Three dimensional virtual surgical planning for patient specific osteosynthesis and devices in oral and maxillofacial surgery. A new era.

Kraeima, Joep

CHAPTER 10

SUMMARY

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Three dimensional virtual surgical planning (3D VSP) has become a structural component in the armamentarium of the oral and maxillofacial surgeon. Over the years the 3D technology has proven to increase the predictability, accuracy and speed of surgical procedures within the field of oral and maxillofacial surgery (OMFS).

This thesis aimed to improve the workflows for 3D VSP, in order to further improve surgical procedures in OMFS and provide definitions of adequate indications for use of 3D VSP.

1. In the new era of 3D VSP, optimisation is required on following components:
2. Integration of multi-modality imaging into a single 3D VSP.
3. Systematic comparison with conventional methods, including thorough testing and validation of new 3D VSP applications.
4. Definition of adequate indications for the use of 3D VSP.
5. Definition of required technical and medical expertise for conforming implementation of 3D VSP.

This thesis addresses these components and aims to presents new and validated methods in three main pillars of OMFS. For each of these applications it is emphasized that the new profession of the technical physician seems to be crucial for translation technological developments and innovations into clinical practice.

Surgery in head and neck oncology

An important step for optimisation of the 3D VSP workflow is to combine multiple image datasets into one 3D model of the patient. **Chapter 2** presents the development and validation of a method to combine both CT and MRI datasets for 3D visualisation of the bone (CT) and the tumour (MRI). This method was developed to optimise the 3D VSP for resection of malignancies related to the mandible. As is presented in **chapter 3** the clinical application of this workflow leads to an improvement of tumour free bone resections of the mandible (100% of the cases in this study). This underlines the added value of having a multi-modality, more complete, 3D model for 3DVSP. However each fusion of data will introduce some error, as the scans have to be aligned and that will not be perfect. This misalignment can be up to 1-2mm. In **chapter 4** a potential solution is explored by means of the MRI-only planning. This chapter presents the addition of the blackbone MRI sequences to the standard diagnostic protocol, in order to enable MRI based 3D bone models. The concept works, however the bone models are not

optimal. It also requires time intensive segmentation and a lot of manual corrections and interpretation. At this stage it is concluded that MRI only 3D VSP requires further optimisation of the MRI protocol for scanning and segmentation.

The workflow developed in **chapter 2** uses only standardised file formats and therefore is easily implemented in other 3D applications as well. An example is described in **chapter 5**, where in addition to CT or MRI data the radiation oncology planning is included in the 3D VSP. This allows a 3D visualisation of the isodose lines that represent the received radiation dose at each desired location of the mandible. In case of severe osteoradionecrosis, when a continuity resection is required, this can support the decision on where to perform the osteotomies.

Orthognathic surgery

In orthognathic surgery 3DVSP has also proven to contribute to the predictability of surgical outcomes and the ability to simulate and evaluate these procedures. In most routines, a 3D VSP of the required translation of the jaws is made, and this is translated towards the surgical procedure by a 3D printed/milled splint. As a next step, not only is 3D VSP used to plan the translation of the jaws in orthognathic surgery, currently also patient specific osteosynthesis (PSO) that fixate the jaws, are applied. This thesis presents the development of a new method for PSO for translation of the maxilla (**chapter 6**) which resulted in accurate translation of the 3D VSP towards the actual surgical procedure. In **chapter 7**, by means of a multi center randomized controlled trial, the added value of this PSO method was defined by comparison with the conventional splint-based method. This resulted in the definition of the indications for use of PSO. It was found that the results for the patients in the PSO group where better (closer to the 3D planned position) in all directions, compared to the control group. Significant differences were found in the anterior-posterior and the left-right directions of translation of the maxilla. In addition it was found that for larger planned translations of the maxilla the difference between the PSO- and the conventional method was larger. As an example, it is stated that planned an anterior-posterior translation of 3.5mm or more is an indication for the use of PSO. This is based on a reported clinically relevant deviation from the planned position of 2mm or more.

Temporomandibular Joint Surgery

Patients who suffer from osteoarthritis, recurrent ankyloses or a tumour in the temporomandibular joint (TMJ) can present with symptoms such as a severely restricted mouth opening, pain or other dynamic restrictions of the mandible. In severe cases a total joint replacement (TJR) may be indicated. Studies have reported that such TMJ-TJR

can improve the maximum mouth opening and reduce the pain. One of the challenges of replacing the TMJ is the imitation of the complex movements of the natural TMJ, including both a rotational and translational component. The Groningen TMJ-TJR device, developed in the 90's, accounted for this problem by the use of a lowered center of rotation. The device was successfully applied in patients. However, as also other TMJ-TJR devices experienced, when fabricated as a stock device, the devices can have a suboptimal fit. This leads to suboptimal post-operative TMJ functioning or requires extensive per-operative re-contouring of the bone. A potential solution is to customize the parts of the prosthesis that fit the bony surface of the mandibular and the skull base. This thesis presents, in **chapter 8**, the development of a customized 3DVSP based TMJ-TJR device, based on the Groningen principle including custom surgical placement guides. A humane cadaver study was performed with a total of n=10 TMJ-TJR devices implanted. Based on post-operative CT data the accuracy of placement was found to be 0.81mm Euclidian distance on average. Thereby it is concluded that the use of 3D VSP and custom production of the TMJ-TJR device enables accurate surgical placement. This provides the first step in improvement of treatment options for patients suffering from restricted mouth opening or pain as a result of TMJ related ankylosis.

General Conclusion

The new strategies for 3D VSP in OMFS, provided by this thesis, improve the treatments in terms of predictability, accuracy and provides detailed possibilities for postoperative evaluation. This thesis optimizes the workflows, systematically compares the 3D VSP methods to conventional methods and objectifies the indications for use of 3D VSP. In the new era of 3D VSP the 3D technology will be applied for every patient, not when we can, but when we should.