

MATERIALS AND TECHNOLOGIES FOR SURGICAL GUIDES

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Abstract

This review looks at the role of surgical guides in dental and maxillofacial surgery, highlighting the benefits and challenges associated with their use. Surgical guides are essential tools that allow surgeons to perform interventions with increased precision, thereby reducing risks and improving long-term outcomes. Made from biocompatible materials such as medical resins, polymers, and metal alloys, these guides are created using advanced technologies, including 3D printing and CAD software. In this context, the review examines the advantages of the guides, such as reducing operative time and minimizing trauma to tissues, as well as disadvantages, such as high costs and rigidity that limit intraoperative adaptability. Future research goals are also addressed, with a focus on biomaterials that can reduce inflammation and accelerate healing, as well as reducing production costs to increase accessibility. The findings suggest that surgical guides represent a major innovation, with the potential to become a standard in surgical practice due to their benefits in terms of safety, efficiency and adaptability. Continuous development in biomaterials and manufacturing technologies will significantly contribute to improving patient experience and surgical outcomes

Keywords: surgical guidelines, biocompatibility, 3D printing, biomaterials, implantology.

Introduction

Surgical guides have revolutionized dental and maxillofacial surgery, providing accuracy and precision that improve patient outcomes and surgical efficiency. These guides are created using advanced imaging and computer-aided design (CAD) technologies to accurately replicate the patient's anatomical structures. The introduction of surgical guidelines allows surgeons to plan and execute procedures with minimally invasive interventions, in line with the trend towards precision and minimally invasive surgery in dentistry. The following review explores the various aspects of surgical guidelines, including the advantages, disadvantages, materials used, and future research directions [1-3].

Surgical guides represent a significant innovation in dental and maxillofacial surgery, playing a crucial role

in ensuring precision and control in complex procedures. Made through advanced imaging and computer modeling technologies, surgical guides are personalized devices designed to replicate each patient's unique anatomical structures. They serve as three-dimensional templates, allowing surgeons to precisely place implants, perform excisions, or perform other maneuvers in delicate areas, reducing risks and significantly improving post-operative outcomes [1-4].

An essential aspect of the development of surgical guides is the materials used. Since these guidelines are applied directly to bone structures or sensitive tissues, it is essential that they are made of biocompatible materials that do not cause side effects and can be effectively sterilized. The most commonly used materials include medical resins and

polymers, which are easy to shape and hold up well to sterilization. Also, advanced materials such as titanium are used for cases that require increased strength, such as

when the guide needs to be firmly stabilized on dense bone structures [2-5, 44-50].

