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Effectiveness of digital planning-assisted orthognathic surgery combined with implantology in the treatment of severe malocclusions: a narrative review of functional and aesthetic outcomes

Eficacia de la cirugía ortognática asistida por planificación digital combinada con implantología en el tratamiento de maloclusiones graves: una revisión narrativa de los resultados funcionales y estéticos

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ABSTRACT

Background: Severe malocclusions impact aesthetics, function, and quality of life, necessitating integrated treatments like orthognathic surgery and implantology. Digital planning has transformed these procedures, improving precision and patient outcomes. This narrative review evaluates the effectiveness of digital planning-assisted orthognathic surgery combined with implantology, focusing on functional and aesthetic improvements in severe malocclusion cases. **Methods:** A systematic search across PubMed, Scopus, and Google Scholar (2014–2024) identified studies on digital planning in orthognathic surgery and its combination with implantology. Inclusion criteria targeted studies involving human subjects that examined functional or aesthetic outcomes. Key focus areas included virtual surgical planning (VSP) and 3D printing and their role in optimising treatment. **Results:** Digital planning-assisted orthognathic surgery significantly improves surgical precision, functional restoration, and aesthetic outcomes. VSP enables detailed 3D simulations, enhancing condylar positioning and soft tissue predictability with millimeter-level accuracy. These technologies reduce surgical errors, optimise implant placement, and facilitate interprofessional communication and patient engagement. Integration with 3D printing supports customised surgical guides, improving workflow efficiency and reducing planning time. Additionally, incorporating transparent aligner systems like Invisalign provides a fully digital continuum of care, enhancing periodontal health, oral hygiene, and aesthetic preferences. **Conclusion**: Digital planning-assisted orthognathic surgery and implantology offer substantial benefits, including improved precision, functional restoration, and aesthetic outcomes. Despite challenges, their potential to enhance patient comfort and surgical success underscores their value in modern dentistry. Future research should address cost barriers and refine predictive models to broaden accessibility.

Keywords: Digital planning, orthognathic surgery, implantology, severe malocclusions, functional outcomes, aesthetic outcomes, virtual surgical planning, 3D imaging.

RESUMEN

Antecedentes: Las maloclusiones graves afectan a la estética, la función y la calidad de vida, por lo que requieren tratamientos integrados como la cirugía ortognática y la implantología. La planificación digital ha transformado estos procedimientos, mejorando la precisión y los resultados en los pacientes. Esta revisión narrativa evalúa la eficacia de la cirugía ortognática asistida por planificación digital combinada con implantología, centrándose en las mejoras funcionales y estéticas en casos de maloclusión grave. **Métodos**: Una búsqueda sistemática a través de PubMed, Scopus y Google Scholar (2014-2024) identificó estudios sobre planificación digital en cirugía ortognática y su combinación con implantología. Los criterios de inclusión se centraron en estudios con sujetos humanos que examinaran los resultados funcionales o estéticos. Las áreas de enfoque clave incluyeron la planificación quirúrgica virtual (VSP) y la impresión 3D y su papel en la optimización del tratamiento. **Resultados**: La cirugía ortognática asistida por planificación digital mejora significativamente la precisión quirúrgica, la restauración funcional y los resultados estéticos. La planificación quirúrgica virtual permite realizar simulaciones 3D detalladas que mejoran la colocación de los cóndilos y la predictibilidad de los tejidos blandos con una precisión milimétrica. Estas tecnologías reducen los errores quirúrgicos, optimizan la colocación de implantes y facilitan la comunicación interprofesional y la participación del paciente. La integración con la impresión 3D permite personalizar las guías quirúrgicas, mejorando la eficiencia del flujo de trabajo y reduciendo el tiempo de planificación. Además, la incorporación de sistemas de alineadores transparentes como Invisalign proporciona una atención continua totalmente digital, mejorando la salud periodontal, la higiene bucal y las preferencias estéticas. **Conclusiones**: La cirugía ortognática asistida por planificación digital y la implantología ofrecen beneficios sustanciales, incluida la mejora de la precisión, la restauración funcional y los resultados estéticos. A pesar de las dificultades, su potencial para mejorar la comodidad del paciente y el éxito quirúrgico subraya su valor en la odontología moderna. Las investigaciones futuras deberán abordar las barreras de coste y perfeccionar los modelos predictivos para ampliar su accesibilidad.

