EDITORIAL

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The new face of oral and maxillofacial surgery: artificial intelligence's expanding role

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I. From AlphaGo to Artificial Intelligence (AI) Surgeons

When AlphaGo defeated a world champion at the ancient game of Go in 2016, it shocked the public and heralded a new era of AI entering daily life. This breakthrough spurred interest in applying AI to complex human endeavors, including medicine. Early on, systems like IBM's Watson were tested for medical diagnosis, showing some promise in differential diagnoses but facing limited adoption due to concerns about accountability and accuracy. Hospitals found that while AI could assist in identifying conditions, any misdiagnosis remained the physician's responsibility – necessitating continuous human oversight. The cost and effort to supervise these systems often outweighed their benefits, hampering widespread use. In late 2022, large language models (LLMs) like ChatGPT burst onto the scene, demonstrating remarkable leaps in natural language understanding and generation. These AI models can draft reports, summarize research, and even aid in medical education. However, their use in highly specialized fields like surgery remains limited. AI "hallucinations" – the tendency of models to produce confident but incorrect information – are a well-documented limitation, meaning content from LLMs must be double-checked by experts[1]. Regulatory bodies and healthcare institutions emphasize that without the ability to discern fact from fabrication, clinicians and patients should treat LLM outputs cautiously. Despite these challenges, AI's momentum in healthcare, and specifically in oral and maxillofacial surgery (OMFS), continues to accelerate. Researchers and clinicians are harnessing powerful deep learning algorithms, advanced robotics, and big data to transform how we diagnose conditions, plan treatments, and perform surgeries.

II. Intelligent Treatment Planning and Virtual Surgery

Planning complex jaw surgeries is as much an art as a science – surgeons must predict surgical outcomes, from bite alignment to facial aesthetics. AI is increasingly lending a hand in this arena. In fact, one of the earliest applications of AI in OMFS dates to 1996 in South Korea, where a neural network was used to assist orthognathic surgery planning. In that pioneering project (Kim SG, Kim MJ, Chee YJ. Application of neural network to diagnosis of the dentofacial deformity and treatment plan. In: Abstracts of the 37th Annual Meeting and Scientific Sessions of Korean Association of Oral and Maxillofacial Surgeons, Gyeongju Educational and Cultural Center, Gyeongju, 11-13 April 1996), surgeons input patient data and the neural network suggested one of four possible surgical plans – for example, bilateral sagittal split osteotomy (BSSO) alone versus BSSO in combination with a LeFort I osteotomy or LeFort II osteotomy.(Fig. 1) Under the multiple selection principle, 54.4% of the AI's recommendations matched expert surgeons' plans—a rate significantly higher than chance. This early success demonstrated the potential for machine learning to capture the decision-making of master surgeons and help guide less experienced clinicians. Fast forward to today, and AI-driven planning has evolved with three-dimensional (3D) imaging and simulation. Modern orthognathic planning software, such as IPS

