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Original Article

# Analysis of reconstructed oropharynx shape after total glossolaryngectomy reconstruction using a free rectus abdominis musculocutaneous flap

Takahiro Hirayama[a,b], Yusuke Shimizu[a,*], Hidetoshi Kinjo[c], Shinya Agena[c], Hitoshi Hirakawa[c], Hiroyuki Maeda[c], Mikio Suzuki[c], Ryogo Kuba[a], Shohei Ishihara[a], Naoki Matsuura[a]

[a] *Department of Plastic and Reconstructive Surgery, University of the Ryukyus Hospital, Okinawa, Japan*
[b] *Department of Plastic and Reconstructive Surgery, Jichi Medical University Saitama Medical Center, Saitama, Japan*
[c] *Department of Otorhinolaryngology, Head and Neck Surgery, University of the Ryukyus Hospital, Okinawa, Japan*

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ABSTRACT

*Introduction:* Restoring oral intake through oropharyngeal reconstruction is vital for patients undergoing total glossolaryngectomy. Despite its importance, research in this area is limited, leaving clinicians with few guidelines. The debate regarding the optimal shape of the reconstructed oropharynx highlights the need for further research.

*Methods:* This retrospective study analysed data from 16 consecutive patients who underwent primary reconstruction with a free rectus abdominis musculocutaneous flap after total glossolaryngectomy at the University of the Ryukyus Hospital between April 2015 and March 2022. Parameters assessed included reconstructed oropharynx shape (flat or funnel-shaped), demographics, flap characteristics, post-operative course and oral intake outcomes.

* Correspondence: Yusuke Shimizu; 207, Uebaru, Nishihara, Nakagami, Okinawa, Japan. Phone: +81 98 895 1768; Fax: +81 98 895 1561
*E-mail address:* yyssprs@gmail.com (Y. Shimizu).

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*Results:* Among the 16 patients, 10 had flat oropharynx, whereas 6 had a funnel-shaped oropharynx. At 6 months post-surgery, 13 patients resumed oral feeding, whereas 3 did not. Significant differences were observed between the groups in preoperative body mass index (21.1 kg/m$^2$ vs 17.8 kg/m$^2$, Welch's t-test, p=0.035) and days until the first oral intake (34.2 days vs 19.2 days, Welch's t-test, p=0.01). However, no significant differences were found in the form of oral intake at 6 months after surgery (Fisher's exact test, p=0.518).

*Conclusion:* This study suggests that the shape of the reconstructed oropharynx (flat or funnel-shaped) does not significantly impact long-term post-operative oral intake. These findings provide valuable insights into oropharyngeal reconstruction outcomes after total glossolaryngectomy and offer guidance for future research in this area. Nevertheless, further studies are warranted to elucidate the clinical implications of these findings and address any limitations of this study, particularly those regarding sample size constraints.



## Introduction

Total glossolaryngectomy, typically indicated for advanced malignancies of the tongue base or posterior oral cavity, results in significant challenges such as dysphagia, profoundly affecting the patients' quality of life.[1-3] Effective oropharyngeal reconstruction is thus paramount for optimal post-operative swallowing function. However, the ideal configuration of the neo-pharynx for maximising swallowing remains a subject of debate.[4]

In 2007, Okazaki et al. proposed a 'funnel-shaped' oropharyngeal reconstruction using a rectus abdominis musculocutaneous (RAM) free flap, suggesting that this design would facilitate gravity-dependent bolus transit.[5] Conversely, a more recent study by Kadota et al. (2017), involving 20 patients, advocated for a flat to mildly protuberant reconstruction, positing that this preserves the ability of the posterior pharyngeal to generate effective swallowing pressure.[6,7] Additionally, other authors have explored alternative flap options such as the anterolateral thigh, jejunum and ileocolic segment for neo-pharyngeal creation.[8-11] Nevertheless, owing to the limited and conflicting evidence regarding the superiority of one reconstructive approach over the others, the optimal flap choice and neo-pharyngeal configuration remain unclear.

To address this knowledge gap, we conducted a retrospective study on patients who underwent total glossolaryngectomy with RAM free flap reconstruction at the University of the Ryukyus, Hospital, Okinawa, Japan. Our objective was to assess the relationship between reconstructed oropharyngeal shape (flat vs funnel) and post-operative swallowing function. We hypothesised that flat reconstruction would be associated with superior long-term oral intake compared to the funnel configuration.

