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ORIGINAL ARTICLE

ACCURACY OF A ROBOTIC DENTAL IMPLANT NAVIGATION SYSTEM IN DENTAL IMPLANT PRACTICE

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Abstract

Objective: To evaluate the implant positioning accuracy using a robotic implant navigation system in dental implant practice.

Methods: The analysis of the treatment of 16 patients using a robotic implant navigation system in stages implant surgery and dental implant prosthetic rehabilitation performed for the period 2022-2023.All patients underwent a complex clinical, laboratory study, computed tomography (CT).

A total of 46 implants were installed using the Navident (ClaroNav) navigation system a flapless or minimal flap approach. 25 implants were completely edentulous and 21 implants were installed in a partially edentulous area.

To assess the accuracy of dental implant placement using preoperative plan cone beam computed tomography (CBCT), deviations between the planned and installed implant positions were analyzed. The coronal deviation was measured as the distance between the centers of the implant coronal platform. Apical deviation was measured as the distance between the centers of the implant apical. Angular deviation was measured as the angle of the axis of the implant center.

Success of implantation and success of prosthetics of implant- supported reconstructions were evaluated. Data were statistically analyzed with.

Results: No intra-operative or immediate post-operative complications were noted after procedure. The postoperative of the patients was favorable.

For all implants, the mean deviations were: 0.21 mm at the entry point (lateral) and 0.27 mm at the apex. The average angle deviation from the actual and planned implant position was 1.32 degrees. Patients were satisfied with the functional and aesthetic results of implantation.

Conclusion: Robotic implant navigation system allows for precise implant placement, the level of experience of the surgeon and the location of the implant do not affect the accuracy of placement and the timing of the procedure.

Keywords: *digital technologies, artificial intelligence, guided implant surgery, dental implant, navigation system.*

Introduction

To eliminate surgical risks in implant treatments, it is very important to have detailed preoperative planning to ensure correct placement of the implant, taking into account the characteristics of the alveolar bone (bone quality, thickness and height) and the anatomical changes in the surgical site (e.g. nasal fossa, mandibular canal, mental foramen) and sinuses).[1]

However, various complications arise at different stages of implantation, such as damage to adjacent structures, aesthetic problems, peri-implant inflammation and even implant rejection.[2]

Along with the development of digital technologies, in the last decade, implantology has gained a lot of popularity guided implant surgery (GIS), which allows the planned restorative design to be transferred directly to the surgical field.[3]

These methods include the use of surgical templates that can be produced using conventional computer-aided design / computer-aided manufacturing (CAD/CAM) technologies (milling or stereolithography).

Thus, the use of a surgical template makes the operation less invasive, reduces the risk of complications and has great prospects for development.[4]

Although there are reports comparing the use of a surgical template and a freehand implant, it is not entirely clear whether a surgical template can actually increase the accuracy of the implant. In that direction, many studies are conducted to evaluate the effectiveness of the method.[5]

In recent years, the use of artificial intelligence has also become widespread in oral implantology.[6]

Artificial intelligence (AI) - imitates human intelligence and improves its characteristics, using deep analysis methods, this model

Computer science, aimed at performing various specific functions that require human intelligence.[7]

There are studies in the literature in which this method was used to interpret anatomical. The use of artificial intelligence systems in the interpretation of CT images provides the doctor with many advantages and can help in detailed implantation planning.[8]

Robotics is a breakthrough technology that will change diagnostic and treatment protocols in dentistry while improving the overall quality and scope of patient care.[9]

Artificial intelligence has been used in various fields of medicine, but its integration in dentistry has occurred quite recently, it is obvious that it will make a great contribution to the development of dentistry, will lead to much better treatment results.[10]

The term "artificial intelligence" was coined by John McCarthy, mathematician, in 1955 and is widely known as the father of artificial intelligence.[11]

In the last decade, the introduction of artificial naturalness (AI) and robotic technologies in implant dentistry has opened up new vistas for the development of the field, ushering in a new era of development of this advanced treatment method. Artificial intelligence (AI) and robotic systems increase the accuracy of implant placement, reducing human error and ensuring high treatment efficiency.[12]

The field of dental implantology has seen tremendous progress in recent years thanks to the integration with robotic technology and artificial intelligence (AI).[13]

AI suites are equipped with algorithms that analyze extensive patient data to aid in diagnosis, treatment planning, optimizing the implant placement process, and increasing implant survival rates.

