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Literature Review Article

DIAR (DENTAL IMPLANTOLOGY ASSISTING ROBOT) AS A FUTURISTIC SOLUTION TO ENSURE AN ACCURATE AND PRECISE DENTAL IMPLANT ABUTMENT PLACEMENT

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ABSTRACT

Introduction. The massive emergence of artificial intelligence (AI) in dentistry 4.0 necessitates a new generation of tools to meet the demands for enhanced precision, efficiency, and success rates, particularly in dental implantology. This paper introduces a conceptual model for a dental implantology AI–based assisting robot, designed to provide a structured and systematic masterplan for treatment, thereby delivering enhanced patient outcomes through minimally invasive procedures. **Method.** This process is highly reliant on integrated imaging modalities, including both extraneous periapical/panoramic radiographs and a dedicated, on-board cone-beam computed tomography (CBCT) scanner. The CBCT data, essential for multiplanar reconstruction and accurate bone measurement, is integrated into a surgical navigation system to ensure precise three-dimensional implant placement, while also enabling crucial sensory nerve mapping to prevent nerve injury. For advanced machine intelligence, the robot utilises convolutional neural networks (CNN) as its deep learning method. CNN is trained on vast datasets (*mega dataset*) to achieve high accuracy in tasks such as implant type recognition and post-surgical assessment (e.g., peri–implant bone loss measurement). **Results and Analysis.** The system culminates in a precise treatment execution phase, supported by 3D guided placement (including potential CAD/CAM fabrication) and an automated robotic hand. Crucially, the system features haptic feedback and a control interface, giving the human operator tactile sensation and control over intricate tasks. **Discussion**. the integration of CNN, CBCT, and haptic control is designed to significantly reduce human errors, leading to more reliable, consistent, and aesthetic results, achieving perfect osseointegration and optimising the complete cycle of dental implant therapy.

Keywords: Dental Implantology, Dental Implantology Assisting Robot, Dental Implant Abutment Placement, Digital AI.

INTRODUCTION

Artificial intelligence (AI) has been experiencing a massive emergence and development in contemporary dentistry 4.0, primarily serving to deliver an enhancement of clinical treatment within the oral cavity. By leveraging advanced algorithmic capabilities, AI facilitates procedures under minimally invasive protocols, thereby dramatically accelerating the overall success rate of treatment. This enhancement is particularly critical for sophisticated procedures such as dental implantology, where the long-term success of the treatment procedures requires quality enhancement on the aspects of precision, efficiency, and overall predictability. The shift from

conventional manual techniques to AI-assisted robotics is driven by the necessity to mitigate human variability and guarantee meticulous execution in these highly sensitive surgical environments (Revilla-León M, Gómez-Polo M, Vyas S, Barmak BA, Galluci GO, Att W, et al, 2021).

A point that must be clearly highlighted and meticulously addressed in the development of any robot prototype is the functionality of the predictive algorithm operating through imaging analysis, which is executed immediately following the initial diagnostic imaging. This algorithm's capacity to generate numerous predictions and speculations during the treatment process—further supported by mechanisms for implant type recognition—is instrumental in managing complex oral conditions. The ultimate goal is to provide a detailed identification report that comprehensively guides clinical decision-making regarding implantology management. This structured, systematic masterplan, meticulously conducted by AI to assist dental practitioners, allows the flow chart plan of treatment to be designed properly and effectively, culminating in the provision of a more precise three-dimensional dental implant placement and leading to a significant enhancement of the overall planning process. By integrating this intelligence, significant benefits are achieved, delivering notably enhanced patient outcomes through the application of an AI-based assisting robot in dental implantology (Altalhi AM, Alharbi FS, Alhodaithy MA, Almarshedy BS, Al-saaib MY, Jfshar RMA, et al, 2023).

Figure 1 Dental Implantology AI–Based Assisting Robot Prototype Constructive Design.

METHOD AND ANALYSIS

The discussion on the potencies of AI assisted dental implantology robot to achieve the most effective, accurate, and precise dental implant abutment placement was conducted through comprehensive literature review of reputable scientific articles. The sources were accessed through established academic databases, including PubMed, ScienceDirect, SCOPUS, and EBSCO. This review focuses on general information about dental implant structure; dental implant abutment placement procedure; the mechanism of how the AI could guide the process; integration of AI within the robot on dental implant abutment placement; and the expected result of the

integrated system effectiveness on placing the dental implant abutment accurately and precisely. The selected articles for this review were published within the past 5 years, specifically from 2019 onwards, to ensure the relevance and currency of the information. Keywords and phrases that facilitated the search included: AI precision; prosthodontics; digital AI; AI assisted dental implant abutment. A total of ten articles were retrieved for the literature review, drawn from a range of sources to provide a well–rounded perspective on the subject.

