



DENTAL IMPLANTOLOGY

COMPUTER SUPPORTED IMPLANT GUIDED SURGERY USING 3D PLANNING SOFTWARE

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Abstract

Purpose: To evaluate the effectiveness of implant treatment using computer 3D modeling and surgical guided.

Materials and Methods: The study included 148 patients who underwent prosthodontics rehabilitation using dental implants in 2017-2022. 3D computer-aided modeling and surgical guide were used to plan the operation. To conduct a comparative analysis of the treatment results, two groups were formed: In group A (included 75 patients, fully guided surgery), in group B (included 73 patients).

Results: In patients Group A intraoperative or immediate postoperative complications were noted (errors in the position, inclination), anatomical risk structures were invaded, after 3 years producing a survival rate of 96.2%. In patients Group B, intraoperative complications were recorded; membrane perforation 4, errors in the position of the implants 16, the inclination of the implants 18, fenestration 12, after 3 years producing a survival rate of 97.6%. Mean marginal bone loss (MBL) patients in Group A were significantly higher than patients in group B ($p < 0.05$). In patients Group A the average surgical time from time of anesthesia to the placement of the healing abutment was 10.6 ± 2.9 min per implant, in patients Group B, the average surgical time was 16.4 ± 1.5 min per implant.

Conclusion: The 3D modeling method and the controlled positioning of the implant allows surgical access with minimal trauma, reducing treatment time and complications.

Keywords: Dental implants, Surgical guide, 3D Printed guides, Errors and Complications

Introduction

The use of dental implants significantly increases the functional and esthetic effectiveness of orthopedic treatment of patients with various forms of tooth loss, providing complete medical and social rehabilitation. However, according to various authors, 5-26% of patients after dental implantation develop complications, accompanied by a complex of functional and structural disorders ¹⁻⁶. One of the important factors predetermining the effectiveness of dental implantation is the correct position of the implant by the plan of prosthetics. The correct placement of the implant has several advantages, such as favorable esthetic and prosthetic results, as well as providing an optimal axis of load on the implant ⁷. Even small deviations from the axis of implant placement cause difficulties in installing the final prosthesis, and installing an implant with the correct axis reduce biomechanical complications and the likelihood of implant failure. Improper positioning of the implant often leads to the desorption of mechanical bone tissue ^{8, 9}. An adequate surgical diagnosis is of utmost importance to evaluate the quality and quantity of bone available to avoid complications and damage to important anatomical structures.

The development of new visualization technologies such as cone beam computed tomography (CBCT) has led to great progress in preoperative planning compared with panoramic radiography since it provides three-dimensional data on the patient's anatomy. Computed tomography and modern dental implant planning programs can accurately calculate the anatomical and topographic parameters, choose the optimal implant size ^{10, 11}.

Now CT or cone CBCT is a common preoperative diagnostic method and provides more complete data on bone quality and quantity, as well as anatomical limitations. Also, it is now possible to put dental implants in an ideal position virtually, using various programs using data provided by CBCT scans. As technologies develop, the use of modern digital technologies significantly changes the classical approaches to planning and treating implant surgery, moving from traditional techniques to computercontrolled technology ¹²⁻¹⁵.

The trend of dental implantation with freehand implant placement technology has changed to the use of surgical guides. For guided implant surgery there are several elements required: an imaging dataset tomography CT, or CBCT surgical planning software, and an x-ray guide for transferring results to planning software. When planning dental implantation, computed tomography, 3D computer-aided modeling and surgical guided with the manufacture of 3D printers can reduce the risk of these complications and increase the effectiveness of treatment. This whole process can be performed in such a way that the ideal position of the implant can be achieved without damaging the surrounding anatomical structures. When preparing a bone bed, the depth of preparation is planned following computer indicators bone tissue parameters ¹⁶. The work of the drill is carried out through metal cylinders placed in a template that provides the right direction and the required depth of the bone bed, maintaining a distance of 2 mm from the anatomical structures. Implant planning software allows for virtual implant placement following future prosthetics needs, taking into account the existing anatomical situation. Justification of the advantages of a guided implant surgery compared to classical implant placement can expand its application in everyday clinical practice. The study aimed to evaluate the effectiveness of implant treatment using computer 3D modeling and surgical guided.

Materials and methods

The study included 148 patients with various forms tooth loss (female (n = 72), male (n = 76), (age range 38-62 years) who underwent prosthodontics rehabilitation using dental implants in 2017-2022. All patients underwent complex clinical, laboratory, and instrumental examinations for diagnosis and treatment planning. CT was used for information regarding anatomical constraints, bone volume and bone quality. 3D computer-aided modeling and surgical guided were used to plan the operation. Patient groups were compiled to evaluate treatment efficacy using computer-assisted 3D modeling and surgical templates. In group A (included 75 patients, fully guided surgery), the preparation of implants sites was accomplished using a surgical guide and implants were placed using a surgical guide. In group B (included 73 patients) the preparation of implants sites was accomplished without a surgical guide and implants were placed without a surgical guide. Total of 583 implants were installed. During the diagnostic and planning stages of the operation, patients of group A underwent a scan of the alveolar bone, which was loaded into 3 Shape Implant Studio (Figure 1).

