



# Development of patient specific models for simulation, guidance and education in orthognathic surgery

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## Introduction

Dentofacial deformities consist of discrepancy between the upper and lower jaws (17 million individuals in 2006, USA). They result in difficulties in chewing, talking, breathing and ultimately the loss of teeth (Fig.1). The correction of such deformities consists of orthognathic surgery, a subspecialty of maxillofacial surgery, which restores facial harmony and dental occlusion through bone cutting, reposition and fixation (Fig. 2).



In our routine practice of orthognathic surgery, we face the limitations of conventional tools (2D radiographs, dental casts) for preoperative planning and simulation, but also the lack of intraoperative assistance.

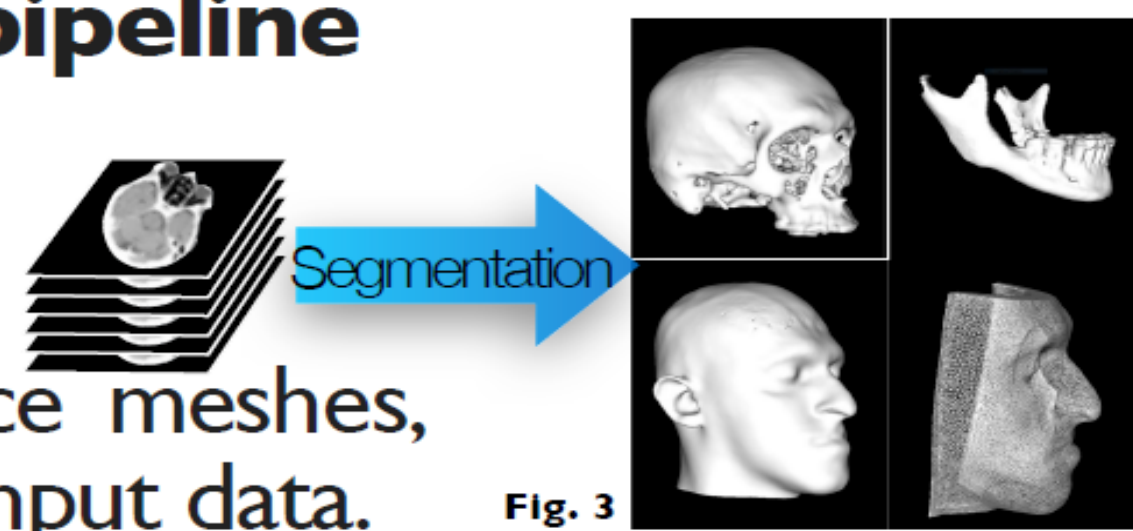
## Aim

To provide novel computer tools in order to improve  
 - preoperative simulation  
 - intraoperative navigation

## Methods

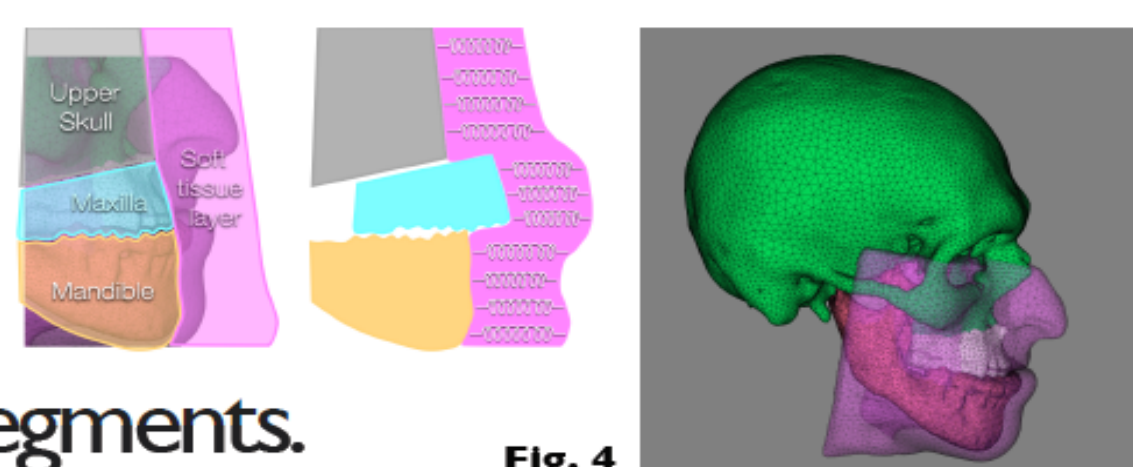
### Development of a semi-automated segmentation pipeline

in order to obtain a patient-specific 3D model consisting of surface meshes, using CT scans as input data.



