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CLINICAL STUDY

Advantages of virtual planning in reconstructive surgery of bone defects in the maxillofacial region

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ABSTRACT

OBJECTIVES: Our analysis focuses on the advantages of virtual surgical planning (VSP) compared to a conventional treatment method as well as on a wider range of parameters influencing the surgical procedure, postoperative care, morbidity and lastly, the survival rate of these patients.

BACKGROUND: Patients with extensive bone defects of different etiologies of the upper or lower jaw who underwent complex reconstructive surgery with a free fibula flap (FFF).

METHODS: We retrospectively analyzed data from a total of 34 patients (12 female and 22 male) whose defects were reconstructed with an osteomyocutaneus FFF. The data were collected over a period of 6 years from 2017 to 2023. We divided the patients into two groups, namely those who underwent conventional surgical treatment (5 patients) and those who underwent computer-planned surgical treatment (29 patients).

RESULTS: The duration of surgery showed a significant difference between the VSP group and the conventional group ($t(32) = 3.316$; $p < 0.01$), with the VSP group having a significantly shorter surgery time (M= 8:10; SD = 1:18) compared to the conventional group (M = 10:52; SD = 2:41). The independent t-test revealed significant differences between the VSP group (M = 45.967; SD 14.548) and conventional group (M = 17.61; SD = 24.996) for the dose of unfractionated heparin per kilogram administrated immediately after vascular micro anastomosis ($t(32) = –3.609$; $p < 0.001$).

CONCLUSION: Among all the risk factors, administering a higher unfractionated dosage of heparin administered immediately after completing the anastomosis was identified as a significant predictor of postoperative complications. Using VSP in cases of advanced stage head and neck malignancy for salvage surgery is highly recommended. Shorter duration of these comprehensive surgeries in the VSP group leads to a significantly favorable outcome *(Tab. 2, Fig. 2, Ref. 19)*. Text in PDF *www.elis.sk*

KEY WORDS: virtual planning, microvascular flap, maxillofacial, free fibula flap, reconstructive surgery.

Introduction

Defects in the maxillofacial region are most often the result of trauma, surgical oncological resection, or congenital anomalies. The conventional treatment of maxillofacial defects can present many challenges due to a variety of tissue-specific requirements and complexity of anatomical structures in that region. At the same time, these are the most aesthetically exposed zones, which often cause very serious somatic and psychological problems for patients. Various three-dimensional printing and milling technologies provide clinicians, engineers, and scientists with the ability to virtually plan and create patient-specific solutions for maxillofacial defects. The desire to restore different types of facial tissues while maintaining the aesthetic result motivates the collaboration of several specialties (prosthetic rehabilitation, maxillofacial reconstruction, and regenerative medicine) and their integration with three-dimensional technologies in order to achieve new innovative therapeutic procedures (1, 2). This virtual surgical planning (VSP) allows reconstructive surgeons to simulate resection, plan osteotomies, and design custom plates or even dental implants (Fig. 1) (3). The debate on comparing conventional or so-called “free-hand” surgery with virtually planned surgery has existed since the earliest publications on the subject. Both sides have their supporters with arguments, but the fact remains that most departments tend to gravitate towards modern methods over time (4, 5).

Current treatment options of defects in the form of reconstructive surgery include local flaps, microvascular flaps, and vascularized composite allograft flaps. For large and complex bone defects, a microvascular flap most often represents the backbone of surgical treatment. Most common among these is the free transfer of a vascularized free fibula. In order to plan the ideal amount and shape of the bony microvascular flap, various computer-aided planning and manufacturing methods can be utilized. As the reconstructive

