Comparison of speech and resonance outcomes across three methods of treatment for maxillary defects

Georgina Papadopoulos-Nydam MSc SLP^{1,2}, John Wolfaardt, BDS, MDent (Prosthodontics), PhD^{1,3}, Hadi Seikaly, MD, FRCSC^{1,3}, Dan O'Connell, MD, MSc, FRCSC³, Jeffrey R. Harris, MD, FRCSC³, Martin Osswald, BDS, MDent,^{1,3} Suresh Nayar, BDS, MDS, MPhil^{1,3}, Jana Rieger, PhD^{1,2} *

¹Institute for Reconstructive Sciences in Medicine (iRSM), Edmonton, Alberta, Canada

²Department of Communication Sciences and Disorders, Faculty of Rehabilitation Medicine, University of Alberta, Edmonton, Alberta, Canada

³Department of Surgery, Division of Otolaryngology – Head and Neck Surgery, Faculty of Medicine and Dentistry, University of Alberta, Edmonton, Alberta, Canada

ARTICLE INFO

Keywords:

Maxillary reconstruction, obturator, intelligibility, nasalance, velopharyngeal orifice area

Corresponding Author:

Dr. Jana Rieger
Department of Communication Sciences and Disorders,
2-70 Corbett Hall, Faculty of Rehabilitation Medicine,
University of Alberta,
Edmonton, AB T6G 2G4;
Canada.
Phone number: 780-492-4992
email: jana.rieger@ualberta.ca

Received: 13 October 2017
Received in revised form: 18 November 2017
Accepted: 20 November 2017

ABSTRACT

Purpose: Treatment of maxillary defects, whether by prosthetic rehabilitation or surgical reconstruction, should aim to restore speech function and resonance balance. With the advent of technology and changing clinical practices related to maxillary defect management, speech outcomes need to be evaluated and compared in order to determine efficacy of differing approaches.

Materials and Methods: One hundred and four patients across three treatment groups for maxillary defects were included: 38 patients who were treated with maxillary obturators (OBT group), 39 patients who were treated with a standard fibular free flap reconstruction that did not involve digital planning of the reconstruction (Standard group) and 27 patients who were reconstructed using a digitally planned surgical design and simulation fibular free flap reconstruction (SDS group). Speech assessments were completed to assess word and sentence intelligibility, resonance balance and aeromechanical orifice estimation among these three groups. Assessments included the Computerized Assessment of Intelligibility of Dysarthric Speech (C-AIDS), nasalance scores via the Nasometer and palatopharyngeal orifice area via the PERCI-SARS.

Results: Significant differences were found in word intelligibility between the SDS and the Standard groups ($p=.035$) and on nasalance scores between the SDS and the OBT groups ($p=.027$).

Conclusions: Patients treated with digital reconstruction (SDS) had better speech outcomes than the other two treatment groups, whose mean scores on certain speech variables were not within normal limits. Speech outcomes in the SDS group were consistently within the normal range across all measured speech variables. (*Int J Maxillofac Prosthetics* 2017;1:2-8)

INTRODUCTION

For the past 50 years, researchers have described speech outcomes associated with different treatment options for maxillary defects. Treatment of maxillary defects, whether by prosthetic rehabilitation or surgical reconstruction, should aim to restore speech so that nasal resonance and intelligibility are preserved. While prosthetic rehabilitation with obturators has been, and still is, the most prevalent form of treatment, reconstruction with an osseous free flap is an alternative that started to appear in the literature a little more than two decades ago.^{1,2} In more recent years, digital surgical planning has been introduced into the surgical reconstruction pathway. The choice of which treatment to pursue in the future

depends on several factors, with one of the most important being expected speech outcomes. Speech outcome measurements, including perceptual evaluation of speech intelligibility,^{3,4} aeromechanical evaluation to determine palatopharyngeal orifice area,³ acoustic evaluation of resonance,^{3,5} articulation,⁶ and patient perception through standardized questionnaires like the Obturator Functioning Scale,⁷⁻⁹ are important to determine the effectiveness of treatment options for maxillary defects.

