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DIGITAL SYSTEMS PREDICTIBLE FOR SUCCESS IN DENTAL MEDICINE

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Dental medicine is currently at a crossroads of past, present and future with ever-evolving therapeutic approaches, techniques and tools. Digital technologies can significantly contribute to the implementation of conservative and minimally-invasive techniques allowing significantly decrease in operative timing and operative invasiveness. Digital systems can be used in various fields of conservative dentistry, including esthetics, restorative dentistry, periodontology, and prosthetics. Conclusions. Digital devices allow detection and diagnostic of early occlusal and proximal dental caries, incipient marginal alveolar bone lysis and periodontal pathology, as well as monitoring of non-cavitary dental caries remineralization non-surgical periodontal diseases. Digital expert systems, currently used in dental medicine, can be successfully implemented in the analysis and planning of treatments in prosthetics and implant-prosthetic treatments of edentulous patients. Digital applications offer the specialist in prosthetics and implantology the opportunity to provide the patient with therapeutic solutions with maximum benefits for long-term success, the time spent and the patient's financial resources. Digital techniques are useful in standardizing the clinical observation sheet, detecting dental diseases in early stages, analyzing the clinical situation as well as prognosis and risk.

Keywords: esthetics, restorative dentistry, prosthetics, digital systems, prognosis.

INTRODUCTION

Dental medicine is currently at a crossroads of past, present and future with ever-evolving therapeutic approaches, techniques and tools.

Over the past two decades, new digital technologies were implemented in various fields of the modern dental medicine broadening operative approaches and increasing predictability of treatment with benefits both for clinician and patient. Also, the digitally-assisted dental medicine brings meaningful improvement in patients’ psychological and physical comfort[10, 27].

Digital technologies have significantly contributed to the implementation of conservative and minimally-invasive techniques allowing significantly decrease in operative timing and operative invasiveness[21, 31].

The digital techniques represent a challenge for dentists who need specialization courses for the accumulation of theoretical and practical knowledge in the use of new technologies.

In dental medicine expert systems are used to assist case therapeutic planning based on a probabilistic analysis of the theoretical schemes underlying therapeutic decisions[11].

Using these systems, we may decrease the frequency of radiographic examen as well as we can improve the accuracy, sensitivity and specificity of dental caries detection and diagnostic. The use of this technology is encouraged by the recommendation of International Commission on Radiological Protection for the decrease of dose radiation in all fields of medicine, including dental medicine.

Novel diagnostic technologies must reach the following goals: detection (determine if disease is or not present); lesion assessment (monitorization of carious lesion evolution, once it has been detected), and diagnosis (professional synthesis of all available data)[13].

DIGITAL SYSTEMS IN RESTORATIVE AND ESTHETIC DENTISTRY

Digital systems are used in various fields of conservative dentistry, including esthetics and restorative dentistry.

Esthetic dentistry benefit from digital devices (intraoral scanners, spectrophotometers) (Fig. 1) that are a easy, fast and reliable way to determine shade both for natural teeth and ceramics, with better results when compared to classic visual methods[28]. A systematic review of literature data reported that dental spectrophotometers provide the highest values of accuracy and precision among different shade selection devices despite the need of clinical setting to control related factors and oral cavity conditions to perform optimally. Also, these devices allow for efficient communication about tooth shade and images both between clinician and patients and between the dental practice and the laboratory[18] developed a digital shade-matching device used to determine teeth color using the support vector machine (SVM) algorithm. A systematic review performed by[2] concluded that intraoral scanners set to the Vita 3D Master shade guide performed better than visual method, but shade should be checked with visual technique[22] found the best results for the intraoral scanner configured for the 3D-MASTER scale (Trios, 3Shape) and for the spectrophotometer configured for the VITA Classical scale (VITA Easyshade Advance 4.0; VITA Zahnfabrik).

The prosthetic treatment of esthetic deficiencies in anterior areas require a dentofacial analysis. Nowadays digital smile design (DSD) software programs can be used to assist clinicians in this process (Fig. 2). The frequently used DSD programs provides various functions in the assessment of the esthetic dentofacial parameters. Some applications perform better in the analysis of dento-gingival and dental esthetic functions or in comprehensive smile analysis while other can better perform 3D analysis and can be used jointly with CAD/CAM system[24].

