	7.00 ±8.47	1.29 ±3.40	1.14 ±3.02	0.75 ±1.49	6.25 ±6.34	1.25 ±2.05	1.25 ±2.05	3.228	.065	.005	.945	.047	.986

*p< .05

[1]BISA15+: Brief Inventory of Swallowing Ability

[2]EAT-10: Eating Assessment Tool

(B) Swallowing, voice, speech related variables

Pre- to post-operative changes in swallowing, voice, and speech-related variables were compared between the anterior and posterior surgical approach groups. In swallowing function, significant improvements were observed in the Dry Swallow Test (DST) for both excursion (p=.002) and promptness (p=.009), as well as in the Water Swallow Test (WST) for excursion (p=.001) and promptness (p=.033) over time. However, there were no significant differences between groups or in time and group interactions, suggesting that both surgical approaches showed similar patterns of recovery in these measures.

In voice function, a significant improvement in coughing was observed over time (p=.048), while Maximum Phonation Time (MPT) demonstrated a significant time and group interaction (p=.033). This interaction indicated that the anterior group showed improved phonation duration, whereas the posterior group experienced a decline. Noise-to-Harmonics Ratio (NHR) also exhibited a significant time and group interaction (p=.043), reflecting varying changes in voice quality between the groups.

For speech function, breathiness significantly worsened over time in both groups (p=.033), indicating increased breathy quality in the voice post-operatively. Regularity in the /puhtuhkuh/ diadochokinesis task improved significantly over time (p=.029), but no significant group differences or interactions were found. Vowel Space Area (VSA) displayed a significant time and group interaction (p=.010), highlighting differing recovery patterns in articulation precision, with the posterior group showing greater variation (Table 31).

Table 31. Comparison of changes in swallowing, voice, speech related variables between anterior and posterior approach groups

Variables	Anterior (n=11)		Posterior (n=10)		Time		Group		Time*Group	
	Pre-op	Post-op[1]	Pre-op	Post-op[1]	F	P	F	P	F	P
DST_excursion	0.36±0.50	0.96±0.96	0.42±0.70	1.04±0.92	11.932	.002*	0.068	.797	0.005	.945
DST_promptness	0.27±0.47	0.86±0.95	0.31±0.48	0.92±0.86	8.122	.009*	0.052	.821	0.003	.954
WST_excursion	0.27±0.47	0.64±0.50	0.35±0.69	1.00±0.82	14.690	.001*	0.907	.351	1.195	.286
WST_promptness	0.00±0.00	0.27±0.47	0.08±0.28	0.58±0.95	5.156	.033*	1.479	.237	0.446	.511
Lip closure	0.36±0.51	0.46±0.69	0.20±0.42	0.40±0.70	1.868	.188	0.215	.648	0.263	.614
Buccal strength	0.27±0.47	0.32±0.56	0.15±0.47	0.40±0.52	3.046	.097	0.010	.921	1.460	.242
Tongue strength	0.09±0.30	0.05±0.15	0.10±0.32	0.10±0.32	0.168	.687	0.087	.772	0.168	.687
Tongue ROM	0.18±0.34	0.09±0.20	0.25±0.54	0.20±0.42	0.478	.498	0.422	.524	0.040	.843
Tongue tip velocity	0.18±0.40	0.18±0.40	0.25±0.54	0.15±0.34	0.156	.698	0.018	.896	0.156	.698
Soft palate movement	0.00±0.00	0.09±0.30	0.00±0.00	0.30±0.68	3.036	.098	0.869	.363	0.869	.363
Coughing	0.18±0.60	0.36±0.67	0.00±0.00	0.20±0.42	4.483	.048*	0.727	.404	0.010	.921
MPT	16.15±5.41	17.50±4.92	17.37±8.68	14.25±5.72	0.822	.376	0.155	.698	5.289	.033*
F0	122.81±24.19	125.55±29.38	150.79±43.61	152.87±34.05	0.730	.403	3.760	.067	0.014	.908
Jitter	0.49±0.21	0.45±0.14	0.36±0.18	0.48±0.29	0.776	.389	0.359	.556	3.491	.077
Shimmer	4.37±2.83	4.41±2.09	3.37±1.28	5.63±3.41	2.939	.103	0.016	.899	2.738	.114
NHR	0.07±0.06	0.06±0.06	0.04±0.04	0.05±0.05	0.857	.366	0.671	.423	4.722	.043*

*p<.05

[1]Post-op: 1 month after surgery

DST: Dry swallow test, WST: water swallow test, MPT: maximum phonation time, VSA: Vowel space area, SWAL-QOL: Swallowing quality of life, VHI: Voice Handicap Index

Table 31. Comparison of changes in swallowing, voice, speech related variables between anterior and posterior approach groups (continued)

Variables	Anterior (n=11)		Posterior (n=10)		Time		Group		Time*Group	
	Pre-op	Post-op[1]	Pre-op	Post-op[1]	F	P	F	P	F	P
Grade	0.82±1.00	1.05±1.11	0.35±0.67	0.55±0.96	2.335	.143	1.504	.235	0.010	.923
Roughness	0.73±0.93	1.14±1.21	0.40±0.70	0.50±0.71	2.184	.156	1.762	.200	0.805	.381
Breathiness	0.18±0.40	0.59±0.80	0.30±0.67	0.50±0.97	5.268	.033*	0.002	.963	0.621	.440
Asthenia	0.00±0.00	0.00±0.00	0.10±0.32	0.35±0.67	1.345	.261	3.857	.064	1.345	.261
Strain	0.18±0.60	0.18±0.40	0.00±0.00	0.10±0.32	0.343	.565	0.732	.403	0.343	.565
/puh/ regularity	0.00±0.00	005±0.15	0.00±0.00	0.20±0.63	1.567	.226	0.621	.440	0.621	.440
/tuh/ regularity	0.00±0.00	0.05±0.15	0.00±0.00	0.15±0.47	1.688	.209	0.483	.495	0.483	.495
/kuh/ regularity	0.09±0.30	0.41±0.80	0.10±0.32	0.00±0.00	0.941	.344	1.397	.252	3.456	.079
/puhtuhkuh/ regularity	0.05±0.15	0.18±0.40	0.05±0.16	0.30±0.54	5.56	.029*	0.224	.642	0.481	.496
/puh/ accuracy	0.09±0.30	0.00±0.00	0.00±0.00	0.10±0.32	0.005	.947	0.005	.947	2.005	.173
/tuh/ accuracy	0.00±0.00	0.09±0.30	0.00±0.00	0.00±0.00	0.905	.353	0.905	.353	0.905	.353
/kuh/ accuracy	0.00±0.00	0.09±0.30	0.00±0.00	0.00±0.00	0.905	.353	0.905	.353	0.905	.353
/puhtuhkuh/ accuracy	0.05±0.15	0.18±0.60	0.00±0.00	0.00±0.00	0.905	.353	0.905	.353	0.905	.353

*p<.05

[1]Post-op: 1 month after surgery

DST: Dry swallow test, WST: water swallow test, MPT: maximum phonation time, VSA: Vowel space area, SWAL-QOL: Swallowing quality of life, VHI: Voice Handicap Index

Table 31. Comparison of changes in swallowing, voice, speech related variables between anterior and posterior approach groups (continued)