RESULT

Predictive Algorithm and Image Analysis

Predictive algorithms which are conducted by learning machines could be applied in AI–based implantology in order to assist dental practitioners in selecting the most proper and suitable implant type and size based on the patient's data. The algorithms provide an accurate prediction time estimation for a patient needing a dental implant so the informed decisions could be made by dental practitioners properly and highly accurate. Later on, the enhancement of implant placement could be possessed by AI–based imaging analysis and deep learning algorithm schemes to reduce the risks and optimize aesthetics (Lyakhov, et.al, 2022). An integrated software with the robot prototype for AI–based implant recognition should be designed and built to be able for analyzing periapical and panoramic images from extraneous parts of the prototype to identify presence of unknown implant and define the patient conditions of teeth and oral cavity by processing many study dataset at the vast amount to enhance more speculated algorithms that lead into mature planning at many different cases by different difficulty. The AI–empowered software also provides simulation with futuristic features that can optimize placement position and angulation for practitioners' learning media to get their best approaches for dental implant placement virtually which is time saving and offer promising chances for getting fine–tuning surgical plan to obtain optimum results (Alharbi MT, Almutiq MM, 2022).

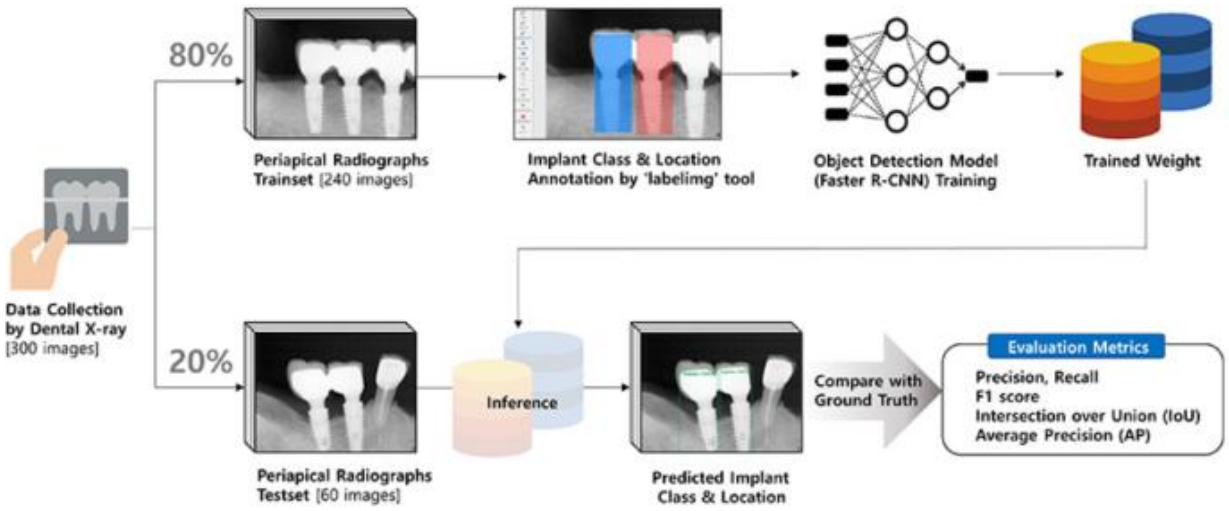

Figure 2 Predictive Algorithm Generated by Robot Prototype Software System by the Presence of Extraneous Periapical Radiographic Data to be Evaluated Further by Many Methods.

The management of dental implantology using this integration system of robot prototype–software also supported by cone beam–computed tomography (CBCT) scanner attached with robot prototype which the analysis results can track anatomical landmark which automatically provide insights by the most optimum approach of dental implant positioning and reconstruction technique to improve surgical precision and patient safety since it is integrated into surgical navigation

system and the robot prototype in order to enhance precision and accuracy of surgical interventions (Dhopte A, Bagde H, 2023).

