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ORIGINAL PAPERS

Digital Systems in Medical Science and Modern Dentistry

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Abstract. Digital expert systems, commonly used in medicine, can be implemented successfully in the analysis and planning of treatments in dentistry. In implant-prosthetic therapy, these software applications represent necessary adjuvant tools in optimizing therapeutic decisions regarding the pro-implant and implant stages as well as in creating a therapeutic planning algorithm. PRODENT Acad Expert (data recording and database) and PRODENT Indices (calculation of biological indices and recommendation for the optimal treatment solution) (Neo-Tech, Romania) are tools that allows the registration and entry of data in the database, registration of clinical and biological indices in pretreatment and post-implant stage, respectively the recommendation of an optimal prosthetic solution. The use of this application is necessary in monitoring changes related to the biological components of the stomatognathic system in postimplant stage. Expert applications for the assessment of mucosal and bone support, planning of bone addition procedures and positioning of dental implants laid the foundations of digital implantology (Implant 3D, Universe; NobleGuide, Nobel Biocare; Digital Smile Design, DSD; SimPlant, Dental Materialize; Virtual Implant Placement, BioHorizons; ImplantMaster, iDent; Implant 3D, Media Lab; EasyGuide, Keystone Dental). The Digital Smile Design favors the planning of prosthetic therapy and the design of the future prosthetic work in accordance with the aesthetic principles and the requirements of the patients, based on a motivational mock-up. Literature data demonstrate the increase in the long-term success rate in digital-assisted implant-prosthetic therapy and justify the widespread expansion of the use of digital applications in current contemporary dental practice.

Keywords: *medicine, dentistry, diagnostic, AI, expert systems, digital*

Introduction

The digital systems using artificial intelligence (AI) have many applications both in medicine and dental science, from recording a patient's

history to data processing, data categorization, extract of the information from the data for diagnosis, and treatment planning.

Naylor et al (2018) highlight the benefits of AI based digital systems in medical sciences (1):

- more systematic and structured recording of patient's data;
- standardization of the variations in patient's examination;
- facilitation of effective care with lower costs of the treatment, and reduced routine tasks;
- facilitation of research and development;
- increases timefor face to face discussion between patient and clinician;
- decreases of diagnostic and treatment costs.

AI use represents a new trend in medicine, due to high volume of unstructured data obtained from electronic health records databases. Expert systems can correlate the recorded information from database with pattern recognition, and generation of actionable insights for medicine professionals.

The methodologies of AI expert systems in medical science and dentistry include artificial neural networks, genetic algorithms, and fuzzy logic (2).

Digital systems based on artificial neural networks can be used for the assistance of the medicine professionals for examination, diagnostic and treatment.

Digital systems based on genetic algorithms are stochastic methods including mutation, inheritance, selection and crossover to search for a better option of the problem.The genetic algorithms work on the basis of problem solution instead of the conventional analytical relations concept, working on simple rules, and being easy to implement (2).

Augmented Reality is based on interactive experiences with the real world in which a 3D virtual object is consolidated in a 3D real environment, leading to superimposition of computer generated virtual content over real environment.

Virtual Reality is used by surgeon to interact with virtual objects in real time, due to immersion (the sense of occurrence in virtual environment) and interaction (ability to modify the virtual environment) (3,4).

AI expert systems in medical science

The artificial neural networks are useful in various areas of medicinal science (diagnosis of diseases, biomedical identification, image analysis, data analysis) (5).

Digital expert system are used in medicine as follows:

- Diagnose one or more diseases
- May indicate appropriate therapy.
- Diagnose the absence of the disease.

- Detect some symptoms or signs due to any exogenous cause (differential diagnosis).
- Can tell the doctor that the patient does not meet the minimum criteria for some of the diseases andsuggest a new evaluation.
- Suggest sending the patient to a specialist.

The categories of AI medical expert systems (6):

- Artificial Intelligence Techniques in Medicine;
- Data Mining and Knowledge Discovery in Medicine;
- Medical Expert Systems;
- Machine Learning-Based Medical Systems;
- Medical Signal and Image Processing Techniques.

