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Review Article

Innovative Digital Technologies in Oral Implantology and Maxillofacial Surgery: A Step Forward

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Abstract

Background: Digital technologies are developing rapidly and have become a part of dentists' daily practice. Digital technologies are applicable in general in all areas of oral and maxillofacial care can contribute to the accurate diagnosis of oral diseases and improve the delivery of health care services.

Purpose: The purpose of this study was to provide a comprehensive overview of the state of fundamental and applied research on Innovative digital technologies oral implantology and maxillofacial surgery, as well as discuss the prospects for its development and application

Methods: The inclusion criteria were full-text articles exclusively published in English language, and the use of digital and robotic technologies in treatments within the fields of oral implantology, oral surgery, mfs and others.

The systematic review included articles from Google Scholar, Medline, Scopus, Web of Sciences, PubMed was conducted.

Results: Using criteria for what to include and what to exclude, we selected 181 studies that were relevant to our review, and narrowed it down to 42 full-text articles were selected of high methodological quality innovative digital and robotic technologies in implantology and oral maxillofacial surgery.

According to our findings and analysis of selected articles, the promise and current advancements of the Innovative digital technology are exciting and are revolutionizing the field of oral implantology and oral maxillofacial surgery.

With the development of science and technology, the use of Innovative digital and robotic technologies in dental and maxillofacial medicine has promoted the development of intelligent, precise and minimally invasive treatments.

Conclusions: The creation of a virtual dental patient using specialized software and the use of sophisticated dental imaging techniques (such as 3D cone beam computed tomography, facial scanning, intraoral scanning) can be used for accurate preoperative clinical diagnosis, simulation, treatment planning in dental practice and better patient compliance with treatment regimen.

Keywords: Guided implant surgery; Digital and robotic oral maxillofacial surgery

Introduction

In the near future, innovative digital technologies will change the existing model of oral and maxillofacial treatment and indicate new directions for further development. Innovative digital technologies have significantly changed the clinical approach in dentistry in recent years. Digital dentistry is an innovative direction in which information technologies are used for the diagnosis and treatment of diseases of the oral cavity [1]. The use of digital technologies allows you to accurately diagnose diseases, accurately plan treatment stages and achieve predictable results [2-4]. Digital innovations are not just changing dentistry, they are taking it to the next level, making processes more accurate, convenient and faster [4].

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These changes not only optimize the work of specialists, but also allow patients to be more informed and actively participate in the treatment process. Digital technologies are significantly reduced the operation time and its invasiveness, also improving the psychological and physical comfort of patients [5-7].

The introduction Digital tools have significantly changed diagnostic processes (e.g., Computed Tomography (CT), Cone Beam Computed Tomography (CBCT), Nuclear Magnetic Resonance (NMR), ultrasonography, etc.) [8-13].

Digital technologies have revolutionized various areas of dentistry, from treatment planning and design to the prototyping stages, from implant procedures to customized dentures and Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM) devices.) [14-17].

Particularly in implant surgery, prosthodontics, and restorative dentistry, the introduction of digital planning and previsualization software's and the have allowed for significative improvements in communication with patients, in the explanation of treatment planning goals, and in patients' operative and psychological comfort [18,19].

3D Digital Modeling of Dental Implantation

The trend in dental implantation with the introduction of digital technologies has stimulated the development of guided implantation surgery using surgical templates allows to reduce the risk of complications and increase the effectiveness of treatment. The use of 3 methods and surgical templates also ensures the ideal position of the implant without damaging the surrounding anatomical structures. When preparing the bone bed, the depth of preparation is planned based on computer indicators of bone tissue parameters [20-22].

The stages

- Computed tomography
- Intraoral scan
- Preparation of a surgical template
- The template can rest on the jawbone, mucous membrane, teeth
- Surgical stage implant placement
- Orthopedic stage crown placement

Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM) technology uses CT scan data to plan implant restorations. Using CAD/CAM and manufacturing technology, the dental team can design a customized dental restoration with high precision and precision fit. CAD/CAM-based surgical guides have many advantages. The accuracy of CAD/CAM technology in dental implant planning and the predictable transfer of the preoperative plan to the surgical field have been documented. The technologies are pre-programmed with individual implant depth, angles, mesiodistal and labiolingual placement [23,24].

