

# Virtual surgical planning and cone beam computed tomography in reconstruction of head and neck tumors – pilot study

## Authors' Contribution:

A – Study Design  
B – Data Collection  
C – Statistical Analysis  
D – Manuscript Preparation  
E – Literature Search  
F – Funds Collection

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## SUMMARY:

**Introduction:** The aim of the study was to prove that a combination of visual surgical planning (VSP) and cone beam computed tomography (CBCT) is an optimal technique in fibular free flap reconstructions after complex tumor resections in the head and neck region and that it leads to better functional and aesthetic outcomes.

**Material and method:** Six patients (3 females, 3 males) with head and neck tumors were included in the study. The region concerned midface in 2 cases and mandible in 4 patients. On the basis of computed tomography of the head, fibular free flap (FFF) reconstruction was planned with the VSP technique. The 3D-printed models were prepared. At the beginning of the operation and a few minutes after the reconstruction, an xCAT CBCT by XORAN was performed. Minor corrections of the angles of the reconstructed bony parts were made where needed. The time of the operation was assessed for each case. Functional and cosmetic results were evaluated in a 1-year follow-up.

**Results:** The mean time of operation was 6 hours and 48 minutes, which was approximately 1 hour and 40 minutes less than standard reconstructive surgery. Functional recovery was achieved in all patients. Aesthetic result was unsatisfactory for 2 patients due to insufficient soft tissue masses of FFF.

**Conclusions:** The authors claim that intraoperative CBCT imaging, regardless of the cost, improves the accuracy of aesthetic outcome of reconstructive surgeries based on VSP, especially in the region of the midface and the mandible. Further studies on a higher number of subjects are required.

**KEYWORDS:** cone beam computed tomography, free flap, head and neck, reconstruction, virtual surgical planning

## ABBREVIATIONS

**CBCT** – cone beam computed tomography

**FFF** – fibular free flap

**H&N** – head and neck

**ICFF** – iliac crest free flap

**RFFF** – radial forearm free flap

**VSP** – virtual surgical planning

## INTRODUCTION

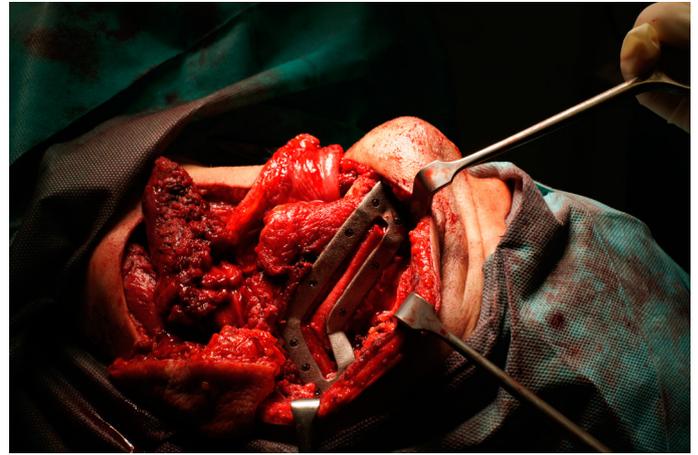
Many new technologies that have been introduced to medicine in the recent years, give more and more opportunities for different specialties. Virtual surgical planning (VSP) has been widely utilized in reconstructive surgery for several years [1, 2]. It is especially useful in the treatment of head and neck (H&N) cancers in cases where the defect after ablative surgery covers bones of the



Fig. 1. xCat CBCT device in the operating room.



**Fig. 2.** Reconstruction box – from the left: 2 cutting guides for tumor resection, cutting guide for the fibula bone osteotomy, anatomical model of the fibula, anatomical models of the mandible before and after reconstruction.



**Fig. 3.** 3D implant made of titanium alloy.



**Fig. 4.** A cutting guide for tumor resection together with a tumor – intraoperative image.



**Fig. 5.** Cutting guide for the fibula bone osteotomy – intraoperative image.

mandible, maxilla or the orbit [1]. Preoperatively, on the basis of computed tomography or magnetic resonance images, 3D-printed models of the operative and donor site as well as bone cutting-guides and titanium plates are prepared. It has been proved that VSP enables accurate matching in the reconstructive procedure giving satisfactory aesthetic results [3, 4]. Yet, the application of intraoperative cone beam computed tomography (CBCT) increases the precision and improves the final outcome. Its greatest advantage is low radiation exposure.

Moreover, the device is mobile and can be precisely positioned over the patient's head in the operating room (Fig. 1).

In the study, the authors presented a novel method of precise virtual surgical planning combined with intraoperative CBCT that was applied in patients who underwent free flap reconstruction due to head and neck tumors. Its superiority over standard reconstruction was discussed as well.