Variables	Anterior (n=11)		Posterior (n=10)		Time		Group		Time*Group	
	Pre-op	Post-op[1]	Pre-op	Post-op[1]	F	P	F	P	F	P
Speech rate	4.47±0.71	4.69±0.98	4.55±0.86	4.71±1.06	2.035	.170	0.019	.891	0.048	.829
Speech intelligibility	0.09±0.30	0.09±0.30	0.00±0.00	0.00±0.00	-	-	0.905	.353	-	-
VSA	283554.40 ±114179.22	234731.30 ±78276.03	211230.24 ±136165.43	274994.95 ±148307.09	0.146	.706	0.106	.748	8.300	.010*
SWAL-QOL	209.00±10.48	206.45±17.83	205.50±6.50	196.20±25.73	1.920	.182	1.349	.260	0.624	.439
VHI	1.82±3.66	1.82±3.00	5.20±10.93	7.80±11.37	0.304	.588	3.219	.089	0.304	.588

*p<.05

[1]Post-op: 1 month after surgery

DST: Dry swallow test, WST: water swallow test, MPT: maximum phonation time, VSA: Vowel space area, SWAL-QOL: Swallowing quality of life, VHI: Voice Handicap Index

B. Within-group changes from pre-to post-op 1 month

(A) Swallowing-related questionnaires

Friedman test was conducted to analyze changes in Bazaz Dysphagia Scores for liquid and solid consistencies across three time points (pre-op, 1 week post-op, and 1 month post-op) in the anterior and posterior approach groups and Wilcoxon signed-rank test was conducted to examine in which time period the changes in scores for liquid and solid consistency in both groups.

In the anterior approach group, significant changes in dysphagia scores were observed for both liquid and solid consistencies (Table 32). For liquid consistency, the scores significantly increased from pre-op to post-op1 ($p=.007$), indicating a transient worsening of dysphagia severity within the first week after surgery. However, no significant changes were noted from post-op1 to post-op2 ($p=.655$). Similarly, for solid consistency, a significant increase in scores was observed from pre-op to post-op1 ($p=.024$) (Table 33).

In contrast, the posterior approach group showed no statistically significant changes in dysphagia scores for either liquid or solid consistencies across the three time points (Table 32). For liquid consistency, the overall change was not significant, with no significant differences observed between specific time points. Similarly, for solid consistency, no significant changes were noted over time including between specific time points (Table 33).

Friedman test and Wilcoxon signed-rank test were conducted for EAT-10 and BISA15+ scores across four time points (pre-op, 1 week post-op, 2 weeks post-op, and 4 weeks post-op) as well.

For the anterior approach group, no statistically significant changes were observed in BISA15+ scores across the four time points. However, the mean scores increased from 1.29±2.36 at pre-op to 4.14±3.98 at 1 week post-op, followed by a decrease to 2.14±2.67 at 2 weeks post-op and 0.71±1.25 at 4 weeks post-op. For EAT-10 scores, no significant changes were observed across the four time points. The mean scores increased from 0.43±0.79 at pre-op to 7.00±8.47 at 1 week post-op, then decreased to 1.29±3.40 at 2 weeks post-op and 1.14±3.02 at 4 weeks post-op (Table 32, 33).

In the posterior approach group, no significant changes were found in BISA15+ scores across the four time points (Table 34). However, as a result of Wilcoxon signed-rank test, a significant change was observed from pre-op to 1 week post-op ($p=.043$) (Table 35). The scores increased from 1.63±2.26 at pre-op to 4.75±5.92 at 1 week post-op, followed by a decrease to 1.63±2.62 at 2 weeks post-op and 2.25±2.77 at 4 weeks post-op. For EAT-10 scores, significant changes were observed across the four time points ($p=.012$) (Table 34). The scores increased from 0.75±1.49 at pre-op to

6.25±6.34 at 1 week post-op, then decreased to 1.25±2.05 at both 2 weeks and 4 weeks post-op. However, between time periods, no significant change was observed (Table 35).

Table 32. Changes in Bazaz Dysphagia score in anterior and posterior approach groups

Measures	Anterior approach (n=11)					Posterior approach (n=10)				
	Pre-op	Post-op[1]	Post-op[2]	X^2	p	Pre-op	Post-op[1]	Post-op[2]	X^2	p
Liquid	0.09±0.30	1.45±1.04	0.27±0.91	15.500	.000*	0.00±0.00	0.70±1.25	0.60±1.08	5.600	.111
Solid	0.00±0.00	0.82±0.27	0.27±0.65	8.000	.019*	0.10±0.32	0.50±0.85	0.20±0.42	3.714	.333

*p<.05

Friedman test

[1]Post-op: 1 week after surgery

[2]Post-op: 1 month after surgery

Table 33. Changes in Bazaz Dysphagia Score between time points in anterior and posterior approach groups

Measures		Anterior approach (n=11)			Posterior approach (n=10)		
		Pre-op	Post-op[1]	Post-op[2]	Pre-op	Post-op[1]	Post-op[2]
Liquid	M±SD	0.09±0.30	1.45±1.04	0.27±0.91	0.00±0.00	0.70±1.25	0.60±1.08
	p	-	.007*	.655	-	.102	.109
Solid	M±SD	0.00±0.00	0.82±0.27	0.27±0.65	0.10±0.32	0.50±0.85	0.20±0.42
	p	-	.024*	.180	-	.157	.317

*p<.05

Wilcoxon signed-rank test

[1]Post-op: 1 week after surgery

[2]Post-op: 1 month after surgery

Table 34. Changes in EAT-10 and BISA15+ scores in anterior and posterior approach groups

Variables	Anterior approach (n=7)						Posterior approach (n=8)					
	Pre-op	Post-op 1 week	Post-op 2 weeks	Post-op 4 weeks	X^2	p	Pre-op	Post-op 1 week	Post-op 2 weeks	Post-op 4 weeks	X^2	p
BISA15+[1]	1.29 ±2.36	4.14 ±3.98	2.14 ±2.67	0.71 ±1.25	7.020	.067	1.63 ±2.26	4.75 ±5.92	1.63 ±2.62	2.25 ±2.77	5.093	.174
EAT-10[2]	0.43 ±0.79	7.00 ±8.47	1.29 ±3.40	1.14 ±3.02	4.143	.321	0.75 ±1.49	6.25 ±6.34	1.25 ±2.05	1.25 ±2.05	9.477	.012*

*p<.05

Friedman test

[1]BISA15+: Brief Inventory of Swallowing Ability

[2]EAT-10: Eating Assessment Tool

Table 35. Changes in EAT-10 and BISA15+ scores between time points in anterior and posterior approach groups

Variables		Anterior approach (n=7)				Posterior approach (n=8)			
		Pre-op	Post-op 1 week	Post-op 2 weeks	Post-op 4 weeks	Pre-op	Post-op 1 week	Post-op 2 weeks	Post-op 4 weeks
BISA15+[1]	M±SD	1.29±2.36	4.14±3.98	2.14±2.67	0.71±1.25	1.63±2.26	4.75±5.92	1.63±2.62	2.25±2.77
	p	-	.141	.593	.276	-	.043*	.102	.461
EAT-10[2]	M±SD	0.43±0.79	7.00±8.47	1.29±3.40	1.14±3.02	0.75±1.49	6.25±6.34	1.25±2.05	1.25±2.05
	p	-	.080	1.000	1.000	-	.104	1.000	.102

*p<.05

Wilcoxon signed-rank test

[1]BISA15+: Brief Inventory of Swallowing Ability

[2]EAT-10: Eating Assessment Tool

(B) Swallowing, voice, speech related variables

Wilcoxon signed-rank test was conducted to evaluate pre-to post-operative changes (pre-op to 1 month post-op) in swallowing, voice, and speech-related variables within the anterior and posterior approach groups.