Figure 1. VITA Easyshade V (https://www.vita-zahnfabrik.com/en/.html).

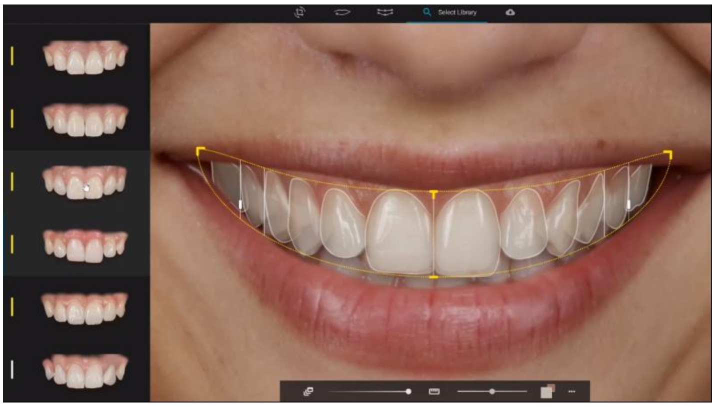

Figure 2 a–b. Smile Design- design of mock-up for future prosthetic reconstruction (https://www.smilecloud.com/).

The detection of dental caries in early stages can be performed with greater accuracy by using digital tools when compared to classic radiographic method (Figures 3–5).

Laser-fluorescence method is based on monitorization the fluorescence light emitted by protoporphyrin (product derived from bacterial metabolic activities) by sending a 655nm beam to the surface of the tooth and quantifying the optical values (range 0–99) by fiber optics[12]. Multiple *in vivo* and *in vitro* research proved the accuracy of fluorescence-based techniques in the detection of early caries lesions on occlusal, approximal or smooth surfaces, in both primary or permanent human teeth[12]. A study found, for sensitivity, specificity and accuracy values 100%, 85% and 95% for cavitated caries and 92%, 90% and 95% for non-cavitated early dental caries. The accuracy of the LFpen (laser-fluorescence technique) was significantly higher when compared to digital bitewing radiography in detecting approximal caries lesions, in posterior permanent teeth (Menem *et al.*, 2017). A study investigated a laserfluoresence based device (SoproLife®), by using scanning electron microscopy with energy dispersive X-ray analysis for camera images on the occlusal surfaces. The research group concluded that SoproLife® is effective in detection of early caries and for longitudinally monitoring of the remineralization therapy[32]. Near-infrared light transillumination (NILT) is a technology based on a specific light of 780 nm wavelength emitted by a laser diode that can penetrate dental crowns, and gingiva allowing to detect the demineralization areas that are displayed as dark shadows. NILT technology is a system that increase patient compliance due as demineralization areas are displayed immediately at high-resolution screening, facilitating communication between dentist and patient, as well as the monitoring by comparison of the previous results with new results[1]. Near-infrared light transillumination had higher sensitivity values (81.80%) than bite-wing radiography (65.90%) for the detection of non-cavitated proximal enamel caries and higher sensitivity values (100%) when compared to bite-wing radiography (81.50%) for the detection of incipient cavitated proximal enamel caries[30]. Kokac *et al.* (2020) compared the clinical performance of three digital methods used in detection of early proximal caries (digital bitewing radiography, near-infrared light transillumination, and laser fluorescence). It was measured accuracy, sensitivity, specificity, and predictive values. Digital bitewing radiography was the technique with highest sensitivity (0.96) and accuracy (0.96), while laser-fluorescence had the lowest values of sensitivity (0.38) and accuracy (0.39). Also, digital bitewing radiography had the highest sensitivity (0.97) and accuracy (0.97) for caries extended in dentinal tissues. Near-infrared light transillumination had higher sensitivity values for enamel caries (0.86) and proved good potential in the detection of proximal caries. The best predictive values in the detection of non-cavitated proximal caries had digital byte-wing radiographic method. However, one researcher recommended fluorescence-based methods only as providers of a second opinion in early dental caries diagnostics and treatment[8].