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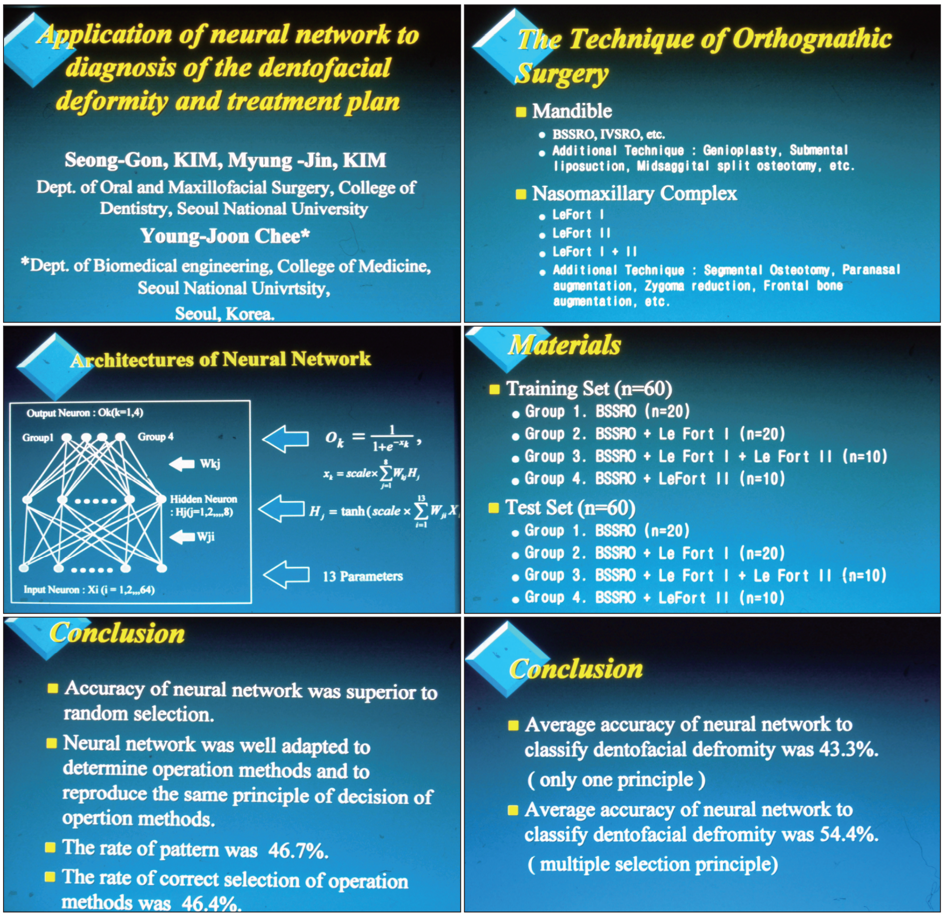

Fig. 1. Representative slides from a pioneering project (presented at the Korean Oral and Maxillofacial Surgery Conference) investigating the use of neural networks for orthognathic treatment planning. Surgeons entered patient data—such as jaw measurements and dental relationships—into the system, and the network proposed one of four surgical plans. (BSSRO: bilateral sagittal split rami osteotomy, IVSRO: intraoral vertial rami osteotomy)
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CaseDesigner (KLS Martin), employs a wizard-based, algorithm-driven workflow with real-time soft tissue simulation and cephalometric analysis rather than relying solely on rule-based or surgeon-driven methods. AI is poised to augment this by analyzing thousands of past cases to optimize surgical plans. Three-dimensional cone-beam computed tomography (CBCT) scans combined with AI algorithms allow for virtual surgical simulations that account for complex facial asymmetries better than 2D plans[2]. Surgeons can virtually "test" different cuts and movements on a patient's jaw model, with the AI predicting outcomes like how the bite will fit or where bone interferences might occur. This is complemented by 3D printing of surgical guides and splints tailored to the AI-augmented plan. The result is a more precise surgery with potentially fewer surprises in the operating room and more predictable results. Indeed, there is now at least one Food and Drug Administration (FDA)-cleared AI software system specifically for jaw surgery planning – in 2023, a company received approval for a tool that generates patient-specific surgical guides and models from CT scans to aid in jaw trauma and reconstruction procedures. Regulatory milestones like this underscore how AI is transitioning from research labs into real-world surgical practice, provided it meets safety and efficacy benchmarks.