Palabras clave: Planificación digital, cirugía ortognática, implantología, maloclusiones severas, resultados funcionales, resultados estéticos, planificación quirúrgica virtual, imágenes 3D.

INTRODUCTION

Malocclusion often develops when a child begins transitioning into mixed dentition. Malocclusion may lead to changes in face anatomy, speech problems, feeding difficulties, and tongue and cheek biting. Since the cause of malocclusion is unclear, an interprofessional team approach is necessary for an earlier diagnosis (Ghodasra & Brizuela, 2023). Classification is used to standardise diagnosis. Orthodontists use various methods, including braces, spacers, palatal expanders, and clear aligners, to treat mala occlusion. Orthognathic procedures often treat severe malocclusions and dentofacial deformities to improve function, appearance, and related conditions such as obstructive sleep apnea (Khadka et al., 2011; Seo & Choi, 2021; Steenen et al., 2014). However, meticulous soft tissue, skeletal, and occlusal planning is necessary for excellent surgical results. Over the last 10 years, orthognathic planning has increasingly shifted from haptic to digital pathways because virtual planning allows the surgeon to reproduce the final occlusion, skeletal movements, and related soft tissue changes. Patients and the treating orthodontist may also be consulted and informed of these plans. Each person's specific needs may be promptly addressed and finalised via a digital planning session. A stable occlusion must be formed for soft tissue and bone healing. It should ideally be composed of a class I skeleton with an aligned midline, a multi-contact occlusal connection, and an adequate overjet and overbite.

For many years, orthognathic occlusion planning was done using a plaster cast model, which gave the planning surgeon tactile feedback on the stability and tooth contacts (Baan et al., 2021; Fleming et al., 2011; Lee et al., 2021; Nadjmi et al., 2010; Plooij et al., 2011; Wiranto et al., 2013). This is why plaster casts are still often utilised with tactile occlusion planning. There are disadvantages to the plaster cast, such as the need for physical storage and the possibility of fracture or wear. Getting impressions for the case is also unpleasant(Conny & Tedesco, 1983; Fleming et al., 2011; Means & Flenniken, 1970; Nadjmi et al., 2010). These factors, along with the fact that plaster casts are more expensive and time-consuming, are driving an increase in the use of intraoral scans (IOS) as an alternative to taking impressions for dental arch scanning and bite registration (Joda et al., 2017; Joda & Brägger, 2015; Ting-shu & Jian, 2015; Van Noort, 2012).

Concurrently, integrating implantology into orthognathic surgery may improve the look and functionality of those with severe malocclusions. The treatment choice depends on the patient's preferences, the skeletal facial type, bone problems, adjacent tooth disorders, and malocclusion. Because implant failure occurs between 0% and 20% of the time and is associated with bone volume, density, and loading distribution, it is ideal for all cases to have a clear visual representation of the results before surgery (Tarraf & Ali, 2018). Clinicians should consider stress-reducing solutions for implant restoration, such as a shorter cantilever, less offset loads to the buccal or lingual, more implants, larger implant diameters, splinting implants together, and appropriate bone quantity and quality (Goodacre et al., 2003). For the above reasons, a comprehensive assessment of the patient's condition is necessary. Previously, physicians could only conduct two-dimensional evaluations. For example, panoramic images restricted their capacity to evaluate the edentulous area and create implants that fit the space's vertical and horizontal dimensions (Tarraf & Ali, 2018). However, due to advances in engineering and computational analysis, the gold-standard imaging tests for most patients undergoing orthodontic treatment combined with restorative procedures are cone-beam computed tomography and digital dental models(Misch et al., 2005). This narrative review examines the effectiveness of digital planning-assisted orthognathic surgery combined with implantology, focusing on functional and aesthetic outcomes. It aims to explore how these technologies contribute to treatment precision, improve patient comfort, and enhance the overall success of orthognathic surgeries.

