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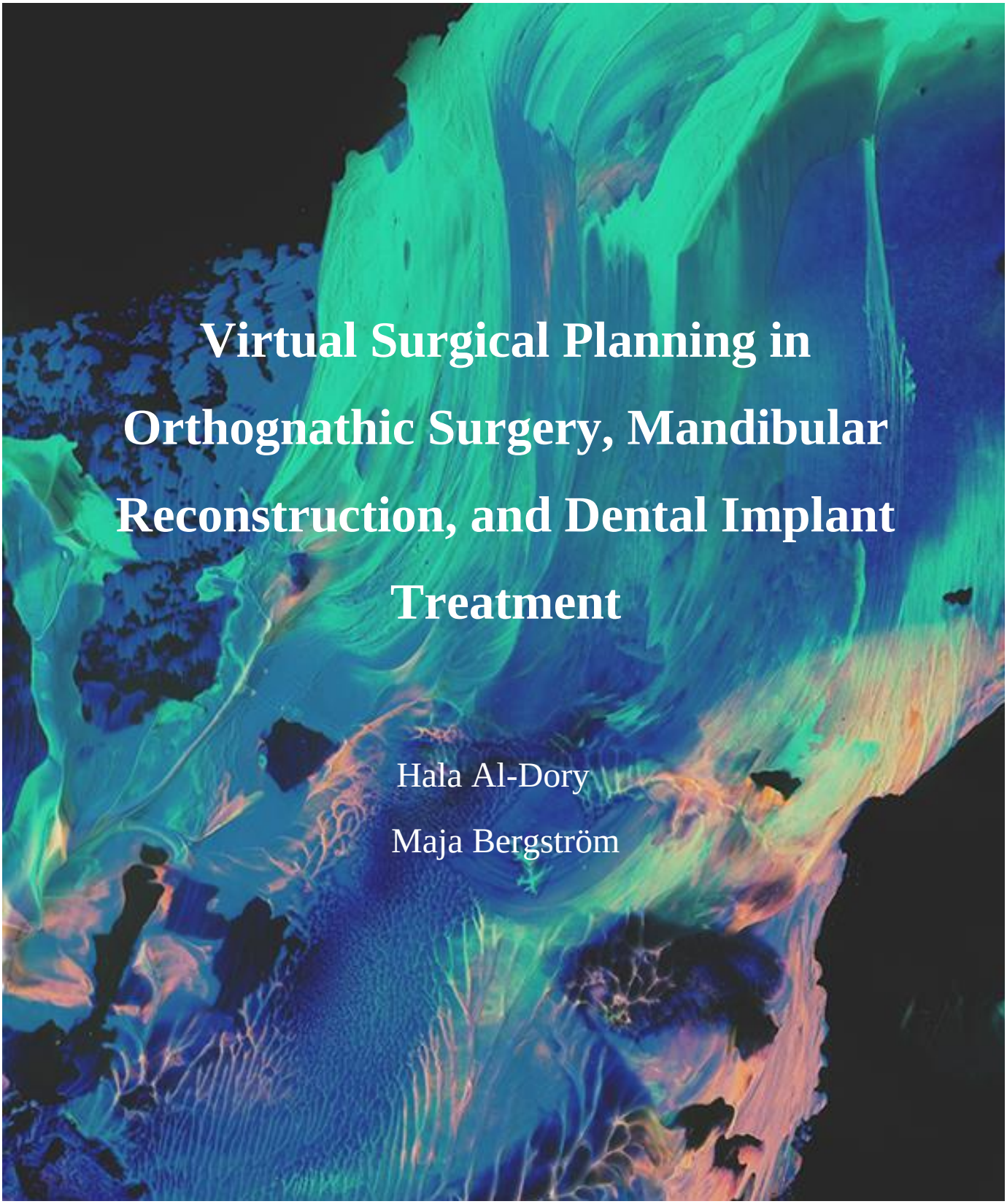

Virtual Surgical Planning in Orthognathic Surgery, Mandibular Reconstruction, and Dental Implant Treatment

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ABSTRACT

Virtual surgical planning (VSP) has the potential to make the work process of oral and maxillofacial surgery more efficient both in terms of performance and cost.

This study aims to investigate how VSP is used among oral and maxillofacial surgery clinics in Sweden, and to analyse VSP with regard to accuracy, healing, patient communication, and overall operative time.

A questionnaire was sent to all (n = 34) oral and maxillofacial surgery clinics in Sweden, concerning their knowledge and practice of VSP. A literature review was also carried out to compare the results from clinics in Sweden with the general view.

94 % of the oral and maxillofacial surgery clinics participated in the study, and all respondents affirmed knowledge of VSP. While 65 % recognise a need for VSP in their work, only 42 % utilise it. The main obstacles reported were economy, training, and availability. This was in high accordance with the literature review. The review also concluded that VSP increased accuracy, reduced planning time, decreased blood loss, and lowered the need for reoperations.

The presented study shows that VSP is beneficial both pre- and intra-operatively in orthognathic surgery, mandibular reconstruction and implant placement. Accuracy, planning, and patient communication are improved with VSP, both according to studies and questionnaire respondents. However, healing, overall operative time, and cost-benefit did not show strong evidence of improvement with VSP, which might explain the contrasted responses in the questionnaire on these subjects.