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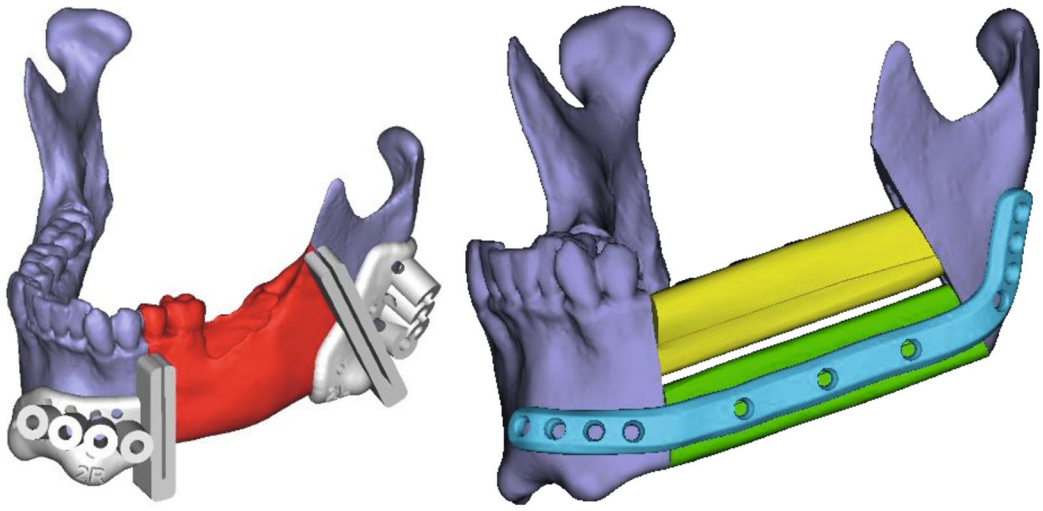

Fig. 1. Left: After the exact virtual planning of osteotomies according to the affected mandible by recurrent ameloblastoma (marked red), individual cutting guides for osteotomies and pre-drilling holes for the prefabricated plates are made (white). Right: Reconstructed defect is localized predominantly in the body of the mandible – with a precise possibility of planning of a stacked or "double barrel" orientation of the fibular flap to achieve adequate vertical height of the mandible with the possibility of inserting intraosseous implants for dental rehabilitation.

function is related to the geometry and biomechanics of flap inset, this is a key step. The process of shaping, plating, and inserting the flap is unfortunately variable and dependent on operator's experience and judgment (6–9). According to Barr et al., the VSP-guided mandibular reconstruction with free fibula flap (FFF) is associated with a significantly decreased operative time (significant reduction in operative time by 44.64 minutes) and mean trend toward shorter hospital admission (mean difference of 1.24 days). In their evaluation, Blanc et al. reported VSP enables 'tailored' surgery that is accurate and reliable and results in operative and ischemia time gain (total ischemia time gain was 36 min; $p = 0.04$). While multiple studies reported a high degree of accuracy, no standard measurement was available for meta-analysis. However, many factors do play important roles in successful reconstructive surgery and postoperative treatment in order to achieve low morbidity and mortality rates (10, 11). We present a retrospective analysis of patients with extensive bone defects of different etiologies of the upper or lower jaw who underwent complex reconstructive surgery with FFF. In our analysis, we focus on the advantages of VSP compared to the conventional treatment method, but also on a wider range of parameters that influence the surgical procedure, postoperative care, morbidity and lastly, the survival rate of these patients. Therefore, we are also aiming to identify the potential risk factors in these complex surgical cases.

Material and methods

This retrospective study on head and neck reconstruction with microvascular free fibula flaps was conducted on patients treated of the Department of Oral and Maxillofacial Surgery, University hospital of Comenius University, Bratislava. All clinical measurements were carried out according to the Declaration of Helsinki. A written informed consent was obtained from all participants in the study prior to initiating the treatment. The gained data were processed in Excel 365 (Microsoft Corp., USA) and the statistical analysis was performed in IBM SPSS Statistic v. 26 (IBM Corp., USA).

We retrospectively analyzed data from a total of 34 patients (12 female and 22 male) whose defects were reconstructed with an osteomyocutaneus FFF by the identical surgical team within our department. The data were collected over a period of 6 years from 2017 to 2023. We divided the patients into two groups; patients who underwent conventional ("free-hand") surgical treatment (5 patients; 14.7 %) and patients who underwent VSP treatment (29 patients; 85.3 %). In 32 cases (94.1 %), the location of the reconstructed defect was in the mandible and in 2 cases (5.9 %), it was in the maxilla. The FFF was harvested from the lower left extremity (27 patients) or from the lower right extremity (7 patients).