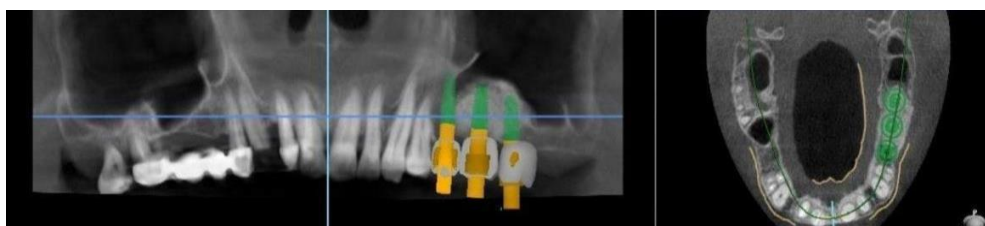


Figure 1: The virtual positioning of the implants in the software.

In the 3 Shape Implant Studios working file, 3D computer modeling and virtual planning of surgical guides were carried out (Figure 2). Surgical guides modeled on a 3 Shape computer program was made of biocompatible printer (Stratasys) (Figure 3).

After checking in the oral cavity, the surgical guides were finally corrected, disinfected, immersed in a 70% ethanol solution for 20-25 minutes, then, after washing with a Chlorhexidine solution, it was placed in a disinfected container and prepared for surgery.



Figure 2: Computer-assisted guided design project in the maxilla



Figure 3: Finished 3D printing guide

The surgical guide was used when drilling the implant site and to perform guided implant placement. Osteotomies were performed according to metal sleeves following the planned positions and angulation of the implants in the bone. In patients in group A, implantation was performed using surgical guides that provided the direction of the axis of the forming bone and the required depth and implants were installed. For patients of group B, implantation was according to the surgical protocol of the implants used. In the postoperative period, patients received prophylactic antiinflammatory therapy and were under dynamic observation. The postoperative control CT image is taken after the implant surgery, to confirm the position of the implants (Figure 4).



Figure 4: Postoperative control CT image is taken after implant surgery, to confirm the position of the implants

To assess the stability of implants, the resonance frequency analysis (RFA) method was used during implant placement, after 3-6 months using Osstell Mentor device. Depending upon the ISQ values and patient preference the loading of the implants was immediate or delayed. In 16 cases implants were immediate functional loaded with ISQ values above 165 and 82 cases implants were delayed functional loaded? The prosthetic phases started with an optical impression with an intraoral scanner and the files were imported into the prosthetic CAD, where the virtual waxing of the restoration was carried out, taking into account the volumes, shapes of the occlusal teeth with the antagonist arch. The prosthesis was tightened to the manufacturer's recommendations (15 Ncm for prosthetic screws and 30 Ncm for abutment screws. The outcomes of the study were collected both directly at the time of surgery (intraoperative complications, the stability of the implant), and the annual checkups (implant survival). Clinical examination was performed to evaluate peri-implant and periodontal tissue, implant stability (Fig. 5). Prosthodontics treatment failure was defined as the need to remake prosthesis for any reason. Patients underwent dynamic and regular clinical and radiation monitoring (Fig. 6.).



Figure 5: Control CT image is taken after prosthetic rehabilitation



Figure 6. Intraoral frontal view partial denture upper jaw

The success of oral implant rehabilitation was; implant success; complications; and marginal bone loss (MBL). A radiograph was used to detect any bony abnormality and evaluate alveolar bone around each implant and made as an average value. Postsurgical change in marginal bone level was assessed by digital x-ray were taken immediately (baseline for comparison) and 3 months after implant installation, after prosthesis loading, 1 year and 3 years after the implant installation.

Statistical analysis

Statistics were used to calculate and analyze the mean marginal bone loss of implants. The differences between followup periods were tested by paired Student's t-test. All analyses were carried out using SPSS (SPSS Software Company, Chicago, IL, USA). p values < 0.05 were considered statistically significant.

Results

Patients in group A did not have any intraoperative or immediate postoperative complications (no errors in the position, inclination, and depth of the implants), no anatomical risk structures (inferior alveolar nerve, maxillary sinus) were invaded, and no cortical bone perforations occurred.

In patients group B intraoperative complications were recorded; membrane perforation 4, errors in the position of the implants 16, the inclination of the implants 18, fenestration 12 (Table 1).