Along with all these benefits, the balance of trust between human factor and robotic technologies must be addressed while maintaining the highest standards of ethical norms.

Artificial intelligence (AI) algorithms make it possible to analyze a huge amount of data, helping doctors to choose optimal and treatment plans by combining it with the clinical anatomical features of the patients and adapting it to the needs of the individual patient.[14]

Artificial intelligence is used to screen, diagnose and treat patients and has also been used in the research of new drugs and vaccines, monitoring and tracking important indicators, symptoms and other data to help identify potential health problems at an early stage.[15]

However, there is little research data on the reliability and accuracy of autonomous robots.

Despite the progress reported in this field, there are challenges and ethical considerations that need to be reviewed and a new approach is needed.

Navigated implant surgery based on CT image data has been introduced in dental implantology to improve the accuracy of implant placement and prevent potential complications. Surgical navigation systems for implant placement, determine virtual location in real time, track implant drills and the patient throughout the operation.

Surgical navigation systems for implant placement, determine virtual location in real time, track implant drills and the patient throughout the operation

One of the main advantages of robotic technology in implant dentistry is its accuracy and precision, as robotic systems can offer optimal solutions among complex anatomical structures with exceptional precision, reducing the risk of errors and complications.[16]

Several successful case studies published in the literature have demonstrated the effectiveness of robotic and artificial intelligence-assisted implant dentistry.[17]

For example, robotic systems have been used to perform complex implant surgeries with high precision, resulting in improved implant survival rates and patient satisfaction.

AI algorithms have helped accurately identify bone quality and quantity, facilitating optimal implant placement and reducing the risk of implant failure. These advances have allowed for shorter operative times, improved aesthetic outcomes, and improved patient comfort.

For example, robotic systems have been used to perform complex implant surgeries with high precision, resulting in improved implant survival rates and patient satisfaction. AI algorithms have helped accurately identify bone quality and quantity, facilitating optimal implant placement and reducing the risk of implant failure.[18] These advances have allowed fo shorter operative times, improved aesthetic outcomes, and improved patient comfort.

Disadvantage of robotic Surgical navigation systems is the ability to determine the torque when inserting the implant.

Despite the many benefits, there are also challenges and ethical considerations associated with the integration of robotics and artificial intelligence in implant dentistry.[19] One of the primary concerns is the proper balance between human expertise and reliance on technology.

In 2017, the FDA approved YOMITM (Neotsis, Miami, Florida, USA), which became the world's first computerized navigation robotic system to improve the clinical accuracy of dental implant surgery.[20]

The YOMI navigation system provided control of drill depth, orientation and position, thereby avoiding custom fabrication of a surgical template and operator hand deviation, providing high predictability and accuracy in preparation for dental implant osteotomy.

Artificial intelligence algorithms help accurately determine the quality and quantity of bone, promoting optimal implant placement and reducing risk, reducing surgical time, improving aesthetic results and increasing patient comfort.[21]

While robots provide precision and artificial intelligence promotes analytical prowess, the human element in dentistry remains.

However, most navigation studies are in vitro studies, so it is important to obtain the results of applying this technique on clinical material

Material and Methods

The analysis of the treatment of 16 patients using, using a robotic implant navigation system in stages implant surgery and dental implant prosthetic rehabilitation performed for the period 2022-2023.All patients underwent a complex clinical, laboratory study, cone beam computed tomography (CT).

The inclusion criteria for this study were as follows:

(1) patients with total or partial defect of dentition,

(2) absence of uncontrolled systemic diseases contraindicated for implantation,

(3) good oral health.

Exclusion criteria were as follows: limited mouth opening, presence of untreated periodontitis, significant resorption in the implantation site, presence of systemic disease that makes the patient unsuitable for implants.

