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# DIGITAL TECHNOLOGIES IN DENTISTRY: MAIN ASPECTS, DEVELOPMENT TRENDS, AND APPLICATION FEATURES IN THE DENTAL MeDICAL CENTER OF BOHOMOLETS NATIONAL MEDICAL UNIVERSITY

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## INTRODUCTION

For most of its history, the main goal of the dental specialty was to address the consequences of diseases affecting teeth, surrounding tissues, and structures. However, in recent decades, driven by scientific advancements and a better understanding of numerous biological processes, new approaches in providing dental care have emerged[16].

The increasing significance of incorporating a model in clinical dentistry, which involves thorough diagnostics and the assessment of clinically significant aspects tailored to each individual case using digital technologies, has become more evident[4,10].

In the automotive and aerospace industries, computer modeling and production have been utilized for many years[11,16]. The adoption of computer technologies has also become an integral part of modern dental practice, although their introduction into dentistry is relatively recent[1,12,17]. The development of precise scanning devices, software capable of compensating for material shrinkage, high-tech milling machines, and the emergence of new ceramic materials have significantly expanded the capabilities of CAD/CAM technologies[2,7,13,15].

Recent advances in this rapidly evolving field have reduced production time and eliminated inevitable operator-related flaws during the restoration creation process. Furthermore, such technologies have made it possible to fabricate durable and aesthetically precise ceramic frameworks[12,14,16].

Digital dentistry studies the implementation of dental technologies or devices in dental procedures that involve digital components or are computer-controlled rather than relying on mechanical or electrical instruments[3,5,11].

Digital protocols have increasingly influenced orthopedic treatment processes. Digital technologies are applied at all stages of patient rehabilitation in clinical prosthodontics: medical documentation, diagnostics, planning, treatment, and fabrication of prosthetic structures[2,6,7,8,17].

The advantages of using digital technologies in dental treatment include high accuracy, simplified and faster production, and optimized use of human resources[8,9,15,16]. Achieving positive long-term outcomes requires understanding the interactions between factors such as clinical and laboratory protocols, materials science, and integrating digital workflows with proper training.

For better understanding by clinicians and students of our University, we propose a step-by-step sequence for using digital technologies and fabricating prosthetic structures, as outlined in the following sections.

## 1. The Process of Fabrication

The Process of Fabrication using digital protocols (DSD and CAD/CAM)

The process of creating restorations with digital protocols can be divided into several stages:

1. Diagnostics

- Filling out medical records (electronic medical cards stored in the institution's medical information systems).
- Video and photographic documentation of the patient (without a smile, with a smile, in profile, and full face) to evaluate function, phonetics, and gum exposure.
- Determining tooth color.
- Creation of diagnostic models.
- Radiological examination (dental computer radiovisiography, digital orthopantomography, computed tomography, 3D scanning of the face and dental arches).
- Additional diagnostic methods such as digital occlusal analysis, computer programs to analyze the specifics of articulatory movements, devices to assess the functional state of the temporomandibular joint, and tools to evaluate the condition of the tooth's supporting tissues, including periodontal functionality.

2. Treatment Planning (Digital Prognosis)

- Creation of a "smile contour" considering facial features using DSD software, which calculates the ideal three-dimensional position of the upper jaw (teeth and gums) in relation to the lips and face during movement.
- Virtual modeling (Wax-up) followed by 3D printing of the model.
- Fabrication of a mock-up to simulate the future restoration's aesthetic appearance.

3. Tooth Preparation

- Preparing teeth for the chosen restoration design.
- Taking optical (digital) impressions.

4. Restoration Design

o Finalizing the design of restorations on the prepared teeth using software.

o Exporting files to the CAD software of the milling machine.

5. Fabrication of Structures

o Laboratory fabrication of restorations (if additional equipment and specific skills are available, temporary and permanent restorations can be fabricated directly in the clinic without involving an external laboratory).

6. Fixation

o Final placement and fitting of the restoration.

Digital technologies also play a crucial role in radiological examinations, an integral stage in creating prosthetic constructions.

## 2. Radiological Examination

For minimizing diagnostic errors, specialized computer programs have been developed. These programs are also used for processing information obtained from dental computer radiovisiography and digital orthopantomography.

- Digital X-Ray Imaging: Transforming traditional images into pixel matrices.
- Dental Computer Radiovisiography: Digital dental X-ray diagnostics where the radiovisiograph reproduces images on a monitor screen based on digital signal processing from the detector (Fig.1).
- Orthopantomography: A panoramic radiograph method offering a comprehensive view of the upper and lower jaws.
- Computed Tomography (CT): A radiological method where a beam of X-rays passes through thin layers of tissue to create a three-dimensional digital image.

**Fig. 1. Dental Computer Radiovisiography**

**Fig. 2. Computed Tomography**

Computed tomography (CT) is a method of X-ray examination in which an X-ray beam passes layer by layer and gradually through a thin layer of tissues of the human body in different directions. Computed tomography allows you to obtain a digital three-dimensional image of an object.