CBCT in Managing Predictive Algorithm Results by Imaging Analysis

The technique offers many advantages for dental implantology management so it is valuable in a whole masterplan of the robot prototype. Multiplanar reconstruction as CBCT's undisputed advantage has revolutionized many specializations in dentistry as dental implantology since its allowance in visualization aspects without two dimensional (2D) limitations (Haiderali Z, 2020). This feature can enhance the accuracy measurement and localization of available bone so virtual implant placement with a precise position under the bone coverage could be enabled so it can prevent misaligned implants and ensure optimum aesthetics and functions as well. Great and visionaire strategy by CBCT to avoid misaligned implants in preventive mode could also enable sensory nerves mapping in the jawbone so the prevention from nerve injury could also be achieved as the whole procedure itself is crucially can damage the localized nervous system of the patient and cause numbness or even paraesthesia. It is also less–radiative and has fast time scanning so safer and more efficient imaging modality for the whole masterplan and implant placement could be obtained (Gupta J, Ali SP, 2023; Mukherji A, Singh MP, Nahar P, Goel S, Mathur H, Khan Z, 2019).

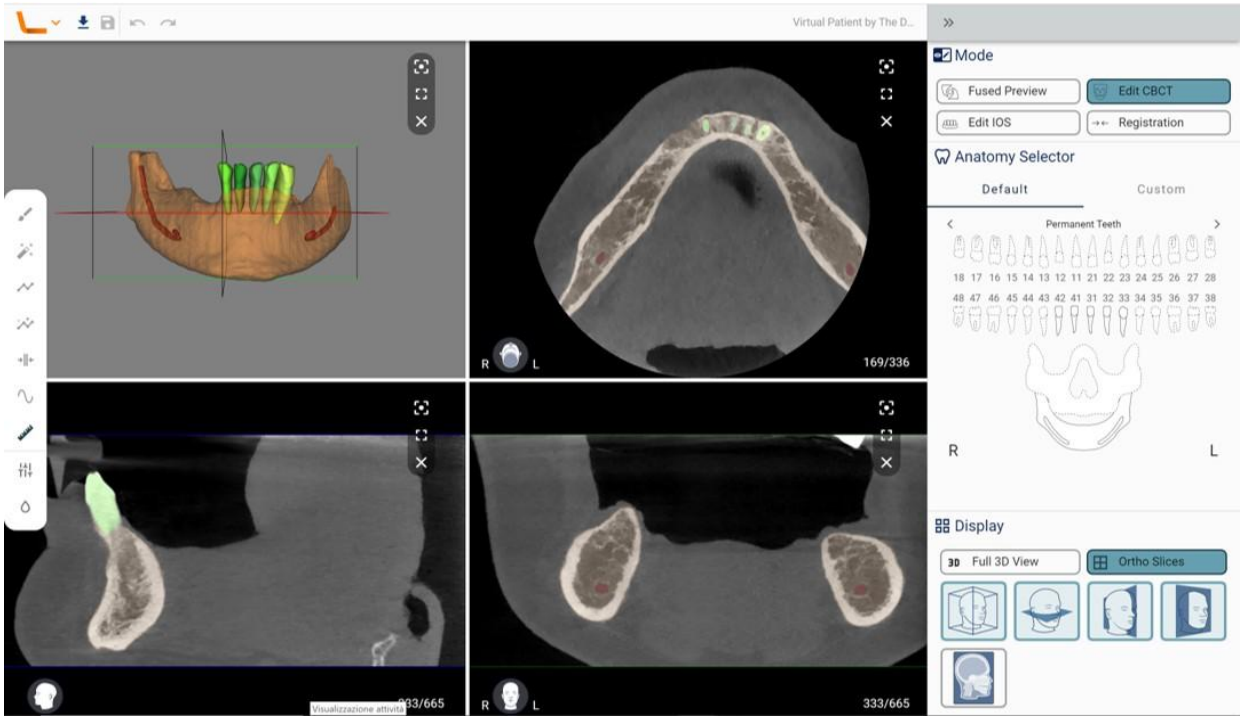

Figure 3 Nowadays Utilization of Futuristic CBCT Scan to Interpret Oral Cavity Region in Many Aspects and Views for Treatment Planning and Dataset Deep Learning Supporting Information.