A total of 46 implants were installed using the Navident (ClaroNav) navigation system a flapless or minimal flap approach. 25 implants were completely edentulous and 21 implants were installed in a partially edentulous area

To assess the accuracy of dental implant placement using preoperative plan cone beam computed

tomography (CBCT), deviations between the planned and installed implant positions were analyzed. The coronal deviation was measured as the distance between the centers of the implant coronal platform. Apical deviation was measured as the distance between the centers of the implant apical. Angular deviation was measured as the angle of the axis of the implant center.

The DICOM CBCT file was imported into the Navident system for treatment planning with design of implant placement, future crown and abutment design (figure 1-7).

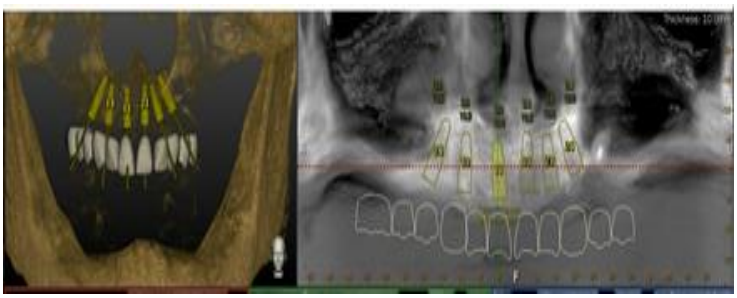

Figure 1. *Upper jaw complete edentulous recovery 6 implants*

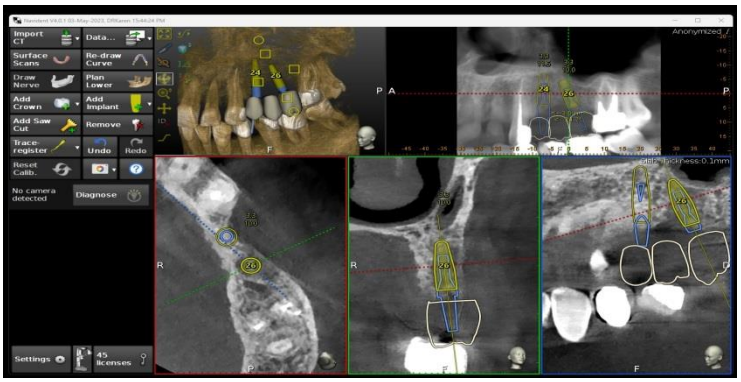

Figure 2. *Upper jaw angular implant placement to bypass sinus floor*

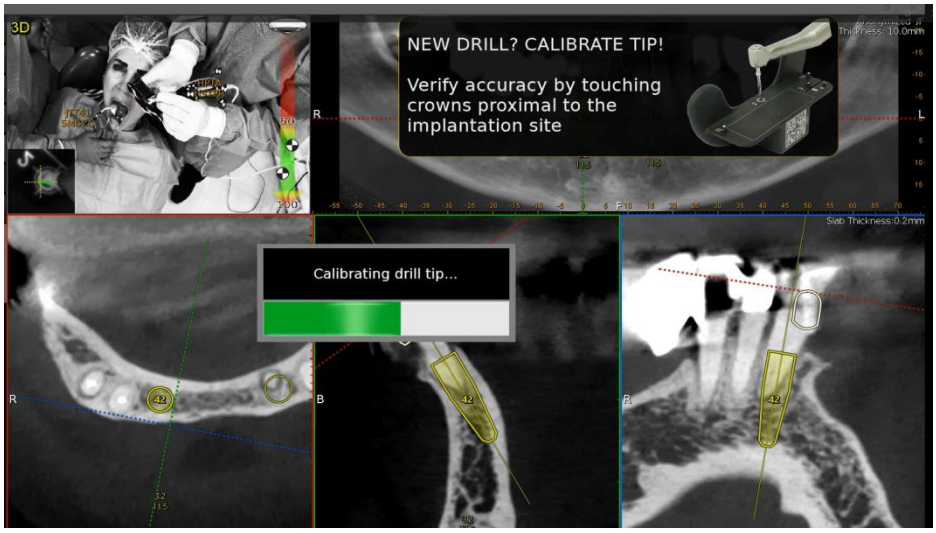

Figure 3. *New drill calibration for the system to recognize prior starting the drilling process*