INTRODUCTION

Craniomaxillofacial (CMF) reconstruction is one of several branches within dental surgery, restoring symmetrical facial contour and oral functions such as speech, swallowing, and mastication (Zielinski *et al.,* 2015). Thorough planning and problem analysis is crucial prior to surgery in the CMF region, as topographic relations and landmarks between anatomic sites is complex. Historically, planning of CMF surgery was conducted using measurements of anatomic landmarks from two-dimensional plain radiography, obtained from craniometrics performed by anthropologists on dried skulls.

Until recently, cephalometric radiographs with tracings (Steinbacher, 2015) or cone beam computed tomography (CBCT) together with stone model surgery (Hammoudeh *et al.,* 2015) has formed the golden standard for most CMF procedures. This technique, however, requires a considerable amount of analytical and radiographic analysis, dental cast fabrication, and splint preparation by a dental technician, which can be very time consuming. It can also potentially amplify inaccuracies during the process (Liu *et al.,* 2009).

During the past decades, the digitalisation has caused a paradigm shift within many professions, including medical services. Today, digital imaging, planning, and refinement can reduce effort in laboratory technical procedures and thus make the work process more efficient both regarding performance and cost. Previous studies (Hirsch *et al.,* 2009; Roser *et al.,* 2010; Sink *et al.,* 2012) indicate that within CMF surgery, the three-dimensional computer-aided treatment planning can be used to visualise and evaluate the planned surgery in advance and with great precision. A study from 2011 (Antony *et al.,* 2011) shows that the use of virtual surgery has the potential to save intraoperative time, improves patient satisfaction, and accelerates the surgeon's learning process. It has also been shown (Hanasono *et al.,* 2013) that virtual planning combined with CAD-technique and rapid prototype modelling increases both speed and accuracy of

mandibular reconstruction surgery.

The availability of computing software combined with the relatively low radiation dose of CBCT lays the foundation in the development of virtual surgical planning (VSP). The tomographic scans of the skeletal area are rendered into a three-dimensional digital image, which offers a highly detailed view regarding anatomy and deformities (Sink *et al.,* 2012; Wrzosek *et al.,* 2016). This helps the surgeon in the planning procedure going through every step of the surgery in advance. In addition to the visual information the CAD/CAM technique has enabled rapid prototype manufacturing, serving the reconstructive surgeon with a physical model of the skeletal image (Juergens *et al.,* 2009). Pre-bent titanium reconstruction plates, osteotomy guides and wafers — depending on the nature of the procedure — can be generated preoperatively based on the stereolithic model of the cranium (Hanasono *et al.,* 2013). The prefabricated guides are sterilised prior to the operation. By making another CBCT scan, as part of the post-operative follow-up, the before- and after images can be superimposed to determine the result and accuracy of the procedure (Antony *et al.,* 2011).

This study aims to investigate to what degree VSP is used among CMF surgery clinics in Sweden, and to determine if the new paradigm has already become more common than conventional surgery procedure among dental surgeons. The purpose of the study is, with the help of a literature review, to analyse the differences between virtually planned and conventionally planned surgery concerning factors such as levels of accuracy, healing, patient communication, and overall operative time.

MATERIALS AND METHODS

The study was split into two parts – part I constituting a questionnaire and part II presenting an overview of the state-of-art methods for virtual planning in dental surgery.

Part I – Questionnaire

Part I consisted of a questionnaire sent to all (n = 34) CMF surgery clinics in Sweden. The clinics were identified through the official website of Swedish Association of Oral and Maxillofacial Surgeons (Svensk käkkirurgisk förening, 2016). Each clinic was contacted to obtain the e-mail and name of the Medical Director of the clinic. The questionnaire was distributed digitally through the Web-based service of Surveymonkey.com, which provides an anonymous link between the responses and respondees. A first reminder was sent four weeks afterwards and a second reminder was sent two weeks after that. Four weeks after, the remaining clinics were contacted to exclude any technical issues. One week after the final reminder, the questionnaire was closed.

The questionnaire was designed digitally, enabling the respondents to answer via smartphone or desktop. The manner of digitalisation was carried out to minimise the bottleneck of additional paperwork such as return via regular mail. Another advantage of digital survey is to allow the respondents to answer the questionnaire "on-the-go".

The second step was to pilot test the questionnaire on a subset of our intended population. A group of 9, consisting of 4 prosthodontists and 5 oral surgeons from University Hospital of Umeå and Örebro University Hospital, were asked to participate in order to confirm the validity of the questionnaire. After collecting the data of the pilot test, some finer adjustments were made on the final design of the questionnaire (see Appendix A).

The final questionnaire consisted of 3, 6 or 17 questions, depending on the respondent's previous answers. This was to ensure that respondents without required qualifications or experience were not exposed to the more detail oriented questions. The respondents were asked about their knowledge of VSP, if they used the technique and, if so, their perception of this new technique. If the respondent did not use VSP they were asked to

precise what, if anything, restricted them. A 5-point Likert-style scale was used for the questions involving rating (Figure 1).

Upon presenting the pie charts in this paper, all questions from the questionnaire have been translated from Swedish to English. The questionnaire in its original form can be viewed in Appendix A.

Part II – Literature review

Part II of the study consisted of a literature review, presenting an overview of levels of accuracy, healing, patient communication, and overall operative time within the field of VSP.