III. Ethical and Regulatory Considerations: AI as Assistant, Not Autopilot

As AI becomes more embedded in surgical practice, ethical considerations and limitations require careful attention. One major concern is the "black box" nature of deep learning models – they often do not explain why a certain recommendation or diagnosis was made. This opacity can be problematic in healthcare, where trust and understanding are paramount. Patients and surgeons may be wary of acting on an AI's advice without an explanation, especially if an AI's suggestion conflicts with a clinician's judgment. To address this, researchers are exploring explainable AI techniques that can provide interpretable reasons (for example, highlighting the area of an X-ray that led to a tumor diagnosis). Ultimately, AI should enhance transparency in decision-making, not obscure it. Some experts argue that for AI to be widely adopted, it must earn trust by not only being accurate but also by justifying its outputs. In practice, this means any AI system used in OMFS should allow a "peek under the hood" – whether through confidence scores, visual maps of image analysis, or clear documentation of its training data limits. The risk of AI errors also underlines the need for continued human oversight. AI systems can falter when faced with data that differ from what they were trained on. For example, an AI that learned from adult skull images might misidentify landmarks on a child's X-ray, or a system trained on one ethnicity's facial structures might perform less accurately on another if not properly diversified. Surgeons must remain the ultimate decision-makers, validating AI suggestions against their expertise. Professional guidelines increasingly recommend a "trust, but verify" approach: use AI as an adjunct, but double-check critical outputs. In fact, many hospitals now require that any AI-generated diagnosis or plan be reviewed by a qualified specialist before being acted upon. This failsafe approach acknowledges AI's impressive capabilities while guarding against overreliance on a tool that can occasionally go off-track. High-profile instances of AI chatbots producing medical misinformation with great confidence have been a cautionary tale, emphasizing that inaccurate AI output can be dangerous if not recognized[1]. Therefore, training healthcare professionals to understand AI's strengths and pitfalls is essential – an OMFS surgeon should know enough about their AI tools to spot when something does not look right. Regulatory challenges also play a big role in how quickly AI permeates surgical practice. Medical AI systems often qualify as medical devices and thus require regulatory approval (such as FDA clearance in the United States or Conformité Européenne marking in Europe). Obtaining this approval demands rigorous evidence of safety and efficacy, which is a high bar to meet. For instance, while dozens of AI algorithms for dental imaging exist in research, only a few have earned FDA clearance for clinical use as of 2025. This cautious approach is warranted – it ensures that AI tools have been validated on large patient datasets and that they do not inadvertently harm patients through bias or error. However, the regulatory process can slow down the introduction of useful innovations. Developers and regulators are now grappling with how to monitor AI systems post-approval, since these models can evolve (or "learn") over time. There is a push for adaptive regulatory frameworks that allow AI to improve via updates while still guaranteeing performance. Until such frameworks are standard, expect that AI in OMFS will roll out gradually, focusing first on high-impact areas like imaging analysis where the risk is relatively low and benefits clear.

IV. Real-World Impact and Future Directions

The effectiveness of AI in OMFS is no longer just theoretical – numerous case studies and clinical trials demonstrate its real-world impact. From the early neural network experiment in 1996 that matched expert surgeons' treatment plans (Fig. 1), to recent deep learning models that detect jaw tumors as accurately as specialists[3], AI has proven its worth as a collaborator in care. In daily practice, dentists and surgeons are using AI-powered software to flag abnormalities on radiographs, saving time and catching issues that might be overlooked during busy clinic hours. Orthodontists employ AI to help analyze growth patterns in young patients' jaws, deciding if and when intervention is needed. At major medical centers, surgeons may rehearse complex tumor resections on virtual platforms where AI predicts the difficulty of various approaches, helping choose the safest path. There are also emerging reports of AI improving post-operative follow-up – for example, algorithms that monitor patients' healing via photos or scans, alerting the care team if there are signs of infection or if a bone is not aligning as expected. Looking ahead, the synergy between AI and human expertise will deepen. Rather than replacing surgeons or dentists, AI is poised to augment their capabilities. Imagine an OMFS clinic soon: a patient comes in with a facial tumor. An AI system has already reviewed the patient's scans, medical history, and even the pathology of similar tumors. Within seconds, it provides a report: highlighting the tumor boundaries on the imaging, suggesting the likely tumor type, recommending surgical margins, and warning that due to the tumor's proximity to a blood vessel, extra caution (or embolization) is advised to prevent bleeding. The surgeon reviews these insights alongside their own assessment and formulates a plan – perhaps modifying the AI's suggestions based on nuances it could not know (like patient preferences or subtle clinical exam findings). During the surgery, an AI-driven navigation system helps ensure the resection aligns with the plan, and a robot holds the drill steady for critical cuts. After surgery, AI-assisted monitoring ensures any complications are caught early. In this scenario, the outcome is a product of human skill and AI support working seamlessly together. For this future to fully materialize, ongoing collaboration between tech developers, surgeons, and regulators is key. Ethical AI use, comprehensive training, and patient education about AI's role will foster trust and acceptance. We must also remain vigilant about data privacy

– AI thrives on data, but patients must consent and their information must be safeguarded. Despite current limitations, the trajectory of AI in OMFS is undeniably upward. As one recent review concluded[4], AI shows tremendous promise in propelling OMFS forward and unlocking innovative strategies to overcome clinical challenges. By embracing these technologies with a balance of optimism and caution, surgeons can truly "face the future" – one where smarter, safer, and more personalized surgical care becomes the norm.

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Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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