Table 1: Complications at the time of surgery

Complications	Patients Group A n=(75)	Patients Group B n=(73)
Sinus Membrane Perforation	0	4
Errors in the Implants Position	0	16
Implants Inclination	0	18
Fenestration	0	12

The mean MBL after prosthetic loading patients Group A n=75 was $0,47 \pm 0.23$ mm, the mean MBL after prosthetic loading patients Group A n=73 was $0,51 \pm 0.28$ mm. The difference between MBL value at 3 years post-installation patients Group A was $0,76 \pm 0,28$ mm and of the patient's Group B was $0,94 \pm 0,31$ mm ($p < 0,05$) (Table 2).

Table 2: MBL of each group and implant installation after 3 years

Time after implantation	Patients Group A n=(75)	Patients Group B n=(73)
After implant prosthetic loading 3 years after implant installation	$0,47 \pm 0.23$	$0,51 \pm 0.28$
Difference between	$1,23 \pm 0.34$	$1,45 \pm 0.61$
MBL value at 3 years postinstallation	$0,76 \pm 0.28$	$0,94 \pm 0.31$

Mean marginal bone loss (MBL) patients in Group B were significantly higher than patients in group B ($p < 0.05$). These MBL results are within the threshold indicating success. In patients Group A the average surgical time from time of anesthesia to the placement of the healing abutment was 10.6 ± 2.9 min per implant, in patients Group B, the average surgical time was 16.4 ± 1.5 min per implant. After 3 years, producing the survival rate of patients in Group A 97.6% and patients of Group B survival rate 96.8%. Discussion For an effective implant, rehabilitation takes into account the anatomical, functional and esthetic requirements. Modern trends in dental implantation dictate the development of minimally invasive procedures with a reduction in the time of surgical intervention and an increase in the healing rate with fewer postoperative complications¹⁷.

The program scans the complete computed tomography of important instruments for the planned and placement of implants. 3D digital imaging techniques gained popularity given their ability to achieve predictable and accurate results. Using a specially designed computer program, virtual implant position planning is then transferred to surgical guided required for dental implant surgery.

CBCT combined with dental implant software; surgical guides will improve the accuracy of implant position to the area of surgery taking into account esthetic, biomechanical and functional requirements 18-20. Safety and efficacy of guided surgery closely related to its accuracy, as implants are inserted in proximity to vital anatomical structures.

There are many studies in the specialized literature on the reliability and accuracy of fully controlled implantation. However, when applying this technique, there may be a deviation between planning and the actual position of the implant, which can occur for various factors: tomographic scanning, the transmission of planning data, manufacturing and inadequate stability of the surgical guide, drilling errors, implant placement ²¹.

As a result of the deviation of the positions of the implants between the stages of planning and intervention, they can cause fenestration, damage to anatomical structures such as the sinus, lower alveolar nerve.

Implant placement accuracy is the sum of all errors that occur during the entire treatment procedure.

General protocol of 3D surgery guide following steps:

Obtaining a three-dimensional virtual maxillofacial model; Virtual implant placement planning;

Virtual planning of surgical guide;

Manufacturing of a surgical guide on a 3D printer.

Sometimes before surgery, the surgical guide makes corrections if necessary. The importance of the clinical significance of 3D guide implant surgery may be appropriate in situations where multiple parallel implants are needed, and where the degree of accuracy is critical for prosthetic restoration. Surgical guide modeled using a 3D computer program ensure placement of the implant with a predetermined optical axis, maintain the necessary distance of the implant from the anatomical structures, ensure the parallelism of the implant, and facilitate proper placement of the implant.

The implant placement can be performed using a surgical guide, the operation is performed with accurate and minimal tissue damage relieves complications. Analysis of nearest and remote results in the presented work to conclude that the use of a surgical guide, reduces risks, complications including damage to the mandibular nerve, sinus perforation, fenestration, or dehiscences and increases the effectiveness of treatment. Implant placement through to precise surgical guidance more accurately than placing a hand in an osteotomy; guides allow the installation of dental implants in the most optimal position for future prosthetics allow you to control the position, depth and inclination of the implant.

3D guide implant surgery allows you to avoid procedures for increasing bone tissue by optimizing the use of existing jaw bone; guides allow flapless surgery while maintaining periosteal microcirculation and lessen the likelihood of edema; with controlled implant surgery, patients experienced less pain intensively and for shorter periods; reduces surgery time compared to conventional implant placement, guide implant surgery was an easier treatment option for patients with severe anxiety about surgery.

Minimally invasive guide techniques prevent the intra and post-operative patient morbidity in terms of pain, swelling and bleeding.

Conclusion

The 3D modeling method and the controlled positioning of the implant allow surgical access with minimal trauma, reducing treatment time and complications. This method should be performed by experienced specialists who have sufficient experience in the routine implantation procedure.

Conflict of Interest

The author declares that he has no conflict of interest and there was no external source of funding for the present study.