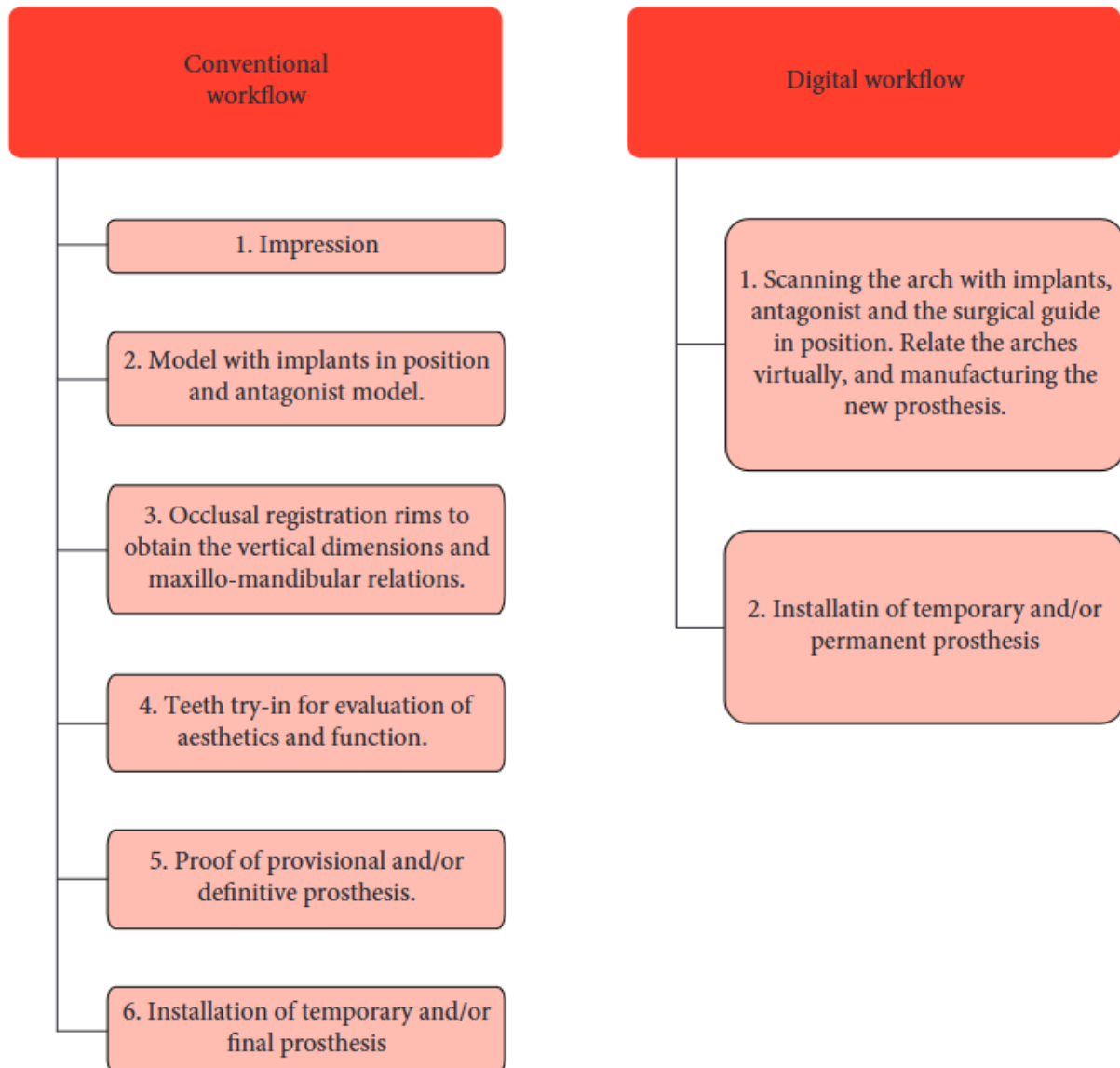


Figure 1. Traditional workflow compared to digital workflow in implantology [5].

Surgical guide manufacturing technologies have developed rapidly in recent years with the advancement of 3D printing and medical imaging. 3D printing technology allows for fast and accurate production of guides, using virtual models based on CT or CBCT images of the patient. Thus, surgeons can visualize and analyze

anatomical structures in detail before the intervention, allowing the creation of a perfectly tailored guide [2-6].

These guides are designed with the help of CAD software, which allows the simulation of interventions and the optimization of implant positioning. This stage is crucial because it ensures that the

guide will fit perfectly on the anatomical structure, providing stability and precise guidance during the intervention [2-6].

Advantages of surgical guides

Surgical guidelines offer several benefits, especially in terms of accuracy and predictability. One of the main advantages is the ability to pre-plan the surgical procedure, allowing for optimal implant positioning and minimizing the risks of complications. [3-7].

They also reduce surgery time, which can help with patient comfort and reduce recovery time. In addition, the accuracy of these guidelines increases the longevity and stability of the implants, contributing to the overall success of the treatment [3-7].

One of the main advantages of using surgical guides is their ability to ensure accurate and predictable implant positioning, thereby reducing the risk of error and improving long-term results. By using these guidelines, surgeons can avoid critical anatomical structures such as nerves or sinuses, thus preventing post-operative complications and ensuring better implant stability [5-8].

In addition to precision, surgical guides contribute significantly to reducing operative time. By pre-planning the intervention, the surgeon has a clear guide to the necessary steps, which reduces the

time required for intraoperative adjustments [6-8].

This operational efficiency is beneficial for both the patient, who spends less time in the operating room, and the medical team, who can work faster and more organized. A shorter operative time also reduces the risk of infections and increases the patient's post-operative comfort, contributing to a faster recovery [6-8].

Another important advantage of surgical guides is that they can reduce the need for invasive interventions. The guides are designed to fit the patient's bone structure perfectly, allowing for a minimally invasive approach with smaller incisions and reduced trauma to soft tissues. This leads to faster healing and a reduction in post-operative discomfort, as well as greater patient satisfaction with the procedure [6-8].

In addition, surgical guidelines improve pre-operative planning. Using 3D images and specialized software, surgeons can simulate the intervention, visualizing exactly how they will place implants or perform other maneuvers. This level of detail allows for better anticipation of outcomes and facilitates discussions with the patient, who can better understand the process and benefits of the intervention [6-8].