METHODS

This narrative review utilised a systematic approach to gather and evaluate the literature on the effectiveness of digital planning-assisted orthognathic surgery combined with implantology in treating severe malocclusions. This framework addresses treating complex malocclusion cases that simultaneously need surgical and implant replacement. Our research team applied official review methods to evaluate the newest findings about how these treatments improve mouth function and appearance.

2.1 Search Strategy:

A systematic search was conducted in major academic databases such as PubMed, Scopus, and Google Scholar. So, key search terms were used to find out the articles that could be pertinent: ‘digital planning in orthognathic surgery,’ ‘implantology in treatment of malocclusion,’ ‘functional outcomes of digital orthognathic surgery,’ ‘aesthetic outcome of orthognathic surgery and implants’ and ‘cone-beam computed tomography for implantology.’ We limited our search to studies in English published between 2014 and 2024, which allowed us to include some of the most recent innovations and techniques in the field.

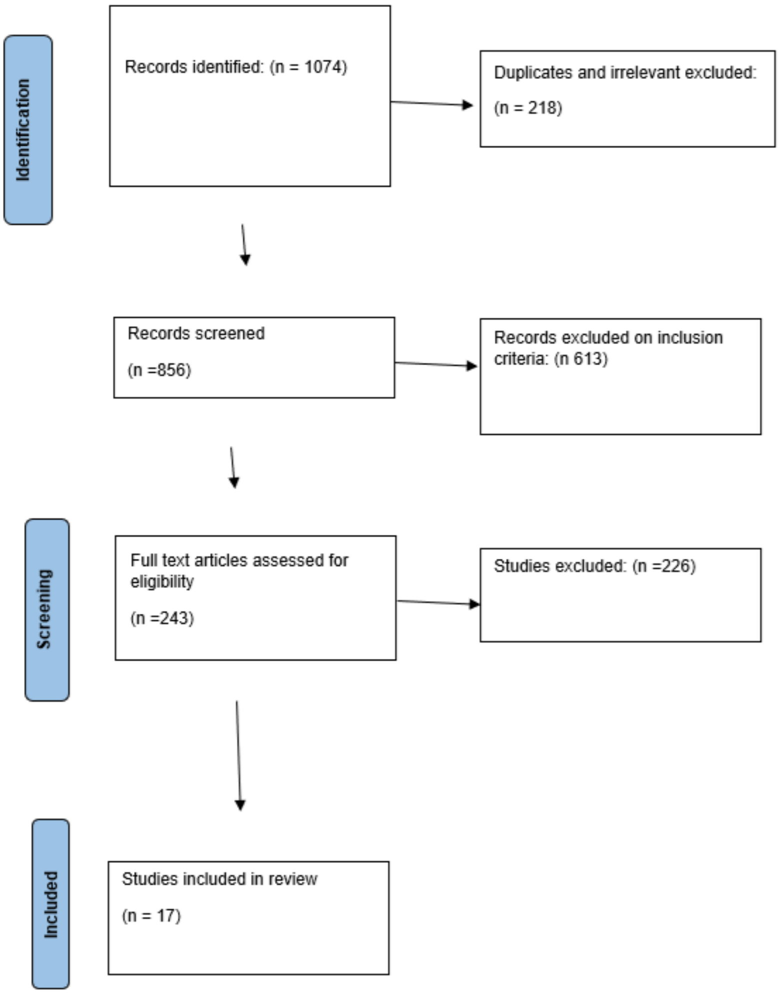
2.2 Inclusion and Exclusion Criteria:

Studies on integrating digital planning orthognathic surgery and its combination with implantology, particularly severe malocclusions, were chosen as eligible studies. The included studies only included studies of human subjects and those that have addressed functional or aesthetic outcomes of these treatments. Studies that failed to demonstrate direct evidence of efficacy or outcomes of these approaches or clear digital focus in their planning were excluded to maintain relevance and to ensure methodological rigour