Source of funding

None of the authors have any relevant financial relationship(s) with a commercial interest. The work was not funded.

Informed consent

Informed consent was obtained from all individual participants included in the study.

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ՀԱՄԱԿԱՐԳԶԱՅԻՆ ՊԼԱՆԱՎՈՐՄԱՐ ԱՏԱՄՆԱՅԻՆ ԻՄՊԼԱՆՏԱՑԻԱԿ՝ 3D ՊԼԱՆԱՎՈՐՄԱՆ ԾՐԱԳՐԱԿԱԶՄԻ ԿԻՐԱՌՄԱՐ

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Ամփոփում

Նպատակը: Գնահատել իմպլանտների բուժման արդյունավետությունը՝ օգտագործելով համակարգչային 3D մոդելավորում և վիրաբուժական շարժում:

Նյութեր և մեթոդներ: Հետազոտությունը ներառել է 148 հիվանդի, ովքեր 2017-2022 թվականներին ենթարկվել են օրթոպեդիկ բուժման իմպլանտների կիրառմամբ: Վիրահատությունը պլանավորելու համար օգտագործվել են համակարգչային 3D մոդելավորում և վիրաբուժական շարժում:

Բուժման արդյունքների համեմատական վերլուծություն անցկացնելու համար ձևավորվել է հիվանդների երկու խումբ՝ A խմբում (ներառյալ 75 հիվանդ, լիովին ուղղորդված վիրահատություն շարժումների կիրառմամբ), B խմբում (ներառյալ 73 հիվանդ առանց շարժումների կիրառմամբ վիրահատություն):

Արդյունքներ: A խմբի հիվանդների մոտ չեն նկատվել են ներվիրահատական կամ անմիջական հետվիրահատական բարդություններ (սխալներ տեղադրված իմպլանտի դիրքում, առանցքի շեղում, անատոմիական կառույցների վնասում), 6 տարի անց ապահովվելով 97,6% գոյատևման մակարդակ; մեմբրանի պերֆորացիա 4, իմպլանտների դիրքի սխալներ 16, իմպլանտների թերություն 18, ֆենեստրացիա 12, 6 տարի հետո գոյատևման 96,2% ցուցանիշ:

B խմբում միջին սահմանային ոսկրային կորուստը (MBL) հիվանդները զգալիորեն ավելի բարձր էին, քան A խմբի հիվանդների մոտ ($p < 0,05$):

A խմբի հիվանդների մոտ վիրահատության միջին ժամանակը էր $10,6 \pm 2,9$ րոպե մեկ իմպլանտի համար, B խմբի հիվանդների մոտ վիրահատության միջին ժամանակը $16,4 \pm 1,5$ րոպե մեկ իմպլանտի համար էր:

Եզրակացություն: 3D մոդելավորման մեթոդը և իմպլանտի վերահսկվող դիրքավորումը թույլ են տալիս ատամնային իմպլանտացիա նվազագույն վնասվածքներով, նվազեցնելով բուժման ժամանակը և բարդությունները:

КОМПЬЮТЕРНАЯ ХИРУРГИЯ ИМПЛАНТАТОВ С ИСПОЛЬЗОВАНИЕМ ПРОГРАММНОГО ОБЕСПЕЧЕНИЯ ДЛЯ 3D-ПЛАНИРОВАНИЯ

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Резюме

Цель: Оценить эффективность имплантационного лечения с помощью компьютерного 3D-моделирования и хирургического шаблона.

Материалы и методы: В исследование включено 148 пациентов, прошедших ортопедическую реабилитацию с использованием дентальных имплантатов в 2017-2022 гг. Для планирования операции использовались компьютерное 3D-моделирование и хирургический шаблон. Для проведения сравнительного анализа результатов лечения были сформированы две группы: в группу А (включили 75 пациентов, операция по полному шаблону), в группу В (включили 73 пациента).

Результаты: (ошибки положения, наклона), прорастание в анатомически опасные структуры, через 3 года выживаемость 97,6%.

У больных группы В зарегистрированы интраоперационные осложнения: перфорация мембраны 4, ошибки в положении имплантатов 16, наклон имплантатов 18, фенестрация 12, через 6 года приживаемость 96,2%.

Средняя потеря маргинальной кости (MBL) у пациентов в группе В была значительно выше, чем у пациентов в группе А ($p < 0,05$).

В группе пациентов А среднее время операции от момента анестезии до установки формирователя десны составило $10,6 \pm 2,9$ мин на имплантат, в группе пациентов В среднее хирургическое время составило $16,4 \pm 1,5$ мин на имплантат.

Заключение: Метод 3D-моделирования и контролируемое позиционирование имплантата позволяют осуществлять хирургический доступ с минимальной травмой, сокращая время лечения и количество осложнений.