Speech outcomes after treatment with a maxillary obturator depend on successful occlusion of the surgical defect to prevent inappropriate nasal escape of air and sound during speech. A study by Rieger and

colleagues showed that speech is severely affected by a maxillary defect, but that nasalance, palatopharyngeal orifice area, and intelligibility of speech can be restored to preoperative function with a maxillary prosthesis.³ Patients who had involvement of the lesion extending onto the soft palate were more likely to have higher nasalance values after prosthetic treatment. Likewise, Umino and colleagues also concluded that soft palate involvement had a significant negative influence on speech outcomes, specifically intelligibility.⁴ Kumar and colleagues showed that distortion errors (mainly associated with dental, alveodental, alveolar and labiodental sounds) decreased when patients were provided with an obturator.⁶ From a patient perspective, research has shown that understandability of speech and normalcy of resonance with prosthetic obturation relates to quality of life and social interaction.⁷⁻⁹ Thus, research has shown that acceptable speech outcomes can be expected with prosthetic rehabilitation of the maxilla. However, there are drawbacks related to maxillary obturation, such as discomfort, inconvenience, and inability to achieve proper retention in an edentulous maxilla,¹⁰⁻¹² which have driven rehabilitative teams to consider alternative treatment options involving microvascular reconstruction of maxillary defects such as surgical reconstruction.

Microvascular bone-containing free flap tissue transfers have become a viable alternative to prosthetic treatment. With an osseous component, osseointegrated implants for future dental rehabilitation can be pursued.¹³ Several different osseous flaps have been used and include the fibular osteocutaneous flap,¹³⁻¹⁹ iliac crest flaps,²⁰ and scapular flaps.²¹⁻²³ Studies on speech outcomes have shown that maxillary reconstruction results in satisfactory speech^{22, 24, 25} and normal intelligibility.¹⁸ Studies have compared speech outcomes between obturation and reconstruction. For example, Genden and colleagues found that patients with an obturator had a higher level of nasality than those treated with maxillary reconstruction.⁵ Conversely, Rieger and colleagues reported no differences in either nasalance outcomes or speech intelligibility between these two treatments.¹⁸ In summation, these findings suggest that maxillary reconstruction results in either similar or better outcomes than prosthetic rehabilitation.

While speech results appeared to be satisfactory with reconstruction, certain aspects of this treatment presented challenges to other team members, especially maxillofacial prosthodontists. When our team first started working with osseous reconstruction of the jaws, the approach was based on intuitive intraoperative decision making to osteotomize and position the fibular free flap. This intuitive approach led to compromise of spatial

positioning of the fibular segments that sometimes negatively impacted the functional consequence for the patient. This also could preclude or compromise osseointegrated implant installation for oral rehabilitation. With the introduction of the digital technology enablers of surgical design applications and additive manufacturing, patient specific digitally-driven workflows could be introduced to optimize the anatomical and functional consequence of bone containing free flap reconstruction. Rohner and his colleagues first described a prefabricated fibular flap technique in 2000²⁶ and this was followed by further descriptions of the two-stage surgical procedure used to reconstruct major discontinuity defects of the jaws.^{14, 15} The Rohner technique is particularly well suited to reconstruction of jaw defects related to acquired conditions involving benign lesion and trauma, as well as congenital conditions. This is due to the technique involving two stages, with a delay of a few months between stages to allow for healing of implants and split skin grafting in the fibula before transfer of the fibular-implant-prosthesis construct to the jaw defect. The delay between the two stages made the technique challenging to adopt in the management of malignancy. Rohner's original technique²⁶ provided a technical breakthrough in that it was an occlusion-based approach to planning bone containing free flap reconstruction. The planning process required a meticulous stepwise analogue approach to planning. In the Medical Modelling Research Laboratory at Institute for Reconstructive Sciences in Medicine (iRSM), the Rohner analogue planning process was transferred into a digital workflow to find efficiency and further innovation of the technique. With the change to digital workflow, the Rohner technique was modified to manage malignant disease, but to still use an occlusion driven digitally planned surgical design process. This modification to the Rohner technique is termed the ART procedure (Alberta Reconstructive Technique). The occlusion-driven digital planning process results in additive manufactured guides for implant installation and fibula osteotomization, as well as a transfer template to position the fibula with installed implants in the jaw defect. In comparison to the Rohner Technique, with an ART procedure, the fibula with installed implants is transferred to the defect in the jaw immediately. After a period of healing of 6-12 months, where radiation therapy is required, a second stage surgery procedure to connect the implants into the oral cavity is completed (see Chuka et al ²⁷ for a more thorough description of these surgical procedures). Evidence exists to show that surgical simulation and design results in improved spatial positioning of the fibula, improved implant positioning in the fibula, and more efficient implant use than a standard intuitive intraoperative surgical approach.^{27,28} What remained unknown was whether or not the described advanced surgical approaches have any impact on speech outcomes.