2.3 Data Categorization and Analysis:

The collected studies were categorised based on their focus areas, orthognathic surgery and implantology and planned in a digital environment with the influence on functional and aesthetic outcomes. Categorising the disciplines made for a thorough review of how each discipline's participation in treatment impacts patients' outcomes. The efficacy of studies that measured clinical effectiveness, patient satisfaction, and long-term stability of treatment outcomes were analysed. It also looked at the use of advanced imaging technologies — cone beam computed tomography and intraoral scans — to increase treatment precision and decrease complications. The findings from the included studies were synthesised to highlight the potential advantages of treatment outcomes, implant placement optimisation, restoration and facial aesthetics using digital planning. This narrative review evaluates the integration of advanced technologies to bring forth the potential benefits of integrating digital planning-assisted orthognathic surgery and implantology technologies, guiding the clinician with the evidence-based management of severe malocclusion cases.

Figure 1. Prisma Flow Diagram



RESULTS AND DISCUSSION

The results of this narrative review suggest that integrating digital planning-assisted orthognathic surgery combined with implantology offers significant improvements in functional and aesthetic outcomes for patients with severe malocclusions. The reviewed studies collectively demonstrate that digital planning enhances the precision of surgical procedures, leading to more predictable results and higher patient satisfaction.

Role of Advanced Imaging Technologies

The evolution of digital technology and software has led to innovative approaches in orthognathic surgical (OGS) planning, enhancing its precision and efficiency. 3D technology applications have replaced traditional two-dimensional (2D) approaches, including human construction and paper-based operations. These applications improve radiograph detection and eliminate the drawbacks of time-consuming 2D methods (Gandedkar et al., 2016). Dental cast simulations employing cone beam computed tomography (CBCT) and substitutes for dental impressions, such as oral scanning, have become popular in the 3D area(Xia et al., 2009)(Naidu & Freer, 2013)(Grünheid et al., 2014). Virtual Surgical Planning (VSP) is a state-of-the-art technology that improves surgical accuracy by providing real-time modifications and 3D visualisation. It is beneficial for intricate operations like orthognathic surgery. Surgeons may use VSP to model different surgical situations, forecast possible results, and precisely adjust the procedure—often to the millimetre—which is essential for both functional and cosmetic outcomes. According to studies, VSP performs more accurately and precisely than conventional surgical planning techniques. For instance, a systematic review conducted by Chen et al. discovered that VSP is noticeably more accurate than traditional techniques for forecasting postoperative outcomes (Chen et al., 2018). Additionally, VSP has been shown to lower surgical margins of error to less than 2 mm, improving overall surgical results. Along with its precision, VSP has significant time-saving advantages. With manual measurements and 2D imaging, traditional planning methods are often laborious; however, VSP may save planning time by up to 30%, increasing efficiency. However, to achieve VSP, gear and software, such as powerful computers and sometimes haptic devices, are needed for an interactive experience (Lin et al., 2023). Real-time changes, scenario simulations, and 3D visualisation tools are all included in the program, and 3D scanners and printers for model and surgical guide creation may be considered hardware.

Several VSP systems are on the market, each with unique advantages and disadvantages. For instance, IPS Case Designer and Dolphin Imaging are two popular systems. While IPS Case Designer offers a more user-friendly interface and requires fewer windows for planning, Dolphin Imaging exhibits better imaging capabilities. Both systems provide equivalent outcomes despite variations regarding acquisition speeds and planning accuracy. In orthognathic surgery, condylar alignment is crucial, and VSP is very good at minimising and improving mistakes. Although the software tissue change prediction models are continually improving, it is generally agreed that VSP provides more accurate predictions than conventional methods. In addition to VSP, the sector has undergone a revolution thanks to 3D printing, which makes it possible to create personalised surgical models and guides that significantly improve surgical accuracy and lower mistakes(Lin et al., 2023). To help with preoperative planning and intraoperative guiding, surgeons may produce precise, patient-specific models utilising technologies like selective laser sintering (SLS), stereolithography (SLA), and fused deposition modelling(FDM). Despite its drawbacks, including high upfront costs and a need for technical know-how, 3D printing offers many more advantages than disadvantages, particularly in customisation and time savings.