## Patients and Methods

This retrospective study enrolled 16 consecutive patients who underwent primary reconstruction using a free RAM flap after total glossolaryngectomy between April 2015 and March 2022. Approval for the study was obtained from the University of the Ryukyus Hospital ethical review committee (Approval No. 23-2164-00-00-00). The study assessed the following parameters: reconstructed oropharynx shape (flat or funnel-shaped), age, sex, body mass index (BMI), harvested flap size, time to the

first post-operative oral intake, form of oral intake at 6 months after surgery, post-operative radiotherapy, perioperative complications and length of hospital stay.

Preoperative BMI was recorded one day before surgery, whereas post-operative BMI was measured 0.5–1.5 years post-operatively. Delta (△) BMI was defined as the difference between pre- and post-operative BMI. Reconstructed oropharynx shape was classified based on Kadota et al.'s classification,[7] into three categories: protuberant, flat and funnel-shaped. 'Protuberant' describes a reconstructed oropharynx that protrudes outward, resembling a natural contour; 'flat' refers to an oropharynx with a relatively smooth contour, lacking significant protrusion or indentation and 'funnel-shaped' indicates an oropharynx that slopes inward from the lips towards the pharynx, creating a funnel-like shape.

Two experienced head and neck surgeons independently reviewed the post-operative CT scans (performed 3 to 6 months post-operatively) to evaluate the reconstructed oropharynx shape for each patient. In cases of disagreement, the CT scans were jointly reviewed by the two surgeons to reach a consensus classification. Figures 1 (A-E) and 2 (A-C) present illustrative cases of flat and funnel-shaped reconstructions, respectively, with intraoperative and post-operative images.

Oral intake was reassessed at 6 months post-operatively, with patients categorised into 'oral intake' and 'non-oral intake' groups based on their feeding status. Although patients were longitudinally followed for years after surgery, their oral intake status was assessed at the 6-month mark to minimise bias stemming from age-related swallowing impairments.

Reconstructed oropharynx shape (flat or funnel-shaped) was analysed with respect to age, sex, BMI, harvested flap size, time to the first post-operative oral intake, form of oral intake at 6 months after surgery, post-operative radiotherapy, perioperative complications and length of hospital stay.

The oral and non-oral intake groups were analysed in terms of reconstructed oropharynx shape, age, sex, BMI, harvested flap size, time to the first post-operative oral intake, post-operative radiotherapy, perioperative complications and length of hospital stay.

### *Statistics*

Statistical differences between the reconstructed oropharynx shape groups (flat vs funnel-shaped) and oral intake status groups (oral intake vs non-oral intake) were analysed using the Fisher's exact test for categorical variables and Welch's t-test for continuous variables. Statistical significance was set at $p<0.05$, and analyses were conducted using EZR statistical software.[12] A multivariate analysis was not feasible owing to sample size limitations.

## Results

Patient demographics and surgical details are summarised in Table 1. The study included 16 patients (14 men, 2 women) with a mean age of 63.3 years and a mean preoperative BMI of 19.8 kg/m$^2$. The average flap size was 249.2 cm$^2$. Recipient arteries included the superior thyroid artery (n=8), lingual artery (n=7) and external carotid artery (n=1), with the internal jugular vein used as the recipient vein in all cases. Post-operatively, 10 patients (62.5%) had a flat reconstructed oropharynx (Figure 1A-E), whereas 6 (37.5%) had a funnel-shaped reconstruction (Figure 2 A-C). The mean time to initial post-operative oral intake was 28.2 days.

### *Factors Associated With Reconstructed Oropharynx Shape and Oral Intake Status*

Analysis of reconstructed oropharynx shape, details of which are presented in Table 2, revealed a significantly higher preoperative BMI in the flat group compared to that in the funnel-shaped group (21.1 vs 17.8 kg/m$^2$, two-sided Welch's t-test, p=0.035). The flat group also experienced a significantly longer time to initial oral intake (34.2 vs 19.2 days, two-sided Welch's t-test, p=0.010), likely due to the higher incidence of post-operative complications such as wound infection, partial flap necrosis and fistula formation.