The cycle of the data recording, data interpretation, data categorization, diagnosis, and treatment planning used by artificial neural networks in the assistance of medical professionals is presented in figure 1. AI based systems are especially important in decision-making stage. The algorithms obtained from AI based systems can be more accurate and clearer and will help clinicians to provide high level diagnosis and treatment to the patients (7).

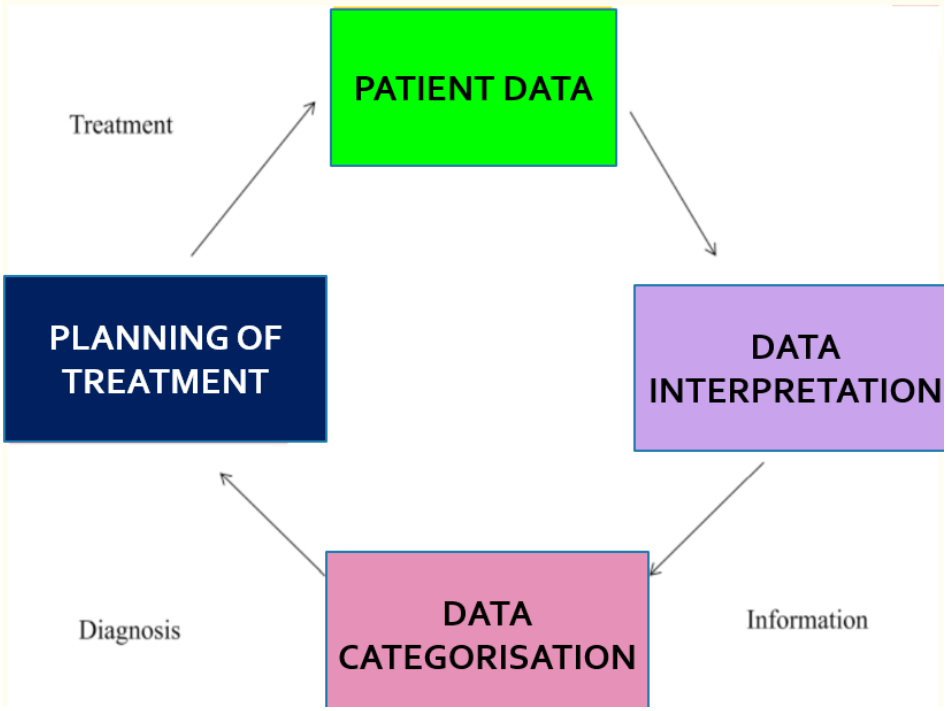

Figure 1. Cycle of diagnostic and treatment planning in medical science (adapted from Tandon, 2020) (2)

In medical science, the digital systems based on Augmented Reality has applications in laparoscopy, plastic surgery and neurosurgery (2).

The domains of medical sciences where AI based systems can be implemented are as follows: disease diagnostic, health monitoring, digital consultations, analysis of health plans, managing of medical data, personalized medical treatment, drug development (8).

AI based health trackers (Fitbit, Apple) can be used in the monitorization of the heart rate, arterial tension, activity levels, sleep levels, ECG tracings, to alert the users about any variation of health parameters and to help doctors for in-depth knowledge of the patients' conditions. Some healthcare systems use health trackers to analyze and detect failure of medical treatments, and ineffective workflow to avoid unnecessary hospitalizations (8).

Widespread implementation of AI based digital systems require the collaboration of the developers, healthcare professionals, and legislators to overpass the challenges and limitations of algorithms and to foster multidisciplinary collaboration (9).

The use of AI in medicine has many advantages (efficiency, accuracy, precision, decreased workload, increased face to face time with patient, better monitoring) and some disadvantages (luck of human-touch empaty, potential for jobs loss) (9).

AI expert systems in modern dentistry

One of the artificial neural network used in dentistry was a model that predicted toothache based on analysis of various parameters. This model helped to predict the development of the toothache by recognizing proper eating habits, oral hygiene, and stress prevention as important factors in preventing toothaches (10). An artificial neural network was used for data mining of the digital oral health documents to analyse survival curves of new restorative materials in a practice-based manner in real-life conditions (11).Another artificial neural network was used to detect and diagnose the lesions of the oral cavity that may go unnoticed by the human eye (12).