PubMed has been the primary source of information, including material available up until October 18th, 2016. The relevant material can be reproduced using the following medical subject heading (MeSH) terms: ((virtual surgical planning OR 3D surgical planning OR "computer-assisted three-dimensional imaging")) AND (maxillofacial surgery OR craniomaxillofacial surgery OR "mandible reconstruction" OR "maxillary reconstruction" OR orthognathic OR "maxillary fractures" OR "mandibular fractures" OR "tumour resection").

The result set is comprised of 411 articles, which were then filtered based on titles and abstracts. Inclusion criteria were full text papers written in English or Swedish, studies conducted on humans and date of publication ranging from January 1st, 1990 to October 18th, 2016. Article types included were randomised controlled trials, systematic reviews and journal articles. Exclusion criteria were articles focusing on soft tissue, technical analyses, TMJ surgery, zygomatic surgery, orbital surgery, computer-assisted surgery, groups with less than five participants, and case studies. Also excluded were articles published in journals with a quartile ranking of less than Q2 according to InCites Journal Citation Reports by Thomson Reuters (Journal Citation Reports, 2016). Further investigation of article references resulted in an additional involvement of 14 articles. After

applying inclusion and exclusion criteria, 69 articles remained for abstract screening, out of which 35 were included in the review (Table 1).

Ethical considerations

No identification of the participants or separate clinics through the questionnaire is possible and the result is published on a group level.

RESULTS

Part I – Questionnaire sent to Swedish Oral and Maxillofacial Surgery Clinics

Out of the 34 Oral and Maxillofacial surgery clinics in Sweden, 94 % participated in the study and answered the questionnaire completely. All respondents affirmed that they had knowledge about Virtual Surgical Planning (VSP).

Regarding years active as an oral and maxillofacial surgeon, half of the participants ranged from 11—20 years. 28 % had more than 20 years of experience in this field and 22 % had less than 10 years (Figure 2). On the following question, concerning how interested the respondent was to use VSP in their work, a slight majority expressed an interest (Figure 3). While 65 % see a need for using VSP (Appendix B Figure 1), only 42 % use it (Appendix B Figure 2).

For participants currently not using VSP, the major obstacles concerned financials (48 %), lack of training (39 %), availability of the technology (39 %) and time limitations (25 %) as shown in Appendix B Figure 14. Although 42 % of the respondents use VSP, only 29 % experienced no hindrance in using the technique. One participant suggested that a reason for limited VSP use might be a lack of understanding in management.

The remaining questions in the questionnaire were only asked participants who are currently using VSP in their work.

Application area and usage

Among the participants actively practising VSP, 46 % had used it for 6—10 years. No one of the respondents had used it for more than 10 years (Appendix B Figure 3).

When asked about the application of the technique (Appendix B Figure 4), all participants use it for pre-operative surgical intervention. 46 % also use VSP for manufacturing implant surgical guides. 23 % use the technique for the manufacture of surgical occlusal guides (so called *wafers*). A minority also use the technique for patient communication, post-operative precision control or reconciliation, and planning or manufacturing of other implants or prosthesis.

As visualised in Appendix B Figure 5, most participants (54 %) answered that they prefer using VSP in their work, while 8% favour the conventional surgical planning to VSP.

According to the participants, the most frequently used field of application of VSP is within implant placement (77 %). VSP in orthognathic surgery was practised by 54 % of the participants while temporomandibular joint surgery had a degree of utilisation of 38 %. VSP in mandibular fracture surgery and reconstructive jaw surgery following tumour resection was only frequently used by a minority of the participants (Appendix B Figure 6).

When asked how many surgeries the respondents had conducted using VSP as part of the procedure during the last 12 months, a majority had experienced fewer than 10 and no respondent had conducted more than 40 VSP guided operations (Appendix B Figure 7).

Application simplicity and operation

VSP is considered easy to learn and apply according to 54 % of the respondents, while 23 % disagree (Appendix B Figure 8). It is concluded by 85 % that VSP benefits the overall planning procedure (Appendix B Figure 9). Also, the experience from using VSP with regard to the operative procedure was for the most part beneficial. As shown in Appendix B Figure 10, the majority (61 %) of the participants think VSP facilitates the operative procedure, while 15 % think it does not.

Healing and accuracy

When asked about whether VSP affects the surgical accuracy, 77% agreed that VSP give higher surgical precision, while 8 % thought otherwise. 15% did not perceive any major difference in surgical precision between conventional and VSP (Appendix B Figure 11).

There was a big diversity in opinions about how VSP affects the post-operative healing process (Appendix B Figure 12). One third (31 %) answered that VSP accelerates the post-operative healing process; another third (31 %) experienced the opposite. The remaining participants (38 %) saw no difference in post-operative healing between conventional and virtual planning.

Patient communication

When asked about communication and delivery of information from the surgeon to the patient, 62 % of the respondents indicated that VSP makes the knowledge transfer more pedagogical, while 15 % of the participants disagreed with this statement (Appendix B Figure 13).

Part II – Literature review

The literature review yielded 69 articles, and out of these, 21 of the articles met the inclusion criteria. An additional 14 articles were obtained from article references and manual search (Table 1). The year of publication ranged from 2004 until 2016 (Appendix B Figure 15).

The resulting 35 articles describe a total of 940 patients and 222 dental implants incorporating VSP technology. Out of this database, 476 patients underwent orthognathic surgery whereof the majority (88 %) were bimaxillary osteotomies, 7 % maxillary osteotomies and 5 % mandibular osteotomies. 464 patients had mandibular reconstruction surgery from which 79 % were free fibula flap, 13 % Iliac bone graft, 3 % scapular graft, and 5 % mandibular fractures.