When VSP and 3D printing are used in tandem, a smooth transition from virtual planning to actual execution is ensured. These technologies work together to improve workflow efficiency, decrease the chance of mistakes, and increase the predictability of surgical results. Ultimately, this integrated strategy improves patient outcomes in orthognathic surgery by enabling more precise preoperative planning and reducing postoperative problems. Despite the difficulties presented by the need for specialised training and significant expenses, VSP and 3D printing are indispensable instruments in contemporary surgical practice.

Digital planning-assisted orthognathic surgery

Orthognathic surgery and orthodontics together are an essential treatment for dental-maxillofacial anomalies, and this approach is heavily influenced by state-of-the-art digital technology (Beek et al., 2022; Steinhuber et al., 2018; Lin et al., 2018; Cheung et al., 2011; Gateno et al., 2011). The future lies in digital therapy, which offers precise diagnosis and treatment planning (Cicciù et al., 2020; Lavorgna et al., 2019). The transformation of orthognathic surgery is primarily made feasible by computer-assisted surgery (CAS), which includes 3D reconstruction, virtual surgical planning and simulation, computer-aided manufacture (CAD/CAM), and other technologies (Hausfeldld & Mühling, 2001). Virtual or augmented reality-based virtual surgery may help produce integrated and methodical operations by facilitating better team communication and objective and quantitative surgical plan creation. The introduction of Invisalign is significant because it extends the digital simulation phase forward and backwards using a virtual design for tooth movement throughout the treatment procedure.

It is well-recognised that orthodontic-orthognathic treatment benefits greatly from standard fixed appliance orthodontics(Mulier et al., 2021; Yen et al., 2020). Furthermore, new studies have shown that transparent aligners may provide results that are just as aesthetically acceptable as those of conventional orthodontics and have some intrinsic advantages. Zhang et al. gest that clear aligners help adults with fewer dietary restrictions meet their aesthetic demands while making it easier to maintain oral hygiene and periodontal health (Zhang & Yang, 2022). Ke et al. found that Invisalign orthodontic aligners may correct malocclusions just as well as conventional orthodontics, and they even provide advantages such as segmental tooth movement and quicker treatment timeframes (Ke et al., 2019). Invisalign orthodontic aligners may be utilised to complete challenging multiple-jaw orthognathic operations without compromising perioperative or short-term clinical outcomes, as shown by (Kankam et al., 2019). Clear aligners are becoming an increasingly popular alternative, particularly for adult patients. As an orthodontic technology, the Invisalign system cannot fully use digital features in the joint treatment process. Thus, the three elements of combination therapy are not systematically connected and remain separate.

This study first examined fully digital management for skeletal Class III malocclusion to prevent postoperative dentition rescanning and guarantee that the postoperative orthodontics were performed by the preoperative orthodontic design. This method included every orthodontic procedure step— during surgery—into the computerised simulation process. Positive findings were also obtained from the first accuracy evaluation of the fully digital procedure. Except for the y-axis linear deviation of the maxillary, all of the skeletal anatomy's linear deviations were less than 1 mm, and the differences between the virtual and actual results were not statistically significant. In patients with skeletal Class III malocclusion, this exceptive deviation on the y-axis may be due to a predisposition for anterior-posterior recurrence of the maxillary segment, particularly in those with the severely depressed paranasal region and significant surgical anterior displacement. Since all the yaw, roll, and pitch angular deviations were less than 1°, the virtual surgical simulation's rotational accuracy was shown. In one case, the dental alignment simulation deviation was more than 2 mm, but in other cases, it was less than 2 mm(Li et al., 2023). Contrary to the precise movement of the bony structures during virtual design and the impact of the bony structures' spatial placement on the external appearance, minor modifications during the orthodontic technique do not affect the final occlusion. " Due to their elastic construction, clear aligners may also be used, even if their design somewhat differs from the existing alignment.