At 6 months post-operatively, 13 patients (81.3%) could resume oral feeding (oral intake group), and 3 (18.7%) remained dependent on tube feeding (non-oral group). Among the oral intake group, 9 had flat reconstructed oropharynx, and 4 had funnel-shaped oropharynx. Reasons for non-oral intake

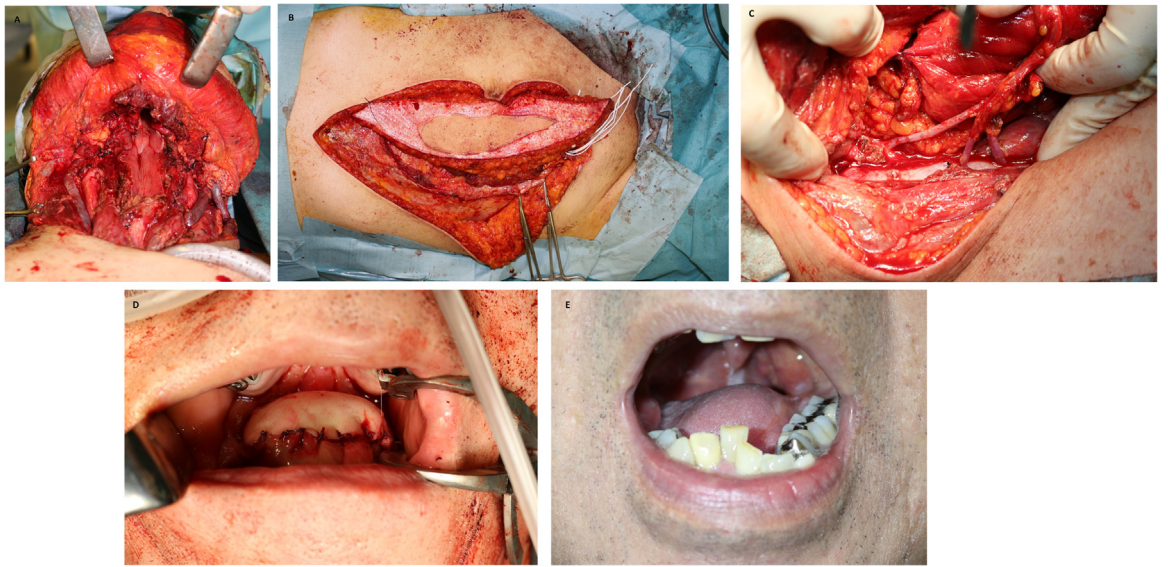


**Figure 1.** Flat Reconstructed Oropharynx in a 55-Year-Old Man (Table 1, Patient No. 12). (A) Total glossolaryngectomy for carcinoma of the tongue base. (B) Harvested Free RAM flap. (C) Anastomosis of the right deep inferior epigastric artery (donor) to the right superior thyroid artery (recipient). (D) Intraoperative photograph. (E) Photograph taken 315 days post-operatively demonstrating a flat oropharynx shape.