Since there is not yet, in the field of VSP, a standardised working process on how to define a successful outcome, nor on how to present data, it is not possible to perform a meta-analysis. Therefore, results in this paper will be presented in a general manner. In accordance with previous publications, the success criteria in osteotomy are presented as linear differences less than 2 mm and angular differences less than 4 degrees. Differences of less than 2 mm have been shown to not be clinically significant (Tucker *et al.*, 2010). Concerning dental implants, an overall mean spatial navigation error of 0.35 mm is acceptable in dental implantology (Casap *et al.*, 2004).

For a more comprehensive literature overview, we recommend the following systematic reviews on VSP: Rodby *et al.*, 2014 and Stokbro *et al.*, 2014.

DISCUSSION

Application simplicity and operation

As seen in the literature review concerning operative time, there are studies showing a significantly decreased operative time for mandible reconstruction with osteocutaneous free flap and iliac crest graft when utilising VSP (Antony *et al.,* 2011; Hanasono *et al.,* 2013; Shu *et al.,* 2014; and Chang *et al.*, 2016). However, some studies did not find a significant decrease in operative time, although they describe a decrease in mean

ischemic time in CAD assisted mandibular reconstructions (Seruya *et al.*, 2013; Ayoub *et al.,* 2014; and Rustemeyer *et al.,* 2015).

Considering time spent planning the procedure of orthognathic surgery, studies concluded that a reduction in overall planning time was achieved with VSP compared to standard treatment planning (Iorio *et al.*, 2011; Baker *et al.*, 2012; and Wrzosek *et al.,* 2016).

A systematic review on oncologic head and neck reconstruction surgeries (Rodby *et al.,* 2011), reported that VSP allowed reduction in intraoperative time in 80% of the cases and a decrease in flap ischemic time in 30% of the cases. Surgeons, in 24% of the cases, reported simplicity of use when using VSP.

Another systematic review concluded that VSP may reduce the overall cost of care in orthognathic surgery due to the decrease in operating time, blood loss, complications, and need for reoperations (Stokbro *et al.*, 2014).

Application area and usage

From the questionnaire data we can deduce that out of the respondents using VSP, half prefer VSP to the conventional planning procedure. The reason why some still prefer the conventional way is inexplicit in the questionnaire, but it could be due to the complexity of the technique, application difficulties, or as a result of the surgeons feeling confident with the conventional pathway.

Although a quarter of the questionnaire participants indicated that the VSP learning curve is time consuming and creates an obstacle for adopting the technique, studies in the literature review show that VSP saves intraoperative time. If clinics invest more time to allow their surgeons to learn VSP, the benefit could motivate that cost in the end. Regarding the learning curve, some studies specifically report an accelerated learning

process associated with mandibular reconstruction (Antony *et al.*, 2011 and Foley *et al.*, 2012).

Healing and accuracy

As seen in the questionnaire, respondents had contradicting opinions on whether the use of VSP increases the healing process or not, but most of them believe the use of VSP improves surgical precision compared to conventional surgical planning. In the literature, a study stated that VSP for mandibular reconstruction after oncological resection decreases postoperative complications. The time reduction stems from reducing operation time, reducing bone graft ischemia time, and by allowing a more precise bone-to-bone contact (Roser *et al.*, 2010). Another study was performed on 24 patients with fractured mandibles using VSP and a custom-fabricated surgical guide (El-Gengehi *et al.*, 2015). When comparing the postoperative results with the preoperative virtual plans, no significant difference was found. This indicates that the computer-based surgical guides helped acquiring accurate mandibular reduction after fractures.

According to a systematic review, an increased accuracy of mandibular reconstruction was reported in a vast majority of the cases, proving to be the major perceived benefit of the technology (Rodby *et al.*, 2014). Similar studies verified an improved accuracy in mandibular reconstruction (Roser *et al.*, 2010; Wang *et al.*, 2013; Ayoub *et al.*, 2014; Shu *et al.*, 2014; and Foley *et al.*, 2015).

The long-term operative outcome of preoperative VSP for osteocutaneous free flap mandible reconstruction has been evaluated in several studies (Shu *et al.,* 2014; Chang *et al.,* 2016). It has been concluded that the use of VSP resulted in less burring, fewer osteotomy revisions, and less bone grafting (Chang *et al.,* 2016).

Various studies have confirmed a high level of accuracy in operations performed with VSP in orthognathic surgery (Baker *et al.,* 2012; Sun *et al.*, 2013; Mazzoni *et al.*, 2015; Li *et al.,* 2015; Lin *et al.,* 2015; Borba *et al.,* 2016). One study highlighted that a higher accuracy was achieved for repositioning of the upper jaw than the lower jaw (Li *et al.*, 2015). A contradicting result was reported by another study, comparing the accuracy between two- and three-dimensional hard tissues planning on 66 patients undergoing orthognathic surgery (Van Hemelen *et al.*, 2015). 31 patients underwent VSP and 35 underwent conventional two-dimensional planning. The results show no significant difference between them. These results support the theory of conventional two-dimensional surgical planning and three-dimensional VSP being comparable to each other. However, the authors suggest that the accuracy of three-dimensional VSP offers strong aid to surgeons during planning and during surgery.