In the anterior approach group, significant worsening was observed in Water Swallow Test (WST) excursion (p=.046), indicating reduced swallowing function post-operatively. No significant changes were observed in other variables.

In the posterior approach group, significant worsening was observed in voice-related variables, including shimmer (p=.005) and NHR (p=.009), reflecting increased vocal instability and noise-to-harmonics ratio post-operatively. MPT showed a statistically significant decline (p=.037), indicating decreased phonation capability post-surgery (Table 36).

Table 36. Pre-to post-op changes in anterior and posterior approach groups

Variables	Anterior approach (n=11)			Posterior approach (n=10)		
	Pre-op	Post-op[1]	p	Pre-op	Post-op[1]	p
DST_excursion	0.36±0.50	0.96±0.96	.066	0.55±0.76	1.05±1.07	.066
DST_promptness	0.27±0.47	0.86±0.95	.112	0.30±0.48	0.90±0.99	.109
WST_excursion	0.27±0.47	0.64±0.50	.046*	0.45±0.76	1.00±0.94	.066
WST_promptness	0.00±0.00	0.27±0.47	.083	0.10±0.32	0.45±0.96	.357
Lip closure	0.36±0.51	0.46±0.69	.317	0.20±0.42	0.40±0.70	.317
Buccal strength	0.27±0.47	0.32±0.56	.317	0.15±0.47	0.40±0.52	.131
Tongue strength	0.09±0.30	0.05±0.15	.655	0.10±0.32	0.10±0.32	1.000
Tongue ROM	0.18±0.34	0.09±0.20	.317	0.25±0.54	0.20±0.42	.655
Tongue tip velocity	0.18±0.41	0.18±0.40	1.000	0.25±0.54	0.15±0.34	.581
Soft palate movement	0.00±0.00	0.09±0.30	.317	0.00±0.00	0.30±0.68	.180
Coughing	0.18±0.60	0.36±0.67	.157	0.00±0.00	0.20±0.42	.157
MPT	16.15±5.41	17.50±4.92	.328	17.37±8.68	14.25±5.72	.037*
F0	122.81±24.19	125.55±29.38	.859	150.79±43.61	152.87±34.05	.508
Jitter	0.49±0.21	0.45±0.14	.859	0.36±0.18	0.48±0.29	.066
Shimmer	4.37±2.83	4.41±2.09	.722	3.37±1.28	5.63±3.41	.005*
NHR	0.07±0.06	0.06±0.06	.286	0.04±0.04	0.05±0.05	.009*

*p<.05

Wilcoxon signed-rank test

[1]Post-op: 1 month after surgery

DST: Dry swallow test, WST: water swallow test, MPT: maximum phonation time, VSA: Vowel space area, SWAL-QOL: Swallowing quality of life, VHI: Voice Handicap Index

Table 36. Pre-to post-op changes in anterior and posterior approach groups (continued)

Variables	Anterior approach (n=11)			Posterior approach (n=10)		
	Pre-op	Post-op[1]	p	Pre-op	Post-op[1]	p
Grade	0.82±1.01	1.05±1.11	.357	0.35±0.67	0.55±0.96	.194
Roughness	0.73±0.93	1.14±1.21	.131	0.40±0.70	0.50±0.71	.564
Breathiness	0.18±0.40	0.60±0.80	.074	0.30±0.67	0.50±0.97	.157
Asthenia	0.00±0.00	0.00±0.00	1.000	0.10±0.32	0.35±0.67	.285
Strain	0.18±0.60	0.18±0.40	1.000	0.00±0.00	0.10±0.32	.317
/puh/ regularity	0.00±0.00	0.05±0.15	.317	0.00±0.00	0.20±0.63	.317
/tuh/ regularity	0.00±0.00	0.05±0.15	.317	0.00±0.00	0.15±0.47	.317
/kuh/ regularity	0.09±0.30	0.41±0.80	.109	0.10±0.32	0.00±0.00	.317
/puhtuhkuh/ regularity	0.05±0.15	0.18±0.40	.180	0.05±0.16	0.30±0.54	.102
/puh/ accuracy	0.09±0.30	0.00±0.00	.317	0.00±0.00	0.10±0.32	.317
/tuh/ accuracy	0.00±0.00	0.09±0.30	.317	0.00±0.00	0.00±0.00	1.000
/kuh/ accuracy	0.00±0.00	0.09±0.30	.317	0.00±0.00	0.00±0.00	1.000
/puhtuhkuh/ accuracy	0.05±0.15	0.18± 0.60	.317	0.00±0.00	0.00±0.00	1.000

*p<.05

Wilcoxon signed-rank test

[1]Post-op: 1 month after surgery

DST: Dry swallow test, WST: water swallow test, MPT: maximum phonation time, VSA: Vowel space area, SWAL-QOL: Swallowing quality of life, VHI: Voice Handicap Index

Table 36. Pre-to post-op changes in anterior and posterior approach groups (continued)

Variables	Anterior approach (n=11)			Posterior approach (n=10)		
	Pre-op	Post-op[1]	p	Pre-op	Post-op[1]	p
Speech rate	4.47±0.71	4.69±0.98	.050	4.55±0.86	4.71±1.06	.445
Speech intelligibility	0.09±0.30	0.09±0.30	1.000	0.00±0.00	0.00±0.00	1.000
VSA	283554.40±114179.22	234731.30±78276.03	.131	2112330.24±136165.43	274994.95±148307.09	.059
SWAL-QoL	209.00±10.48	206.45±17.83	.959	205.50±6.50	196.20±25.73	.444
VHI	1.82±3.66	1.82±3.00	.916	5.20±10.93	7.80±11.37	.310

*p<.05

Wilcoxon signed-rank test

[1]Post-op: 1 month after surgery

DST: Dry swallow test, WST: water swallow test, MPT: maximum phonation time, VSA: Vowel space area, SWAL-QOL: Swallowing quality of life, VHI: Voice Handicap Index

5. Changes in normality of acoustic variables

A. changes in normality of acoustic variables

The normality of acoustic parameters including jitter, shimmer, and noise-to-harmonics ratio, was evaluated for all 33 participants preoperatively and 1 month postoperatively by McNemar's test.

For jitter normality, 93.1% of participants with normal preoperative jitter maintained normal values postoperatively, while 6.9% transitioned to abnormal values. Among participants with abnormal preoperative jitter, all (100%) remained abnormal postoperatively. However, the changes in jitter normality were not statistically significant (p=.500).

For shimmer normality, a statistically significant change was observed (p=.006). Among participants with normal preoperative shimmer, 64.7% developed abnormal values postoperatively. Conversely, 93.8% of those with abnormal preoperative shimmer remained abnormal one month after surgery.