DISCUSSION

CNN as Robot Prototype's Deep Learning Method for Implant Type Recognition

Deep learning mechanisms of the AI integrated–robot prototype using convolutional neural networks (CNN) could significantly impact various aspects of dental implant treatment planning, diagnostics, and assessments such as classification systems to

demonstrate the potency for accurate and automated identification of implant types (Sukegawa S, Yoshii K, Hara T, Yamashita K, Nakano K, Yamamoto N, et al, 2020). CNN has been used for identification of dental implants on panoramic radiographs and osseointegration quality assessment (Ossowska A, Kusiak A, Świetlik D, 2022). The spectrum usage becomes wider after majority success cases of dental imaging advanced tasks such as peri–implant bone loss measurement, sinus/fossae identification, and implantology post–surgical complication prediction since it has high accuracy and feasibility in identifying dental implant systems and assessing peri–implant bone loss as indication for potential widespread use in sectors of dental surgery and implantology (Huang C, Wang J, Wang S, Zhang Y, 2023). In conclusion, integration of convolutional neural networks (CNN) with AI has become promising in automatizing and enhancing the complete aspects of dental implantology from classification of implant systems to treatment planning and post–surgical assessment.

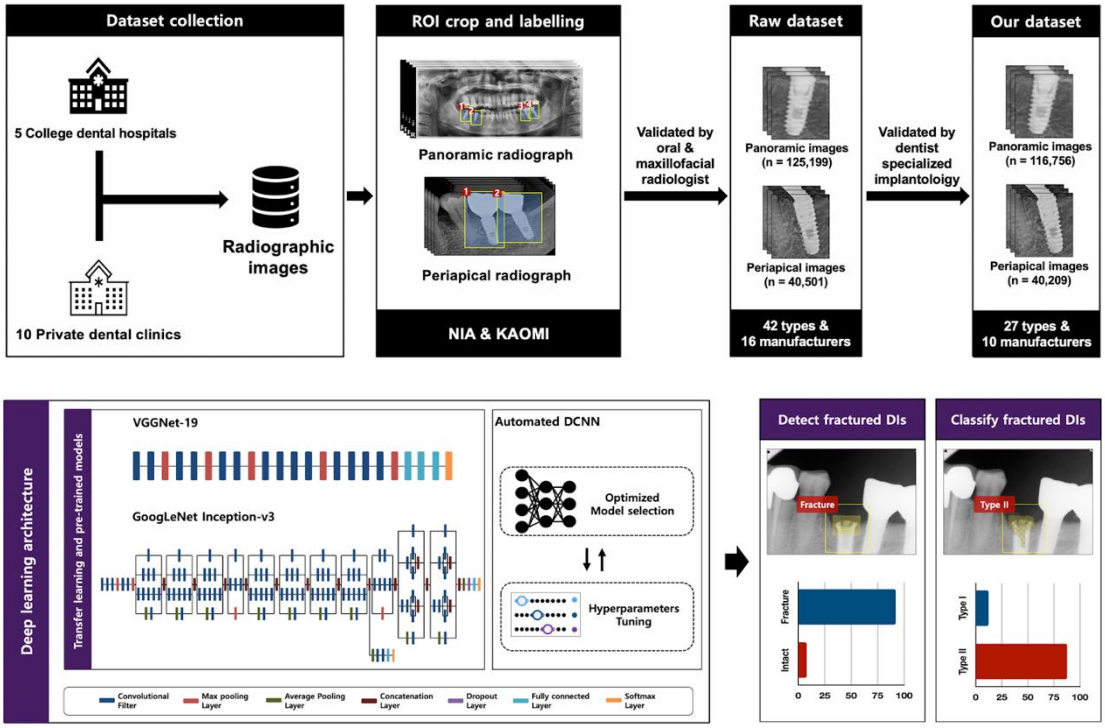

Figure 4 Schematic View of Vast Amounts Extraneous Data Processing of Dental Implants Case Reports Captured from Randomized Dental Hospitals being Processed in Mega Dataset System and Discovered by the AI System at Prototype via Convolutional Neural Networks (CNN).

Further, implant type recognition system could be designed and constructed based on AI–CNN integration with advancement of CBCT imaging by noticing many aspects such as machine learning models to be trained efficiently to be able for identifying and categorizing dental implant system based on feature extraction in the form of shape and/or using panoramic and periapical imaging from extraneous sources processed by AI models to conduct the mega dataset as the further study of dental implantology planning and placement by many different cases in order to enhance diagnostic accuracy and improve treatment planning as desired outcomes (Benakatti VB, Nayakar RP, Anandhalli M, 2021). Advanced development for the system could be conducted by cross–sectional study method in creating an accurate database for each region and building the classification models for different systems and models to

enhance the accuracy in classification (Sultan H, Owais M, Park C, Mahmood T, Haider A, Park KR, 2021). Supported with AI algorithm analysis results, it can extend patient data by references from vast amounts of data based on evidence decisions and tailor treatment plans to an individual so the capability for diagnostics can be enhanced.

