DEVELOPMENTS IN ORAL AND MAXILLOFACIAL SURGERY WITH EMPHASIS ON ORTHOGNATHIC SURGERY

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Abstract. Orthognathic surgery, a foundational component of oral and maxillofacial surgery (OMFS), has undergone substantial evolution driven by technological integration. This literature review synthesizes contemporary developments in OMFS, emphasizing digitally-enhanced orthognathic procedures and highlighting innovations that have transformed surgical protocols. Advanced three-dimensional virtual surgical planning (VSP), patient-specific customized osteosynthesis, and computer-assisted surgical simulation have significantly improved functional and aesthetic outcomes. Key findings from recent peer-reviewed studies reveal a paradigm shift toward integrated digital workflows, minimally invasive orthognathic surgery (MIOS), and data-driven outcome protocols. Evidence demonstrates that these technological integrations enhance surgical precision, reduce operative duration, and facilitate superior skeletal stability while optimizing airway dynamics and temporomandibular joint function.

Keywords. Orthognathic surgery; Oral and maxillofacial surgery; Virtual surgical planning; 3D imaging; Computer-assisted surgery; Patient-specific implants; Minimally invasive surgery; Digital workflow; Surgical navigation

Introduction. Oral and maxillofacial surgery (OMFS) encompasses a comprehensive range of procedures addressing congenital, developmental,

traumatic, and pathological conditions of the facial skeleton. Within this specialized domain, orthognathic surgery represents a principal intervention for the surgical correction of dentofacial deformities and skeletal malocclusions. The historical paradigm of surgical planning relied predominantly on two-dimensional cephalometric analysis, analog model surgery, and manual prediction tracings. Contemporary practice has undergone revolutionary transformation through the integration of three-dimensional imaging modalities, computer-aided design and manufacturing (CAD/CAM), and intraoperative navigation systems, fundamentally altering conventional surgical approaches. The implementation of digital surgical technologies enables surgeons to achieve unprecedented precision in osteotomy design, enhanced craniofacial symmetry, and reduced operative time while improving postoperative predictability. This comprehensive review synthesizes evidence from contemporary clinical investigations to elucidate the trajectory of technological innovation and quantify resulting advancements in clinical outcomes throughout the orthognathic surgical continuum.

Relevance. Understanding recent innovations in orthognathic surgery is imperative for optimizing patient outcomes, minimizing procedure-related complications, and standardizing evolving surgical protocols. Given the increasing prevalence of dentofacial deformities and escalating patient expectations for both functional and aesthetic success, the relevance of digital transformation in OMFS cannot be overstated. This review emphasizes the clinical implications of integrated digital workflows, patient-specific instrumentation, and quantitative postoperative evaluation methodologies that collectively define the contemporary standard of care. Furthermore, the emergence of minimally invasive approaches and robotic-assisted surgical systems represents a significant advancement requiring thorough assessment for appropriate clinical integration and validation of efficacy.

Materials and Methods. This literature review synthesized data from recent peer-reviewed publications focusing on technological advancements in OMFS and orthognathic surgery. Sources were identified through systematic database search and digital object identifiers (DOIs), prioritizing studies addressing surgical innovation, digital planning integration, and clinical outcome quantification. The selected articles were analyzed for methodological rigor, technological sophistication, and relevance to contemporary orthognathic surgical practice. Key sources included comprehensive reviews and clinical studies highlighting the evolution of virtual surgical planning (VSP), advancements in surgical accuracy through virtual modeling, implementation of minimally invasive protocols, development of full-digital workflow systems, and the impact of customized fixation systems on postoperative stability.

Results. The reviewed literature demonstrates substantial progression in both preoperative and intraoperative phases of orthognathic surgery, with quantified improvements across multiple outcome measures:

1. Digital Planning and Virtual Surgical Simulation

- Virtual surgical planning (VSP) has emerged as the cornerstone of contemporary orthognathic practice, providing precise three-dimensional simulation of skeletal movements and enabling custom fabrication of surgical splints and patient-specific fixation plates. The integration of cone-beam computed tomography (CBCT) with intraoral digital scanning facilitates creation of composite models that enhance diagnostic accuracy and enable detailed soft tissue simulation.

- Clinical outcomes reflect the efficacy of these approaches, with one study reporting a median surgical accuracy of 1.420 mm

(standard deviation 0.425) when comparing preoperative planning to postoperative results through voxel-based analysis.

2. Advanced Manufacturing and Surgical Execution

- Three-dimensional printing technologies have revolutionized surgical implementation through production of patient-specific implants (PSIs), anatomical models, and surgical cutting guides. The utilization of digital light processing (DLP) printing with biocompatible resins enables fabrication of precise surgical splints that facilitate accurate translation of virtual plans to operative execution.

- Computer-assisted implant surgery (CAIS) modalities—including static guides (s-CAIS), dynamic navigation (d-CAIS), and robotic assistance (r-CAIS)—demonstrate superior accuracy compared to freehand approaches, with meta-analyses indicating progressive improvement across these technologies.

3. Minimally Invasive Surgical Approaches

- Minimally invasive orthognathic surgery (MIOS) incorporates modified techniques such as reduced incision dimensions and limited tissue dissection to decrease postoperative morbidity. Evidence indicates MIOS achieves comparable skeletal outcomes while reducing intraoperative blood loss and enhancing postoperative comfort.

- The learning curve for MIOS has been quantified, with studies indicating approximately 12 procedures required to achieve proficiency, after which significant improvements in operative duration and procedure standardization are observed.

4. Workflow Optimization and Clinical Efficiency

- Implementation of full-digital workflow protocols has demonstrated capacity to improve patient selection and surgical

planning, with one prospective study reporting a 26.5% increase in identification of candidates for less invasive single-jaw surgery through comprehensive digital assessment.

- The integration of structured digital protocols facilitates more precise orthodontic preparation and enhances interdisciplinary communication throughout the surgical-orthodontic continuum.

Conclusion. Orthognathic surgery has undergone fundamental transformation from conventional model-based planning to comprehensively digitalized, patient-specific workflows. The implementation of virtual surgical planning, intraoperative navigation, and customized fixation systems has elevated surgical precision and postoperative results to unprecedented levels. Current innovations emphasize the integration of artificial intelligence algorithms for predictive planning and the refinement of minimally invasive protocols to further enhance patient recovery and outcomes. Future research priorities should focus on validating predictive soft tissue algorithms, establishing standardized digital protocols, expanding accessibility to advanced planning technologies, and conducting long-term comparative outcomes assessments to definitively establish the value proposition of these technological integrations in orthognathic surgical practice.

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