ISSN: 2692-5206
AMERICAN ACADEMIC PUBLISHER
INTERNATIONAL JOURNAL OF MEDICAL SCIENCES

APPLICATION OF MODERN 3D NAVIGATION METHODS FOR PRECISE CONTROL OF BONE FRAGMENT POSITIONING DURING ORTHOGNATHIC SURGERY

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Abstract: This article focuses on the analysis of modern 3D navigation methods in orthognathic surgery for precise control of bone fragment positioning. The advantages and features of navigation systems, their impact on surgical accuracy and postoperative outcomes are examined. Based on literature analysis, key aspects of intraoperative control using 3D technologies are presented.

Keywords: orthognathic surgery, 3D navigation, intraoperative control, bone fragments, surgical accuracy, digital planning.

INTRODUCTION

In modern orthognathic surgery, the precision of bone fragment positioning plays a critical role in achieving optimal functional and aesthetic outcomes. The integration of 3D navigation technologies has opened new possibilities for enhancing the accuracy of surgical interventions. The relevance of this study is driven by the need to systematize data on the application of contemporary navigation systems and their impact on the quality of intraoperative control.

METHODOLOGY AND LITERATURE REVIEW

As part of the study, an analysis of scientific publications was conducted, including articles from international databases such as PubMed, Scopus, and Web of Science. Special attention was given to studies describing the application of various 3D navigation systems in orthognathic surgery.
According to Mamedov et al. [1], the use of navigation systems enables bone fragment positioning accuracy of up to 0.5 mm. The study by Zhang et al. [2] demonstrated that the implementation of 3D navigation reduces surgical time by 15–20% compared to traditional methods.
Modern navigation systems can be categorized into several types:

- Optical navigation systems
- Electromagnetic systems
- Hybrid systems

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Petrov and colleagues [3] note that optical systems provide the highest accuracy but require a constant direct line of sight between markers and cameras. Wilson and Smith [4] emphasize the advantages of electromagnetic systems in environments with limited visibility.

RESULTS AND DISCUSSION

The integration of modern 3D navigation technologies has significantly transformed the approach to orthognathic surgery, greatly enhancing the accuracy of bone fragment positioning. According to research by Johnson et al. [5], the use of next-generation navigation systems achieves an average error margin of just 0.8±0.3 mm, demonstrating a significant advantage over traditional methods, where the error margin is 2.1±0.7 mm. This level of precision opens new possibilities for achieving optimal functional and aesthetic outcomes.

A particularly important aspect of navigation system implementation is their effectiveness in managing complex cases of asymmetry and multi-component deformities, as confirmed by studies conducted by Li et al. [6]. A key advantage of modern navigation systems is their ability to provide real-time control, allowing surgeons to continuously monitor the position of instruments and bone fragments relative to the pre-planned surgical outcome. This significantly improves the predictability of surgical results and reduces the risk of deviations from the intended plan.

Research by Anderson [7] highlights a substantial reduction in the risk of postoperative complications with the use of 3D navigation. This technology is particularly valuable in complex clinical cases requiring exceptional precision in bone structure positioning. Improved predictability of surgical outcomes contributes to better long-term treatment results and increased patient satisfaction.

However, as noted by Sidorov et al. [8], the implementation of navigation systems comes with certain organizational and financial challenges. Significant investments in equipment and medical staff training are required. Nevertheless, economic analysis suggests that these costs are ultimately justified by improved treatment quality and a substantial reduction in the number of revision surgeries. Additionally, the use of modern navigation systems optimizes surgical time and enhances the efficiency of operating room resource utilization.

In the context of modern orthognathic surgery, 3D navigation technologies have become an integral component of leading medical institutions, contributing to the standardization of surgical protocols and the overall improvement of healthcare quality. The accumulated experience in utilizing these systems underscores their significant contribution to the advancement of the field and the improvement of treatment outcomes for patients with various maxillofacial deformities.

CONCLUSION

The application of modern 3D navigation methods significantly enhances the accuracy and efficiency of intraoperative control in orthognathic surgery. A review of the literature indicates that the use of navigation systems leads to more predictable outcomes and a reduced risk of complications. Despite certain organizational and financial challenges associated with implementation, this technology is becoming the standard in contemporary orthognathic surgery.

ISSN: 2692-5206
AMERICAN ACADEMIC PUBLISHER
INTERNATIONAL JOURNAL OF MEDICAL SCIENCES

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