Examples of genetic algorithms used in contemporary dentistry are presented as follows:

- optimization of dental implant positioning to reduce the potential of mechanical fracture and to provide long term implant resistance (13);
- improvement of the tooth color matching which is one of the greatest challenges in prosthodontic dentistry (14);
- detection of the non-cavitary and micro-cavitary dental caries (15);
- reconstruction of missing parts of the tooth by using a set of control points in computer aided design to regulate the reconstructed surface and to maintain its smoothness (15).

An example of digital system based on genetic algorithm is PRODENT (Neodent), used in Faculty of Dental Medicine (U.M.F."Grigore T.Popa" Iasi) to assist dental students and teachers in the recording of the patients' data, analysis of the loco-regional and local conditions, and the planning of the pro-prosthetic and pro-implant stages, as well as the selection of the best therapeutic solution (fig.2).

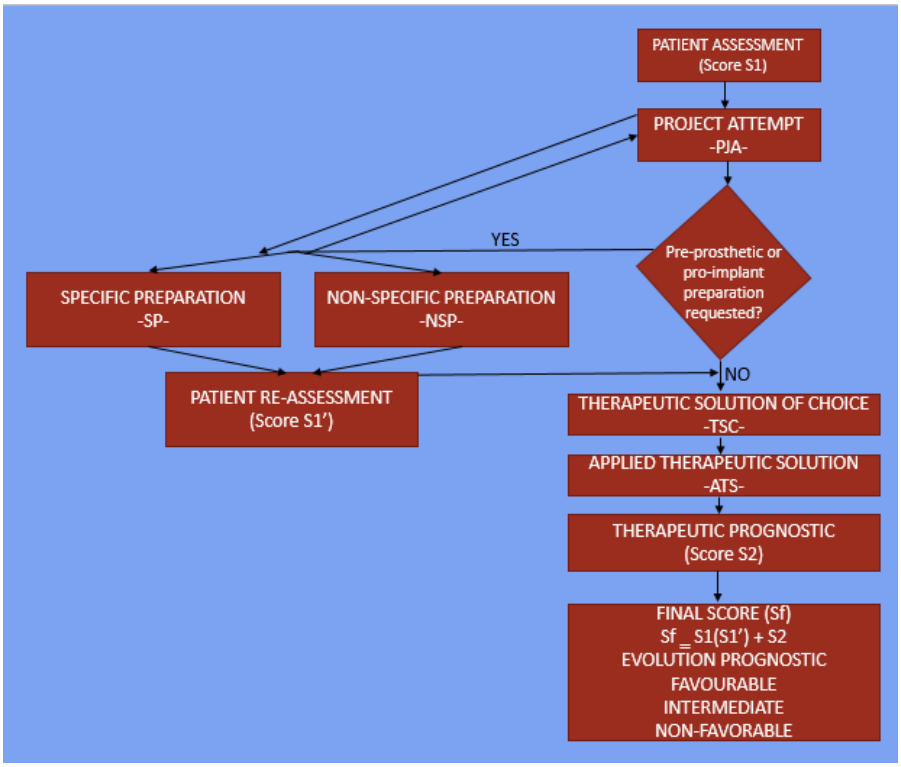

Fig.2. Algorithm of PRODENT system

Fuzzy logic systems work by imitation of the human reasoning ability that works with unclear terms. Examples of fuzzy logic systems are a s follows:

- system using imprecise values of the dental sign-symptoms associated with mobile teeth to assist dentists in treatment plan decisions making (16);
- system for the prediction of the teeth color changesfollowing tooth bleaching; the system is based on a set of rules related to the initial chrome valuesof the teeth (17).

New digital techniques based on CBCT images processing are introduced in the modern dentistry to optimize the implant-prosthetic planning (pro-implant and implant stage), to increase the accuracy of the dental implant positioning, and to improve the design of the future implant-prosthetic restoration. The digital

analysis of CBCT images has applications especially in endodontics, implantology and orthodontic therapy.

In implant-prosthetic therapy, software application are used for the measurements of height and width of the alveolar bone, the measurement of osteodensity as well as for the visualization and evaluation of the distances to the tissues and areas (sinus, mandibular canal) that must be protected during surgical implant procedures (figures 3.a-b).