**Table 1**
Patient summary

| No. | Age | Sex | BMI | Δ BMI | Harvested flap size ($cm^2$) | Reconstructed oropharynx shape | Time to the first oral intake (days) | Form of oral intake at 6 months (dietary form) | Post-operative radiother-apy | Complications | Length of hospitalisa-tion (days) | Follow-up period (days) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 38 | Male | 19.7 | -1.69 | 135 | Flat | 14 | Liquid | No | NA | 27 | 276 |
| 2 | 86 | Male | 20.2 | -2.69 | 300 | Flat | 19 | Liquid | No | NA | 54 | 324 |
| 3 | 46 | Male | 20.7 | -0.87 | 243 | Flat | 38 | Normal | 63 Gy | Wound infection | 66 | 1498 |
| 4 | 69 | Female | 19.3 | -0.56 | 205.9 | Flat | 29 | Liquid | No | Partial necrosis | 40 | 2147 |
| 5 | 69 | Male | 17.3 | -0.37 | 408 | Funnel | 19 | Non-oral feeding (feeding tube) | 66.6 Gy | fistula formation | 163 | 801 |
| 6 | 80 | Male | 18 | -2.4 | 217 | Funnel | 21 | Soft | No | NA | 34 | 922 |
| 7 | 78 | Male | 19.1 | 2.15 | 280 | Funnel | 24 | Non-oral feeding (gastrostomy) | 66.6 Gy | Partial necrosis | 160 | 1217 |
| 8 | 46 | Male | 23.6 | -5.1 | 451.4 | Flat | 55 | Soft | No | Partial necrosis | 59 | 1721 |
| 9 | 66 | Male | 13.5 | 4.24 | 172.5 | Flat | NA | Non-oral feeding (feeding tube) | 30Gy | Fistula formation | 119 | 96 |
| 10 | 60 | Male | 18.8 | 0.49 | 280 | Flat | 49 | Soft | No | Fistula formation | 57 | 312 |
| 11 | 66 | Male | 20.6 | -2.24 | 234 | Funnel | 21 | Mixer | No | Partial necrosis | 56 | 507 |
| 12 | 55 | Male | 26.6 | -1.36 | 224 | Flat | 34 | Liquid | No | Wound infection | 44 | 746 |
| 13 | 70 | Male | 23.7 | -2.69 | 225 | Flat | 42 | Soft | 8 Gy | Wound infection | 113 | 528 |
| 14 | 55 | Female | 24.6 | -4.01 | 228 | Flat | 28 | Soft | 70 Gy | Partial necrosis | 51 | 203 |
| 15 | 68 | Male | 16.6 | -0.31 | 176 | Funnel | 16 | Liquid | 66 Gy | NA | 56 | 362 |
| 16 | 61 | Male | 15.1 | -0.81 | 208 | Funnel | 14 | Soft | No | NA | 43 | 369 |
| Average | 63.3 | | 19.8 | -1.14 | 249.2 | | 28.2 | | | | 71.4 | 777.3 |

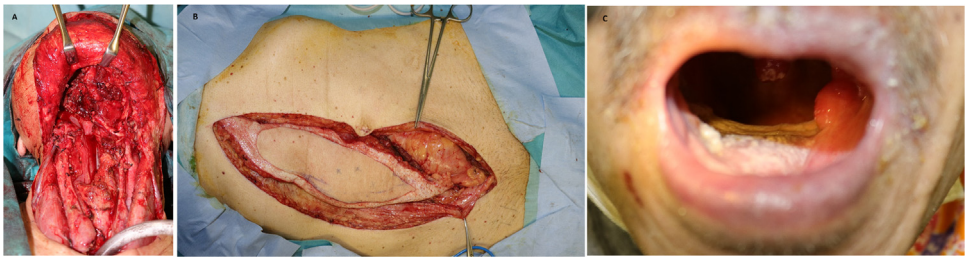

**Figure 2.** Funnel-Shaped Oropharynx Reconstruction in a 66-Year-Old Man (Table 1, Patient No. 11). (A) Total glossolaryngectomy for carcinoma of the tongue base. (B) Harvested Free RAM flap; preserved skin paddle, de-epithelialised remaining components; anastomosis of the right deep inferior epigastric artery (donor) to the left superior thyroid artery (recipient). (C) Photograph taken 406 days post-operatively demonstrating a funnel shape.

**Table 2**
Patient characteristics in the flat and funnel-shaped oropharynx groups

| Characteristics | Flat-shaped group (n=10) | Funnel-shaped group (n=6) | *p*-value |
|---|---|---|---|
| Age, years | 59.1 | 70.3 | 0.056 |
| Men/Women, n | 8 / 2 | 6 / 0 | 0.5 |
| Preoperative BMI, kg/m$^2$ | 21.1 | 17.8 | **0.035†** |
| Δ BMI | −1.4 | −0.7 | 0.484 |
| Flap size, cm$^2$ | 246.5 | 253.8 | 0.869 |
| Initial oral intake, days | 34.2 | 19.2 | **0.01†** |
| Oral intake at 6 months, Able/Unable | 9/1 | 4 / 2 | 0.518 |
| Post-operative radiotherapy, Yes/No | 4 / 6 | 3 / 3 | 1 |
| Post-operative radiotherapy, Gy | 42.8 | 66.4 | 0.201 |
| Complications, Yes/No | 8/2 | 3 / 3 | 0.299 |
| Mean length of hospitalisation, days | 63.0 | 85.3 | 0.423 |

※Values are expressed as n or mean. †: Considered statistically significant.