Better cosmetic performance and non-detrimental clinical outcomes are only two advantages of this novel approach above conventional joint orthodontic-surgical treatment (Kankam et al., 2019). In terms of long-term treatment process visualisation and predictability, the digital simulation component of the Invisalign system performs better than fixed appliance orthodontics. Furthermore, periodontal health and tooth hygiene are better maintained with the transparent aligner. Secondly, the integration of the Invisalign system finally connects the digital components of the procedure, leading to complete digitalisation and more uncomplicated cross-sectional communication. Furthermore, early in the procedure, orthodontic and surgical simulation may be used to monitor the bone placement and the occlusal connection after treatment. This facilitates patient education and explanation of treatment plans as well as timely feedback. However, it has to be improved since it contains several flaws. Even though the fully digital approach necessitates skilled and experienced collaboration, its widespread promotion may be hindered by the need for skilled medical professionals and specific computer-aided surgical instruments. While conventional orthodontics may eliminate extraction gaps and provide adequate occlusal contact, Invisalign is more effective for moderate to severe malocclusion (Djeu et al., 2005; Li et al., 2023). Patient compliance is essential because compliance is essential. After all, each aligner must be changed often. This was an exploratory study, and only skeletal class III patients were included in the small-group experiment. Therefore, many individuals with a range of anomalies must be examined in future studies. However, the development of digital technology and explicit aligners will make the entirely digital technique a viable substitute for treating dental-maxillofacial abnormalities. This is because there is a favourable correlation between the tangible dependability of precise simulation and orthodontics and orthognathic surgery.

Implant Success and Stability

Accurate implant placement is crucial for the long-term stability and longevity of dentimimplants and the success and functionality of prosthetic restorations Correct three-dimensional (3D) placement is crucial for osseointegration, the process by which the implant fuses with the bone and significantly impacts the therapy's biological, functional, and esthetic outcomes (Xing et al., 2024). Improper implant placement may lead to significant adverse effects such as bone resorption, peri-implantitis, and minimal esthetic results(Kraft et al., 2020; Chrcanovic et al., 2014). Furthermore, because it promises shorter recovery times, fewer surgical procedures, and less bone loss in the peri-implant alveolar ridge—all of which can improve soft-tissue healing and potentially improve aesthetic results—immediate implant placement—in which the implant is placed immediately after tooth extraction—has gained popularity (Xing et al., 2024). There are many challenges with immediate implant implantation instead of implant insertion in healed alveolar ridges. These challenges are brought on by the complex architecture of the alveolar process, the gap between the implant surface and the surrounding bone, and other factors that might complicate matters (Araújo et al., 2019; Frizzera et al., 2019). Therefore, careful planning and execution are necessary for quick implantation in order to avoid complications. In this case, surgical guidance and digital planning are essential.

Digital template-guided implant surgery is one method to improve accuracy, especially in quick implant placement. Dentists may improve the predictability of implant placement by using preoperative 3D planning with cone-beam CT or multislice CT imaging and then creating 3D surgical templates (Poeschl et al., 2013; Arisan et al., 2013). These computerised tools reduce the risk of biological and technical problems by guaranteeing that the implants are positioned accurately (Tallarico et al., 2021). Computerised guides enhance patient satisfaction and accuracy, especially for anterior dental implants with essential aesthetic outcomes. Furthermore, implant placement precision may be maintained even in urgent implant surgeries when variances are more common. Digital recommendations promote optimal placement, enhancing stability and yielding physiologically stable outcomes (Chandran K R et al., 2023).

One significant advantage of digitally guided surgery is the reduced soft tissue tension, often brought on by the vast incisions required for flap surgery. With computer-guided surgery, land ap computer-guided surgery; , lap flipping is avoided, recuperation is accelerated, and postoperative (Laverty et al., 2018)v. This reduction in soft tissue manipulation also improves overall surgical accuracy, which is important for delicate, urgent implant procedures. Research on the accuracy of digitally guided implant surgery shows encouraging results. Studies have shown that quick implant insertion using digital guidance provides relatively acceptable accuracy, with errors measured at 0.74 mm for coronal deviation, 1.01 mm for apical deviation, 0.50 mm for depth deviation, and 2.34° for angle deviation. These results are far better than those obtained using traditional methods (Schneider et al., 2009). Additionally, there was no discernible difference in deviation between immediate and delayed implantation; immediate implant insertion demonstrated a somewhat superior accuracy in depth deviation (Feng et al., 2022)(Han et al., 2021). However, it is crucial to realise that individual studies differ and that several factors, including the kind of operation (completely guided vs. partially guided), patient anatomy, and guide design, may impact accuracy (Tallarico et al., 2019; Schnutenhaus et al., 2016).

