# Cloud-based Collaboration Platform for Orthognathic Surgical Planning

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**Abstract**

Many medical departments use several multi-disciplinary technologies to support the planning of the surgery. For complex operations a collaboration between different experts can improve the success rate, but the tools are mostly on-premises software and limit the good cooperation. In this case, the orthognathic and dental surgery uses 3D and CT scans to plan the surgery beforehand by making use of 3D image processing, visualization and planning tools. We researched the possibility to create an online cloud-based platform to run the currently used surgical planning tools to improve the collaboration between several experts. We achieved multiple two-factor authentication user logins for security, simultaneous surgical planning sessions for collaboration and lightweight multi-platform support for existing technologies.

Keyword(s): [Orthognathic surgery; Dental surgery; Planning tool; Cloud service]

## 1. INTRODUCTION

The medical faculty of KU Leuven has a maxillofacial surgery department that is focusing on tools and methods for computer assisted orthognathic surgery. In this kind of surgery, surgical corrections can be made in the maxilla (i.e. upper jaw) and/or in the mandible (i.e. lower jaw) bone structure. An illustration of orthognathic surgery examples in maxilla and mandible bone structures are illustrated in figure 1.

Fig. 1. *Examples of maxilla (left) and mandible (right) orthognathic surgery.*

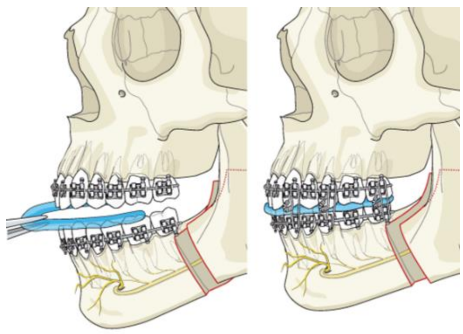

Fig. 2. *Repositioning the cut mandible bone structure with the use of wafers as templates.*

For the operation, the bone structure in the maxilla and/or mandible needs to be cut and reposition carefully by means of support plates and screws. For obtaining better surgical results, it is very important to accurately reposition and correctly fixate the split bone structures. Therefore, the operation is carefully planned upfront. Wafers with the occlusion planned by the surgeon and with the dental imprint of the maxilla are preproduced and used as a repositioning reference for the fixation as illustrated in figure 2.

In previous cooperation among the University Hasselt and the research group of Prof. Politis, algorithms have been implemented to automatically determine the alveolar nerve channel in the mandible (1) based on cone beam CT scanned 3D images. By means of 3D printers, Dr. Y. Sun realized in his Ph.D. thesis (2) a 3D digital workflow for the creation of wafers. Figure 3 shows an example of a 3D representation of a designed wafer.

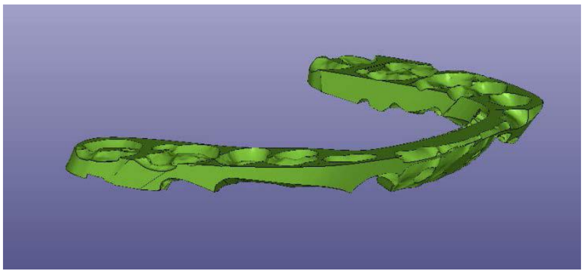

Fig. 3. *The 3D representation of a designed orthognathic wafer.*

The 3D design of the wafers using 3D CAD tools can be carried out by experts experienced with the workflow and software tools, or by the surgeon during the planning stage. The designs need to be verified by the surgeon, in case the experts do the design instead of the surgeon. Most of the time the experts and surgeons are working in a different hospital. Therefore, a centralized workflow would be an improvement to the collaboration between the experts and the surgeons. With the centralized workflow the surgeons can remotely inspect the 3D designed wafers and give feedback to the experts. Finally, the designed wafers can be 3D printed before the surgery takes place.

## 2. CLOUD-BASED SURGICAL PLANNING

In our case, UZ Leuven Sint-Rafaël, is MeVisLab the 3D surgical CAD tool. This is an on-premise software package which makes remote collaboration on the same data very difficult. Our primary goal is to make collaboration on the same patient data possible and to provide simultaneous access for multiple users to this stand-alone planning tool.

This service could be provided by a terminal server, but compared to a cloud-based solution there are some limitations:

- Scalability, i.e. a terminal server is limited to the hardware that is provided during the installation.
- Redundancy, i.e. a backup system needs to be managed by the terminal server itself.
- Accessibility, i.e. terminal servers are usually located within the company network and only accessible when connected to this network.
- Maintenance, i.e. it is usually an administrator from the company who needs to manage the hardware of the terminal server.