At our institution, we have progressed through different methods for maxillary defect management based on available technology and surgical innovation. Initially, all patients with maxillary defects were treated with a maxillary obturator. With advances in microvascular free flap osseous reconstruction, the team began to reconstruct defects in the maxilla using a fibular free flap in 2001. This was our primary treatment modality for the following decade except in cases where surgery was contraindicated. In 2011, our team began to use advanced surgical planning and simulation, as well as additive manufacturing to create cutting and drilling guides, to plan and carry out maxillary reconstruction using the ART procedures. The purpose of the present study was to investigate speech outcomes across these three different approaches to maxillary defect management so as to understand which treatments restore patients' speech to the most normal level.

MATERIALS AND METHODS

Participants

This retrospective study was approved by the human research ethics board at the University of Alberta. Chart reviews of clinical speech data collected between 1996 and 2016 were completed for three groups of patients with maxillary defects who were seen at iRSM: patients with a maxillary obturator, patients with standard fibular free flap reconstruction (no digital surgical planning), and patients with surgically designed and simulated fibular free flap reconstruction. All patients seen in the clinic during this time frame were considered for inclusion in this study. Patients with involvement of the soft tissues of the oral cavity and pharynx, including the soft palate, were excluded because of the effects that these types of resections can have on intelligibility and resonance. Patients who did not have any post-operative data also were excluded. To be included, patients must have been English-speaking and could not have a history of any cognitive impairment.

Instrumentation and Data Analysis

All speech assessments were completed at iRSM by a team of speech-language pathologists. Nasalance was assessed using a Nasometer (model 6200, PentaxMedical, Mississauga, ON) while patients read the Zoo Passage. Nasalance provides an indication of the relative acoustic transmission of sound during speech via the oral and nasal cavities.²⁹ Palatopharyngeal orifice area was calculated using the PERCI-SARS (Microtronics Corporation, Chapel Hill, NY) while patients produced repeated utterances of a stimulus word /papa/. This test estimates the size of an opening between the oral and nasal cavities

during speech. Intelligibility of speech at the word and sentence level was assessed using the Computerized Assessment of Intelligibility of Dysarthric Speech (CAIDS)³⁰ (Pro-Ed, Austin, TX). Patients were audio-recorded while reading a set of 50 randomized words and 22 randomized sentences. Listeners, who were unfamiliar with the patients, transcribed the speech samples for comparison to a key kept in the patient's file. For details on these speech assessments, please see Rieger et al.³

Most patients attended several clinical appointments over the span of their rehabilitation. For this study, data from the last clinical visit on record were used. The amount of time lapsed (i.e., the number of days post-operative) between maxillary surgery and the last clinical visit for speech assessment potentially could affect the results of the study and, therefore, was considered an important variable. Another variable of interest was age: the range across the three groups of patients was known to be large. Thus, both time since surgery and patient age were explored as variables in the statistical analyses.

Statistical Analyses

Prior to running the main analysis, a Pearson correlation was run to assess whether 'days post-operative' and 'age' were significantly related to the speech outcomes across groups. There were no significant relationships at the $p < 0.05$ level and, therefore, these variables were not included in any other analyses. Furthermore, the relationship between sex and group was analyzed using a Chi-Square test of independence. There were no significant differences found between groups. A one-way MANOVA was completed to assess the speech variables of interest across groups. The between-subjects factor (group) had 3 levels (obturator [OBT]; standard reconstruction [Standard]; surgically designed and simulated reconstruction [SDS]). The dependent variables in the analyses included: nasalance; palatopharyngeal orifice area; word intelligibility; sentence intelligibility. Alpha levels were set at $p < .05$. All analyses were performed using IBM SPSS Statistics 24. Bonferroni post-hoc analyses were completed.

RESULTS

A total of 128 charts were reviewed. Twenty-four charts were excluded because they lacked post-operative data, leaving a total of 104 patient charts included for analyses. Of these, 38 were in the OBT group, 39 in the Standard, and 27 in the SDS group. Demographic details are provided in Table 1. It should be noted that a previous publication by Rieger and colleagues¹⁸ includes a subset of the patients from the present study in the obturator and standard reconstruction groups.