Implant placement was reported significantly more precise when performed with VSP than with the free-hand method (Nickenig *et al.*, 2009; Pettersson *et al.*, 2010). However, the accuracy achieved with manual implantation is considered sufficient for most clinical situations.

A common way to put VSP to the test is by comparing preoperative virtual data to the actual postoperative outcome. The literature review found in one study that the error in distance of the mandibular osteotomy versus virtual osteotomy were acceptable (Shu *et al.*, 2014). As were the volume between the actual harvested graft versus the virtual graft. This lead to the conclusion that VSP-aided mandibular reconstruction increases the accuracy of surgery, reduces donor-site morbidity, and also, making participating surgeons more comfortable with the operation procedure. According to the same study, a variety of factors that generally affect operation errors can never be eliminated, but can be reduced with VSP.

In the literature review, it appears that VSP not only aids the surgical accuracy, but also the pre-surgical diagnosis. It is claimed that VSP

increases precision in pre-surgical diagnosis in orthognathic surgical treatment (Farronato *et al.*, 2015). The 15 patients in this study underwent orthodontic preparation for surgery using splint guides and orthodontic planning. The results also show that three-dimensional imaging, such as VSP, using CBCT gives more accurate anatomical images, compared to conventional two-dimensional imaging, which could save time and give better aesthetic results.

Comparing three-dimensional VSP and conventional two-dimensional surgical planning methods is rather complicated. The ideal scenario would be if both methods were applied to the same patient, but performing two surgeries — one using two-dimensional surgical planning and the other using three-dimensional VSP — on the same patient is not realistic and in many cases also unethical.

Patient communication

According to the literature, VSP has the potential to facilitate the operator's communication with the patient through virtual images and stereolithographic models. There may be a positive effect on the patient's outcome and recovery by reducing preoperative anxiety (Wang *et* al., 2013).

One study, focusing on patient satisfaction, showed that when expressed on a scale of 0–100, satisfaction was reported higher for patients with VSP treatment in comparison to conventional treatment, with a score of 88 compared to 68 (Modabber *et al.*, 2012).

One of our initial hypotheses was that one of the major benefits of VSP would be the communication between surgeons and patients. However, several studies in the literature review indicate that enhanced communication *between the surgical teams* is one of the main advantages of VSP (Hirsch *et al.*, 2009; Antony *et al.*, 2011; and Baker *et al.*, 2012).

A disadvantage of VSP, not covered by the questionnaire, is mentioned in one of the systematic reviews (Stokbro *et al.*, 2014). They discuss the possible limitations and advantages of three-dimensional VSP, and identify the increased CBCT radiation exposure both pre- and postoperatively as one of the major disadvantages. On the other hand, the authors highlight more simple means to store, visualise, and share the virtual treatment plan as benefits of the technique. They also credit VSP to be cost-efficient due to decreased operating time and fewer postoperative complications.

Conclusion

The outcome of this thesis work is that oral surgery performed with VSP is reliably reproduced and has a higher accuracy than conventionally planned oral surgery. Literature studies also report a decrease in ischemic time for mandibular reconstruction, reduction in overall planning time, decreased blood loss and lowered need for reoperations, which in turn may result in improved recovery. There are still contradictious results whether VSP results in a reduced total intraoperative time, fewer complications and, furthermore, in a lower total cost of care. One of the most highlighted benefits with the new technology was, according to operators in the literature, the enhanced communication between the ablative and the reconstructive surgeons in tumour surgery. Also, being able to easily visualise and consult treatment plans with colleagues anywhere in the world was highly appreciated.

The findings from the literature review were mostly congruous with the responds from the questionnaire sent out. Concerning the planning, the operative procedure, the precision of the surgical treatment, and patient communication the respondents perceived improvements with VSP. The highest level of disagreement, in the questionnaire, was noted in the question concerning the post-operative healing process, which also has the least scientific evidence to date.

Through the questionnaire, it was noted that implant placement was both considered one of the most useful field of application and the most frequently used subdomain. This presumably derives from implant placement being the earliest adopter of VSP.

As the questionnaire revealed, it was surprisingly few that conducted VSP guided surgery, considering the high interest. The obstacles mentioned were economy, training and availability. The literature review did not report strong evidence for the cost-benefit of VSP, which correlates to our questionnaire findings.

A weakness in designing the questionnaire is that due to anonymity the respondents were not possible to categorise into private clinics and university hospitals. Separating the two fields might have yielded additional information of interest concerning classification of the answers.

It is of interest to conduct this study in other parts of the world to examine the responses for various regions and cultures and to see if they would differ from the responses of Swedish participants.

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TABLES

Table 1. Table illustrating the event of inclusion and exclusion criteria applied in the literature review.

Articles in study	Event
411	PubMed search results with inclusion criteria
425	Including additional references found in articles
69	After exclusion criteria have been applied
35	Included in study after article review

FIGURES WITH LEGENDS

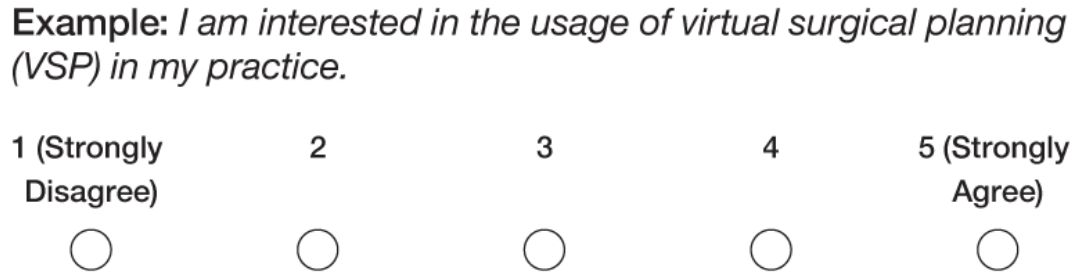

Figure 1. Example of 5-point Likert scale.