When planning dental implantation, computerized stratigraphy, computerized 3D modeling, preparation of surgical templates [25,26].

With the use of 3D printers, it is possible to reduce the probability of these complications. This three-dimensional computer-aided implantation and surgical planning not only allowed for an accurate preoperative assessment of anatomical constraints, but also facilitated preoperative planning of implant position along with virtual implant placement and subsequent transfer of virtual treatment plans to the surgical phase through static (guided) or dynamic (navigation) systems, based on CAD/CAM technology [27-29].

Computer-assisted implantology, being highly predictable and minimally invasive in nature, has also made it possible to place implants in patients with complex problems after significant changes in bone anatomy due to atrophy. Given the significant advances in the field of computer-aided implantology, attempts are currently being made to fully automate implantology. Digital planning and fabrication of a virtual wax-up, implant position, abutment design, surgical guide, provisional restoration, and as well as final restoration.

Disadvantages and limitations associated include computerized 3D modeling [30-32]:

- Error in receiving data or incorrect image processing
- Deviations from the planned position of the implants, especially in the coronal and apical parts of the implants, as well as in the angle of inclination of the implants.
- Inaccurate fixation of the template, leading to its displacement during perforation.
- Mechanical errors caused by tilting drills during perforation.
- Change in position of surgical instruments due to decreased mouth opening.
- Potential for thermal injury due to limited access for external irrigation during osteotomy preparation during flapless implant placement using surgical guides.
- Does not allow intraoperative change of implant position.

The use of navigational implantology allows the procedure to be carried out faster, safer and more precisely, reduces the surgical time, increases the predictability and efficiency of the treatment. Thanks to the further development of computer technology, dynamic navigation is now increasingly used in the clinical practice of implantology [33,34]. The implant bed can be prepared in the far distal areas where vertical space is limited.

Dynamic navigation assumes that tool positions can be recognized by a reference body and assigned during virtual planning. The location of the markers varied significantly between systems. Further development of surgical procedures using virtual and augmented reality technologies will improve the quality of implantological care [35-37].

Dynamic navigation systems with intraoral markers enable accurate implant positioning, which is comparable to the static-guided implant surgery. 3D-printed markers provide less accurate results compared to prefabricated markers, attached before CBCT scan.

Use of custom implants and digital additive manufacturing technologies and methods made it possible to create individual implants based on Cone Beam Computed Tomography (CBCT) data for each individual clinical case opens up new possibilities for the rehabilitation of patients with significant resorption of jaw bones [38]. Selective Laser Melting (SLM), is a CAD/CAM technique that allows the creation of complex Three-Dimensional (3D) structures created using image-based computer-aided design techniques.

With Selective Laser Melting (SLM) technology, individual implants can be made for individual patients. Oral rehabilitation in patients with severe atrophy using an individual titanium subperiosteal implant could be a solution with great potential to solve the well-known problems of traditional implantology [39].

Robotic System Applications in Oral Implantology

In 2011, an image-guided robotic system for dental implants was proposed [40].

Three years later, an improved version of this robotic system was introduced, allowing more accurate drilling of complex types of implants.

Robotic applications in oral implantation mainly include [41]

- Preoperative digital 3D scanning of the implant site and imaging data collection/diagnosis analysis;
- Digital implant surgery plan design;
- Real-time navigation and automatic drilling during the operation to improve the accuracy of dental implant surgery, reduce surgical trauma, and shorten the operation time.

Robotic applications in implantology can perform minimally invasive surgery by drilling directly into the gum mucosa, which significantly reduces surgical and wound recovery time. During drilling, the robot can also monitor the patient's movement to calibrate the position, reducing human error to a lower level, making the process more accurate and safer [42].