Gathered were key parameters with the potential to contribute to or corelate with a higher risk of complications during or after microvascular reconstructive surgery (12 patients; 35.3 %), including the weight and height of patients before surgery, and 1 and 3 months after surgery. The pathological staging of patients, if applicable, was obtained after the surgical treatment from the same histopathology team. Pre- and postoperative radio- and chemotherapies, including the dosage and type, were included. Intraoperatively administered doses of unfractionated heparin after micro anastomosis (being adjusted to weight accordingly) and different types of postoperative antithrombotic therapy (including anticoagulation and/or antiplatelet drugs) were analyzed. The duration of surgery was measured from the first incision of the tracheostomy (performed in every patient) up to the last suture. Measurements of each gap between individual bone segments after surgery were taken postoperatively from the analysis of OPG and/or cone

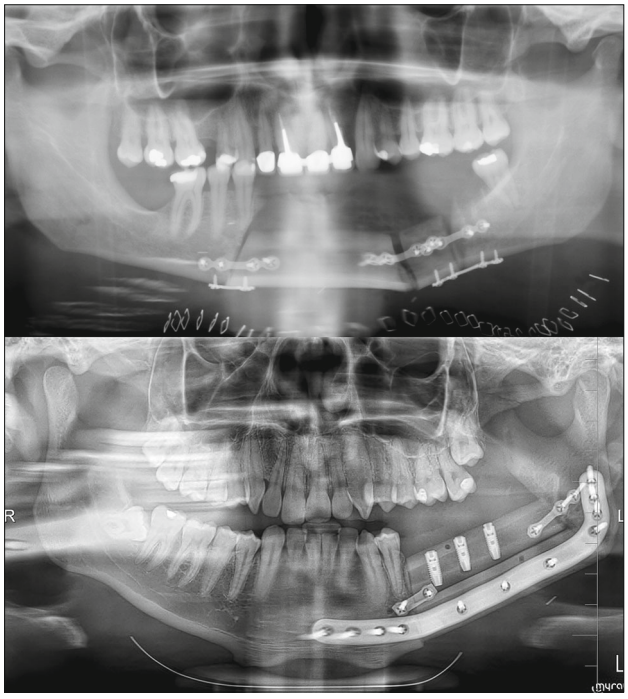

Fig. 2. Visual comparisons showing two examples of follow-up postoperative OPGs after mandibular FFF reconstruction. Approximation of individual fibular segments with the conventional "free-hand" method (top). Approximation of individual fibular segments with patient-specific titanium plate and surgical guides using virtual planning surgery (bottom) according to the plan as shown in Figure 1.

beam CT scan. Two measurements, specifically the shortest and longest distances between each fibula segment and each fibula-jaw transition (on both left and right sides). These measurements were taken in order to calculate the average distance and provide a more objective interpretation of the data (Fig. 2). The amount of harvested fibula bone segments and necessary osteotomies were also included in the analysis. The locations of arterial and venous anastomoses were also evaluated due to the complex anatomy of the neck and diverse course of vessels with the potential to kink (12). The trend toward shorter hospital admission led us to observe not only the duration of hospitalizations but also the number of days spent in the ICU, which largely contributes to the cost and potentially to higher morbidity and mortality rates. Tracheostomies have early and late complications and are badly tolerated by patients (13). We aimed to find factors with a potential to reduce the number of postoperative days required before the removal of tracheostomy. Furthermore, the necessity to remove the titanium specific reconstruction plate proved to be another complication and inconvenience for the patient, since it requires another hospital admission and general anesthesia. Time intervals were measured between the dates of initial surgery and titanium plate removal. All parameters and data were compared to the patient survival rate (in years) after surgery.

We examined the correlations between these findings, as well as their relationship with the timing of complications and revision surgery. Since none of the patients in either group reported any significant subjective worsening of walking or reduced lower extremity functionality three months after surgery as compared to their pre-surgery state. We did not include the donor site for analysis in this paper.

Results

This retrospective study involved 34 consecutive patients with a mean age of 58.9 years (SD = 11.034). Among them, the mean age for males was 57.95 years (SD = 11.741) and for females, it was 60.75 years (SD = 9.27). The most frequent cause for surgical treatment was a malignant lesion (31 patients; 91.2 %) while neoadjuvant oncological therapy was administered to 10 cases (29.4 %) (radio- and/or chemotherapy). Pathological staging of the resected tumors revealed that 61.8 % of tumors were classified as T4 stage, 20.6 % as T3 stage, and 8.8 % as T2 stage. Benign lesions were present only in 3 cases (8.8 %), specifically 2 cases of recurrent ameloblastomas and 1 case of chronic osteomyelitis. Lymph node pathological staging revealed that over a half of the patients (54.8 %) had positive lymph node spreading (N1 29 %; N2b 16.1 %; N2c 6.5 %; N3b 3.2 %). Distant metastases were present only in 1 patient (3.2 %).