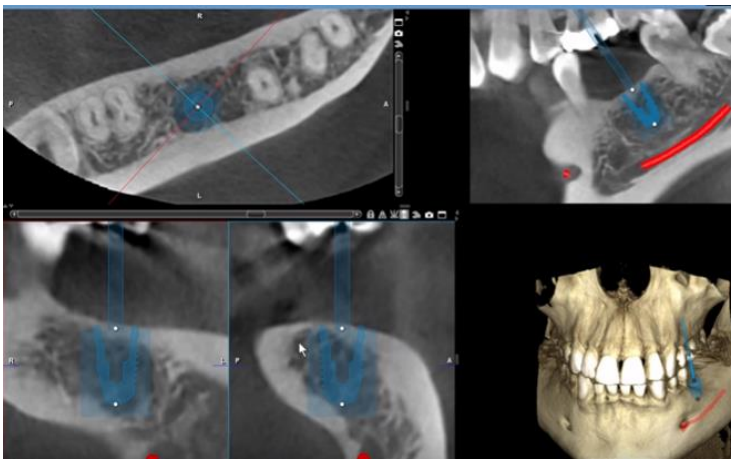

Figure 3.a. CBCT processed images during implant-prosthetic therapy (www.planmeca.com/software/)

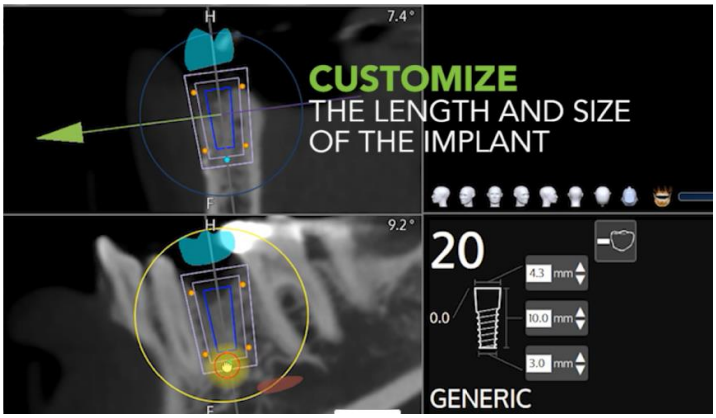

Figure 3.b. Software X-Guide (Nobel Biocare) for the planning of implant stage (www.nobelbiocare.com/en-int/x-guide)

Expert digital systems used for the assessment of mucosal and bone support, planning of bone addition procedures and positioning of dental implants laid the foundations of digital implantology are as follows: Implant 3D, Universe;

NobleGuide, Nobel Biocare; Digital Smile Design, DSD; SimPlant, Dental Materialize; Virtual Implant Placement, BioHorizons; ImplantMaster, iDent; Implant 3D, Media Lab; EasyGuide, Keystone Dental).

3D Navigation Systems (i.e., Robodent, GmBh, Germany) are systems that use augmented reality. They assist dental surgeons and implantology specialists by providing images of operative sites that is then modified from a data source (18). Augmented Reality is used to assist the future positioning of the dental implants as to reduce the risk of failure, the time of execution and the costs. Dental implant placement guided by augmented reality method had better accuracy and lower working time, than the traditional 2D image navigation method. (19). Augmented reality can also be used in orthognathic surgery allowing partial visual immersion employing a head-mounted display (20).3D Navigation Systems has many applications both in planning and execution stages. Apart from planning stage, 3D navigation systems are especially useful in the navigation and the insertion of the implants, allowing the preview and order of the surgical guide as well as high accuracyduring implant procedures, by interface guidance of the dental professionals (figure 4.a-b). The advantages of the use of 3D navigation systems are as follows:

- real-time visualization of the depth and angle of the burr;
- fully automatic recording of the patient and of the procedures applied;
- one software for planning and navigation;
- extensive collection of generic implants and implants;
- measurement and analysis of bone density.