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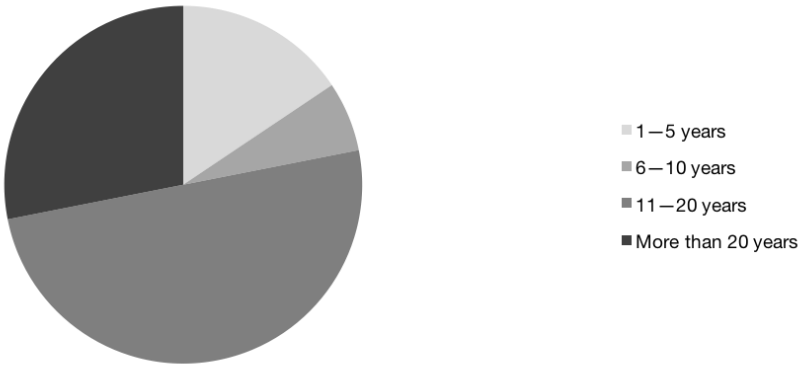

Figure 2. "For how long have you been working actively as an Oral and Maxillofacial Surgeon?"

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Figure 3. "I am interested in using Virtual Surgical Planning (VSP) in my work."

APPENDIX A — QUESTIONNAIRE

Enkätutskick från
Tandläkarhögskolan i Umeå

1. Hur länge har du varit verksam som käkkirurg?

- ◯ 1—5 år
- ◯ 6—10 år
- ◯ 11—20 år
- ◯ Mer än 20 år

2. Känner du till konceptet "virtuell operationsplanering" inom käkkirurgi? (På engelska "virtual surgical planning", förkortat VSP)

- ◯ Ja
- ◯ Nej

3. Jag har ett intresse av att använda mig av virtuell operationsplanering (VSP) i mitt arbete.
(Ange lämplig siffra. 1= Håller inte med alls, 5= Håller fullständigt med)

- ◯ 1 *(Håller inte med alls)*
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5 *(Håller fullständigt med)*

4. Jag upplever att det finns ett behov av virtuell operationsplanering (VSP) i mitt arbete.

- ◯ 1 *(Håller inte med alls)*
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5 *(Håller fullständigt med)*

5. Använder du dig av virtuell operationsplanering (VSP) i ditt arbete som käkkirurg?

- ◯ Ja
- ◯ Nej

6. Hur länge har du använt virtuell operationsplanering (VSP) i ditt arbete som käkkirurg?

- ◯ 0—2 år
- ◯ 3—5 år
- ◯ 6—10 år
- ◯ Mer än 10 år

7. Vilka delar av den virtuella operationsplaneringen (VSP) har du mest nytta av?
Välj max tre alternativ.

- [ ] Planering av ingreppet
- [ ] Patientinformation
- [ ] Framställning av operationsguide/borrmall vid implantatkirurgi
- [ ] Framställning av operationsguide/wafer vid ortognatkirurgi
- [ ] PrecisionsavstämningpostoperativtviasuperimpositionavCBCT
- [ ] Annat

8. Jag föredrar att använda mig av virtuell operationsplanering (VSP) på min arbetsplats.
(Ange lämplig siffra. 1= Håller inte med alls, 5= Håller fullständigt med)

- ◯ 1 *(Håller inte med alls)*
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5 *(Håller fullständigt med)*

9. Inom vilka områden använder du dig mest frekvent av virtuell operationsplanering (VSP)?
Välj max tre alternativ.

- [ ] Implantatbehandling
- [ ] Ortognatkirurgi
- [ ] Rekonstruktiv käkkirurgi — tumörresektion
- [ ] Käkledskirurgi
- [ ] Frakturkirurgi
- [ ] Annat

10. Hur många operationer har du utfört under de senaste 12 månaderna där arbetet har inkluderat virtuell operationsplanering (VSP)?

- ◯ Färre än 10
- ◯ 11—20
- ◯ 21—30
- ◯ 31—40
- ◯ 41—50
- ◯ Mer än 50

11. Jag tycker att det är enkelt att ta till mig tekniken kring virtuell operationsplanering (VSP).
(1= Håller inte med alls, 5= Håller fullständigt med)

- ◯ 1 *(Håller inte med alls)*
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5 *(Håller fullständigt med)*

12. Jag upplever att **planeringen** av den kirurgiska behandlingen underlättas av virtuell operationsplanering (VSP).

- ◯ 1 *(Håller inte med alls)*
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5 *(Håller fullständigt med)*

13. Jag upplever att det **operativa ingreppet** underlättas av virtuell operationsplanering (VSP).

- 1 *(Håller inte med alls)*
- 2
- 3
- 4
- 5 *(Håller fullständigt med)*

14. Jag upplever att **precisionen** av den kirurgiska behandlingen underlättas av virtuell operationsplanering (VSP).

- 1 *(Håller inte med alls)*
- 2
- 3
- 4
- 5 *(Håller fullständigt med)*

15. Jag upplever att **läkningsförloppet** efter den kirurgiska behandlingen underlättas av virtuell operationsplanering (VSP).