Among other factors, the kind of supporting tissue—bone-, mucosa-, or tooth-supported—affects how successful digital guiding is (Lou et al., 2021). Research indicates that tooth-supported guides often provide more accuracy, especially for somewhat edentulous (Schnutenhaus et al., 2016). Moreover, digitally guided treatments in the mandible are often more accurate than those in the maxilla due to the rounded shape of the maxilla, which limits angular control (Zhou et al., 2018). Fully guided procedures, which rely on the guide throughout the process, are more accurate than partially guided operations, which remove the guide before implant insertion (Younes et al., 2018; Cassetta et al., 2013).

Notwithstanding the positive results, there are certain disadvantages to using computerised assistance for immediate implant placement. Testing the guide in advance is difficult since the tooth is not present at the extraction site, which might lead to an incorrect guide fit. Future research should examine alternative solutions, such as enhanced preoperative planning or flexible guide designs, since this limitation may affect the operation's overall result.

In conclusion, computerised planning and template-guided surgery are significant advancements in dental implantology and rapid implant placement. These technologies enhance functional and cosmetic results, speed recovery, and reduce failure rates and issues by increasing implant position precision. As technology advances, new advancements in digital guiding and surgical planning tools will likely result in higher success rates and more consistent outcomes in implant dentistry.

Long-Term Outcomes

Patient-reported outcomes are becoming more crucial in the quickly evolving area of orthognathic surgery for evaluating the efficacy and success of traditional and innovative techniques, such as VSP and 3D printing. These outcomes primarily focus on the quality of life after surgery, satisfaction with the surgical result, and other patient-centrededrics that accurately reflect the patient's experience throughout the surgical operation (Silva et al., 2016; Soh & Narayanan, 2013). Numerous studies have examined the quality of life trajectories after orthognathic surgery, measuring the changes in patient experiences using general health and condition-specific approaches. Choi et al. saw significant improvements in mental and physical health assessments after treatment (Choi et al., 2010), indicating a genuine impact on quality of life. Following surgery, patients reported improved quality of life in both the functional and psychological categories, according to several studies (Silva et al., 2016; Sun et al., 2018). Notably, improvements were more pronounced in class III malocclusion in older patients and those who had double jaw surgery (Sun et al., 2018).

Further investigation on patient satisfaction reveals that most patients feel happy after orthognathic surgery. Studies have shown benefits in self-esteem, self-confidence, facial appearance satisfaction, and reduced anxiety and social functioning issues (Seh et al., 2020; Liddle et al., 2015). The fact that a small percentage of responders remain dissatisfied is significant because it suggests a variety of responses that might influence individual traits, upbringing, and interpersonal relationships.

This highlights the necessity for a nuanced approach in patient consultations to encourage realistic expectations and understanding (Hanafy et al., 2019). As technology continues to permeate the surgical sector, it is critical to consider how it impacts patient outcomes. In a study comparing traditional occlusal wafers with CAD/CAM bone splints, Hanafy et al. found that while both groups improved their quality of life after surgery, the technological intervention did not significantly outperform the traditional approach Quality of life after different approaches of orthognathic surgery(Hanafy et al., 2019). This research emphasises how important it is to combine rapid technological advancements with reasonable expectations and to regularly evaluate how these advancements impact patient outcomes in the real world.

The scientific community advocates for study designs with more excellent evidence, including more significant and varied patient groups and extending follow-up duration, to better grasp the long-term consequences of orthognathic procedures on the quality of life (Soh & Narayanan, 2013). The growing understanding of the need for psychological support during treatment and adapting to face changes after surgery also reflects a trend towards a more thorough approach to patient care in orthognathic surgery (Liddle et al., 2015).

In conclusion, patient-reported outcomes are a crucial lens to evaluate the evolving field of orthognathic surgery and provide insightful information about patients' life experiences. Even if technical advancements herald a new era in surgical techniques, patient satisfaction and improved quality of life remain complicated and depend on various factors, including individual medical histories, realistic expectations, and psychological preparedness. Therefore, a thorough understanding of these results gleaned from a complex tapestry of patient stories and statistical data is necessary to guide the future directions of orthognathic surgical treatments.