**Table 3**
Patient characteristics in the oral intake and non-oral intake groups

| Characteristics | Oral intake group (n=13) | Non-oral intake group (n=3) | *p*-value |
|---|---|---|---|
| Age, years | 61.5 | 71 | 0.112 |
| Men/Women, n | 11/3 | 2/0 | 1 |
| Preoperative BMI, kg/m$^2$ | 20.6 | 16.6 | 0.118 |
| Δ BMI | −1.9 | 2 | 0.0883 |
| Flap size, cm$^2$ | 240.6 | 286.8 | 0.573 |
| Initial oral intake, days | 29.2 | 21.5 | 0.128 |
| Post-operative radiotherapy, Yes/No | 4/9 | 3/0 | 0.0625 |
| Post-operative radiotherapy, Gy | 51.6 | 54.4 | 0.895 |
| Complications, Yes/No | 8/5 | 3/0 | 0.509 |
| Mean length of hospitalisation, days | 53.8 | 147.3 | **0.0118†** |

※values are expressed as n or mean. †: Considered statistically significant

included tumour recurrence (n=2) and appetite loss (n=1). There was no significant difference in the proportion of patients achieving oral intake at 6 months between the flat and funnel-shaped groups (two-sided Fisher's exact test, p=0.518).

### *Comparison of the Oral and Non-oral Intake Groups at 6 Months Post-operatively*

Details presented in Table 3 demonstrated a significantly longer hospital stay in the non-oral group (147.3 vs 53.8 days, two-sided Welch's t-test, p=0.012), attributable to the higher rate of post-operative radiotherapy and related complications. No significant differences were noted in age, BMI,

**Table 4**
Summary of the merits and demerits of reconstructed oropharynx shapes after total glossolaryngectomy

| Reconstruction type | Merits | Demerits | References |
|---|---|---|---|
| Protuberant to Flat | - Allows solid/liquid diets<br>- Can create sufficient swallowing pressure if certain conditions are met† | - Difficult narrow surgical field<br>- Higher complication risk<br>- May not create sufficient swallowing pressure† | 7 |
| Funnel-Shaped | - Easy to suture, fewer complications<br>- Prevents stenosis | - Requires feeding tube<br>- Often limited to liquids/soft solids | 5, 13 |

† Where the following 3 conditions are or are not met: (i) contraction capacity of the residual pharyngeal posterior wall, (ii) nasopharyngeal closure function and (iii) lip closure function

flap size or post-operative complication rates between the groups (two-sided Welch's t-test or Fisher's exact test, $p>0.05$ for all comparisons).

## Discussion

Total glossolaryngectomy, often employed as an initial treatment for advanced malignancies of the tongue or tongue base and as a salvage therapy for recurrent cases, typically results in speech loss and severe impairment of swallowing and chewing, significantly diminishing the patients' quality of life. Despite the importance of oropharyngeal reconstruction in optimising post-operative outcomes, there is limited recent literature on the ideal reconstruction method following total glossolaryngectomy. Free flaps, such as the RAM flap, are commonly used to reconstruct the resected oropharyngeal cavity.[5–7,9-12]

In Japan, a 'funnel-shaped' oropharynx, resembling a slide-like morphology, has been considered ideal for facilitating gravity-dependent bolus transit [5,9]. However, Kadota et al. recently proposed that swallowing depends on gravitational flow and residual posterior pharyngeal wall function, advocating for a flat to mildly elevated reconstructed oropharynx shape with a narrow cavity to utilise the remaining pharyngeal function.[7] To address the limited recent data on the impact of reconstruction shape, we conducted a retrospective study evaluating the relationship between reconstructed oropharynx shape and oral intake in 16 consecutive patients who underwent primary reconstruction after total glossolaryngectomy at our institution.

In all cases, we aimed to achieve a 'protuberant oropharynx shape' using a RAM free flap, as this is generally locally believed to be the ideal configuration for the reconstructed tongue following simple glossectomy.[13] However, we could not achieve this shape in any of our patients, likely owing to the additional resection of the larynx, which would have otherwise functioned as a base for the flap, and the difficulty in obtaining sufficient flap thickness and volume in patients with a low BMI. Consequently, 10 patients had a flat oropharynx and 6 had a funnel-shaped oropharynx.

The preoperative BMI was significantly higher in the flat oropharynx group compared to that in the funnel-shaped group, suggesting that patients with an extremely low BMI and thin abdominal subcutaneous fat may be more likely to have a funnel-shaped reconstruction. Additionally, most patients experienced weight loss post-operatively, with only three patients maintaining or gaining weight. These findings highlight the challenge of maintaining preoperative weight after total glossolaryngectomy using oral feeding alone and the potential benefit of incorporating nutritional supplements into patients' daily diet.