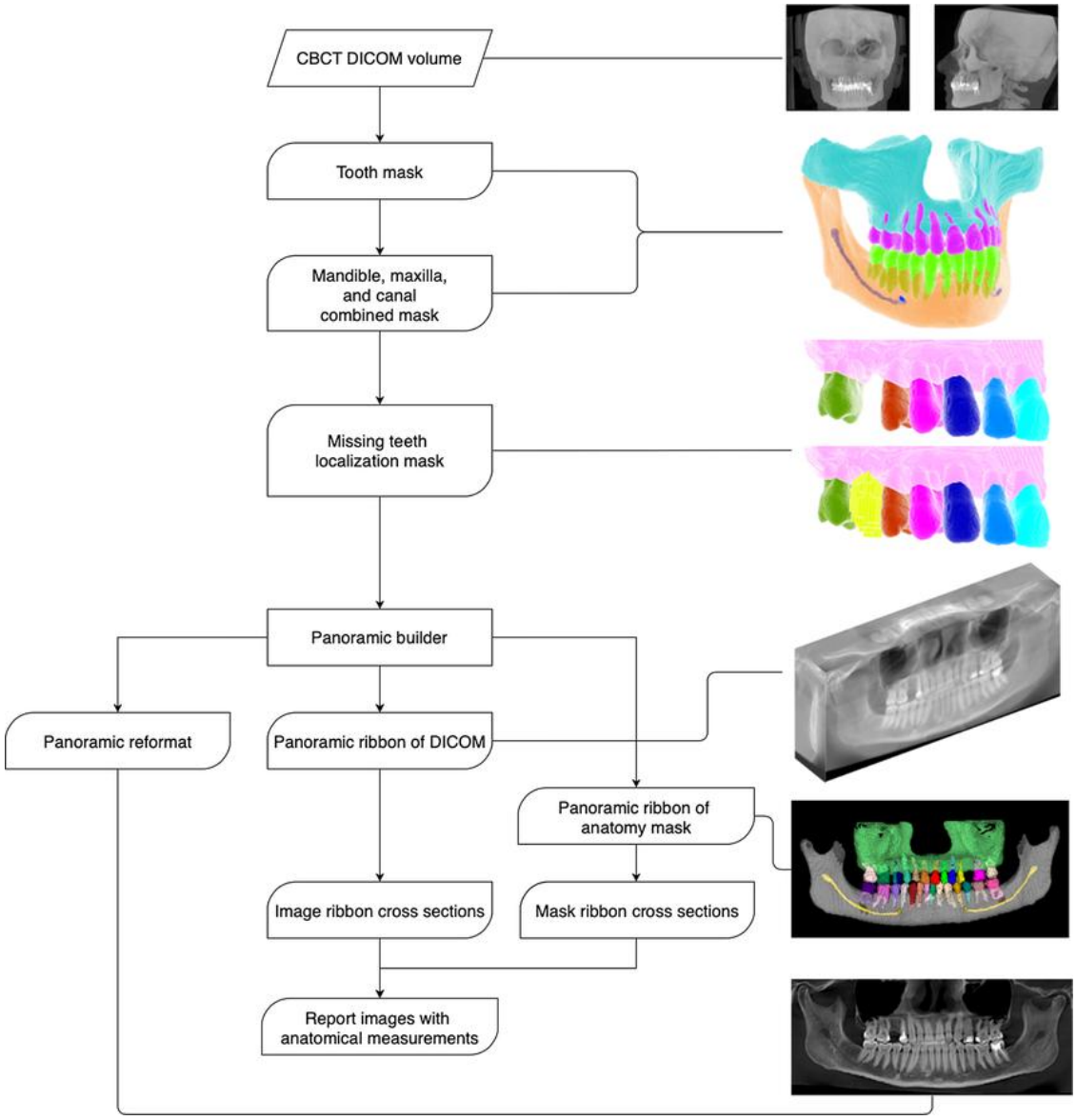

Figure 5 Structurized and Systematic Conceptual Mapping Generated by Convolutional Neural Networks (CNN) as Deep Learning Method for Many Dental Implant Cases Treatment Planning Supported by the Extraneous Radiographic Information and Automated CBCT Integrated with AI.