For NHR normality, 96.7% of participants with normal preoperative NHR maintained normal values postoperatively, while 3.3% became abnormal. All participants with abnormal preoperative NHR remained abnormal postoperatively. No significant changes in NHR normality were detected (p=1.000).

These findings suggest that significant changes in normality were primarily observed in shimmer values, suggesting that a potential impact of cervical spine surgery on certain acoustic parameters. However, jitter and NHR showed limited variations in normality postoperatively (Table 37).

Table 37. Changes in normality of acoustic variables (n=33)

Variables			Post-op jitter normality			Pre-op to Post-op[1]
			Normal	Abnormal	Sum	
Pre-op Jitter normality (>1.04)	Normal	Frequency (n)	27	2	29	P
		Proportion (%)	93.1	6.9	100	
	Abnormal	Frequency (n)	0	4	4	
		Proportion (%)	0	100	100	.500
	Sum	Frequency (n)	27	6	33	
		Proportion (%)	81.8	18.2	100	
Variable			Post-op Shimmer normality			Pre-op to Post-op [1]
			Normal	Abnormal	Sum	
Pre-op Shimmer normality (>3.81)	Normal	Frequency (n)	6	11	17	P
		Proportion (%)	35.3	64.7	100	
	Abnormal	Frequency (n)	1	15	16	
		Proportion (%)	6.2	93.8	100	.006*
	Sum	Frequency (n)	7	26	33	
		Proportion (%)	21.2	78.8	100	
Variable			Post-op NHR normality			Pre-op to Post-op [1]
			Normal	Abnormal	Sum	
Pre-op NHR normality (>0.19)	Normal	Frequency (n)	29	1	30	P
		Proportion (%)	96.7	3.3	100	
	Abnormal	Frequency (n)	0	3	3	
		Proportion (%)	0	100	100	1.000
	Sum	Frequency (n)	29	4	33	
		Proportion (%)	87.9	12.1	100	

*p<.05

McNemar test

[1]Post-op: 1 month after surgery

IV. DISCUSSION

Although oropharyngeal dysphagia and dysphonia are well-recognized complications following cervical spine surgery, comprehensive evaluations of swallowing, voice, and speech functions before and after surgery remain limited. In particular, studies focusing on the posterior surgical approach are relatively scarce, and the risk factors contributing to postoperative dysphagia have not been fully elucidated. This study aimed to explore the risk factors associated with postoperative dysphagia following cervical spine surgery. Participants were categorized into groups depending on whether they exhibited the identified risk factors. Then pre- to post-op changes in swallowing, voice, and speech were analyzed between groups and within each group.

The factors associated with swallowing difficulties were cerebral palsy, higher Neck Disability Index (NDI ≥17), prior neck surgery history, and surgical approach. Pre-operatively, cerebral palsy, higher Neck Disability Index score (NDI ≥17), prior neck surgery, and surgical approach were associated with increased rates of swallowing complaints. At 1 week post-operation, cerebral palsy and NDI remained significant factors influencing dysphagia. Individuals with cerebral palsy and those with higher NDI scores showed a higher likelihood of swallowing difficulties. At 1 month post-operation, cerebral palsy, NDI, prior neck surgery, and surgical approach were again identified as relevant factors. The proportion of patients reporting swallowing complaints peaked at 1 week postoperatively in all the identified factors and decreased, except for the cerebral palsy group.

The Neck Disability Index (NDI) was identified as a consistent predictor of postoperative swallowing difficulties and increased Bazaz Dysphagia Scores for both liquid and solid consistencies at 1 week and 1 month post-operation. Additional factors, including cerebral palsy, prior neck surgery, and combined surgical approaches, significantly contributed to higher dysphagia severity. It has been reported that generally higher Neck Disability Index (NDI) score, NDI score beyond 17, and above 50% are associated with poorer postoperative recovery or less favorable surgical outcomes.[41, 42] Consistent with previous studies, positive correlation was confirmed between NDI score and post-operative Bazaz dysphagia scores in this study. Also, NDI score of 17 or above was found to be associated with post-operative swallowing discomfort.

Patients with cerebral palsy are inherently at a higher risk of postoperative complications due to their unique physiological and functional challenges. These patients often present with comorbidities such as dystonia, poor nutritional status, and compromised respiratory function, which

can significantly impair their recovery after cervical spine surgery.[43] Given the anatomical and functional proximity of the cervical spine to structures involved in swallowing and voice production, dysphagia and hoarseness are commonly observed complications, particularly after multilevel cervical surgeries.[44]

Furthermore, patients with cerebral palsy frequently undergo posterior or multilevel surgical approaches, which can increase the strain on the surrounding musculature and neural structures.[45] Studies have reported that dysphagia is more prevalent and persists longer in this population compared to non-cerebral palsy patients, with higher rates observed following procedures at the C2-3 and C3-4 levels.[46] These findings underscore the importance of tailored preoperative and postoperative care strategies, including nutritional support and swallowing rehabilitation, to mitigate the heightened risk of dysphagia and related complications in patients with cerebral palsy.

Regarding the surgical approach, the combined approach was associated with a higher likelihood of swallowing difficulties and more severe Bazaz dysphagia scores, while the posterior approach showed a lower likelihood of swallowing difficulties. These results highlight the potential impact of surgical techniques on postoperative outcomes. However, all patients who underwent the combined approach had cerebral palsy, which likely contributed to the observed outcomes. To better understand the differences between anterior and posterior approaches, the posterior approach group was regrouped into a group of 10 participants by excluding 4 patients with cerebral palsy and 3 patients with a history of prior neck surgery. Significant deterioration was observed only in the anterior approach group, and the siginificant difference occurred specifically between the preopreative period and 1 week postoperatively where swallowing difficculties were most prounounced in general. This finding correlates with the previous study, swallowing discomfort was transient in majority of participants.[6]

This aligns with previous findings suggesting that the anterior surgical approach may cause greater mechanical damage or inflammatory responses to the larynx and surrounding structures. The anterior approach to the cervical spine is associated with a higher incidence of postoperative dysphagia compared to the posterior approach, primarily due to the retraction and manipulation of the esophagus and adjacent tissues during surgery. Such mechanical irritation and inflammation can contribute significantly to swallowing difficulties. Studies have indicated that the incidence of dysphagia following anterior cervical spine surgery can reach up to 71% within the first two weeks postoperatively.[47] Swallowing difficulties and voice complaints resolve within 2 to 3 months of

surgery dysphagia,[48] and persisting over a year is very rare.[6] In contrast, the posterior approach typically involves minimal disruption to anterior neck structures, resulting in a comparatively lower incidence of swallowing difficulties. Nevertheless, dysphagia may still occur due to factors such as postoperative swelling, muscle trauma, or nerve injury.[49]

Several studies have reported that surgeries performed at higher cervical levels, particularly within the C1 to C4 range, are associated with an increased likelihood of postoperative complications, including swallowing and voice issues.[2, 4, 14] Higher cervical levels are closer to the neural structures that control swallowing, and surgical interventions in these areas can cause increased trauma to the surrounding tissues and nerves. This can compromise swallowing functions, making patients more susceptible to dysphagia postoperatively.[14] In this study, a statistically significant correlation was not found. The proportion of participants reporting swallowing discomfort was lower among those who had surgery involving cervical vertebrae above the C4 level compared to those whose surgical procedures did not extend to vertebrae above C4 in this study at 1 week post-op but higher at 1 month post-op.