Figure 3. Diagnocam (KaVO)- detection of early occlusal and proximal dental caries by transillumination (https://www.kavo.com/dental-instruments/diagnocam-vision-full-hd-diagnostic-devices).

Figure 3.a–b. DiagnodentPen (KaVO)- detection of early occlusal and proximal caries by laser-fluorescence (https://www.kavo.com/dental-xray-machines-and-diagnostics/diagnodent-pen-diagnostic-devices).

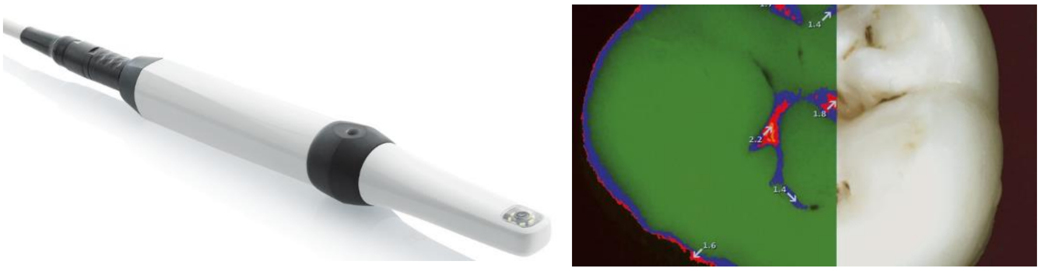

Figure 4 a–b. VISTACam (DürrDental)- detection of early occlusal and proximal caries by spectrophotometry(https://www.duerrdental.com/en/products/imaging/intraoral-diagnostics/vistacam/).

DIGITAL TOOLS IN PERIODONTAL THERAPY

In periodontal therapy accurate measurements of periodontal parameters (pocket depths, gingival contour) are important for the long-term therapeutic success. As manual probes are dependent on adequate pressure and correct readouts, new digital devices (electronic probes) (Fig. 5.a–b) improve and facilitate the diagnostic process[20]. Manual probing and electronic probe correlate well, while difference in periodontal pocket depth measurements is below 1 mm. The benefit of electronic probe is the avoidance of subjective inter-examiner reading errors and the decrease of time for documentation (Laugisch *et al.*, 2022). Digital measurements using electronic probe improve reproducibility and lower the intra-operatory variance as well as that between different practitioners.

Figure 5 a–b. (a) Manual probe; (b) Electronic probe, disposable tip, periodontal chart (automatically generated) (Laugisch *et al.*, 2022).

DIGITALLY-ASSISTED PROSTHETICS AND IMPLANT-PROSTHETIC THERAPY

The use of digital workflows in implant-prosthetic therapy can lead to more predictable results and a higher success rate compared to classical techniques.

Software applications represent adjunctive tools necessary to optimize execution and therapeutic decisions in the pro-implant and implant stages and to create a therapeutic planning algorithm for the future prosthetic restoration with implant support.

Expert systems type applications allow the introduction of data from anamnesis, clinical and paraclinical examination for the primary evaluation of the parameters of the prosthetic field. After performing the pro-prosthetic, pre-implantation and pro-implantation stages and the transitional prosthesis, the secondary evaluation can be performed with the help of these applications. Prosthetic field indices recorded in the initial evaluation and the secondary evaluation can be compared:

– socio-economic indices;
– psycho-behavioral indices;
– clinical-biological indices:
– systemic status;
– bone support;
– dental support;
– mucous support;
– periodontal support;
– occlusion;
– mandibular-cranial relations.

The algorithm of expert system Prodent Indici, used in the past by Faculty of Dental Medicine, U.M.F. “Grigore T. Popa” Iasi, in the planning of the prosthetic therapy (with natural and implant support) is exposed in Figure 6.

The expert systems used in implant-prosthetic therapy allow the recognition of the site of the implant surgical intervention through dynamic vision in all spatial planes, the manipulation of implants in the mesial-distal, buccal-palatine/ lingual, coronal-apical planes, the detection of anatomical obstacles, the possibility of determining bone density peri-implantation, the management of the relationships between implants and adjacent structures (relationships with anatomical structures, angulation, inter-implant distance), respectively the creation of the implant-prosthetic project[6].