In the present study, there were instances where not all speech assessments were completed. For example,

in 1996, the assessment protocol was slightly different than in later years and some intelligibility assessments were not administered. Additionally, there were cases across the years where an equipment malfunction prevented collection of certain speech assessments related to the Nasometer and PERCI-SARS. In these instances, data were imputed with the group mean so that the patient case could still remain in the statistical analysis for the variables that were collected. Overall, 20% of the data were imputed in the OBT group, 9% in the Standard group, and 7% in the SDS group. Descriptive data for the dependent variables can be found in [Table 2](#).

The Wilks' Lambda multivariate test completed for group within

the MANOVA analysis was significant at $p=.035$. The between-groups test for the dependent variables revealed a significant main effect for word intelligibility ($p=.027$) and nasalance ($p=.032$). Bonferroni post hoc tests revealed a significant finding ($p=.035$) for word intelligibility, where the SDS group performed better (94%) than the Standard group (84%). The difference between the SDS (94%) and OBT group (85%) was not significant. For the main effect related to nasalance, the post hoc test revealed that there was a significant difference between the SDS group and the OBT group ($p=.027$), where the SDS group performed better (17%) than the OBT group (27%). There was no significant difference between the SDS group (17%) and the Standard group (23%).

Table 1. Demographic data.

	OBT group	Standard group	SDS group
Number of patients (total)	38	39	27
Date range of initial surgery	1987-2005	2001-2010	2011-2016
Sex (Number)			
Male	21	17	19
Female	17	22	8
Age (years)			
Mean	52	51	49
Range	15 - 79	17 - 77	17 - 69
Post-operative (days)			
Mean	2262	605	538
Range	43 - 9896	28 - 3040	30 - 1721
Diagnosis			
Squamous cell carcinoma	8	14	12
Ameloblastoma	2	3	3
Adenocarcinoma	9	7	1
Mucoepidermoid carcinoma	2	2	2
Trauma	3	0	1
Other	7	13	8
Unknown	7	0	0

OBT=obturator; **SDS**=surgically designed and simulated; Post-operative (days)=The amount of time lapsed between maxillary surgery and the last clinical visit for speech assessment.

Table 2. Descriptive statistics for the dependent variables across groups.

	Groups	Mean	Standard Deviation	Significant Differences
Word intelligibility (%)	OBT	84.9	14.5	SDS vs Standard ($p=.035$)
	Standard	83.7	20.1	
	SDS	93.7	6.8	
Sentence intelligibility (%)	OBT	93.8	9.4	SDS vs OBT ($p=.027$)
	Standard	94.3	10.4	
	SDS	97.6	2.9	
Nasalance (%)	OBT	27.3	17.7	SDS vs OBT ($p=.027$)
	Standard	23.4	17.3	
	SDS	16.7	8.9	
Palatopharyngeal orifice area (mm²)	OBT	8.3	18.1	
	Standard	12.5	30.6	
	SDS	0.3	0.8	

OBT=obturator; **SDS**=surgically designed and simulated.

DISCUSSION

This study sought to examine speech outcomes across three different types of maxillary defect management: patients with a maxillary obturator, patients with standard fibular free flap reconstruction using an intuitive intraoperative approach, and patients with surgically designed and simulated fibular free flap reconstruction. We found that patients who were treated with surgically designed and simulated digital reconstruction had speech outcomes that were consistent with what would be expected normally. In the OBT and Standard groups, mean scores on certain speech variables were outside of normal limits.

With respect to speech intelligibility, the results from the present study indicated that patients with SDS reconstruction had better word intelligibility scores than the group who had standard reconstruction. A previous study³¹ revealed that word intelligibility can be expected to be above 90% in a control population without speech impairment. In the present study, word intelligibility scores were 94% for the SDS group, whereas they were 84% for the Standard group and 85% for the OBT group. Thus, even though the scores in the OBT group were not significantly different from the SDS group, they were still lower than what would be expected and similar to the Standard group outcomes. The differences in word intelligibility between the SDS group and the other two groups could be related to resonance balance. Both the OBT and Standard groups had mean acoustic and aeromechanical scores that were outside the range of what would be considered clinically acceptable and that are associated with resonance disorders. The reduced word intelligibility scores in these two groups could be associated with the effect that a resonance disorder can have on a listener's ability to understand speech, especially when words are presented in isolation.