As a result of a tomographic study, a large number of points with different optical densities are obtained. Using the optical density regulator, teeth, bone, and the surface of the skin can be highlighted according to CT data. Soft tissues, such as the surface of the gums, cannot be distinguished without the use of special techniques using CT. For their visualization, 3D scanning methods of the oral cavity are used.

## 3. 3D Scanning

The 3D scanning method enables the creation of digital models of oral cavity objects. Technologies for 3D scanning are categorized into two types:

1. Contact Scanners (Mechanical): These rely on direct contact with the object using tactile sensors that transmit the 3D coordinates to a computer. Advantages: High accuracy, independence from lighting and surface reflectivity.

Disadvantages: Long processing times and difficulty scanning internal angles.

2. Non-Contact Scanners (Optical): Utilize optical or laser scanning, preferred for their speed in processing larger objects.

Types of Dental Scanners:

- Extraoral Scanners: Suitable for scanning gypsum models, with a scanning field of 80×90 mm or 90×90 mm and a precision of 5–15 μm.
- Intraoral Scanners: Provide time and resource efficiency, eliminating the need for impressions and models, though their accuracy is slightly lower (approximately 30 μm).

**Fig. 3. Laboratory 3D scanner Medit Identica Light (Bohomolets national medical university)**

**Fig. 4. Intraoral scanner**

The initial scan result is a cloud of dots (file format – .asc). In order to be able to edit the scanned object, it is converted into a grid (file format – .stl).

Equally important is the photographic method of recording and storing information on the received images.

## 4. Photographic Methods in Dentistry

Photography in dentistry is a combination of techniques used to examine patients by capturing images for further analysis by specialists. Dental photography provides accurate visual representations of dental arches and the soft tissues surrounding them.

**Fig. 5. Obtaining a dental photograph**

**Objectives and Tasks of Dental Photography**:

- Understanding the clinical situation.
- Aesthetic analysis of the face and smile.
- Transmission of color and morphological characteristics of teeth.
- Treatment planning and interdisciplinary coordination.
- Systematic documentation of treatment results.
- Monitoring patient progress over time.
- Patient motivation.

**Photographic Methods Include**:

1. **Documentary Portrait Photography**: Captures images of the patient's face to provide reliable visual details.
2. **Dental Macro Photography**: Close-up shots of teeth, taken at scales ranging from 1:15 to 20:1, using macro lenses or standard fixed lenses.
3. **Video Interviewing**: Modern technique for recording clinical data using video.

Documentary portrait photography is an image of a person, made with the help of a camera, the purpose of which is to convey reliable visual features.

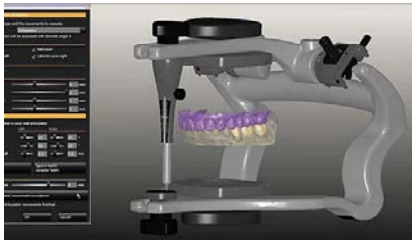
Dental macro photography is a type of photography from a closer location on a larger scale (from 1:15 to 20:1), which is implemented with macro or conventional fix lenses.

Video interviewing is a modern way of capturing the patient's clinical data using a video recording.

## 5. Additional Diagnostic Methods

Digital technologies enable additional diagnostic approaches, such as:

- **Virtual Articulators**: These tools replicate dynamic occlusion during prosthetic modeling by transferring real-world articulator data into digital software using supporting scanners.
- **Digital Occlusal Diagnostics**: The T-Scan analyzer measures individual occlusal contacts with high precision.
- **Temporomandibular Joint (TMJ) Assessment**: Devices like BioJVA (BioResearch, USA) detect TMJ vibrations for analysis.



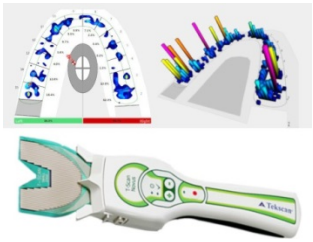


**Fig. 6. Virtual Articulators. Fig. 7. T-scan (Teksan, USA)**

**Fig. 8. Detect TMJ vibrations BioJVA (BIORESEARCH)**

## 6. Application of digital technologies at the planning and manufacturing stage of orthopedic construction

Digital smile design (Digital Smile Design) is a multifunctional conceptual tool for dental treatment planning that improves diagnosis, feedback between the doctor and the patient, and the predictability of the

treatment result. Concept development (DSD) began in 2007, but has undergone changes since then.

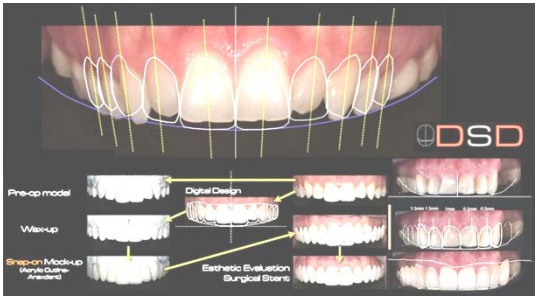



**Fig. 9. The process of digital smile planning**

Digital Smile Design (DSD) is a multifunctional tool for planning dental treatment. It enhances diagnosis, communication between the dentist and patient, and the predictability of treatment outcomes.