With respect to the number of cervical levels involved, studies report that patients who underwent multiple level surgery tend to complain about swallowing difficulties after cervical surgeries.[13, 50-53] The incidence of dysphagia after multilevel anterior cervical spine surgery was reported to be approximately 12.6%.[54] Patients who underwent surgery involving more than two levels had a higher probability of experiencing swallowing difficulties compared to those who had surgery at only one level.[55] In contrast, no significant association between the number of cervical levels operated and dysphagia rates was found.[56, 57] No significant association was observed in this study.

In terms of voice, significant change was observed in shimmer normality. Among participants with normal preoperative shimmer, 64.7% developed abnormal values postoperatively, and 93.8% of those with abnormal preoperative shimmer remained abnormal after the surgery. Shimmer, inidicating amplitude purterbations, is frequently used to assess voice quality along with jitter assessing pitch variability.[58] Abnormality in these variables are associated with irregular vocal fold vibration. The acoustic outcomes of various disorders may vary depending on the specific condition, sample size, and assessment methods. However, patients with voice disorders, such as, vocal nodules, vocal polyps, or vocal cord paralysis, generally exhibit higher values in variability

parameters such as jitter and shimmer, as well as noise-related parameters, compared to healthy individuals.[59]

In a previous study, in patients who underwent ACDF, voice parameters showed a significant decline compared to those who had PCDF without apparent nerve injury. although these changes typically improved within three months post-surgery. Potential explanations for these observations include retraction of the vagus and recurrent laryngeal nerves, postoperative swelling of the strap muscles, trauma to the vocal folds during intubation, and impacts on other laryngeal structures.[58]

Although statistically significant deterioration in auditory-perceptual variables was not consistently observed within each group, the overall severity increased postoperatively, indicating a decline in voice quality. Additionally, the rise in the number of participants with abnormal shimmer values suggests that patients may experience voice alterations after surgery, emphasizing the importance of providing vocal hygiene education.

This study has several limitations. First, overall small sample size limits the generalizability of the findings. Similarly, the number of participants within each risk factor group was insufficient, preventing analysis of more diverse subgroups and constraining the statistical significance of the group-based analyses conducted. Second, objective swallowing assessments, such as Videofluoroscopic Swallowing Study (VFSS) were not performed in patients without comorbidities due to cost and concerns over radiation exposure, limiting their application in this study. Increased use of such objective evaluations could enhance the reliability of the research findings. Third, it is essential to verify whether the identified risk factors contribute to persistence of dysphagia and dysphonia symptoms.

Despite the limitations, this study identified key factors associated with postoperative swallowing difficulties following cervical spine surgery and examined changes in swallowing, voice, and speech. The findings also highlight that postoperative swallowing difficulties are most pronounced during the early postoperative period and tend to subside in most patients, with the exception of those with cerebral palsy.

5. CONCLUSION

This study identified the factors associated with postoperative swallowing complaints following cervical spine surgery, and explored pre- to post-op changes in swallowing, voice, and speech related variables between and within the groups categorized according to the identified risk factors.

Cerebral palsy, higher NDI score, operation approach, and prior neck surgery were associated with swallowing complaints. The findings identified cerebral palsy and high Neck Disability Index (NDI) scores as critical predictors of postoperative dysphagia. The analysis further revealed that posterior surgical approach was associated with lower likelihood of swallowing complaints at 1 week post-op, while combined approaches posed higher risks. However, it cannot be concluded that the combined approach is a predictor of postoperative dysphagia following cervical surgery, as all five patients who underwent this approach had cerebral palsy, which may have influenced the results. These results underscore the importance of comprehensive preoperative assessments to identify high-risk patients and implement tailored management strategies.

Moreover, the study demonstrated that postoperative swallowing difficulties typically peak during the early postoperative period, within a week and subside in most patients. However, swallowing difficulties tended to prolong in patients with cerebral palsy.

A significant difference in shimmer normality was found and overall deterioration was observed across auditory-perceptual variables even though statistically significant difference was not consistently observed across different groups. In terms of speech, prominent changes were rarely observed. Between the groups, significant differences were observed in most of the variables, but recovery trajectory was similar.

Patients with reported risk factors should be considered with more caution before undergoing cervical spine surgery, and in this study, higher NDI score, cerebral palsy, operation approach, and prior neck surgery history were confirmed as affecting factors to post-operative dysphagia.

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APPENDICES

Appendix 1. Swallowing-Related Quality of Life (SWAL-QoL)

(SWAL-QOL)

이 설문지는 삼킴 문제 관련 삶의 질을 측정하기 위해 제작되었습니다.
삼킴의 어려움은 다양한 신체적 문제를 동반할 것입니다.
그러나 본 설문에서는 삼킴에만 초점을 두고 답해 주시기 바랍니다.
문장을 읽으신 후, 질문에 대한 귀하의 의견과 가장 일치한다고 생각되는 보기를 선택해 주십시오.
모든 항목이 다르게 구성되어 있으므로 유사한 질문에도 모두 답해주시기 바랍니다.

지난 한달 동안 느낀 정도에 O 표시를 해주세요.

	항상 그렇다	자주 그렇다	보통 그렇다	가끔 그렇다	전혀 아니다
삼킴문제를 대하는 것이 매우 어렵다.	1	2	3	4	5
삼킴문제는 내 삶의 주요 방해요소이다.	1	2	3	4	5
끼니를 거르는 것에 괘념치 않는다. (늘상 먹든 안 먹든 상관하지 않는다)	1	2	3	4	5
다른 사람들보다 먹는데 시간이 오래 걸린다.	1	2	3	4	5
거의 배고픔을 느끼지 못한다.	1	2	3	4	5
식사를 마치는데 오래 걸린다.	1	2	3	4	5
더 이상 먹는게 즐겁지 않다.	1	2	3	4	5

지난 한 달 동안, 삼킴장애로 인해 다음의 문제를 얼마나 자주 경험하셨나요?

	항상 그렇다	자주 그렇다	보통 그렇다	가끔 그렇다	전혀 아니다
기침	1	2	3	4	5
음식을 먹을 때 숨이 막힘	1	2	3	4	5
액체를 마실 때 숨이 막힘	1	2	3	4	5
걸쭉한 침 또는 가래 생김	1	2	3	4	5
구역질	1	2	3	4	5
침흘림	1	2	3	4	5
씹기 어려움	1	2	3	4	5
과도한 침 또는 가래 생김	1	2	3	4	5
목을 가다듬어야 함	1	2	3	4	5

목구멍에 음식물이 들러붙음	1	2	3	4	5
입에 음식물이 들러붙음	1	2	3	4	5
입 밖으로 음식 또는 액체가 흘러나옴	1	2	3	4	5
코로 음식 또는 액체가 나옴	1	2	3	4	5
음식물이나 액체가 목에 걸리면 기침을 해서 입 밖으로 뱉어냄	1	2	3	4	5

지난 한 달 동안, 삼킴문제가 식사에 어떤 영향을 미쳤나요?