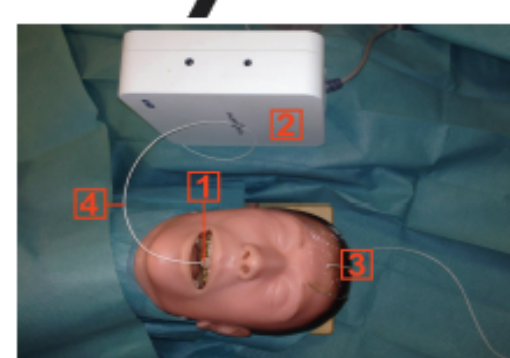
### Development of a software program to simulate the alterations of facial soft tissues

resulting from the surgical displacement of underlying bone segments. High quality volume meshes were generated using the TetGen® library to operate the Bullet® mechanical engine. A mass-spring model was used.



### Development of a navigation system

based on real-time minimally invasive electromagnetic tracking and augmented virtuality interface.



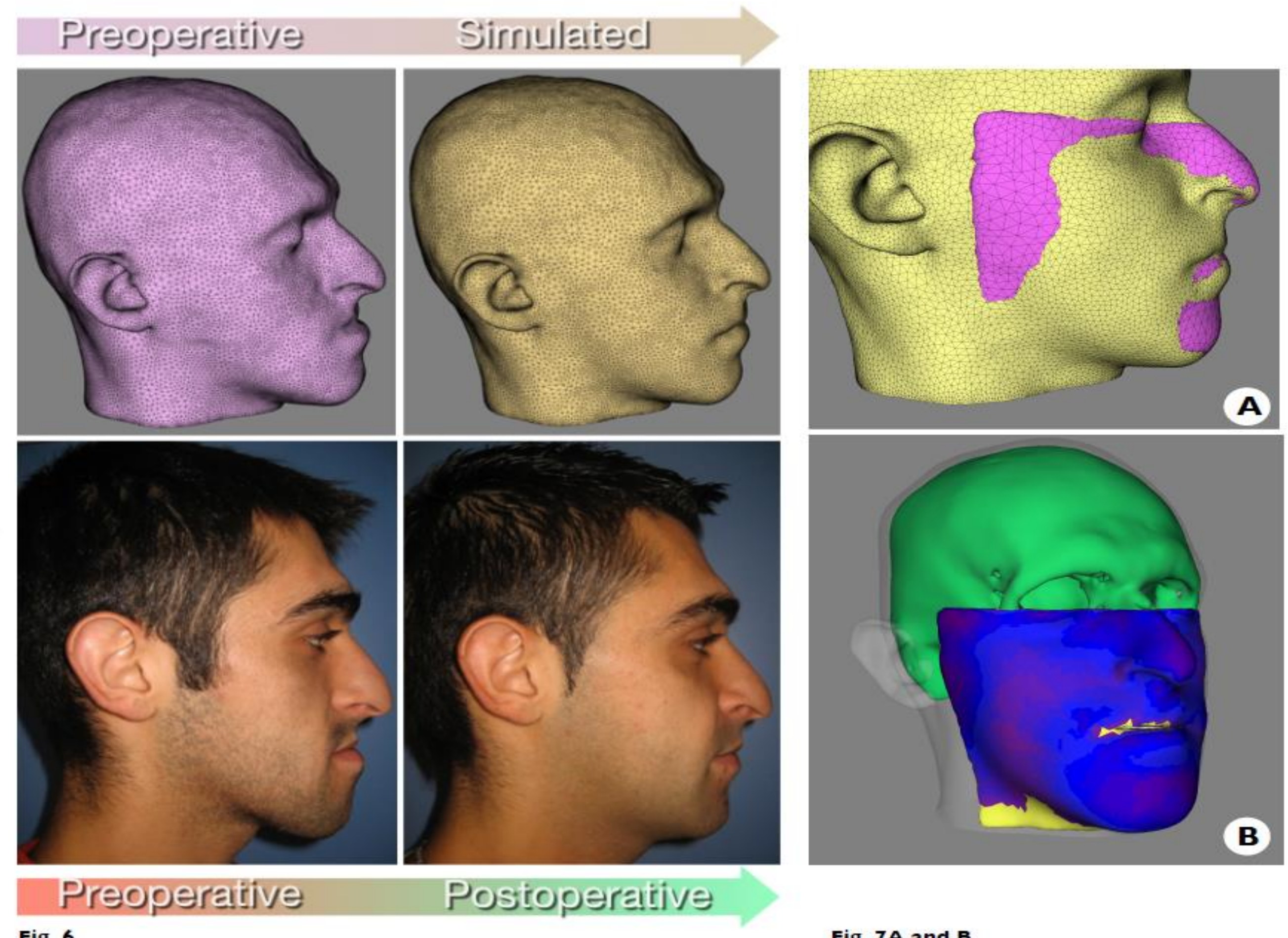
## Results

**Simulation** quantitative evaluation: point-to-weighted surface error measured between the external surface of the simulated volume mesh and the surface mesh extracted from the postoperative CT scan (ground truth) (Fig. 7A).

Qualitative evaluation was also conducted using distance maps (Fig. 7B).

**Accuracy was found < 1mm**, therefore proving the simulation to be realistic, as expected from the comparison with clinical radiographs (Fig. 6).