- 1 *(Håller inte med alls)*
- 2
- 3
- 4
- 5 *(Håller fullständigt med)*

16. Jag som kirurg anser att information kring operationen på ett mer pedagogiskt sätt överförs till patienten med hjälp av virtuell operationsplanering (VSP)?

- 1 *(Håller inte med alls)*
- 2
- 3
- 4
- 5 *(Håller fullständigt med)*

17. Finns det hinder för dig att använda virtuell planering i ditt arbete?
Välj max tre alternativ.

- [ ] Ekonomi
- [ ] Tid
- [ ] Utbildning
- [ ] Tillgänglighet
- [ ] Nej, det finns inget hinder för att använda virtuell planering i mitt arbete
- [ ] Annat

APPENDIX B — SUPPLEMENTARY FIGURES WITH LEGENDS

Figure 1–15

Appendix B Figure 1. "I see a need for Virtual Surgical Planning (VSP) in my work"

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Appendix B Figure 2. "Do you use Virtual Surgical Planning (VSP) in your work as an Oral and Maxillofacial Surgeon?"

Appendix B Figure 3. "For how long have you been using Virtual Surgical Planning (VSP) in your work as an Oral and Maxillofacial Surgeon?"

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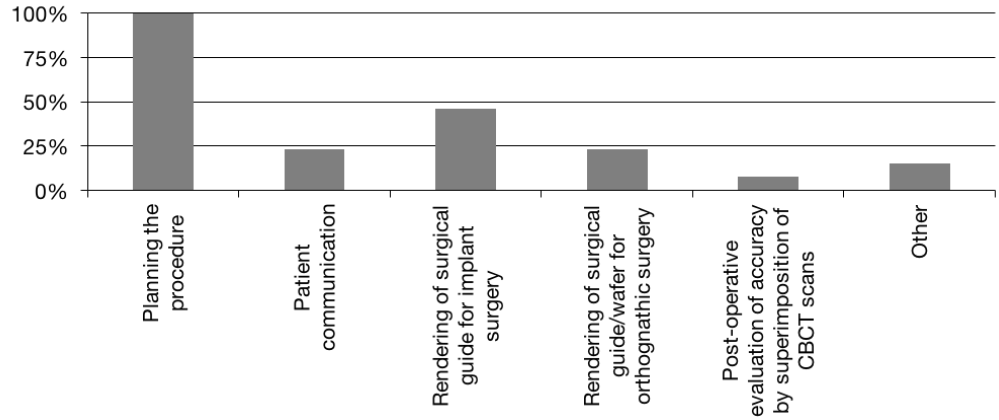

Appendix B Figure 4. "Which application areas of Virtual Surgical Planning (VSP) are most useful to you? Choose at most three options."

Appendix B Figure 5. "I prefer using Virtual Surgical Planning in my work"

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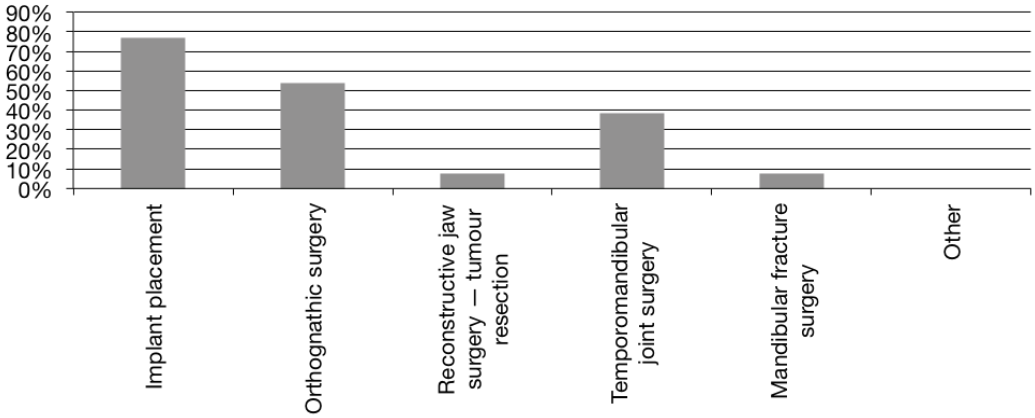
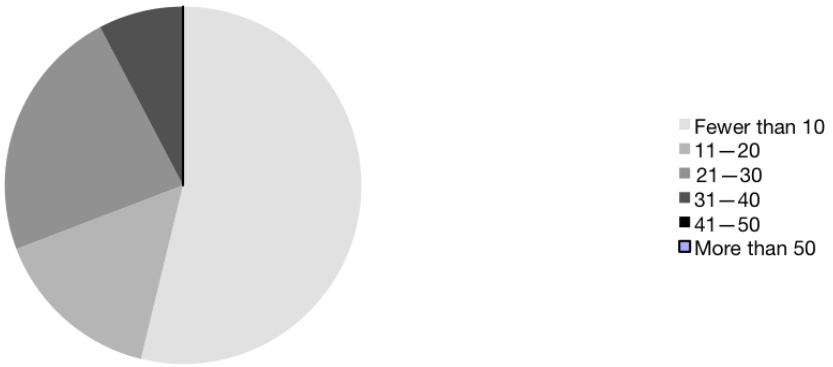


Appendix B Figure 6. "Within which subdomains do you apply Virtual Surgical Planning most frequently? Choose at most three options."