**Components of DSD**:

1. **Design (CAD)**: Creating a virtual model of the restoration using computer software based on scanned tooth data.
2. **Manufacturing (CAM)**: Utilizing milling or 3D printing systems to fabricate restorations based on digital designs.

**Two Main Methods of Production**:

1. **Subtractive Method**: Removing excess material from a solid block (e.g., milling).
2. **Additive Method**: Layer-by-layer construction using 3D printing or laser sintering.

Modern CAD/CAM systems integrate advanced features such as dental anatomy databases and virtual catalogs for precise modeling.

DSD involves the design and manufacture of an orthopedic structure with the help of a hardware and software complex of planning and reproduction – the so-called CAD/CAM systems.

Design using computers (Computer-Aided Design – CAD) – reproduction or modeling of the future design on a tooth model, obtained by methods of contact or optical scanning in three-dimensional space with subsequent manufacture of a prosthesis using an automated production system (Computer-Aided Manufacturing – CAM) which consists of abrasive tools and devices that "carve" the structure and controls.


**Fig. 10. Computer-Aided Manufacturing – CAM**

CAD/CAM are terms that entered the practice of dentists in the 80s of the 20th century. SIRONA is a pioneer in the field of digital dentistry.


CEREC 1, ING BRANDESTINI AND DR MORMANN, UNIV ZURICH

Doctor W. Mormann together with engineer M. Brandestini developed the CEREC system (University of Zurich), the first manufacturer was Siemens Dental Corp., Bensheim (Germany), later SIRONA (Germany). The system was focused on the production of all-ceramic inlays.

Today, a large number of different CAD/CAM systems have appeared on the market, capable of solving various tasks, starting with the design of all types of dental prostheses and ending with templates for implantation. The most popular among dentists are the products of the companies Amann Girrbach, Sirona, 3Shape, Exocad Technologies, Kavo, Zirconzahn, Bego.

A modern CAD / CAM system includes the following elements:

– Module for scanning – allows you to convert the geometry of the object into digital data. Different variants of scanners are used. The result of the scan is called a digital (virtual) model.

– CAD module – software (software) for visualization of the received information and modeling of the product (dental prosthesis, template, individual abutment, skull bone).

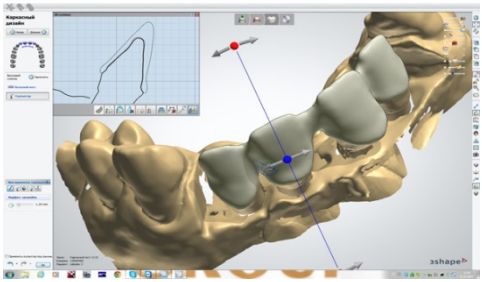


**Fig. 11 The process of modeling the orthopedic structure in the CAD module**

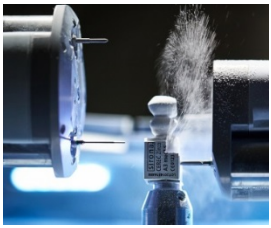


**Fig. 12, 13. Subtractive manufacturing methods**

**Fig. 14. Selective laser sintering**

To facilitate the construction of an adequate virtual model, the possibility of using a dental database is provided in most modern CAD/CAM systems. The virtual catalog includes several thousand variants of the anatomical shape of the teeth.

– CAM module – production technology (milling unit, 3D printer) that transforms digital data into a finished product. In the vast majority, these are milling modules for processing standard industrial blanks of material in the form of software-controlled machines into which a virtual model of the prosthesis is loaded.

However, new additive manufacturing methods of dental restorations are becoming more and more widespread – systems of rapid prototyping, selective laser sintering (SLS – Selective Laser Sintering), etc.

This system can be strictly closed or open. In closed systems, the software works only with the router and scanner of the manufacturer's company.

The production of prosthetic structures with the help of CAD/CAM technology in dentistry can be classified as either "subtractive" (Fig. 12, 13) or "Additive" manufacturing methods. Subtractive manufacturing methods include machining and milling (CAM) and laser ablation technologies, while additive manufacturing methods includes 3D printing and laser melting technologies (Fig. 14).

**CONCLUSIONS**

The development of digital technologies in general, and dental digital protocols in particular, causes not only a high level of people's attention to their health and appearance, but also, in a certain way, leads to a significant increase in the aesthetic requirements of patients, who today want not only functional, but also beautiful, aesthetic restorations that do not differ in appearance from natural teeth.

The constant development of digital technologies, their use in clinical dentistry, makes dental treatment less invasive and relatively simple.

The involvement of digital technologies in the educational process allows future dentists to feel the growing demands for aesthetic results of therapy and to feel the advantages of this decision-making model.

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