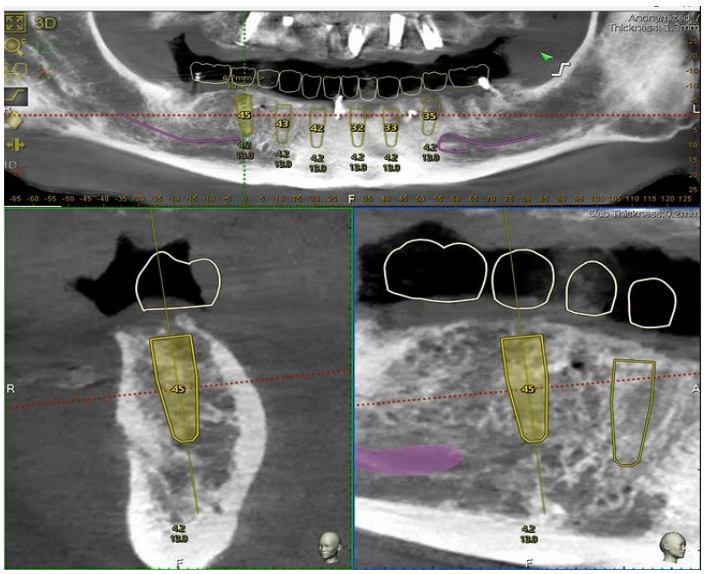

Figure 4. *Lower jaw implants, nerve position*

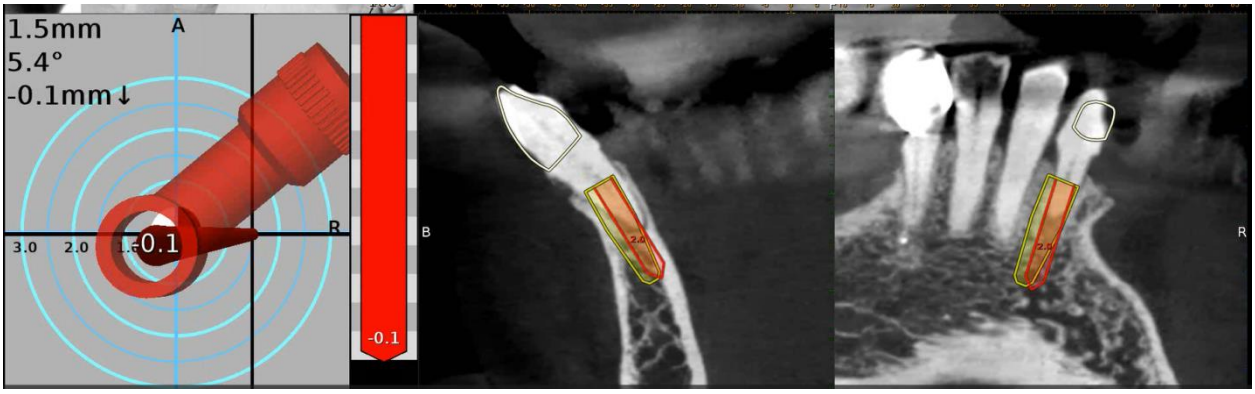

Figure 5. *Drill is too far from the placed implant on CBCT*

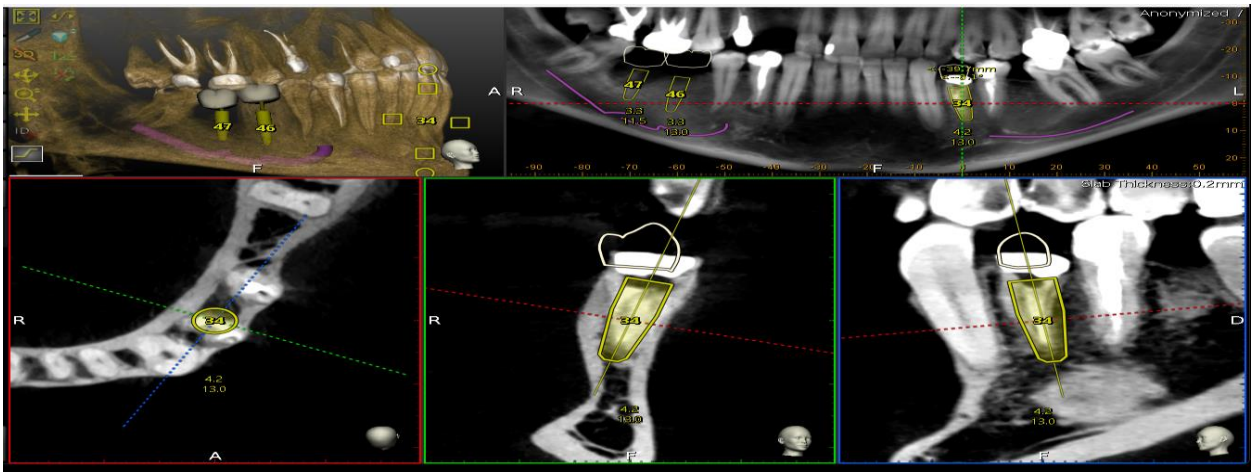

Figure 6. *Lower jaw implants placement taking into notice the important structure (nerve)*

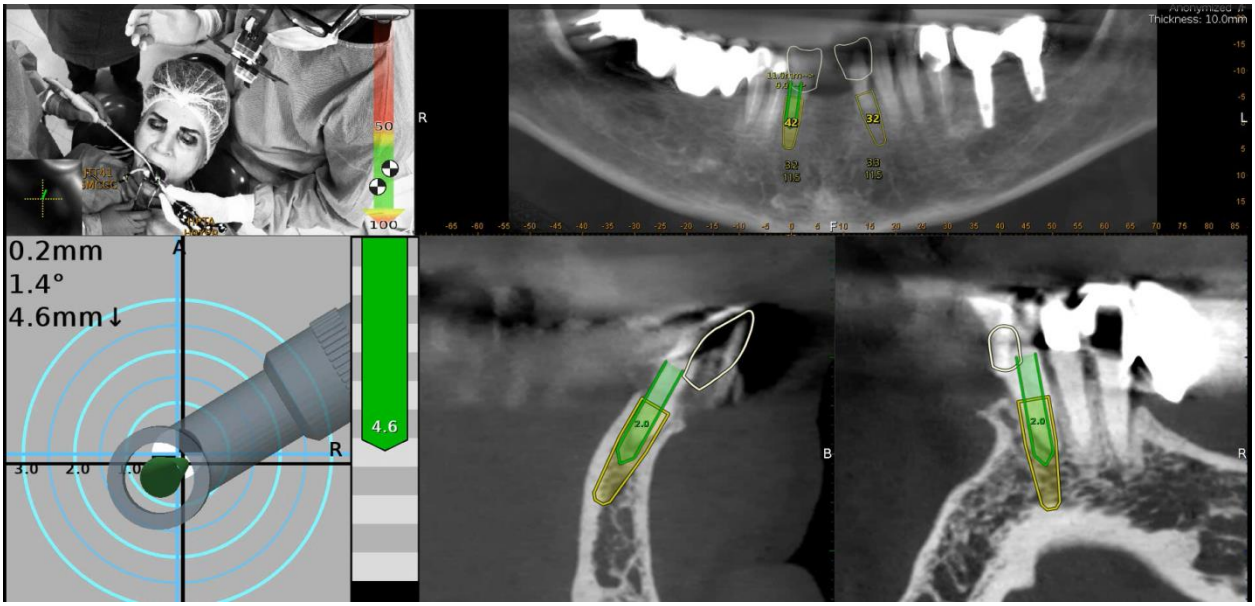

Figure 7. *Drill is in the correct position according to the plan*

Surgical procedure

The Head-Tracker has been installed and tested for stability. Trace registration was performed by marking four landmarks on the teeth using a panoramic 3D image of the jaw and then tracing the landmark areas using the tracing tool while the camera and software collected 100 points on each tooth. Navident automatically registered the Head-Tracker to a CBCT scan of the patient's maxilla based on the collected points.