## MATERIALS AND METHODS

The study was conducted between February 2018 and February 2020 on a group of 6 patients (3 females, 3 males; mean age:



**Fig. 6.** Anatomical model of the midface after virtual reconstruction and the cutting guide for the fibula osteotomy.

51 years) with head and neck tumors who required ablative surgery. Preoperatively, a meticulous evaluation of tumor staging, histopathology, co-existing diseases and prognosis according to a standard protocol of qualification was made in every patient. The CT scans of the head and neck were thoroughly analyzed by the reconstructive surgeon. The margins of tumor

**Tab. I.** Characteristics of the study group. F – female, M – male, FFF – fibular free flap, RFFF – radial forearm free flap, RTH – radiotherapy.

INITIALS	GENDER	AGE	DATE OF OPERATION	ANATOMICAL REGION	PATHOMORPHOLOGICAL FINDINGS	FLAP	COMPLICATIONS/ REVISIONS	ADJUVANT THERAPY	FOLLOW-UP
S.M.	F	60	21.02.2018	Mandible	Squamous cell carcinoma	FFF + RFFF	Skin nectrectomy-9d – RFFF; hemorrhage –10d	Preoperative chemotherapy –2017, RTH –06.2018	01.2019 – recurrence, no contact since 02.2019, died in 04.2019
R.M.	M	68	23.05.2018	Midface	Squamous cell carcinoma	FFF	None	RTH	Fistula (palate); 1 cm –03.2019 – healed
F.D.	F	57	31.10.2018	Midface	Squamous cell carcinoma	FFF + RFFF	RFFF necrosis	Palliative RTH –02.2019	Recurrence – died in 04.2019
K.T.	M	69	10.06.2019	Mandible	Ceratocystic odontogenic tumors	FFF	None	None	Fistula (submentally) –healed
S.B.	F	24	10.09.2019	Mandible	Multicystic ameloblastoma	FFF	None	None	2 fistulas (submentally) –healed
L.J.	M	33	24.02.2020	Mandible	Squamous cell carcinoma	FFF	None	RTH	Fistula (neck) – healed

resection were defined and the decision on the appropriate free flap (ICFF – iliac crest free flap or FFF – fibular free flap) was made for each individual. Once the free flap was selected, CT of the lower limb was performed. Only fibular free flaps were included in the study. Thanks to virtual planning the exact length and angles of the osteotomies in the fibula were set.

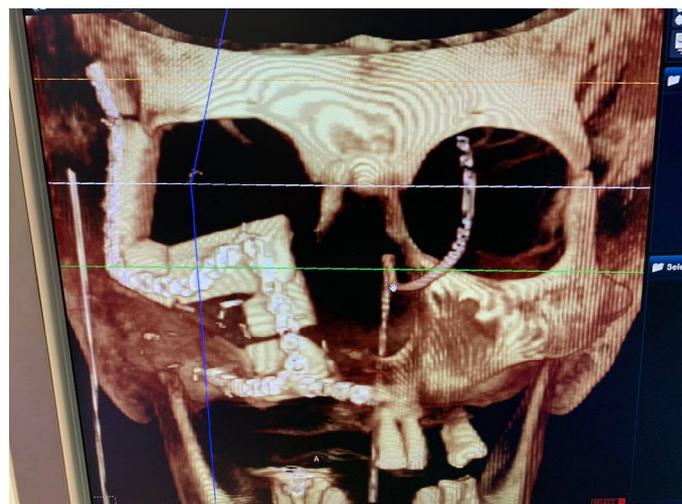
On the basis of the above mentioned procedures in the collaboration with Chirurgia3D Blog- Modelling and 3D Printing in Medical Applications, three-dimensional models of the anatomical structures were created.

A personalized reconstruction box (Fig. 2.) contained:

- custom-made 3D implant made of titanium alloy Ti6Al4V (Fig. 3.),
- cutting guide for tumor resection (Fig. 4.),
- cutting guide for fibula bone osteotomy (Fig. 5.),
- anatomical models of the mandible (before and after surgery) – see Fig. 2.,
- anatomical model of the midface (before and after surgery) (Fig. 6.),
- anatomical model of the fibula – see Fig. 2.

All patients underwent the resection of the tumor according to indications. The reconstruction used FFF in all patients and it was completed with radial forearm free flap (RFFF) in two cases. Intraoperatively, CBCT scans with the application of the xCAT device manufactured by the American company XORAN were performed before the onset of the operation and after the reconstruction (Fig. 7.). The thickness of the reconstructed layer obtained by the device was 0.1 mm.

The functional and aesthetic outcomes were assessed in each patient in a 1-year follow-up. The study was approved by the Ethics Committee of the Maria Skłodowska-Curie National Research Institute of Oncology Gliwice Branch – approval No. KB/430-15/17.



**Fig. 7.** Intraoperative CBCT scan after reconstruction in the midfacial region.

## RESULTS

The characteristics of the study group is presented in Tab. I.

The histopathology findings revealed squamous cell carcinoma in 4 subjects. T4 staging of the tumor was observed in all those patients. Nodal invasion included N2a in two patients and N1 in two of them. Adequate lymphadenectomy was performed in each case. There were no distant metastases found. In one case, multicystic ameloblastoma was observed. One patient suffered from keratocystic odontogenic tumor.