The successful application of medical robots has also garnered enthusiasm for research on robotics in dentistry, which breaks through the previous oral diagnosis and treatment models and promotes a new avenue of technological innovation. With the development of static surgical guidance over the past few decades, implant placement protocols have made tremendous strides in ensuring accurate placement of dental implant fixtures. Robotic implant surgery is a new form of dynamic surgical guidance that, in addition to visual navigation, offers tactile guidance for implant planning, osteotomy preparation, and implant placement [43,44].

Robotic dental implant placement represents a new form of dynamic surgical guidance that, in addition to visual navigation, offers tactile guidance for implant treatment planning and osteotomy preparation. and implant placement [45-49].

Use of Digital Technology Jaw Reconstructive Surgery

The development of digital technology in computer-aided surgery has revolutionized jaw reconstructive surgery. The use of 3D printing technology in maxillofacial surgery includes operations for injuries, defects of pathological origin, complex reconstruction of the jaw joint, and correction of complex facial asymmetries [50,51]. With the development of preoperative design, computer-assisted maxillofacial surgery continued to improve. Robotics has been successfully applied in oral and maxillofacial surgery, and robots are also being developed for special operations in oral and maxillofacial surgery, such as velopharyngeal surgery [52,53].

The role of robots in oral and maxillofacial surgery mainly includes:

- Acquisition and reconstruction of 3D cavity image data mouth and maxillofacial area before surgery, analysis of the characteristics of the lesion and development of a targeted surgical plan; and
- Precise segmentation, reshaping, displacement, and fixation of the craniofacial bone according to the surgical plan.

Virtual surgical planning is quickly becoming the standard of surgical planning for orthognathic surgery. Computer surgical simulation has significantly improved the efficiency and accuracy of the treatment of dentoalveolar deformities in orthognathic surgery, improves the efficiency of preoperative examination and makes it possible to illustrate multidimensional correction at the dental and skeletal level [54-57].

Virtual surgical planning provides preoperative surgical information, and the production of guide templates can help reduce intraoperative surgical inaccuracies. In orthognathic surgery, a robotic system has been developed to help reposition bone segments [58]. An autonomous maxillofacial surgery system has been developed with the assistance and control of a surgeon.

Use of Three-Dimensional (3D) Computer Technology Treatment of Gunshot Wounds of the Face

Manufacturing (CAD/CAM) in the medical field has revolutionized reconstructive surgery, which is well documented for head and neck reconstruction and among another disciplines [59,60]. Treatment of gunshot wounds of the face using Three-Dimensional (3D) computer technology, Virtual Surgical Planning (VSP), three-dimensional modeling using custom titanium implants has significantly improved the efficiency and accuracy [61,62].

Based on CT images of the skull, a biomodel of the skull is digitally created in CAD, then the biomodel is printed on a 3D printer and a custom implant is manufactured. Individual implants for the reconstruction of craniofacial defects had high dimensional accuracy, showed high efficiency, reduced operation time and good aesthetic results [63]. Together with the development of artificial intelligence, new horizons are opened in the diagnosis and treatments of diseases dentistry and OMFS

The benefits of digital dentistry include:

- The ability to carry out all stages of treatment at a qualitatively new level, which implies
- High precision restorations,
- Long warranty period
- Impeccable aesthetic qualities

Together with the development of artificial intelligence, new horizons are opened in the diagnosis of diseases. Predictive diagnostics based on algorithms of artificial intelligence allows to detect possible problems related to the health of teeth and gums in the early stages, even before they become noticeable to the patient or the doctor. This gives an opportunity to prevent the development of the disease and start treatment at early stages.

Along with the development of innovation, the need for training specialists who are able to work with the latest technologies increases. This requires a revision of curricula, the introduction of digital medicine courses and an emphasis on the practical application of new tools in dentistry.

Conclusion

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Author Statements

Conflict of Interest Disclosure

The author declares that he has no competing Interest. None of the authors have relevant financial relations with a commercial interest.

Authors' Contributions

MK: Conceptualization, Methodology, Writing – original draft, Writing – review & editing; HG Supervision, Validation, review & editing.

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