	항상 그렇다	자주 그렇다	보통 그렇다	가끔 그렇다	전혀 아니다
내가 먹을 수 있는 것과 먹을 수 없는 것을 구별하기가 어렵다.	1	2	3	4	5
내가 좋아하면서 동시에 먹는 것이 가능한 음식을 정하는 것이 어렵다.	1	2	3	4	5

지난 한 달 동안, 삼킴문제가 의사소통에 얼마나 자주 영향을 미쳤나요?

	항상 그렇다	자주 그렇다	보통 그렇다	가끔 그렇다	전혀 아니다
사람들은 내 말이 이해하기 어려워한다.	1	2	3	4	5
명료하게 말하는 것이 어렵다.	1	2	3	4	5

다음은 삼킴문제를 가진 사람들이 가끔씩 말하는 걱정에 관한 내용입니다.
지난 한 달 동안, 다음의 느낌을 얼마나 자주 경험했나요?

	항상 그렇다	자주 그렇다	보통 그렇다	가끔 그렇다	전혀 아니다
나는 음식을 먹을 때 숨이 막힐까봐 두렵다.	1	2	3	4	5
나는 폐렴에 걸릴까봐 걱정이다.	1	2	3	4	5
나는 액체를 마실 때 숨이 막힐까봐 두렵다.	1	2	3	4	5
나는 음식을 먹으면서 언제 숨이 막힐지 알 수 없다.	1	2	3	4	5

지난 한 달 동안, 삼킴문제로 다음의 내용을 얼마나 자주 경험했나요 ?

	항상 그렇다	자주 그렇다	보통 그렇다	가끔 그렇다	전혀 아니다
삼킴문제는 나를 우울하게 한다.	1	2	3	4	5
조심해서 먹거나 마셔야 하는 것이 나를 화나게 한다.	1	2	3	4	5
삼킴문제는 나를 낙담시킨다.	1	2	3	4	5
삼킴문제는 나를 절망스럽게 한다.	1	2	3	4	5
삼킴문제를 대할 때 나는 참을성이 없어진다.	1	2	3	4	5

다음의 항목에 얼마나 동의하십니까?

	항상 그렇다	자주 그렇다	보통 그렇다	가끔 그렇다	전혀 아니다
삼킴문제 때문에 외식을 하지 않는다.	1	2	3	4	5
삼킴문제 때문에 사회생활이 어렵다.	1	2	3	4	5
삼킴문제 때문에 나의 일 또는 여가 활동이 변했다.	1	2	3	4	5
삼킴문제 때문에 사람들과의 모임이 즐겁지 않다.	1	2	3	4	5
삼킴문제 때문에 가족과 친구들 내에서 나의 역할이 바뀌었다.	1	2	3	4	5

지난 한 달 동안, 다음의 신체적 증상을 얼마나 자주 경험했나요?

	항상 그렇다	자주 그렇다	보통 그렇다	가끔 그렇다	전혀 아니다
신체적으로 약한가?	1	2	3	4	5
잠드는 게 어려운가?	1	2	3	4	5
피곤함을 느끼는가?	1	2	3	4	5
잠든 상태를 유지하는 게 어려운가?	1	2	3	4	5
신체적으로 지치는가?	1	2	3	4	5

지난 한 주 동안,
가장 자주 먹었던 음식의 농도나 질감을 가장 잘 묘사한 항목을 선택해 주십시오.

정상적인 식이 (갈비, 당근, 빵, 샐러드, 팝콘과 같이 씹기 어려운 다양한 종류의 음식)
씹기 쉽고 부드러운 음식 섭취 (찜 요리, 과일 통조림, 부드럽게 익힌 야채, 다진 고기, 또는 크림스프)
갈거나 가공된 음식 섭취 (푸딩이나 생크림)
대부분 섭식관으로 영양을 섭취하지만, 가끔 아이스크림, 푸딩, 사과주스, 또는 다른 군것질 섭취
섭식관을 통해서만 영양 섭취

지난 한 주 동안, 가장 자주 마신 액체의 농도를 가장 잘 묘사한 항목을 선택해 주십시오.

물, 우유, 차, 과일주스, 커피와 같은 액체를 마신다.
액체의 대부분이 농도가 짙어서 수저를 뒤집으면 천천히 아래로 흔든다. (예: 토마토 주스, 두유)
액체가 중간 정도의 농도여서 빨대로 빨기 어렵고, 꿀과 같이 수저를 뒤집으면 한 방울씩 떨어진다.(예: 호박죽, 꿀)
액체의 농도가 상당히 진해서 수저를 뒤집으면 수저에 붙어있다. (예: 푸딩, 생크림)
입으로 액체를 전혀 마시지 못하거나 얼음 조각만 먹는다.

현재 자신의 전반적인 건강 상태가 어떠하다고 생각하십니까?

약함
보통
좋음
매우 좋음
최상

Appendix 2. Brief Inventory of Swallowing Ability (BISA15+)

삼킴기능 간이평가 (BISA15+)

	전혀 그렇지 않다	그렇다	자주/ 많이 그렇다
1. 물이나 음식이 코로 넘어온다.	0	1	2
2. (딱딱한) 음식을 씹기가 힘들다.	0	1	2
3. 평소에 식사할 때 숨이 차다.	0	1	2
4. 컵으로 물 마실 때 흘린다.	0	1	2
5. 마른 음식(예: 크래커)을 먹기가 힘들다.	0	1	2
6. 예전에 비해 말하는 목소리가 변했다.	0	1	2
7. 알약을 넘기기가 힘들다.	0	1	2
8. 음식을 먹은 후에 혀 밑에 음식물이 남아있다.	0	1	2
9. 평소에 숨 쉬는 것이 힘들다.	0	1	2
10. 예전에 비해 (집에서의) 식사 시간이 오래 걸린다.	0	1	2
11. 물이나 액체에 사레가 걸린다.	0	1	2
12. 음식을 씹으면서 흘린다.	0	1	2
13. 음식을 입에 넣으면서 흘린다.	0	1	2
14. 나에게 씹는 문제가 있다.	0	1	2
15. 나에게 삼키는 문제가 있다.	0	1	2
16. 씹는 문제 때문에 한 끼 식사량이 줄었다.	0	1	2
17. 씹는 문제 때문에 사람들과의 모임을 꺼린다.	0	1	2
18. 씹는 문제 때문에 속상하다.	0	1	2
19. 삼키는 문제 때문에 식사시간이 오래 걸린다.	0	1	2
20. 삼키는 문제 때문에 사람들과의 모임을 꺼린다.	0	1	2

Appendix 3. Eating Assessment Tool (EAT-10)

Eating Assessment Tool (EAT-10)					
※ 어느 정도의 삼킴 문제가 있는지 항목에 표기해주세요.					
질문의 적절한 점수에 동그라미 하세요.	0 = 전혀 문제되지 않는다. 4 = 심각한 문제가 있다.				
1. 삼킴 문제 때문에 체중이 감소하였다.	0	1	2	3	4
2. 삼킴 문제로 인해 외식하는 것이 꺼려진다.	0	1	2	3	4
3. 액체류를 삼킬 때 더 많은 노력이 필요하다. (예: 빨대 등 기구사용, 소량씩 섭취)	0	1	2	3	4
4. 고형식(예: 밥, 과자, 씹는 음식)을 삼킬 때 더 힘이 든다.	0	1	2	3	4
5. 알약을 삼킬 때 더 힘이 든다.	0	1	2	3	4
6. 삼키는 것이 불편하고 힘들다.	0	1	2	3	4
7. 삼킴 문제로 인해서 먹는 즐거움이 감소했다.	0	1	2	3	4
8. 음식물을 삼킬 때 목에 걸리는 것 같다.	0	1	2	3	4
9. 음식을 먹을 때 사레가 걸린다.	0	1	2	3	4
10. 음식물을 삼킬 때 스트레스를 받는다.	0	1	2	3	4
	Total EAT-10:				