Before use, each drill was calibrated and checked for accuracy. A small incision was made to accommodate the reduction flap. All osteotomies were performed at 800 rpm. the virtual implant was repositioned intraoperatively using Navident software, and the rest of the site preparation was performed according to the final angulation using drills. Osteotomies were performed at two angles and monitored in real time, and the same procedure was used for implant placement. The cover screw was attached before the surgical site was sutured.

To assess the accuracy of dental implant placement using preoperative plan cone beam computed tomography (CBCT), deviations between the planned and installed implant positions were analyzed. The coronal deviation was measured as the distance between the centers of the implant coronal platform. Apical deviation was measured as the distance between the centers of the implant apical. Angular deviation was measured as the angle of the axis of the implant center.

Once the surgery was completed, the file was converted to an STL file, allowing the laboratory to access the treatment plan.

Success of implantation and success of prosthetics of implant- supported reconstructions were evaluated. Data were statistically analyzed with.

Results

No intra-operative or immediate post-operative complications were noted after autografting procedure. The postoperative of the patients was favorable.

For all implants, the mean deviations were: 0.21 mm at the entry point (lateral) and 0.27 mm at the apex. The average angle deviation from the actual and planned implant position was 1.32 degrees. Patients were satisfied with the functional and aesthetic results of implantation.

Discussion

Research is currently underway to improve the integration of artificial intelligence with computer design and manufacturing (CAD/CAM) to optimize the entire implantation process, providing a more predictable and efficient implantation process.[22,23]

One of the most important factors influencing the result of implantation therapy is the accuracy of implant placement. To ensure the correct position of the implant installation in accordance with the design of the prosthesis a surgical guide is used, however, the errors of surgical guides generated by computed tomography (CT) depend on the manufacturing method and design.[24]

In the modern world, artificial intelligence refers to a technology that can imitate human cognitive skills, such as problem solving, which depends on algorithms for predicting results based on a set of data.[25]

Thanks to a large number of artificial neurons (or nodes) connected into neural networks, the system evaluates large volumes of data to perform specific tasks, among which diagnostic data, personalized treatment, and treatment evaluation play an important role.[26]

Neural networks are a set of algorithms that compute signals through artificial neurons that function like the human brain. The medical robotics industry has recently shifted its focus to autonomous robotic technologies that can independently perform a procedure without constant supervision.

The development of artificial intelligence (AI) in healthcare research has led to its spread in dentistry. Artificial intelligence in dentistry is emerging as an auxiliary tool as a central principle for ensuring safe and effective treatment. When applied to dentistry, artificial intelligence has enormous potential for simplifying diagnostics, eliminating unnecessary procedures, minimizing postoperative complications and predicting treatment results. All this has a positive impact on the quality of treatment due to fewer interventions, diagnostic accuracy and more reliable recovery.

The application of artificial intelligence to predict implant success and optimize implantation has shown great potential, but additional research is needed to further develop and evaluate the clinical effectiveness of artificial intelligence models for widespread implementation in the field of implantology.[27]

Despite the prediction that the widespread adoption of artificial intelligence (AI) in dentistry could revolutionize dentistry, research on the use of artificial intelligence in dental technology is still scant in the literature.

One of the applications of AI in implantology is the use in digital three-dimensional (3D) treatment planning based on CT data and can help the practitioner determine the optimal number, size, location for implant installation, and the development of dentures, thereby reducing the risk of complications during surgery and increasing success of implant installation.

The next stage of this achievement was the introduction of this planning into the dynamic implant navigation system.

The use of artificial intelligence will revolutionize implantology in the coming years. Today, in implantology, thanks to artificial intelligence (AI), software allows the dentist to view holographic 3D models of the patient and use them to make the correct diagnosis, as well as illustrate the selected treatment plan to the patient.

A breakthrough in implantology was a new computer navigation system for implant installation.

Currently, dynamic navigation is the most effective way to communicate the planned implant position to a real patient, as it guides surgeons' movements using real-time feedback.