An independent t-test showed a significant difference in the duration of surgery between the VSP and conventional groups ("free hand") ($t(32) = 3.613$; $p < 0.001$). The VSP group had a significantly shorter surgery duration (M = 8:10; SD = 1:18) as compared to the conventional group (M = 10:52; SD = 2:41). ,It is worth noting that the VSP group had more complex reconstruction procedures due to a slightly higher number of osteotomies and fibula segments on average (M = 2.03, SD = 0.548) as compared to the conventional group (M = 1.40, SD = 0.680), although this difference was almost statistically significant $t(32) = –1.969$; $p = 0.058$). The results also showed a negative moderate correlation between the surgery date and the duration of surgery ($r(34) = –0.541$; $p < 0.001$). No statistically significant results were found when comparing the size of gaps between the two groups. More details on the differences and comparisons between the groups are shown in Table 1.

In our retrospective study, we observed a moderate negative correlation between the female sex and the number of postoperative days with tracheostomy ($r(34) = –0.438$; $p = 0.012$). Independent t tests also revealed significant differences in gap measurement (in all cases) between patients who survived and those who did not (Tab. 2).

Significant differences were revealed by the independent t-test between the VSP group (M = 45.967; SD 14.548) and conventional group (M = 17.61; SD = 24.996) in terms of the dose of unfractionated heparin per kilogram administrated immediately after vascular micro anastomosis ($t(32) = –3.609$; $p < 0.001$). A moderate positive correlation was observed between the perioperative dosage of unfractionated heparin and the number of segments ($r(34) = 0.410$; $p = 0.016$). Furthermore, a strong negative correlation was found between the perioperative dose of unfractionated heparin (administered immediately after vascular anastomosis) and the

Tab.1. Comparison of individual categories that yielded statistically significant differences between the two groups of operation processes (conventional and VSP).

Category	Operation process	No	Mean	SD	Std. Error Mean
Postoperative length of hospitalization	Conventional	5	12.60	2.702	1.208
	VSP	28	13.64	4.612	.872
ICU postoperative care days	Conventional	5	3.20	.447	.200
	VSP	29	4.66	2.819	.524
Age	Conventional	5	60.40	12.422	5.555
	VSP	29	58.69	11.000	2.043
Gap right – fibula-mandible	Conventional	5	11.2960	13.70845	6.13061
	VSP	27	.9443	.72554	.13963
Gap between fibula segment	Conventional	2	21.2950	24.61439	17.40500
	VSP	21	1.0964	.77910	.17001
Gap left – fibula-mandible	Conventional	5	15.4660	16.72895	7.48141
	VSP	27	1.1752	1.02412	.19709
Number of fibula segments	Conventional	5	1.40	.548	.245
	VSP	29	2.03	.680	.126
Days of tracheostomy	Conventional	5	7.20	1.095	.490
	VSP	27	10.44	6.015	1.158

Tab. 2. Statistically significant differences in comparing gap sizes in between the mandible and fibula segments respectively with the vitality status of patients. It shows a strong negative correlation between the size of the gap and patients' life expectancy.

Intersegmental gaps	Vital status	Number	Mean	SD	Independent t-tests
Gap fibula – mandible right	alive	25	1.003	0.67633	t(30) = –2.977;
	dead	7	8.1286	12.44187	p = 0.006
Gap between fibula segments	alive	19	1.3044	0.99464	t(21) = –2.235;
	dead	4	10.2075	19.0026	p = 0.036
Gap fibula – mandible left	alive	25	1.4692	1.49909	t(30) = –2.857;
	dead	7	10.3329	15.94104	p = 0.008

time to re-exploration in hours (r(6) = –0.912; p = 0.011). Additional treatment with antiplatelet medication showed only a weak positive correlation with the risk of requiring additional surgery for titanium plate removal (r(34) = 0.348; p = 0.044). Nevertheless, logistic regression analysis proved this to be statistically not significant. No other correlations between antiplatelet medication and higher likelihood of plate removal were observed.

The process of choosing the type of surgical approach and planning is essentially impacted by the factor of availability and by the financial aspect of any new method

Discussion

The aspect of availability and financial considerations are important factors in selecting the type of surgical approach and planning. The availability of various computer-aided methods varies from country to country. When implementing a computer-assisted elective surgery program, it is highly recommended to use an experienced and validated technology source for instead of attempting to develop an in-house method. The latter approach can be even costlier and, in some cases, lack proper certification (5). Apart from the availability, the VSP offers a great potential of simply improving the existent gold standard conventional method. This statement is also supported by our results in correlating the surgery date and duration of surgery. This resulted in an interesting negative moderate correlation between the date and duration of surgery. Surgeries conducted at later dates are shown to have a shorter average surgery time. This can most probably be attributed to the continuous improvement of surgeons' skillset and/or by a gradually more frequent use of VSP. The independent t-test between the VSP and conventional group showed a significant difference in the duration of surgery. The duration of surgery is an important factor in lowering surgical stress and in turn reducing complications and patient morbidity (14).