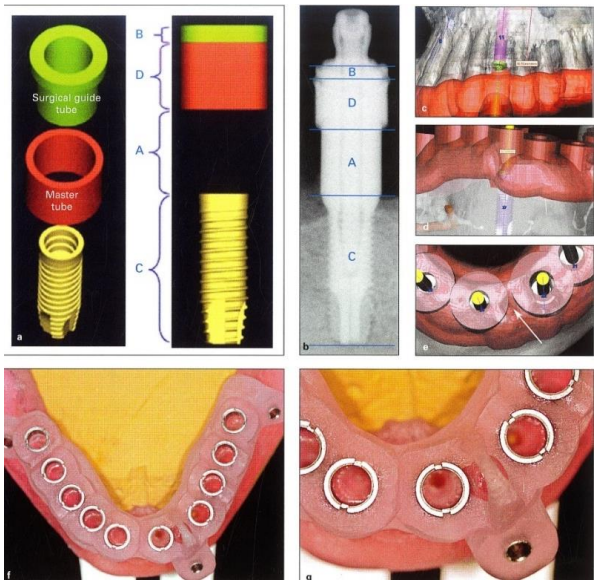

Figure 4.a. The preview of the surgical guide in Robodent system

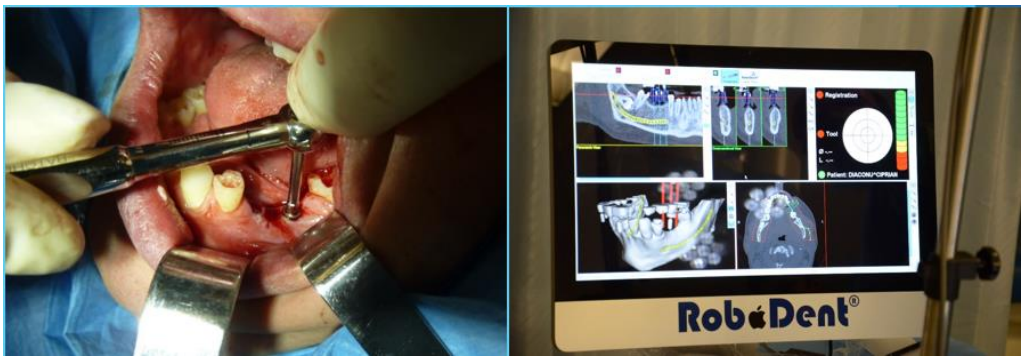

Figure 4.b. Robodent interface during implant stage

Digital impression based on intraoral scanners is used in the modern dentistry due to benefits as follows: accuracy, lower working time, reliability with clinical workflows, higher acceptance from patients. Restorations manufactured with currently digital impression systems and intraoral scanners have clinically acceptable ranges of marginal gap in direct and indirect procedures (21).A research proved higher accuracy and decreased working time for digital impression regarding the marginal and internal fit of CAD/CAM fabricated zirconia crowns and three-unit fixed dental prostheses, when compared with conventional procedure (22).

Digital Smile Design is another system that favors the planning of prosthetic therapy and the design of the future prosthetic work in accordance with the aesthetic principles and the requirements of the patients, based on a motivational mock-up.

When are implemented in dental faculties, the digital systems assisted by 3D navigation systems or augmented reality can be useful tools in the dental education system in restorative dentistry, prosthetics, oral and oro-maxillo-facial surgery as well as orthodontics.

Regarding the use of the digital systems in contemporary dentistry, apart from major advantages (reliable decisions, accurate diagnostic and execution, procedures standardization), the dental professionals that intent to use these systems in their practice must consider some disadvantages and limits:the necessity of proper training period; complex systems and mechanisms; higher acquisition and maintenance costs.

As the dental professionals are yet reluctant to implement on large scale AI based digital systems in dentistry, it should be considered systems that combine both AI and human elements for easy processing of data collection and categorization becomes easy as well as for preservation of the human aspects of dental care (2).

Conclusions

- Expert systems and 3D navigation systems can be used to optimize the alveolar bone rehabilitation, the implants positioning (associated to CAD-CAM manufacturing of the surgical guide), the periodontal procedures related to esthetic outcome, the design of the future prosthetic structure as well as the biomechanical factors.
- The combination of classic procedures and digital techniques increases significantly the long-term success of the implant-prosthetic therapy.
- The challenge for dental professionals is to learn the digital technologies and to integrate them into the current daily practice.

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