Real time simulation could be achieved. The human machine interface (HMI) allowed swift and easy assessment of soft tissue alterations.



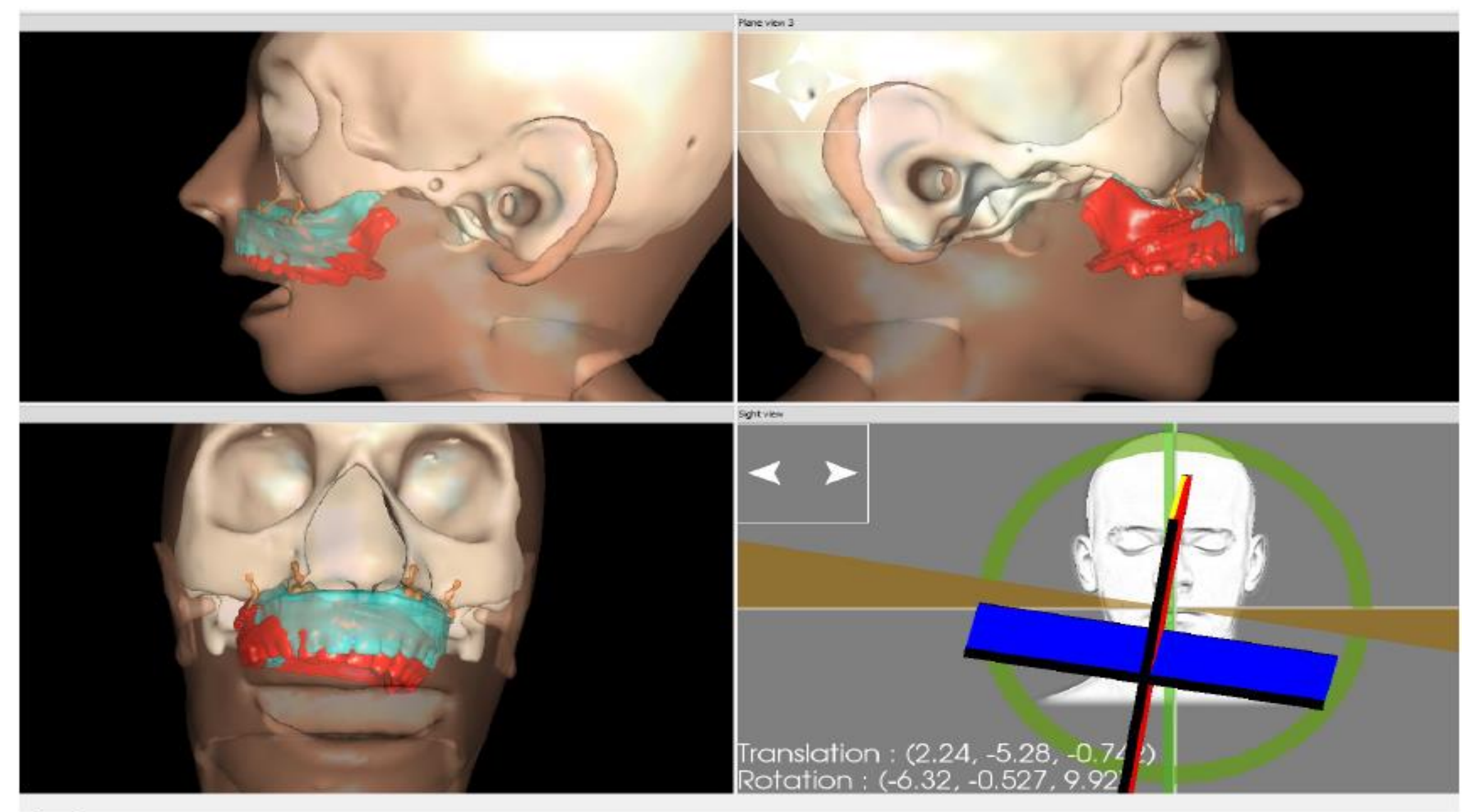
**Navigation** was assessed through quantitative and qualitative evaluation by a sample of 12 surgeons.

**Accuracy was improved for every surgeon.**

The mean improvement in angular accuracy was at 33%.  
 The mean improvement in translational accuracy was at 46%.

Operative time was homogenized between all categories of surgeons.

Navigation **decreased operative time** especially in surgeons with the smallest experience.



HMI was considered relevant and user-friendly especially its crosshair design (Fig. 8).

## Conclusion

We generated a simple mass-spring model which allowed a realistic and real time simulation of the postoperative result providing an accuracy better than 1 mm.

We have developed a navigation system

- with a novel, user-friendly interface providing redundant visual information on real-time 3D movements of the maxilla.
- minimally invasive
- considering patient head movements
- affordable
- improving surgical accuracy
- improving operative time especially in trainee surgeons, therefore demonstrating educational benefices.
- especially relevant in complex cases.

These developments are thought to contribute to improvement of patient care.

## References

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