All data on measurements between each segment and individual jaw suggest that larger gaps shorten the patient's life expectancy. This correlation is most likely caused by the surgical delay due to an advanced oncological stage. The conventional free-hand method is often favored for acute and last-resort salvage surgery for residual or recurrent disease, especially when a longer waiting period for VSP is not a suitable option. Patients with this type of condition typically undergo only salvage surgery with some form of last-minute reconstruction, which is subsequently associated with higher mortality rates. Salvage surgery for recurrent advanced stage of head and neck squamous cell carcinomas is recognized to lead to a poor prognosis (15). Some publications included the measurements of precision comparing the gap sizes and angles of individual segments, but with no significant outcomes. However, there are no current publications determining the reference range of gap sizes between FFF segments or their influence on any type of complication, which is an parameter worth considering(10, 16).

The complexity and quantity of segments might be the reason for a prolonged tracheostomy in patients treated with VSP. Even though statistically not significant, it raises some questions regarding the potential drawbacks of VSP. For it to be valid, it unfortunately requires a much larger cohort of patients in both groups. Interestingly, the results showed that women are less compliant with tracheostomy care and less cooperative in terms of postoperative rehabilitation and swallow exercises. Not many publications mention or compare tracheostomy care or morbidity with gender, but those that do, report that the male sex is among the risk factors associated with an increased risk to develop ventilator-associated pneumonia and increased ICU mortality. Many departments, including ours, do not have a sufficient nursing and support staff and therefore, an improvement in that area might be of great benefit to the patient and contribute to earlier rehabilitation (17, 18).

A strongly negative correlation of perioperatively administered dosage of unfractionated heparin (despite being adjusted to

weight) and postoperative time to surgical re-exploration is a high-risk factor to be considered. The most probable cause is the subsequently increased postoperative bleeding, which potentially leads to oedema and compression of vessels and/or microanastomoses. In cases with such complications, a revision surgery is inevitable and necessary. Consequently, it is imperative for reconstructive surgeons to contemplate (or reconsider) their perioperative regime if they find an increased number of complications in the form of postoperative hemorrhage (19).

Conclusion

Out of all the risk factors and categories we gathered and compared the factor of high dosage of unfractionated heparin administered right after completing the anastomosis is a strong indicator of postoperative bleeding complications . The perioperatively administered dosage of unfractionated heparin and the postoperative time to surgical re-exploration are high-risk factors to be considered when comprising an antithrombotic algorithm. Salvage surgery for recurrent advanced stage head and neck squamous cell carcinoma is recognized to lead to a poor prognosis, especially when a longer waiting period for VSP is not a suitable option. Given the subsequently higher mortality rates, the viability of VSP is becoming questionable. On the other hand, a significantly shorter surgery duration in the VSP group is therefore an outstanding benefit for the patient in the all-out outcome of these comprehensive reconstructive procedures. Apart from the variable regional availability and time of planning of the VSP approach, it affirmatively simplifies the work of the surgeon and serves as a positive addition, especially in more complicated cases. The above-mentioned benefits also contribute to improved outcomes for the patient. Owing to its easy implementation and greater predictability of outcomes, our department also tends to align with the international trend of progressively favoring the method of VSP.

References

1. Nyberg EL, Farris AL, Hung BP, Dias M, Garcia JR, Dorafshar AH et al. 3D-Printing Technologies for Craniofacial Rehabilitation, Reconstruction, and Regeneration. Ann Biomed Eng 2017; 45(1): 45–57.

2. De Caxias FP, Dos Santos DM, Bannwart LC, De Moraes Melo Neto CL, Goiato MC. Classification, History, and Future Prospects of Maxillofacial Prosthesis. Vol 2019, International Journal of Dentistry. Hindawi Limited; 2019.

3. Cho MJ, Hanasono MM. Virtual Surgical Planning in Free Tissue Transfer for Orbito-Maxillary Reconstruction. Semin Plast Surg 2022; 36 (3): 183–191.