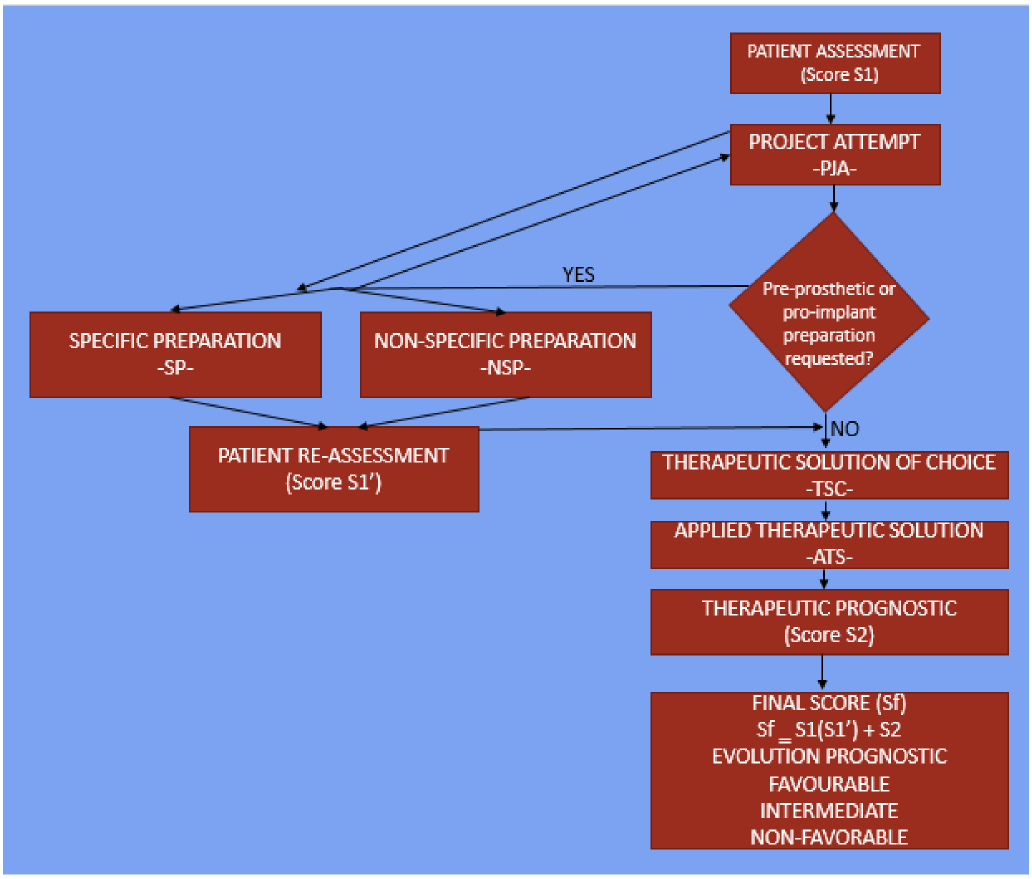

Figure 6. Algorithm in planning of prosthetic therapy of edentulous patients.

Table 1

Independent variables in process of decision in implant-prosthetic therapy by using algorithm C5.0 (Chiang *et al.*, 2013)