Perioperative complications requiring revision were noted in two patients. Functional recovery was observed in four patients, yet a late (min. 6 months postoperatively) fistula in the operated region was observed in those cases. Non-surgical treatment allowed for successful healing of the wound. Recurrence of the cancer was revealed in two patients, one of which died. No data regarding the physical state of one of the subjects was obtained.

The aesthetic result was unsatisfactory in two cases due to insufficient volume of soft tissues, which resulted in the asymmetry of the face. The patients have been already qualified for secondary reconstruction of soft tissues in order to achieve an acceptable cosmetic effect.

The mean time of the operation with the application of VSP and CBCT was 6 hours and 48 minutes and it remained similar to the procedures in which only VSP was used. It was approximately 1 hour and 40 minutes less than regular reconstructive surgery.

## DISCUSSION

The authors believe that the combination of both visual surgical planning and intraoperative CBCT highly increases the accuracy of bony free flap reconstructions after ablative operations due to head and neck tumors.

The usefulness of VSP in head and neck reconstruction has been already proved by many scientists. For instance, Tang et al. claim that VSP itself is significantly beneficial in terms of improved orthognathic accuracy, ischaemic times and intraoperative times without any significant increase in complications when compared to non-VSP fibular free flap reconstructions [4].

Mazzola et al. state that VSP technology is a helpful tool in complex reconstructions and it adversely influences the overall cost of treatment [2]. It also decreases surgeon's stress intraoperatively [5–10]. Contrary to the above statements, Chang believes that excellent accuracy can be achieved solely by a well-experienced microsurgeon, without VSP [11].

Nevertheless, none of the current studies presented the combined application of AND VSP in complex reconstructions in head and neck surgery. The authors claim that such a method is superior to standard VSP in terms of better accuracy of the reconstructed area.

Although the cutting guides should provide for a total precision, some minimal corrections were required in several patients. Intraoperative CBCT imaging was the ideal solution in those cases. It enabled for perfect matching of the osteotomies and minor alterations of the angles while the patient was still under general anaesthesia. Such a management had a crucial influence on the final aesthetic outcome.

It is also worth mentioning that reconstructive surgeries in the midfacial region, i.e. concerning the maxilla, orbit, zygomatic arch and nose are more challenging than those performed in the region of the mandible. Many different aspects apart from the final aesthetic outcome have to be considered preoperatively in order to avoid any complications such as facial nerve paralysis, malfunctions of the trigeminal nerve, diplopia (as a result of inappropriate reconstruction of the orbital rim) and/or nasal blockage. In those complex cases fibular free flap is the most recommended one.

The authors would also like to notice that in case of FFF it is crucial to set the proper distance of proximal and distal osteotomies of the fibula in order to avoid ankle and knee joint dysfunctions. A lot of attention should be paid to tumor expansion in terms of the adherence of cutting guides to bone. Namely, if tumor growth is external to a bone, for instance the mandible, the cutting guides should be designed in a way tumor tissues to adhere strictly to the bone. Otherwise the resection is impossible to be performed. Tumor infiltration towards the floor of the mouth and tongue seems to be less complicated when planning the cutting guides. Also, the length of the vascular pedicle must be precisely assessed.

The presented combination of VSP and intraoperative CBCT gives novel opportunities for microsurgions, yet it is not free of some disadvantages.

The VSP was introduced to reconstructive surgery in order to shorten the time of the surgical procedure [12]. As far as intraoperative CBCT is concerned, some important aspects should be mentioned. Namely, the examination time itself is about 5–40 s and it decreases potential artifacts caused by patient's movements [13]. However, the whole process of positioning the CBCT device and the patient can be time-consuming. Yet, the overall time of the surgical procedure is comparable to the cases where only VSP was utilized and it still remains about 1 hour shorter than without 3D planning.

Another issue that needs to be taken into consideration is the cost of the CBCT device as well as manufacturing of the 3D guides and models. The cCAT by XORAN belongs to very sophisticated imaging tools that, unlike regular CBCT devices used in many dental offices, meets sufficient criteria for its application in the operating theatre. Therefore, due to a high cost, such a facility can be still unaffordable for many Polish district hospitals.

The cost of manufacturing 3D guides, models and implants is approximately 2,500–3000 Euro per one operation and according to the Polish law, it is not refunded by NFZ (equivalent of the National Health System). Therefore, not every oncological Polish centre can afford such high costs.

## CONCLUSIONS

It is our firm belief that intraoperative CBCT imaging, regardless of the cost, improves the accuracy of the aesthetic outcome of the reconstructive surgeries based on VSP, especially in the region of the midface. In cases of good prognosis and anticipated long 5-year recurrence-free survival, it is worth carrying high costs of the operation.

New regulations regarding the refund of the described procedures by NFZ should be urgently introduced so that more patients can be operated on with the best standard available. Further studies are required to obtain statistically significant results.

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