4. Lignon J, Guerlain J, Bozec A, Gorphe P, Lauwers F, Vergez S et al. Multicentre evaluation of the interest in planned surgery for mandibular reconstruction with fibula free flap: a retrospective cohort study. European Archives of Oto-Rhino-Laryngology 2021; 278 (9): 3451–3457.

5. Li SS, Copeland-Halperin LR, Kaminsky AJ, Li J, Lodhi FK, Miraliakbari R. Computer-Aided Surgical Simulation in Head and Neck Reconstruction: A Cost Comparison among Traditional, In-House, and Commercial Options. J Reconstr Microsurg 2018; 34 (5): 341–347.

6. Broyles JM, Abt NB, Shridharani SM, Bojovic B, Rodriguez ED, Dorafshar AH. The fusion of craniofacial reconstruction and microsurgery: A functional and aesthetic approach. Plast Reconstr Surg 2014; 134 (4): 760–769.

7. Fisher M, Dorafshar A, Bojovic B, Manson PN, Rodriguez ED. The evolution of critical concepts in aesthetic craniofacial microsurgical reconstruction. Plast Reconstr Surg 2012; 130: 389–398.

8. Dorafshar AH, Bojovic B, Christy MR, Borsuk DE, Iliff NT, Brown EN et al. Total face, double jaw, and tongue transplantation: An evolutionary concept. Plast Reconstr Surg 2013; 131(2): 241–251.

9. Avraham T, Franco P, Brecht LE, Ceradini DJ, Saadeh PB, Hirsch DL et al. Functional outcomes of virtually planned free fibula flap reconstruction of the mandible. Plast Reconstr Surg 2014; 134 (4): 628e–634e.

10. Barr ML, Haveles CS, Rezzadeh KS, Nolan IT, Castro R, Lee JC et al. Virtual Surgical Planning for Mandibular Reconstruction with the Fibula Free Flap: A Systematic Review and Meta-analysis. Ann Plastic Surg Lippincott Williams and Wilkins; 2020; 84: 117–122.

11. Blanc J, Fuchsmann C, Nistiriuc-Muntean V, Jacquenot P, Philouze P, Ceruse P. Evaluation of virtual surgical planning systems and customized devices in fibula free flap mandibular reconstruction. Eur Arch Oto-Rhino-Laryngol 2019; 276 (12): 3477–3486.

12. Biglioli F, Rabagliati M, Gatti S, Brusati R. Kinking of pedicle vessels and its effect on blood flow and patency in free flaps: an experimental study in rats. http: //www.sciencedirect.com.

13. Fernandez-Bussy S, Mahajan B, Folch E, Caviedes I, Guerrero J, Majid A. Tracheostomy Tube Placement Early and Late Complications [Internet] 2015. www.bronchology.com.

14. Hirose M, Okutani H, Hashimoto K, Ueki R, Shimode N, Kariya N et al. Intraoperative Assessment of Surgical Stress Response Using Nociception Monitor under General Anesthesia and Postoperative Complications: A Narrative Review. J Clin Med MDPI; 2022; 11.

15. Elbers JBW, Veldhuis LI, Bhairosing PA, Smeele LE, Jóźwiak K, van den Brekel MWM et al. Salvage surgery for advanced stage head and neck squamous cell carcinoma following radiotherapy or chemoradiation. Eur Arch Oto-Rhino-Laryngol Springer Verlag; 2019; 276: 647–655.

16. Craig ES, Yuhasz M, Shah A, Blumberg J, Salomon J, Lowlicht R et al. Simulated surgery and cutting guides enhance spatial positioning in free fibular mandibular reconstruction. Microsurgery 2015; 35 (1): 29–33.

17. Forel JM, Voillet F, Pulina D, Gacouin A, Perrin G, Barrau K et al. Ventilator-associated pneumonia and ICU mortality in severe ARDS patients ventilated according to a lung-protective strategy. Crit Care 2012; 16 (2).

18. Forni R, Jacot E, Ruoppolo G, Amitrano A, Ogna A. Resuming Swallowing and Oral Feeding in Tracheostomized COVID-19 Patients: Experience of a Swiss COVID-Center and Narrative Literature Review. Med Sci 2022; 10 (4): 57.

19. Wax MK, Azzi J. Perioperative considerations in free flap surgery: A review of pressors and anticoagulation. Oral Oncol 2018 ; 83: 154–157.

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