Interestingly, the groups did not differ on sentence intelligibility outcomes. This is likely due to the fact that listeners have context to draw upon when completing sentence intelligibility tasks. When completing word intelligibility ratings, however, listeners do not have any context to draw upon. Thus, it may be considered a more discriminating task. In contrast to our findings, Genden and colleagues⁵ compared connected speech intelligibility in obturator and standard reconstruction groups using a subjective rating of patients' 1-minute monologues. In that study, patients with obturators were judged to be, on average, 75.5% (SD=35.14) intelligible and patients with standard reconstruction 96.80% (SD=2.56), showing that the standard reconstruction group had better results than the obturator group.

In the present study, we did not find differences in connected speech between groups. The differences between these two studies may be related to the stimulus that was used to elicit connected speech and what is required of the listener. With the sentence

intelligibility test, a listener is able to hear the sentence twice before finalizing their decision about what was said. In addition, they are only asked to write down what the patients said and not to make any other judgments on it. When judging a monologue, the rating is based on a longer sample and the judgement made on the speech may be more subjective in nature. Because of other speech factors, such as nasality, raters tasked to assign a percentage based on what they hear instead of what is said, might be influenced by qualitative factors such as degree of nasality.

With respect to resonance, the findings of the present study revealed that nasalance scores were lower for patients treated with surgically designed and simulated reconstruction than patients with a maxillary obturator. Percentages ranging in the high twenties or above have been associated with the perception of nasal speech.^{32,33} Patients in the SDS group achieved levels on par with norms established for Western Canada (12.8%, SD=5.1),³⁴ whereas patients in the OBT group had scores above the upper end of this range. The abnormal scores in the OBT group might be explained by potential retention issues while wearing the obturator, which may result in an imbalance where there is an inappropriately high amount of nasal acoustic speech energy. Genden and colleagues⁵ found that patients with obturators had higher nasalance scores than their reconstruction group, with scores of 40.81% (SD=24.28) in the obturator group and 20.72% (SD=12.35) in the reconstruction group. While their scores for the patients with obturators were higher than in the present study, those for the reconstruction group were comparable.

The scores for palatopharyngeal area did not differ significantly between groups in the present study. However, from a clinical standpoint, the differences were notable. For example, normal palatopharyngeal orifice area values range between 0-5mm². Values between 10 and 20 mm² have been demonstrated to lead to a perception of hypernasal speech.^{35,36} In the present study, both the obturator and standard reconstruction groups had scores that would cause concern regarding the normalcy of resonance. In the OBT group, these abnormal outcomes, once again, might be due to retention issues related to the prosthesis. In the Standard group, this finding was unexpected. No patients were found to have fistulas, which could be one potential explanation. The more likely explanation relates to positioning of the fibula and the resulting effect that it had on the soft palate. In cases where large palatopharyngeal openings were recorded, nasendoscopy revealed that the soft palate was not able to contact the velopharyngeal wall. The positioning of the osseous bone strut in a more anterior position than the native maxilla, or the positioning of the bone strut without the aid of SDS guidance can often result in a non-anatomical position of the bone. This combined with the soft tissue rotation

limitations of the skin paddle may have resulted in anterior directed displacement of the soft palate. In the SDS group, the palatopharyngeal orifice area scores were within normal limits indicating that the surgical planning of the fibular placement led to the soft palate remaining in an appropriate position as well.

There are several limitations of the present study that should be recognized. First, the study was retrospective in nature. This led to variability in the time frames of the speech assessments that were completed. We attempted to control for this by statistically assessing the impact of the time differences on speech outcomes. The impact appeared to be non-existent. Second, there were instances of missing data. Instead of deleting cases and losing all information related to those patients, we chose to impute data in order to retain our patient numbers and keep a higher level of statistical power.³⁷ Finally, patients were not randomized into groups but were treated based on what was the current clinical practice over a twenty-year time frame.

CONCLUSION

In conclusion, this research showed that there is a benefit to speech outcomes when maxillary reconstruction is completed using surgical design and simulation techniques. As a result of these findings and of the improvements in reconstructed jaw spatial positioning for osseointegrated implant installation, our current standard of care is to surgically plan all of our maxillary reconstructions. The approach used is an occlusion-driven digital design of the bone containing free flap reconstruction of the jaws to achieve more predictable functional outcomes of care.

