ABSTRACT

Background

Orthognathic surgery represents the elective method for treating dentoskeletal malocclusions, with the goal of achieving a stable and correct dental occlusion and harmonious facial aesthetics. The development of virtual surgical planning, supported by increasingly precise software, and the *in-hospital* production of customized devices have enabled better quality post-operative outcomes,, but discrepancies remain between preoperative predictions and postoperative results, especially in the vertical and anteroposterior directions. Furthermore, predicting soft tissue behaviour remains a critical aspect for the aesthetic evaluation of surgical outcomes.

Objectives

This study has main goals. To describe the surgical planning process carried out within the hospital structure. To quantitatively analyze the discrepancies between planned and actual postoperative skeletal movements, assessing the accuracy and clinical significance of the planning; And to study soft tissue displacement following hard tissue displacement, developing and validating a geometric-statistical model based on Partial Least Squares (PLS) regression for the three-dimensional prediction of soft tissue displacement.

Materials and Methods

The study includes 20 patients who underwent combined orthognathic surgery between October 2023 and July 2024, with a minimum follow-up period of 6 months. The morpho- functional outcome was assessed using the FACE-Q|Aesthetics© scale, a modified version of the Katsuragy scale, GAIS, and the Visual Analog Scale (VAS) for pain and aesthetics. The clinical-surgical outcome was evaluated through comparative analysis of pre- and post- operative 3D models. Discrepancies between planning and actual results were calculated for each landmark in the three spatial directions (left-right, front- posterior, up-down) and statistically analyzed using the t-test/ Wilcoxon test, Bland-Altman analysis, and Cohen's effect size. The results indicate high planning accuracy in the latero- lateral and antero-posterior directions, with more significant errors in the vertical components, which are clinically relevant in specific anatomical areas.

Results

According to virtual planning and follow-up criteria, 13 patients were included in the study—10 females and 3 males. Patients were classified according to the type of dentoskeletal malocclusion. Twelve patients underwent bimaxillary surgery, and one underwent only a Le Fort I osteotomy. Genioplasty was performed in nearly half of the cases.

Intermediate and final splints were produced and used in most procedures.

No patient reported pain on palpation of the temporomandibular joints or temporal muscles;

2 reported pain in the masseter, and 9 in the pterygoid region. No severe sensory deficits were detected, although 53.9% reported paresthesia. From an aesthetic standpoint, the average satisfaction score increased from 3.8 to 8.4 (VAS), with a marked improvement in facial symmetry. The 3D data showed strong correspondence between the virtual planning and post-operative results for maxillary and mandibular advancements, with minimal bony discrepancies within clinically accepted limits.

Conclusions

For the first time, a *fully digital in-hospital* virtual planning protocol for orthognathic surgery has been introduced in the Maxillofacial Surgery Department of Hospital Molinette in Turin. The establishment of the "3D Lab" facilitated effective collaboration between surgeons and engineers. This standardized workflow enables precise transfer of the virtual surgical plan and necessary tools directly to the operating room.

Clinical and radiological results confirm the protocol's accuracy, reliability, and temporal stability, as well as the high aesthetic satisfaction of patients. Virtual surgical planning helps bridge the experience gap between senior and junior surgeons, standardizing clinical outcomes and providing valuable training support.

Regarding the prediction of the soft tissue the results obtained in this study demonstrated the possibility of modeling soft tissue response through a statistical approach based on Partial Least Squares (PLS), applied to the residuals between geometric prediction and actual post-operative configuration. Even though it is based on a limited number of cases, the model showed consistent behavior without overfitting, confirming the validity of the method and the robustness of the implemented alignment, normalization, and validation procedures.

From a clinical perspective, the developed model represents an autonomous predictive system, capable of estimating soft tissue response based solely on preoperative bone information and planning parameters.