Treatment Decision and Execution by AI–Integrated Robot

Dental implant placement therapy should have a strong foundation by noticing many aspects from three dimensional (3D) guided dental implant placement itself until advanced toward automation. Three dimensional (3D) systems have been playing much roles in this treatment such as dental implant placement to allow implant positioning by more improved accuracy, safety, and efficiency using 3D planning in virtual mode, but can be empowered by an approach involving 3D printed guide to cross–match between virtual mode positioning and actual implant positioning

(Mistry A, Ucer C, Thompson JD, Khan RS, Karahmet E, Sher F, 2021). It has the potential to be used since the 3D printed implant designed in accordance with conventional implants then produced by this whole system could immediately enhance osseointegration which is promising to improve implant outcomes (Suh HM, Lee DS, Lee JW, Seol YJ, Lee YM, Koo KT, 2023). These approaches become helpful and essential to avoid the risks of complications may be caused from the procedures since the treatment crucially may damage the stability of soft tissue and hard tissue surrounding dental implants so the desired aesthetic and functional results could be achieved. Later, the execution of the systems will be performed by advanced toward tools in automated mode by using computerized implant–dentistry principle, specifically three–dimensional imaging, implant–planning software, and computer–aided–manufacturing (CAD/CAM) which may improve predictive and efficient implant placement by offering biological advancements as the implant abutments come into contact with gum tissue, shaped, and polished into natural looks so aesthetic outcomes could be enhanced (Târtea, et.al., 2023). The utilization of CAD/CAM to fabricate the whole dental implants feature such as crown, abutment, and framework shows better survival rates than conventionally fabricated dental implants (Unsal G, Turkyilmaz I, Lakhia S, 2020).

Figure 6 CAD/CAM Fabricated Dental Implants Which Can Possess Better Quality in Contact with Gum Tissue, Aesthetics, and Strength.

Haptic Feedback for an Effective Way of Robotic Hand Controlling

The robot prototype will be completed with the automated hand robot holding dental instruments that are integrated to each other with the software systems so it can mimic the operators' motion in managing dental surgery treatment and implant placement processes by being highly precise and accurate (Yan B, Zhang W, Cai L, Zheng L, Bao K, Rao Y, et al, 2021). The specifications and features owned by the robot prototype might be quite complex as human but the integration with the AI and deep learning through mega dataset could perform the function as dental implantology robot very well by also considering ergonomy

aspects of the patient to perform comfortability of the patient and efficiency of the robotic hand manage patient's oral cavity at the targeted site. Robotic hand articulations also have been designed to perform bending angles with well controlled–perfect range of angle following human's hand bending angle, even better (Liu LP, Watanabe M, Ichikawa T, 2023).

In the perspective of the operator as the controller of the robot prototype, haptic feedback feature also will be added into the overall system to give tactile feedback sensation to the operator so they call feel touch and defensive mode during the procedures so the operator could perform more controlled motion for better results in futuristic clinical dentistry treatment with AI (Navalesi P, Oddo CM, Chisci G, Frosolini A, Gennaro P, Abbate V, Prattichizzo D, Gabriele G, 2023). The haptic feedback mode also will be completed with a control interface to improve the interaction between the operator and the systems through touch screen panel, joystick, and other input sources for the robot prototype controllers (Yan B, Zhang W, Cai L, Zheng L, Bao K, Rao Y, et al, 2021). By integration of these combinations, the safety of the patient could be guaranteed and potentialized with other supportive modes such as force sensing to limit the motion which can manage into tissue damages and avoidance mode to prevent undesired contact between instruments and oral cavity (Saeed A, Alkhurays M, AlMutlaqah M, AlAzbah M, Alajlan, 2023).