Interestingly, we found no significant differences between the reconstructed oropharynx shape and oral intake at 6 months post-operatively, suggesting that the shape itself may not be a strong predictor of suitability for oral intake. Notably, a depressed and extremely wide reconstructed oropharynx may hinder the creation of adequate swallowing pressure.[6] Table 4 summarises the advantages and disadvantages of different reconstructed oropharynx shapes based on the current literature and our study findings. Although a protuberant or flat shape may allow for solid and liquid food intake and potentially create sufficient swallowing pressure when certain conditions are met,[7] it can be challenging

to achieve owing to the limited surgical field and may be associated with a higher risk of complications. On the contrary, a funnel-shaped reconstruction may be easier to achieve surgically and may help prevent stenosis,[5] but it often requires a feeding tube and may limit patients to a liquid or soft diet.[5,13]

The funnel-shaped oropharynx group had a significantly shorter time to first oral intake compared to the flat oropharynx group, possibly due to the higher incidence of post-operative complications, such as wound infection and fistula formation, in the flat group. These complications likely stem from the limited surgical field, hindering suturing. As suggested by Okazaki et al., reconstructing with an overlapping de-epithelialised flap and muscle when glossolaryngectomy is performed without mandibulectomy may help prevent fistula formation by improving blood supply to the remnant posterior mandible mucosa.[5]

The hospital stay was significantly longer in the non-oral intake group, primarily due to post-operative radiation and related complications, such as pharyngocutaneous fistula formation. Despite the lack of a protuberant oropharynx shape in any of our patients, 81.3% could resume oral feeding 6 months after surgery, which is relatively consistent with the reported rates of 20-89% in the literature.[11,13-15] This may be attributed to the sufficient residual post-operative oropharyngeal posterior wall function, as there was no noticeable nasopharyngeal or oropharyngeal closure insufficiency. Although not statistically significant, older age and post-operative radiotherapy showed a trend towards association with non-oral intake, possibly due to impaired residual posterior pharyngeal wall function secondary to irradiation.

One limitation of our study is the lack of objective assessment of functional characteristics, such as posterior pharyngeal wall contraction, presence or clearance of residue, and nasopharyngeal closure during swallowing, as the evaluation of reconstructed oropharynx shape was performed using CT scans 3 to 6 months post-operatively. Additionally, the study's retrospective nature, single-centre design, and small sample size may limit the power to detect group differences. The uneven distribution of oropharynx shapes and lack of protuberant shapes limit generalisability. The absence of long-term follow-up data beyond 6 months hinders the evaluation of the long-term impact of shape on oral intake. The use of multiple subgroup analyses increases the risk of type 1 error, and the absence of multivariate analysis to control for confounding factors such as tumour characteristics and surgical margins limits interpretation of our results.[16]

To address these limitations and build upon our findings, future studies should consider incorporating videofluoroscopic or fibreoptic endoscopic evaluation of swallowing to assess functional characteristics in addition to the anatomical assessment provided by CT scans. Moreover, objective classification criteria for reconstructed oropharynx shape, dietary intake level, and pre- and post-operative quality of life and functional outcome measures should be included. A prospective, multi-centre study with a larger sample size and consistent evaluation methods across sites would provide more robust evidence to guide reconstructive decision-making in this patient population.

## Conclusion

In conclusion, our study suggests that the shape of the reconstructed oropharynx (flat or funnel-shaped) does not significantly affect long-term post-operative oral intake in patients undergoing total glossolaryngectomy. However, age and post-operative irradiation may influence oral intake. Nutritional supplements should be considered post-operatively to maintain preoperative BMI. Further research is needed to investigate the factors that impact oral intake and identify the optimal reconstructive approach for this challenging patient population.

## Declaration of Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Financial Disclosure Statement

The authors have no financial interest to declare in relation to the contest of this article

## Institutional Review Board approval

This study was approved by the institutional review board of the University of the Ryukyus Hospital Ethical Review Committee (Approval No. 23-2164-00-00-00). All procedure followed were in accordance with the ethical standards of the responsible committee on human experimentation (international and national) with Helsinki Declaration of 1975, as revised in 2008.

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