	Category	**Independent variable**	**Definitions/codes**
1	Demographics	1. Age group 2. Gender	M/F 0: Female 1: Male
2	Systemic status	1. Diabetes 2. Breast cancer 3. Osteoporosis 4. Dialysis	1: Healthy 2: Medium 3: Moderate/severe
3	Lifestyle	1. Smoking 2. Alcohol consume 3. Bad habits (biting hard objects) 4. Bruxism	0:Never 1: Post-implant smoking quitting 2: Post-implant smoking 0:Never 1: Post-implant alcohol consume 2: Post-implant alcohol consume 0:Never 1: Post-implant bad habit quitting 2: Nu Absence of quitting in bone healing time 0: Never 1: Bruxism healing following bone healing stage 2: Bruxism following bone healing stage
4	Oral hygiene	1. Pre-implant stage 2. Post-implant stage	1: Never 2: 1-2 time/daily 3: 3 times/daily 4: Daily flossing
5	Anatomic features	1. Immediate implant 2. Maxillary/mandible 3. Position 4. Bone density 5. Form and volume	0: No 1: Yes 1: Maxillary 2: Mandible 0: Anterior teeth 1: Bicusps 2: Molars 1: Type I 2: Type II 3: Type III 4: Type IV 1: Type A 2: Type B 3: Type C 4: Type D 5: Type E
6	Implant parameters	1. Abutment angle 2. Diameter 3. Lenght	0: without abutment 1: with abutment, no angulation 2: with abutment, angulation Scale ratio Scale ratio
7	Prosthetic restoration	1. Sinus lift 2. Adittion technique	0: No 1: Yes 0: No 1: Alloplast 2: Autogenous bone

Chiang *et al.* (2013) presented an algorithm (C5.0) that can be used both in medicine and in decision-making in implanto-prosthetic therapy.

The C5.0 algorithm can process medical data with multiple attributes, uses information theory and an inductive learning method to build a decision tree. Table I shows the independent variables that can influence decision trees (Chiang *et al.*, 2013).

Performance indicators (accuracy, sensitivity, specificity) were used to evaluate the performance of the decision tree model.

Chiang *et al.* (2013) proposed this model to allow implantologists to predict the results of implant-prosthetic treatment prior to the surgical stage of implantation in relation to relevant individual parameters.

Digital implantology involves the processing of 3D images obtained with the computer tomograph by means of complex software to realize the virtual positioning of the dental implants and the design of the prosthetic restoration with implant support. The data obtained from the processing of CBCT images allow the analysis of the thickness and structure of the bone tissue and the areas adjacent to the future dental implants. These data are combined with aesthetic parameters and patient requirements to obtain a 3D model that can be displayed and analyzed from all angles. The digital application calculates and displays on the screen the best implant insertion option (thickness, height, depth, angle) depending on the state and shape of the hard and soft tissues, and the desired aesthetic objective. Later, the treatment plan will be developed and the implementation of the implant insertion assisted by 3D navigation systems. Virtual implantation and planning in 3D models allow the elimination of positioning errors prior to the actual surgical stage[25].

Nowadays, the digital workflow components in the planning stage are the following: data collection, computer-aided design/computer-aided manufacturing (CAD/CAM techniques), virtual positioning of dental implants. Digital systems used in implant therapy include expert systems based on the processing of data entered into electronic databases and CBCT images used in the analysis of alveolar bone support and planning of pro-implant surgical procedures, intraoral scanners (IOS), software applications used in the virtual positioning of dental implants and the design of surgical guides, CAD/CAM systems used in the manufacture of surgical guides, respectively software applications used in the creation of digital mock-up and prosthetic restorations with implant support[5,14].

The use of applications based on CBCT image processing is useful both in the pre-surgical diagnosis and in the pre-operative planning of the rehabilitation techniques of the implant sites, respectively of the insertion stage of the dental implants under the conditions in which the variables dependent on the CBCT device and those specific to the patient are optimized[16,4,3].

Two types of guided implant surgery protocols are currently in use – static and dynamic. The static guided system uses a static surgical template that reproduces the virtual position of the implant directly from the CBCT data at the level of a surgical guide, which does not allow intraoperative modification of the implant position[29]. An alternative is the stereolithographic method, which uses software designed to virtually design the surgical stent followed by fabrication by photopolymerization of a liquid resin. Dynamic guided surgery systems, which appeared at the beginning of 2000, allow the direct reproduction of the virtual implant position from the CBCT data and intraoperative changes of the implant position. These systems are based on motion tracking technology with which the position of the dental drill and the patient can be tracked in real time throughout the surgical intervention[29].

Flügge *et al.* (2018) reported that conventional impressions of angled implants are less accurate (with statistically significant differences) compared to those of implants positioned in the axis of the alveolar bone; the scanning protocol has a significant impact on the accuracy and precision of fingerprints.