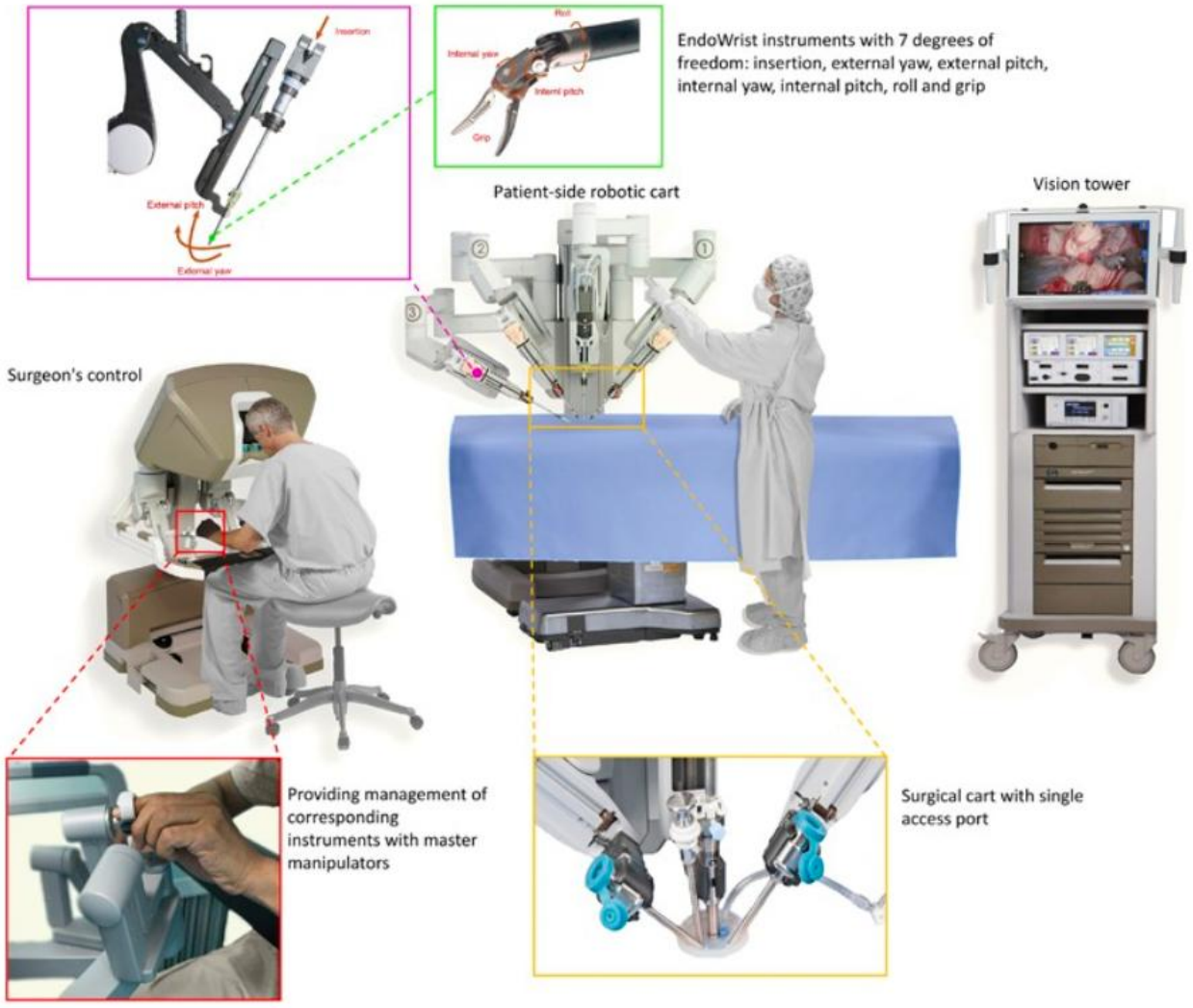

Figure 7 Robot Prototype Utilization Scheme with Haptic Feedback and Control Interface Mode as System's Controller for Operator.

CONCLUSION

Overall, all futuristics technologies empowered with AI that are provided by the dental implantology robot prototype will lead into advancements in clinical treatment services in dentistry and convenience for the patient' as self treatment also could be planned automatically to enhance the post–treatment progresses into the most optimum outcomes as desired. Otherwise, utilization of AI features such as convolutional neural networks (CNN) as deep learning method; CBCT scan technology to interpret the conditions by imaging analysis; schematic predictive algorithm as foundation of mega masterplan for the dental implant treatment; haptic feedback and control interface as the controller of the scalpels and instruments of the robot prototype for operators, are incorporated into the system to make operators be able to work on the intricate tasks of dental implant placement so human errors may be reduced significantly. It automatically will lead to more reliable and consistent results of dental implant perfect placement until perfect osseointegration between implant and alveolar bone is achieved.

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