ACKNOWLEDGEMENTS

This research was funded by a grant from the Alberta Health Services Cancer Strategic Clinical Network.

REFERENCES

1. Anthony JP, Foster RD, Sharma AB, Kearns GJ, Hoffman WY, Pogrel MA. Reconstruction of a complex midfacial defect with the folded fibular free flap and osseointegrated implants. *Ann Plast Surg* 1996;37:204-210.
2. Nakayama B, Matsuura H, Hasegawa Y, Ishihara O, Hasegawa H, Torii S. New reconstruction for total maxillectomy defect with a fibula osteocutaneous free flap. *Br J Plast Surg* 1994;47:247-249.
3. Rieger J, Wolfaardt J, Seikaly H, Jha N. Speech outcomes in patients rehabilitated with maxillary obturator prostheses after maxillectomy: A prospective study. *Int J Prosthodont* 2002;15:139-44.
4. Umino S, Masuda G, Ono S, Fujita K. Speech intelligibility following maxillectomy with and without a prosthesis: an analysis of 54 cases. *J Oral Rehabil* 1998;25:153-8.
5. Genden E, Okay D, Stepp M, Rezaee R, Mojica J, Buchbinder D, et al. Comparison of functional and quality of life outcomes in patients with and without palatomaxillary reconstruction. A preliminary report. *Arch Otolaryngol Head Neck Surg* 2003;129:775-80.
6. Kumar P, Jain V, Thakar A. Speech rehabilitation of maxillectomy patients with hollow bulb obturator. *Indian J Palliat Care* 2012;18:207-12.
7. Seignemartin C, Miranda M, Luz J, Teixeira R. Understandability of speech predicts quality of life among maxillectomy patients restored with obturator prosthesis. *J Oral Maxillofac Surg* 2015;73:2040-8.
8. Chigurupati R, Aloor N, Salas R, Schmidt B. Quality of life after maxillectomy and prosthetic obturator rehabilitation. *J Oral Maxillofac Surg* 2013;71:1471-8.
9. Rieger JM, Wolfaardt JF, Jha N, Seikaly H. Maxillary obturators: The relationship between patient satisfaction and speech outcome. *Head Neck* 2003;25:895-903.
10. Keyf F. Obturator prostheses for hemimaxillectomy patients. *J Oral Rehabil* 2001;28:821-829.
11. Triana RJ Jr, Uglesic V, Virag M, Varga SG, Knezevic P, Milenovic A, et al. Microvascular free flap reconstructive options in patients with partial and total maxillectomy defects. *Arch Facial Plast Surg* 2000;2:91-101.
12. Brown JD, Burke AJC: Benefits of routine maxillectomy and orbital reconstruction with the rectus abdominis free flap. *Otolaryngol Head Neck Surg* 1999;121:203-209.
13. Mukoyama H, Haraguchi M, Sumita Y, Iida H, Hata Y, Kishimoto S, et al. Rehabilitation of a bilateral maxillectomy patient with a free fibular osteocutaneous flap. *Oral Rehabil* 2005;32:541-4.
14. Rohner D, Guijarro-Martinez R, Bucher P, Hammer B. Importance of patient-specific intraoperative guides in complex maxillofacial reconstruction. *J Craniomaxillofac Surg* 2013;41:382.
15. Rohner D, Jaquière C, Kunz C, Bucher P, Maas H, Hammer B. Maxillofacial reconstruction with prefabricated osseous free flaps: a 3-year experience with 24 years. *Plast Reconstr Surg* 2003;112:748-57.
16. Nguyen C, Driscoll C, Coletti D. Reconstruction of a maxillectomy patient with an osteocutaneous flap and implant-retained fixed dental prosthesis: A clinical report. *J Prosthet Dent* 2011;105:292-5.
17. Zaghi S, Danesh J, Hendizadeh L, Nabili V, Blackwell K. Changing indications for maxillomandibular reconstruction with osseous free flaps: A 17-year old experience with 620 consecutive cases at UCLA and the impact of osteoradionecrosis. *Laryngoscope* 2014;124:1329-35.
18. Rieger JM, Lam Tang JA, Wolfaardt J, Harris J, Seikaly H. Comparison of speech and aesthetic outcomes in patients with maxillary reconstruction versus maxillary obturators after maxillectomy. *J Otolaryngol Head Neck Surg* 2011;40:40-47.
19. Dziegielelewski PT, Mlynarek AM, Harris JR, Hrdlicka A, Barber B, Al-Qahtani K, et al. Bone impacted fibular free flap: a novel technique to increase bone density for dental implantation in osseous reconstruction. *Head Neck* 2014;36:1648-1653.
20. Genden E, Wallace D, Buchbinder D, Okay D, Urken M. Iliac crest internal oblique osteomusculocutaneous free flap reconstruction of the postablative palatomaxillary defect. *Arch Otolaryngol Head Neck Surg* 2001;127:854-61.
21. Urken M, Bridger A, Zur K, Genden E. The scapular osteofasciocutaneous flap; A 12-year experience. *Arch Otolaryngol Head Neck Surg* 2001;127:862-9.
22. Ugurlu K, Sacak B, Hutbut I, Karsidag S, Sakiz D, Bas L. Reconstructing wide palatomaxillary defects using free flaps combining bare serratus anterior muscle fascia and scapular bone. *J Oral Maxillofac Surg* 2007;65:621-9.