Appendix 4. Voice Handicap Index (VHI)

음성장애지수 (Voice handicap index, VHI)

자신의 음성에 대해 자신이 느끼는 증상이 어느 정도인지 숫자에 'O 또는 V표시' 해 주세요.
(0=전혀 그렇지 않다, 1=거의 그렇지 않다, 2=가끔 그렇다, 3=자주 그렇다, 4=항상 그렇다)

P						
1	말하는 동안 숨이 차는 것 같다.	0	1	2	3	4
2	하루 중에도 목소리가 자주 변한다	0	1	2	3	4
3	사람들이 나에게 목소리가 왜 그러냐고 묻는다.	0	1	2	3	4
4	목소리가 갈라지고 탁하다.	0	1	2	3	4
5	목소리를 내려면 힘을 주어야 나오는 것 같다.	0	1	2	3	4
6	목소리가 언제쯤 맑게 잘 나올지 알 수가 없다(예측이 어렵다).	0	1	2	3	4
7	목소리가 좋게 들리게 하려고 음성을 바꿔보기도 한다.	0	1	2	3	4
8	말할 때 힘을 주어(애를 쓰면서) 이야기하는 것 같다.	0	1	2	3	4
9	저녁이 되면 목소리가 더 잠긴다.	0	1	2	3	4
10	말하다가 목소리가 나오지 않아 말을 이을 수 없을 때도 있다.	0	1	2	3	4
F						
1	목소리 때문에 상대방이 내 말을 알아듣기 힘들어한다.	0	1	2	3	4
2	시끄러운 곳에서는 사람들이 내 말을 이해하기 어려워한다.	0	1	2	3	4
3	집안 어디서든 내가 부르는 말소리를 가족들이 잘 듣지 못 한다.	0	1	2	3	4
4	목소리 때문에 전화통화를 가급적 줄인다.	0	1	2	3	4
5	내 목소리 때문에 여러 사람이 모인 자리를 피하게 된다.	0	1	2	3	4
6	내 목소리 때문에 친구, 친척 혹은 이웃들과 대화를 덜 하게 된다.	0	1	2	3	4
7	얼굴을 마주보고 대화할 때도 상대방이 다시 말해 달라고 한다.	0	1	2	3	4
8	음성 문제로 개인 생활과 사회생활에 제한을 받는다.	0	1	2	3	4
9	내 목소리 때문에 대화에 끼지 못하여 소외감을 느낀다.	0	1	2	3	4
10	음성 문제로 인해 소득(수입)에 감소가 생긴다.	0	1	2	3	4
E						
1	목소리 때문에 타인과 대화를 할 때 긴장을 한다.	0	1	2	3	4
2	내 목소리 때문에 사람들은 짜증이 날 것이다.	0	1	2	3	4
3	다른 사람들은 내 음성 문제를 잘 이해하지 못한다고 생각한다.	0	1	2	3	4
4	내 목소리 문제로 속이 상한다.	0	1	2	3	4
5	내 목소리 문제로 적극적이지 못할 때가 있다.	0	1	2	3	4
6	음성 문제가 장애로(핸디캡으로) 여겨진다.	0	1	2	3	4
7	사람들이 나에게 다시 말해 달라고 할 때 기분이 언짢다.	0	1	2	3	4
8	사람들이 나에게 다시 말해 달라고 할 때 창피함을 느낀다.	0	1	2	3	4
9	목소리 때문에 무능력하게 느껴져 자신감이 떨어진다.	0	1	2	3	4
10	목소리 때문에 수치심을 느낀다.	0	1	2	3	4

Appendix 5. Autumn passage

우리나라의 가을은 참으로 아름답다. 무엇보다도 산에 오를 땐 더욱 더 그 빼어난 아름다움이 느껴진다. 쓰다듬어진 듯한 완만함과 깎아놓은 듯한 뾰족함이 어우러진 산등성이를 따라 오르다 보면 절로 감탄을 금할 수가 없게 된다. 붉은색, 푸른색, 노란색 등의 여러 가지 색깔들이 어우러져 타는 듯한 감동을 주며 나아가 신비롭기까지 하다.

숲 속에 누워서 하늘을 바라보라. 쌍쌍이 짝지어져 있는 듯한 흰 구름, 높고 파란 하늘을 쳐다보고 있노라면 과연 예부터 가을을 천고마비의 계절이라 일컫는 이유를 알게 될 것만 같다. 가을에는 또한 오곡백과 등 먹거리가 풍성하기 때문에 결실의 계절이라고도 한다.

햅쌀, 밤, 호두 뿐만 아니라 대추, 여러 가지 떡, 크고 작은 과일들을 맛볼 수 있는데, 가을의 대표적인 명절인 추석에 우리는 이것들을 쌓아놓고 조상님들께 차례를 지내기도 한다. 또한 가을은 독서의 계절이라고도 하여 책을 읽으며 시시때때로 명상에 잠기기도 하는데, 독서는 우리에게 마음을 살찌우고 아름답게 하는 힘을 주기 때문이다.

Appendix 6. Neck Disability Index

다음 설문지를 완성해주세요.
다음은 당신의 목과 팔의 통증이 어떻게 일상생활 능력에 영향을 주는지를 알아보기 위한 설문조사입니다.
각 문항에서 현재 자신의 상태와 가장 근접한 항목 하나에만 표시하세요.

제 1 항목 – 통증 강도

ⓞ 전혀 통증이 없다.

① 약한 통증이 있다.

② 중간 정도의 통증이 있다.

③ 심한 통증이 있다.

④ 매우 심한 통증이 있다.

⑤ 상상할 수 없을 정도의 극심한 통증이 있다.

제 2 항목 – 자기 관리(씻기, 옷 입기…)

ⓞ 통증 없이 정상적으로 나 자신을 돌볼 수 있다.

① 정상적으로 나 자신을 돌볼 수 있지만 통증이 있다.

② 나 자신을 돌보기가 고통스럽고 천천히 조심스럽게 움직인다.

③ 약간의 도움이 필요하지만 대부분의 자기 관리를 할 수 있다.

④ 대부분의 자기 관리를 위해서 매일 도움이 필요하다.

⑤ 옷을 입지 못하고 힘들게 씻으며 침대에만 누워 지낸다.

제 3 항목 – 들어올리기

ⓞ 통증 없이 무거운 물건을 들 수 있다.

① 무거운 물건을 들 수는 있지만 통증이 심해진다.

② 통증으로 인해 바닥에서 무거운 물건을 들어 올릴 수는 없지만 탁자 위와 같이 편한 위치에 있는 경우에는 무거운 물건도 들어 올릴 수 있다.