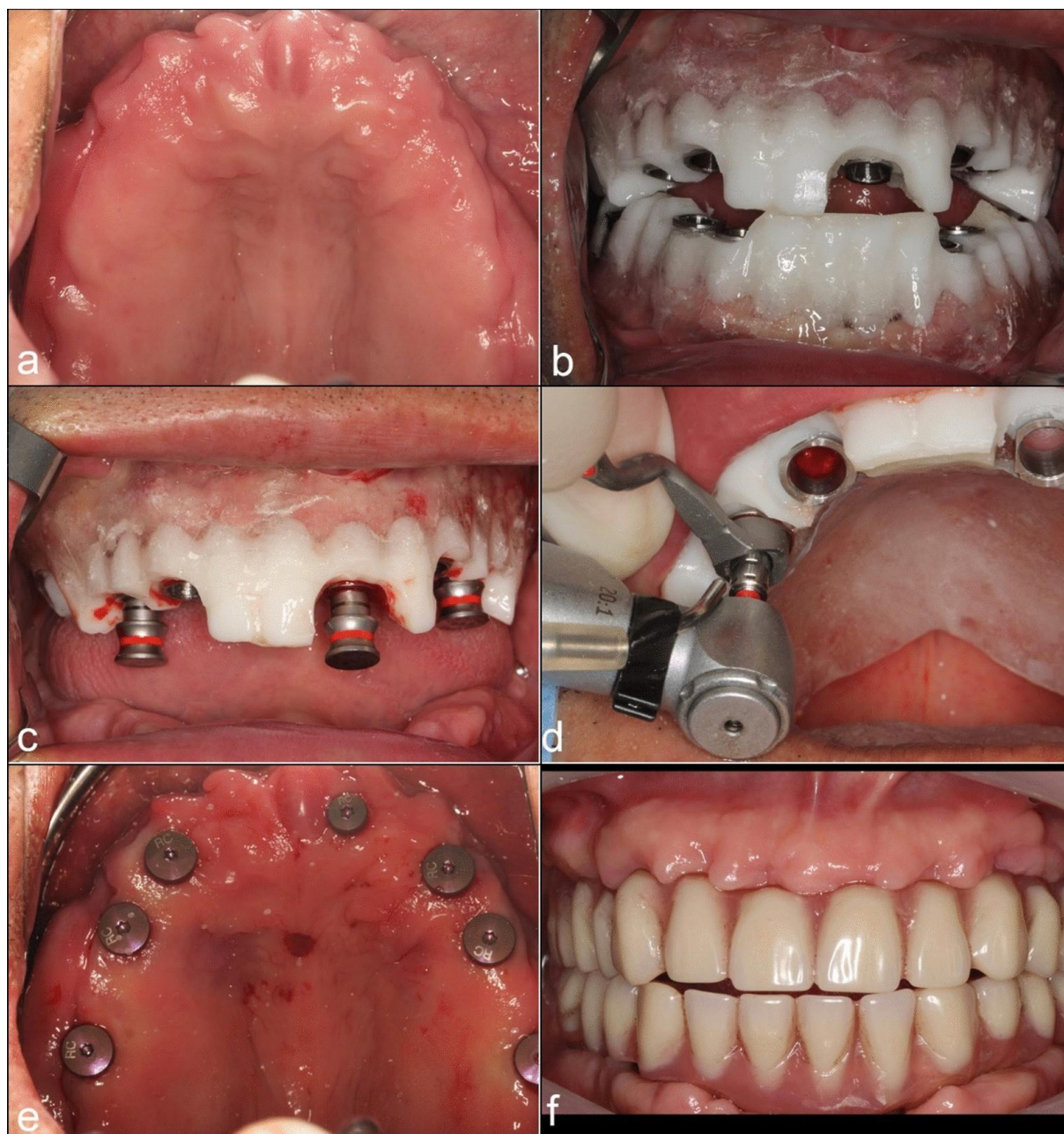


Figure 2. Guided surgery utilizing a mucosa-supported guide produced through CNC milling. a) An edentulous maxilla presenting adequate keratinized gingiva. b) Surgical guides created for both the upper and lower jaws. c) The guide was secured onto the edentulous arch using fixation anchors placed through its sleeves. d) Osteotomy was performed with the assistance of drill guides and precision instruments. e) A total of seven implants were inserted following a flapless surgical protocol. f) A screw-retained fixed prosthesis was immediately installed, adapted from a previously used complete denture [8].

Disadvantages of surgical guides

Despite their benefits, surgical guidelines also have limitations. They can be expensive, both in terms of production

and the need for advanced technology. Creating guides takes time and specialized software, which may not be accessible to all practitioners. In addition, the guidelines are

rigid and do not take into account unexpected changes during the intervention, which can limit adaptability during the procedure [9-11].

Although surgical guidelines have brought significant improvements in the precision and efficiency of surgical procedures, they also have certain drawbacks and limitations. First, the high cost is a major barrier to the widespread use of surgical guides. Their production involves advanced technologies, such as 3D imaging and computer-aided design (CAD) software, which require expensive equipment and skilled specialists. Thus, not all practitioners have access to these resources, limiting the use of the guidelines only to certain clinics or centers with adequate resources [9-12].