Discussion

The results of this narrative review highlight the efficacy of digital planning-assisted orthognathic surgery integrated with implantology as a transformative approach to treating severe malocclusions. The new imaging tools, VSP, and 3D printing devices have seriously improved how well surgery works and how a person's appearance changes. Modern CT scans (CBCT) and mouth-scanning devices help doctors find hidden dental problems and improve treatment plans. Moving from 2D images to 3D systems lets researchers get more accurate results and make better measurements, according to research by Gandedkar et al. (2016). New technology processes set better workflows for treatment and better results (Xia et al., 2009; Grünheid et al., 2014). Naidu and Freer (2013) found that 3D imaging lets dentists examine detailed views of hard-to-see body parts during planning treatment.

Virtual surgical planning (VSP) has become a vital new way of doing surgery because it lets surgeons plan and make adjustments with unmatched accuracy. Using virtual simulations before surgery, VSP helps surgeons do their job right the first time and gives patients their best chance at getting better after treatment (Chen et al., 2018). Science shows that using VSP reduces planning surgery time and works better than standard methods (Lin et al., 2023). Even though it is costly to buy and operate and requires special training, VSP gives orthognathic surgery the steady and reliable outcomes doctors need today (Lin et al., 2023).

The inclusion of 3D printing makes the entire surgical step easier. With SLS and FDM technology, doctors can make exact surgical guides and 3D models that make planning transitions faster (Lin et al., 2023). Current research shows that 3D printing lowers surgery complications and raises safety levels for both the patient and surgeon (Mulier et al., 2021). Few places use 3D printing extensively because making machines and finding skilled workers are expensive.

The better combination of ortho work and jaw treatment actively helps improve patient treatment results. More patients are getting Invisalign aligners designed within their digital treatment planning system. By analysing teeth without braces, the study discovered that these aligners look better and help people clean their teeth while fixing complex bite problems (Zhang & Yang, 2022). New research by Ke and two colleagues confirms that Invisalign aligners make treatment more comfortable and cause less waiting than metal braces. The problem lies in how well current aligners work with digital planning tools, but researchers are working to fix this (Mulier et al., 2021). Despite promising results, several research factors were discovered that need better study. Research results cannot be applied universally because many studies use small groups and look back at past events (Chen et al., 2018

Additionally, combined study outcomes from different quality assessments caused difficulties when comparing and understanding the available data. Researchers must do more prominent, longer monitoring studies to see how well these tech works over time, as recommended in studies by Lin and team (Lin et al., 2023). The ability of people to use technology and how much it costs are two significant hurdles in this field. Limited access to expensive digital technologies in resource-limited communities creates unfair possibilities for many to benefit from them. Researchers must work to make low-cost solutions that can fill the gap between current treatment methods (Mulier et al., 2021). Machine learning and artificial intelligence advances are helping improve surgical planning and how accurate models work. AI's ability to assist in making better choices and working more effectively will be a primary focus of future technology exploration (Grünheid et al., 2014).

Compared to traditional methods, digital planning with implantology surgery now sets new standards for treating severe bite problems. Combining advanced imaging, VSP, and 3D printing helps surgeons work more accurately, reduces time, and leads to happy patients. We must find ways to handle current study weaknesses, the high costs involved, and the technological gaps to make these improvements fully accepted and work well over time. This study gives clinicians new information for practising evidence and shows that we must continue researching this growing field.

CONCLUSIONS

Combining digital planning-assisted orthognathic surgery with implantology significantly advances treating severe malocclusions. By using VSP with 3D printing, surgical precision is increased, planning time is reduced, and practical and cosmetic outcomes are improved. Patients benefit from increased self-worth, a better quality of life, and more satisfaction with their appearance. Despite some disadvantages, such as high costs and the need for specific training, digital technology in orthognathic surgery and implantology offers several benefits, making it an essential tool for improving patient outcomes and surgical success. Future research must address the small percentage of patients still dissatisfied with their results and further develop these technologies.

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