De Angelis *et al.* (2020) analyzed patient and operator related outcomes through visual analogue scale (VAS) questionnaires in implant-prosthetic therapy by digital workflow versus conventional approach. The digital workflow conducted to better outcomes for patients regarding anxiety, convenience, pain and breathing difficulties when compared to conventional implant procedures. Clinicians had better scores for the digital approach concerning convenience, impression procedure, operative time and workflow. Patient and operators' preferences favored fully digital approach *versus* classic therapy.

The limits of digital workflow-based techniques are related to the degree of accuracy of data collection from CBCT images or the combination of data sets (radiological images, images from optical intraoral scanning or conventional extraoral impression scanning) (Marques *et al.*, 2021).

The number of high-quality randomized clinical trials investigating fully digital workflows in implant-prosthetic therapy is low. Further well-designed prospective studies are requested in the field of digitally-assisted implantology and fixed prosthetics[17].

Digital navigation system Robodent (GmbH, Germany) used in Implantology Discipline of Dental Medicine Faculty, U.M.F. "Grigore T. Popa" Iasi is presented in Figures 7 a–b.

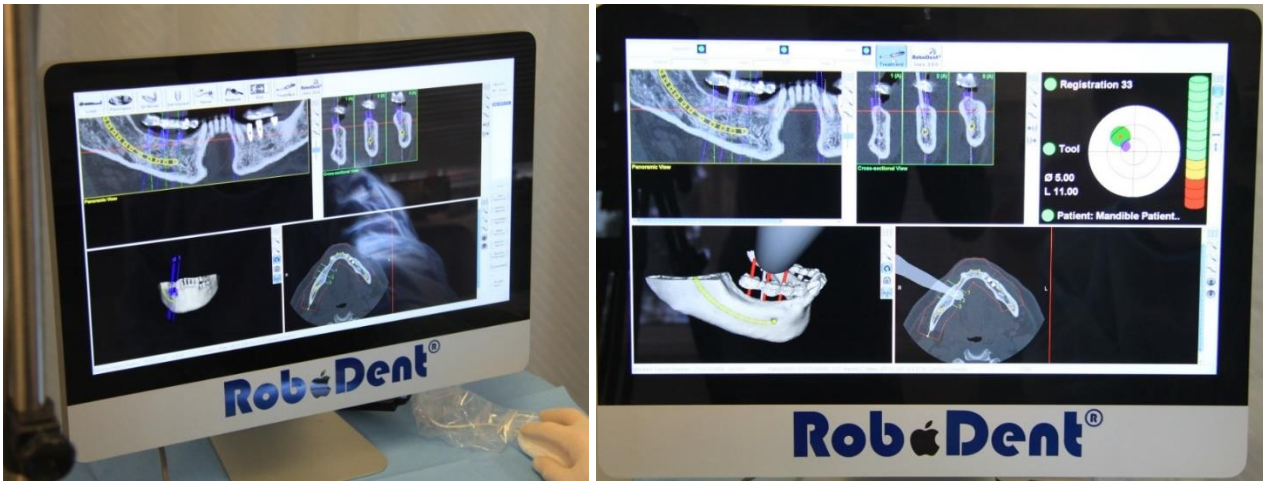

Figure 7 a–b. 3D navigation system Robodent
(Faculty of Dental Medicine, U.M.F. "Grigore T. Popa" Iasi).

CONCLUSIONS

Digital devices allow detection and diagnostic of early occlusal and proximal dental caries, incipient marginal alveolar bone lysis and periodontal pathology, as well as monitoring of non-cavitary dental caries remineralization non-surgical periodontal diseases.

- Digital expert systems, currently used in dental medicine, can be successfully implemented in the analysis and planning of treatments in prosthetics and implant-prosthetic treatments of edentulous patients.
- Digital applications offer the specialist in prosthetics and implantology the opportunity to provide the patient with therapeutic solutions with maximum benefits for long-term success, the time spent and the patient's financial resources.
- Digital techniques are useful in standardizing the clinical observation sheet, detecting dental diseases in early stages, analyzing the clinical situation as well as prognosis and risk.

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