23. Choi N, Cho J, Jang J, Cho J, Cho Y, Baek C. Scapular tip free flap for head and neck reconstruction. *Clin Exp Otorhinolaryngol* 2015;8:422-9.
24. Joseph S, Thankappan K, Buggaveeti R, Sharma M, Mathew J, Iyer S. Challenges in the reconstruction of bilateral maxillectomy defects. *J Oral Maxillofac Surg* 2015;73:349-56.
25. Zhong L, Chen G, Fan L, Zhao S. Immediate reconstruction of maxilla with bone grafts supported by pedicled buccal fat pad graft. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2004;97:147-54.
26. Rohner D, Kunz C, Bucher P, Hammer B, Prein J. Neue Rekonstruktionsmöglichkeiten von ausgedehnten Kieferdefekten mit vorbereiteten mikrovaskularen Fibulatransplantaten und ITI-Implantaten. *Mund Kiefer GesichtsChir* 2000;4:365-372.
27. Chuka R, Abdullah W, Rieger J, Nayar S, Seikaly H, Osswald M, Wolfaardt J. Implant utilization and time to prosthetic rehabilitation in conventional and advanced fibular free flap reconstruction of the maxilla and mandible. *Int J Prosthodont* 2017;30:289-294.
28. Logan H, Wolfaardt J, Boulager P, Hodgetts B, Seikaly H. Pilot study: evaluation of the use of the convergent interview technique in understanding the perception of surgical design and simulation. *J Otolaryngol Head Neck Surg* 2013;19:40.
29. Sweeney T, Sell D. Relationship between perceptual ratings of nasality and nasometry in children/adolescents with cleft palate and/or velopharyngeal dysfunction. *Int J Lang Commun Disord* 2008;43:265-282.
30. Yorkston K, Beukelman D. *Assessment of Intelligibility of Dysarthric Speech*. Portland, Ore: CC Publications, 1981.
31. Strong MJ. A prospective study of cognitive impairment in ALS. *Neurology* 1999;53:1665-1670.
32. Dalston RM, Neiman GS, Gonzalez-Landa G. Nasometric sensitivity and specificity: a cross-dialect and cross-culture study. *Cleft Palate-Craniofac J* 1993;30:285-291.
33. Hardin MA, Van Demark DR, Morris HL, Payne MM. Correspondence between nasalance scores and listener judgements of hypernasality and hyponasality. *Cleft Palate-Craniofac J* 1992;29:346-351.
34. Rochet AP, Rochet BL, Sovis EA, Mielke DL. Characteristics of nasalance in speakers of western Canadian English and French. *J Speech-Lang Pathol Audiol* 1998;22:94-103.
35. Gillespie MB, Eisele DW. The uvulopalatal flap for reconstruction of the soft palate. *Laryngoscope* 2000;110:612-615.
36. Warren D, Dubois A. A pressure-flow technique for measuring velopharyngeal orifice area during continuous speech. *Cleft Palate-Craniofac J* 1964;16:52-71.
37. Dong Y, Peng CJ. *Principled missing data methods for researchers*. Springerplus 2013 May 14;2(1):222.