Appendix B Figure 7. "How many surgeries have you conducted the last twelve months, where Virtual Surgical Planning (VSP) has been part of the procedure?"

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Appendix B Figure 8. "I find if simple to grasp the techonology around Virtual Surgical Planning (VSP)."

Appendix B Figure 9. "In my experience, the planning of the surgical treatment benefits from using Virtual Surgical Planning (VSP)."

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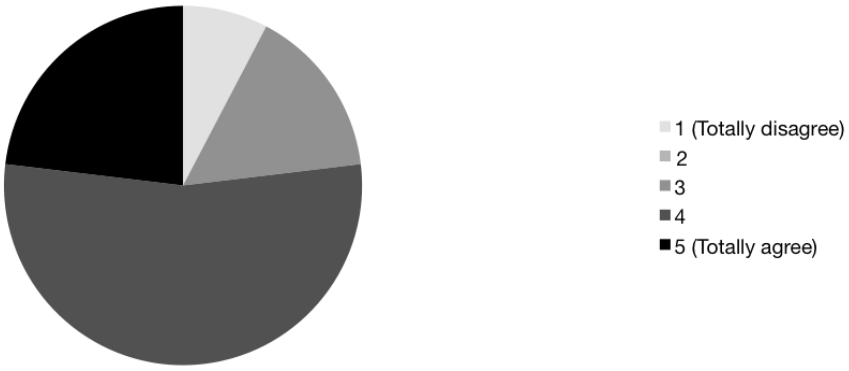
Appendix B Figure 10. "In my experience, the operative procedure benefits from using Virtual Surgical Planning (VSP)"



Appendix B Figure 11. "In my experience, the precision of the surgical treatment is improved by using Virtual Surgical Planning (VSP)."

.....

Appendix B Figure 12. "In my experience, the post-operative healing process benefits from the use of Virtual Surgical Planning."

Appendix B Figure 13. "I as a Surgeon is of the opinion that information regarding the surgery is transferred to the patient in a more pedagogical manner when using Virtual Surgical Planning (VSP)."

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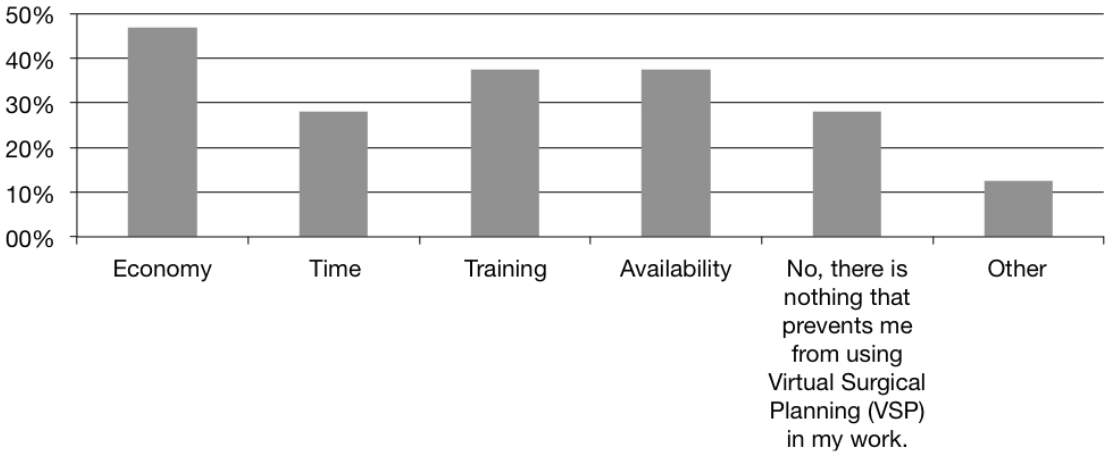
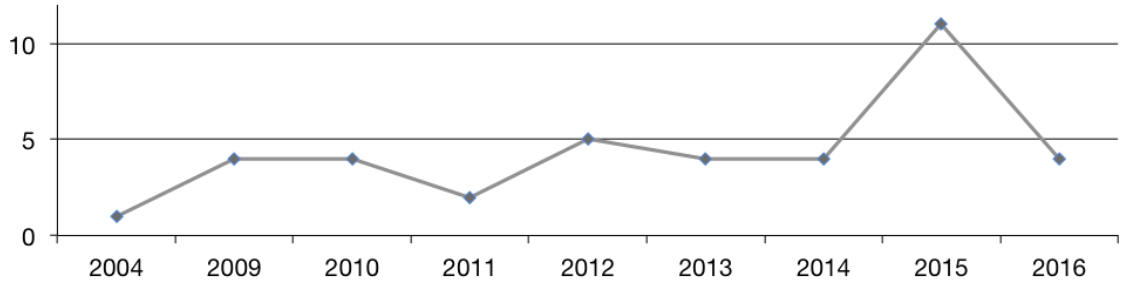


Appendix B Figure 14. "Are there obstacles preventing you from using Virtual Surgical Planning (VSP) in your work? Choose at most three options."



Appendix B Figure 15. Chart illustrating the amount of article citations by year.

APPENDIX C — SUPPLEMENTARY REFERENCES

Svensk käkkirurgisk förening (2016) — the official website of Swedish Association of Oral and Maxillofacial Surgeons. [Online] [Cited 2016 Oct 18]. Available from:

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