Our research was aimed at studying the effectiveness of the use of artificial intelligence in the practice of dental implantology.

Implants were installed using the Navident (ClaroNav) navigation system. This dynamic navigation system allowed precise placement of the implant within 0.5 mm of the treatment unit.

The handpiece tracker (Rocket) allowed the hand to be tracked throughout the process from multiple angles, enabling precise and efficient surgical intervention. Navident provided visibility of drill movement from the simplest to the most complex cases. The system allowed for minimally invasive surgery to bypass critical structures. The optical camera in the Navident system allowed (175 degrees horizontal and 90 degrees vertical movement) precise and accurate tracking of the surgical area throughout the entire process.

Deviations between planned and installed implant positions, implantation success, and prosthetic success of implant-supported reconstruction were assessed. For all implants, the average deviations from the actual and planned position of the implant were insignificant, which did not affect the effectiveness of implantation. Patients were satisfied with the functional and aesthetic results of implantation.

Thanks to its enormous advantage, artificial intelligence is an additional assistant for specialists and its use is not intended to replace the dentist, but to increase the efficiency of treatment and procedures and give the doctor more confidence to monitor the condition of his patient at every stage of the most complex procedures.

The use of artificial intelligence in implantology is just beginning, and in the coming years it will create a revolution, as it will lead to much better results; however, multicenter long-term studies are needed on all aspects to give an objective assessment

Conclusion

Robotic implant navigation system allows for precise implant placement; the level of experience of the surgeon and the location of the implant do not affect the accuracy of placement and the timing of the procedure.

Declarations

Conflict of interest and financial disclosure

The author declares that he has no conflict of interest and there was no external source of funding for the present study. None of the authors have any relevant financial relationship(s) with a commercial interest.

Ethical approval

Research protocol was approved by the local Ethical Committee (2018/23) and in accordance with those of the World Medical Association and the Helsinki Declaration.

Informed consent

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

Source of Funding

Non funding.

Availability of Data and Materials

Not applicable.

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ԻՄՊԼԱՆՏՆԵՐԻ ՆԱՎԻԳԱՑԻՈՆ ՀԱՄԱԿԱՐԳԻ ՃՇԳՐՏՈՒԹՅՈՒՆԸ ԻՄՊԼԱՆՏՆԵՐԻ ՊՐԱԿՏԻԿԱՅՈՒՄ

Կարեն Գրիգորյան

Երևանի Մ. Հերացու անվան պետական բժշկական համալսարանի դոցենտ, Ավանտա նորարարական բժշկության կենտրոնի հիմնադիր-նախագահ, Երևան, Հայաստան

Ամփոփում

Նպատակը. Գնահատել իմպլանտների դիրքավորման ճշգրտությունը՝ օգտագործելով ռոբոտային իմպլանտների նավիգացիոն համակարգը ստոմատոլոգիական իմպլանտոլոգիայում:

Մեթոդներ. Մենք վերլուծել ենք 16 հիվանդի բուժումը՝ օգտագործելով ռոբոտային իմպլանտների նավիգացիոն համակարգ՝ փուլային իմպլանտացիայի վիրահատության և իմպլանտների վրա հենված ատամների պրոթեզավորման ժամանակ, որոնք կատարվել են 2022-2023 թվականներին: Բոլոր հիվանդները ենթարկվել են համալիր կլինիկական և լաբորատոր հետազոտություն և համակարգչային տոմոգրաֆիա (CT):

Ընդհանուր առմամբ 46 իմպլանտներ են տեղադրվել՝ օգտագործելով Navident (ClaroNav) նավիգացիոն համակարգ: 25 իմպլանտ տեղադրվել է ամբողջությամբ անատամ հատվածում, իսկ 21 իմպլանտը տեղադրվել է մասամբ անատամ հատվածում: Իմպլանտների տեղադրման ճշգրտությունը գնահատելու համար պլանավորված և տեղադրված իմպլանտների դիրքերի միջև շեղումները վերլուծվել են՝ օգտագործելով նախավիրահատական ճառագայթային համակարգչային տոմոգրաֆիան (CBCT): Պսակի շեղումը չափվել է որպես իմպլանտի պսակային հարթակի կենտրոնների միջև հեռավորություն: Գագաթային շեղումը չափվել է որպես իմպլանտի գագաթային մասի կենտրոնների միջև հեռավորություն: Անկյունային շեղումը չափվել է որպես իմպլանտի կենտրոնի առանցքի անկյուն:

Գնահատվել է իմպլանտացիայի արդյունավետությունը և իմպլանտների վրա հենված պրոթեզների արդյունավետությունը: Տվյալները վիճակագրորեն վերլուծվել են՝ օգտագործելով:

Արդյունքները. Իմպլանտացիայի ժամանակ ներվիրահատական կամ անմիջական հետվիրահատական բարդություններ չեն արձանագրվել: Հիվանդների հետվիրահատական շրջանը բարենպաստ է եղել:

Բոլոր իմպլանտների համար միջին շեղումները եղել են՝ 0.21 մմ մուտքի կետում (կորոնային) և 0.27 մմ ծայրամասում: Միջին անկյունային շեղումը իմպլանտի իրական և պլանավորված դիրքից եղել է 1.32 աստիճան: Հիվանդները գոհ էին իմպլանտացիայի ֆունկցիոնալ և էսթետիկ արդյունքներից:

Եզրակացություն. Իմպլանտների նավիգացիոն ռոբոտային համակարգը թույլ է տալիս իմպլանտների ճշգրիտ տեղադրում; Վիրաբույժի փորձի մակարդակը և իմպլանտի տեղադրման հատվածը չեն ազդում տեղադրման ճշգրտության և ընթացակարգի ժամանակի վրա:

ТОЧНОСТЬ РОБОТИЗИРОВАННОЙ СИСТЕМЫ НАВИГАЦИИ ДЕНТАЛЬНЫХ ИМПЛАНТОВ В ПРАКТИКЕ ДЕНТАЛЬНОЙ ИМПЛАНТАЦИИ

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Абстракт

Цель: Оценить точность позиционирования имплантата с помощью роботизированной системы навигации в практике дентальной имплантологии.

Методы: Проведен анализ лечения 16 пациентов с использованием роботизированной системы навигации имплантатов в поэтапной имплантационной операции и протезировании зубов на имплантатах, проведенных за период 2022-2023 гг. Всем пациентам проведено комплексное клинико-лабораторное исследование, компьютерная томография (КТ).

Всего было установлено 46 имплантатов с использованием навигационной системы Navident (ClaroNav) безлоскутным или минимальным лоскутным подходом. 25 имплантатов были полностью беззубы и 21 имплантат установлен в частично беззубом участке.

Для оценки точности установки дентального имплантата с помощью предоперационной плановой конусно-лучевой компьютерной томографии (КЛКТ) анализировали отклонения между запланированным и установленным положениями имплантата. Корональное отклонение измеряли как расстояние между центрами коронковой платформы имплантата. Апикальное отклонение измеряли как расстояние между центрами апикальной части имплантата. Угловое отклонение измеряли как угол оси центра имплантата.

Оценивались успешность имплантации и успешность протезирования с опорой на имплантаты. Данные были статистически проанализированы с помощью .

Результаты: При дентальной имплантации не было отмечено никаких интраоперационных или ближайших послеоперационных осложнений. Послеоперационный период у пациентов был благоприятным,

Для всех имплантатов средние отклонения составили: 0.21 мм в точке входа (латерально) и 0.27 мм на верхушке. Среднее угловое отклонение от фактического и запланированного положения имплантата составило 1.32 градуса. Пациенты были удовлетворены функциональными и эстетическими результатами имплантации.

Заключение. Роботизированная система навигации позволяет точно установить имплантат, уровень опыта хирурга и расположение имплантата не влияют на точность установки и сроки проведения процедуры.

Grigoryan K. Accuracy Of A Robotic Dental Implant Navigation System In Dental Implant Practice. *Bulletin of Stomatology and Maxillofacial Surgery*. 2023;19(4):72-82. doi: 10.58240/1829006X-2023.19.4-72