Another disadvantage is the time required to produce the surgical guide, which can delay the planning and implementation of the intervention. The process involves several stages, from scanning the patient and processing the images to printing or making the guide itself. This waiting period can be uncomfortable for the patient, especially if the intervention is urgent. In addition, any change in the surgical plan or the patient's anatomy between the time of the scan and the time of the intervention may require adjustment or rework of the guide, which adds additional time and costs [10-13].

Types of materials used for surgical guides

Surgical guides are usually produced from biocompatible materials, such as medical resins and polymers. These materials are chosen for their compatibility with imaging technologies and their ability to withstand sterilization. Other materials,

such as titanium, can be used in cases that require additional rigidity and durability. The choice of material is essential to ensure patient safety and the success of the procedure [10-14, 50-56].

The materials used for surgical guides are essential to ensure their biocompatibility, durability and precision during interventions. The most common materials are medical resins and biocompatible polymers, which are easy to mold and hold up well to sterilization, making them ideal for use in sterile environments in operating rooms. Acrylic resins, for example, are commonly used due to their rigidity, which allows the guides to remain stable on bone structures [11-14].

For cases that require a higher level of durability, such as complex procedures or those involving dense bone structures, guides made of metal alloys such as titanium can be used. Titanium is highly resistant and biocompatible, but its use is rarer due to higher costs [11-15].

With the advancement of 3D printing, materials such as polyetheretherketone (PEEK) and other thermoplastics have gained popularity. They allow the manufacture of customized guides, which can be adjusted according to the specific structure of the patient, providing flexibility and increased precision in surgical procedures. The choice of material thus depends on the needs of the procedure and the patient's specifications [12-16].

Future research objectives and the importance of biomaterials

The future of surgical guide research focuses on optimizing materials and technologies to improve the performance and affordability of these devices. A major

objective is the development of biomaterials that offer increased biocompatibility, reducing inflammation and side effects in contact with human tissues, thus essential oils can be used for soothing and anti-inflammatory farceutical effects. Innovative biomaterials, such as biodegradable polymers and advanced metal alloys, have the potential to integrate surgical guides into natural healing processes, contributing to faster and more efficient recovery for patients [17-23].

Future research also aims to increase the flexibility of the guidelines to allow for greater adaptability during interventions. Current guidelines are relatively rigid, and surgeons face difficulties in cases where intraoperative adjustments are necessary. The development of flexible and modular materials, which offer surgeons greater freedom of adaptation, could revolutionize the way guides are used in surgery [23-26].

Another goal is to reduce the costs associated with producing surgical guides, making them more accessible to a wide range of practitioners and patients. 3D printing and CAD technologies are evolving rapidly, and research is pursuing more economical production methods that allow custom guides to be manufactured at a lower price [26-33].

As biomaterials and 3D technology continue to advance, there are promising prospects for personalized surgical guidelines tailored to each patient's specific needs. In the future, surgical guides could become standardized devices in surgical practice due to their ease of production, increased biocompatibility, and customizability. Thus, these innovations would contribute to improving the safety and efficiency of surgeries, significantly

transforming the patient experience and outcomes [34-43].

Conclusions

Surgical guidelines represent a significant advance in dental and maxillofacial surgery. Their ability to provide precision, reduce intervention time, and improve implant stability highlights their value in modern practice. However, the challenges of cost, rigidity and affordability must be addressed through continuous research and technological innovation. As the field continues to evolve, surgical guidelines will likely become more adaptable and accessible, bringing additional benefits to practitioners and patients.

Surgical guides combine high-quality materials with advanced technologies, providing essential support for surgeons in performing complex procedures. They contribute to increasing accuracy, reducing intervention time and improving patient safety. As research continues to evolve, surgical guidelines have the potential to become the standard in surgical practice, providing patients with predictable, high-quality outcomes.

Surgical guides provide precision, efficiency and risk reduction, which are essential for the success of surgical procedures. With well-executed planning and the use of these personalized guides, surgeons can achieve superior results, thus making the surgical experience safer and more efficient for patients.

Although surgical guides offer notable advantages, they also have limitations related to cost, production time, rigidity and patient comfort. These drawbacks should be considered whenever planning the use of a surgical guide so that

a balance is struck between the benefits offered and the potential drawbacks.

Future research in the field of surgical guidelines focuses on improving materials and techniques to increase their precision and flexibility. There is a growing interest in using biomaterials that integrate better with human tissue, thereby reducing

healing times and improving outcomes. Advances in 3D printing and materials science are expected to play a pivotal role in the development of next-generation surgical guides. Research is also geared towards reducing production costs and increasing the accessibility of these advanced tools.

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