We need a cloud-based platform that supports Windows applications as the existing legacy needs to be supported. Microsoft Azure (3) is one of the platforms that supports this possibility. We have implemented a cloud-based virtual machine on the Microsoft Azure platform and installed MeVisLab on this virtual machine to continue our research.

### 2.1 Cloud-based platform

A cloud-based service platform (e.g. Azure) provides the possibility to create a virtual machine from one or more virtual hard disk (VHD) images. One image must contain a bootable operating system to start from. Therefore, the images need to be uploaded into the cloud service and can be used during the creation of the virtual machine. Due to these VHD images, the virtual machine does not have to be located on a fixed machine and provides a certain redundancy to the service. Furthermore, it is also easy to scale a virtual machine, because it can easily be transferred to different hardware. The same applies for hardware maintenance, as the virtual machine and the VHD images can easily be cloned, and thus no maintenance have to be done on a live server. Also, VHDs that contain only data can be uploaded and can be made accessible for the virtual machines. Because of the fact that the virtual machine is a cloud-based service, it is continuously accessible through the internet.

The specifications of the virtual machine needs to be defined when creating one. These specifications like memory, process power, … will define the fixed cost. The variable cost scales linear with the usage, so the final price is mainly based on the real usage. In our specific example, the running virtual machines are stored on VHD images which are located in Azure Storage blobs. Because of this, there is certain redundancy that ensures that the virtual machine will not disappear due to disk and hardware failures.

### 2.2 Collaboration

In our use case, we need multiple simultaneous user sessions for the collaboration between several experts. Therefore, we have implemented TSplus (4) on the virtual machine. This software package provides seamless remote application, load balancing, multiple login sessions, universal printer, … as a service. Every user login passes through this service and the user gets its published applications. This tool is also responsible for the user policies.

### 2.3 Security

Due to the possibility that the virtual machine is always available and accessible through the internet, there could be a security issue. Anyone can try to connect to the virtual machine from anywhere. At this point, the only user verification (i.e. user name and password) is a single login. In this case, it is confidential patient data that is now online available, thus additional security measurements are mandatory.

To protect the user logins on the virtual machine, a two-factor authentication software is implemented. To verify the authentication a secondary device will be used. For our research the security is provided by Duo Security (5).

## 3. RESULTS

An on-premise surgical planning software is elevated to a cloud-based collaboration platform without adapting the software package itself, thus we conclude that the main goal is achieved.

### 3.1 Run MeVisLab

MeVisLab can be used as a cloud-based service, without maintaining and installing the on-premise software itself. On any device with an active internet connection, it is possible to run the MeVisLab as if it is installed locally. The minimal additional latency in the user interface is the only downside. This additional latency depends on the latency of the internet connection with the service.

### 3.2 Allow Multiple Users To Access The Service Simultaneously

The maximum amount of simultaneous user sessions is only limited by the software license provided by the user session software (i.e. TSplus) and by the configuration of the virtual machine. The exact same files (on a shared location) can be opened in different sessions due to the working of the MeVisLab application. But the application is obligated to do its own version control and that is not programmed. Therefore, files can be overwritten by other users without any warning to the users.

### 3.3 Collaboration On Shared Data

For collaboration, all users can share surgical data with specific users. The operation system handles the permissions. This implies that an administrator is needed to manage the needs of the users.

### 3.4 Publish Applications For Specific Users

For an administrator it is possible to give specific users rights to specific applications. The users can then only access the published applications. The chosen software (i.e. TSplus) provides an additional feature so you can run these as seamless applications. No installation is needed to run the available applications on the local machines. This improves the accessibility on any device that has an active internet connection and the overall user experience.

### 3.5 Lightweight Multi-platform Support

All the applications are executed on a remote machine thanks to the cloud-based approach. This approach makes it also possible to run the applications on any device as long as they have an active internet connection. For the device, it is now lightweight although MeVisLab is a heavy 3D CAD program. In our research, we have successfully run this application on different operating systems (i.e. iOS, Linux, Android, Windows and Mac OS) and on different devices (i.e. laptop, smartphone and tablet). This is even an improvement to the previous possibilities, because now different devices can be used of the user preference (e.g. surgeon can bring its tablet in a meeting for a review).

### 3.6 No Downtime Due To Maintenance

It became clear, during our research sessions, that it is possible to upgrade the software even while the virtual machine is still in use. During the maintenance (i.e. software upgrades) there was no influence on the current user sessions. So the administrator had enough time to test extensively the new version before releasing this version.

### 3.7 Security

In our security tests, it turned out that the sole use of full credentials is not enough to access the cloud. Every attempt to login, has to be approved by a secondary device. We have also tested all the different approaches (i.e. SMS, phone call, mobile app) available in the currently selected service (i.e. Duo Security). All of these approaches have to be done in a limited amount of time and use a single button authentication.

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