③ 통증으로 인해 무거운 물건을 들어 올릴 수는 없지만 탁자 위와 같이 편한 위치에 있는 경우는 가볍거나 중간 정도 무게의 물건이라면 들어 올릴 수 있다.

④ 아주 가벼운 물건만 들 수 있다.

⑤ 전혀 물건을 들거나 옮길 수 없다.

제 4 항목 – 읽기

ⓞ 목 통증 없이 원하는 만큼 독서할 수 있다.

① 약간의 목 통증은 있지만, 원하는 만큼 독서할 수 있다.
② 중간 정도의 목 통증은 있지만, 원하는 만큼 독서할 수 있다.
③ 중간 정도의 목 통증 때문에 원하는 만큼의 독서를 할 수 없다.
④ 극심한 목 통증 때문에 거의 독서를 할 수 없다.
⑤ 전혀 독서를 할 수 없다.

제 5 항목 – 두통

ⓞ 전혀 두통이 없다.
① 드물게 약간의 두통이 있다.
② 드물게 중간 정도의 두통이 있다.
③ 자주 중간 정도의 두통이 있다.
④ 자주 심한 두통이 있다.
⑤ 거의 항상 두통이 있다.

제 6 항목 – 집중도

ⓞ 아무 어려움 없이(원하면) 언제든 집중할 수 있다.
① 약간의 어려움은 있으나, 언제든 집중할 수 있다.
② 집중 시 중간 정도의 어려움이 있다.
③ 집중 시 많은 어려움이 있다.
④ 집중 시 상당히 많은 어려움이 있다.
⑤ 전혀 집중할 수 없다.

제 7 항목 – 일

ⓞ 내가 원하는 만큼 일 할 수 있다.
① 일상 생활은 할 수 있지만 그 이상은 불가능하다.
② 대부분의 일상 생활은 할 수 있지만 그 이상은 불가능하다.
③ 일상 생활이 불가능하다.
④ 어떤 일도 거의 할 수 없다.
⑤ 어떤 일도 전혀 할 수 없다.

제 8 항목 – 운전(운전을 하는 경우만 답해 주세요)

ⓞ 목 통증 없이 운전할 수 있다.

① 약간의 목 통증은 있지만 내가 원하는 만큼 운전할 수 있다.
② 중간 정도의 목 통증은 있지만 내가 원하는 만큼 운전할 수 있다.
③ 중간 정도의 목 통증 때문에 내가 원하는 만큼의 운전을 할 수 없다.
④ 심한 목 통증 때문에 거의 운전할 수 없다.
⑤ 전혀 운전할 수 없다.

제 9 항목 – 수면

ⓞ 수면 시 전혀 문제 없다.
① 수면 시 아주 약간의 문제가 있다(잠들지 못하는 시간이 1 시간 이하이다).
② 수면 시 약간의 문제가 있다(1-2 시간 이상 잠들지 못함).
③ 수면 시 중간 정도의 문제가 있다(2-3 시간 이상 잠들지 못함).
④ 수면 시 상당히 문제가 있다(3-5 시간 이상 잠들지 못함).
⑤ 수면이 불가능하다(5-7 시간 이상 잠들지 못함).

제 10 항목 – 여가 생활(취미생활, 여행 등)

ⓞ 목 통증이 전혀 없이 모든 여가 생활이 가능하다.
① 약간의 목 통증이 있지만, 모든 여가 생활이 가능하다.
② 목 통증 때문에 모두는 아니지만 대부분의 일상 여가 생활은 가능하다.
③ 목 통증 때문에 몇 가지 여가 생활만 가능하다.
④ 목 통증 때문에 거의 여가 생활이 불가능하다.
⑤ 어떠한 여가 생활도 전혀 할 수 없다.

Abstract in Korean

경추 수술 후 삼킴장애의 관련 요인

경추 수술 후 삼킴장애와 음성장애는 흔히 보고되는 합병증이다. 그러나 대부분의 연구가 후향적으로 이루어졌으며, 음성 및 말 기능의 변화에 대한 연구는 부족한 실정이다. 또한, 합병증의 위험 요인에 대한 연구결과들은 일관적이지 않다. 이에 본 연구는 경추 수술 후 삼킴장애와 관련된 위험 요인을 알아보고, 이러한 요인에 따라 분류된 그룹 간 및 그룹 내에서 삼킴, 음성, 및 말 기능의 변화를 평가하는 것을 목적으로 한다.

총 33 명의 경추 수술 환자(평균 연령: 54.09±11.12)를 대상으로 연구가 진행되었으며, 이 중 11 명은 전방 접근법, 17 명은 후방 접근법, 5 명은 복합 접근법을 받았다. 전반적인 삼킴, 음성, 말에 대한 평가가 수술 전, 수술 후 1 개월 시점에서 이루어졌다. 삼킴 곤란의 정도를 평가하기 위해 Bazaz Dysphagia Score 가 세 번 (수술 전, 수술 후 1 주 이내, 수술 후 1 개월 시점) 수집되었으며, BISA15+ 와 EAT-10 의 경우, 23 명으로부터 네 번 (수술 전, 수술 후 1 주, 2 주, 1 개월 시점) 수집되었다.

삼킴장애의 위험 요인으로는 높은 Neck Disability Index (NDI) 점수, 뇌성마비, 수술접근법, 경추 수술 이력으로 확인되었다. 로지스틱 회귀분석에서는 NDI 점수가 삼킴장애 중증도의 일관된 예측 인자로 확인되었으며, 후방 접근법은 삼킴장애 호소 확률이 낮은 것으로 나타났다. 삼킴장애의 위험 요인으로 분류된 그룹간 차이는 대부분의 영역에서 유의한 것으로 나타났지만, 그 회복 양상은 대체로 비슷했다. 삼킴장애 중증도의 경우, 전반적으로 유의한 변화가 확인되었으며, 1 주일 시점의 중증도가 가장 두드러졌고 대부분의 환자에서 완화되는 양상을 보였다. 그러나 뇌성마비 환자의 경우, 삼킴 곤란이 지속되는 경향이 관찰되었다.

음성과 관련하여, shimmer 정상성에서 유의미한 변화가 관찰되었다. 청지각적 변수의 경우, 통계적으로 유의한 변화가 일관적으로 나타나진 않았지만 전반적으로 점수가 증가하여 음성의 질 저하가 시사된다.

경추 수술 후, 삼킴 영역에서 주로 두드러진 변화가 관찰되었다. 삼킴 곤란의 중증도는 위험 요인이 있는 그룹에서 전반적으로 더 심각하게 나타났다. 또한, shimmer 정상성 변화와 청지각적 변수의 전반적인 악화는 경추 수술 후 음성 관련 불편함이 발생할 가능성을 시사한다.

이러한 결과는 높은 NDI 점수 혹은 뇌성마비와 같은 삼킴장애의 위험 요인을 가진 환자들은 경추 수술 후 삼킴장애 및 음성장애에 더 취약할 수 있음을 시사한다. 본 연구의 결과는 환자들에게 수술 전 합병증 가능성에 대한 상담의 중요성을 뒷받침하는 근거로 활용될 수 있을 것이다.

핵심되는 말: cervical spine surgery, dysphagia, dysphonia, Bazaz Dysphagia Score, Neck Disability Index