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INTEGRATION OF ARTIFICIAL INTELLIGENCE INTO DIGITAL STOMATOLOGY: AN INNOVATIVE APPROACH TO THE AUTOMATED DESIGN AND PRODUCTION OF FRAMING CROWN CORPORATE FRAMES

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Abstract

The article presents Modular Dental Solution (MDS) - a comprehensive new generation technology designed for digital design and production of dental structures of varying complexity. MDR combines physical and digital systems, ensuring individualization, high accuracy, optimization, and automation of processes, as well as the ability to use data multiple times without repeated scanning.

The physical part of MDR - Modular Dental Anatomical System (MDAS) - includes a frame module made of titanium or cobalt chromium using the selective laser alloying method (SLM) and an external anatomical module printed from a hybrid Cerasmart (GC) nanoceramic material on a component BD printer. The design ensures high strength, wear resistance, thermal stability, minimal tooth preparation, and the ability to be installed even with minimal number of support teeth.

Digital Part - Modular Dental Digital System (MDSS) -

includes a web platform for downloading STL scanners and managing orders, as well as an artificial intelligence system for automated module design and file preparation for printing. Training AI in one type of design increases the accuracy of model generation.

The presented technology opens up new possibilities for clinical practice by reducing production time, improving the quality of structures, and simplifying repeated prosthetics without repeated diagnostics.

Keywords: modular dental solution, modular dental anatomical system, modular digital dental system, BD printing, selective laser alloying, Cerasmart, hybrid materials, micromechanical fixers, digital dentistry, artificial intelligence, PointNet++, 3D U-Net, automated design,dental prosthetics, multiple use of digital models

Introduction

Modern dentistry is undergoing a stage of active digitalization, leading to radical changes in approaches to designing and manufacturing dental structures. The use of additive production, automated design systems, and artificial intelligence technologies allows for increased accuracy, reduced treatment time, minimized invasiveness of interventions, and individualized design. These

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trends are especially important in the prosthetics of patients with partial tooth loss and a complex clinical situation.

Traditional methods require significant preparation of the hard tissues of the tooth, complex manual modeling, and multi-stage production, which prolong the treatment period and increase its cost. The limited possibility of replacing structural elements without re-scanning the patient also creates additional difficulties in the long term.

To solve these problems, Modular Dental Solution (MDS) has been developed - a new generation of integrated technology that combines physical and digital systems to create individual dental structures of varying complexity. MDR includes the Modular Dental Anatomical System (MDAS) - a physical part consisting of a frame module and an external anatomical module, as well as the Modular Dental Digital System (MDDS) - a platform for data design and management with the integration of artificial intelligence.

MDR provides minimal tooth preparation, high module placement accuracy, reduced manufacturing time, and the ability to reuse digital models multiple times without repeated scanning. The presented work is aimed at describing the MDR architecture, the materials and production methods used, and discussing the advantages of the technology for clinical practice.

Materials and methods

Modular dental solution (MDR) is implemented as the integration of physical and digital systems to create individual dental structures of varying complexity.

Modular Dental Anatomical System (MDAS) MDAS includes two main modules:

• Frame module (MC) - Framing Crown module (US9,055,990 B1 New York, USA.), is made by selective laser alloying (SLM) method from titanium or cobalt-chromium. The frame has minimal weight, high strength, and is equipped with micromechanical fixers for attaching the external anatomical module.

• External anatomical module (AAM) - printed on a component SD printer made of hybrid Cerasmart (GC) nanoceramic material. The material provides high strength, wear resistance, heat resistance, and excellent aesthetic results. The VAM provides the possibility of quick replacement without dismantling the frame during wear.

Key features of MDAS:

• high wear resistance and thermal stability of the structure;

• minimum weight (2-3 times less compared to classical technologies due to the design and materials);

• minimal tooth preparation;

• the possibility of installing and securely fixing the structure on the minimum number of support teeth (two chewing teeth and one front one).

Modular Dental Digital System

MDSC includes:

• Web platform - for downloading STL scanners and patient clinical information, order management, archiving digital models, and interaction between clinics and laboratories.

• Artificial Intelligence System (AI) - a design module implemented as a hybrid of neural network architectures and classical procedure generation algorithms.

Applied models and methods

Component Description Function in the system

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PointNet++ Neural network architecture for point clouds STL scanning segmentation, support teeth selection
3D U-Net 3D convolutional neural network Module anatomical form generation
DenseNet 3D Network for Checking Geometry Accuracy
Classical algorithms Procedure generation algorithms Detailing and form matching
XGBoost (ML) Machine Learning Predicting Load Areas and Contacts
AI work stages
1. Cleaning the scanner and normalizing the geometry
2. Segmentation and identification of supporting teeth
3. Frame generation taking into account biomechanics
4. Formation of the external anatomical module taking into account aesthetics
5. Preparing STL files for printing
6. Reusable model archiving
Advantage
Training AI on a single type of design (MDS) provides high accuracy.
model generation and result recurrence.
Production process
1. Obtaining an intraoral tooth or dental row scan and forming a BT file
2. Uploading data to the MDCS web platform
3. Automated generation of 3D models of MC and VAM using AI
4. Printing MK using the SLM method on an industrial 3D printer
5. VAM printing on a component 3D printer
6. Post-processing and connection of modules using micromechanical fixers.

Results

During the development and testing of the Modular Dental Solution (MDS)
the following results were obtained:
• The full production cycle time (from scanning loading to the finished design) has been reduced from 72 hours (in traditional manual modeling) to 2-3 hours when using AI and a digital platform.
• The weight of modular structures turned out to be 2-3 times less compared to classical solid-cast crowns and bridge-shaped prostheses due to the framework architecture and materials used.
• Installation of modules on the dental row model ensured fit accuracy within 50-80 microns without additional mechanical adjustment.
• The external anatomical module demonstrated the geometry's stability after multiple replacements, confirming the possibility of reproducing the structure without the need for repeated scanning.
• Tests on model chewing loads showed high stability of the structure when simulating chewing force up to 600 N.
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• The MDR has been successfully adapted to install the minimum number of supporting teeth (two chewing and one front), while maintaining stability and uniform load distribution.
Debate

The presented results confirm the effectiveness of the proposed Modular Dental Solution (MDS) as a modern technology for digital design and production of individual dental structures. MDR provides a number of advantages compared to traditional methods of making crowns and bridge-shaped prostheses.

The key features of MDR are:

• High accuracy and reproducibility of the design due to the use of an artificial intelligence system trained on the same type of modular designs. This allows for minimizing the risk of errors associated with manual modeling and improving landing quality.

• Reduced production time: the introduction of a digital platform and AI has reduced the production time of modules to 2-3 hours compared to the traditional 72-hour cycle.

• Minimal tooth preparation: The construction of the frame and external anatomical module requires significantly less machining volume, which improves patient comfort and preserves more solid tissues.

• Less structural weight: due to the framework architecture and the use of titanium or cobalt chromium, the modules weigh 2-3 times less compared to classic prostheses.

• Flexibility in clinical application: MDR can be established even with minimal number of supporting teeth (two chewing and one front), which expands treatment possibilities in complex clinical cases.

• Convenience of repeated prosthetics: through digital storage of models, it is possible to reproduce the external anatomical module multiple times without the need for repeated scanning, which significantly simplifies the replacement of worn-out elements.

MDR demonstrates prospects for integration into existing SLO/SLM platforms and can be supplemented by the possibility of automated occlusion analysis and integration with virtual models of the maxillofacial system.

Conclusion

Modular dental solution (MDR) represents an innovative technology of the next generation that combines the modular principle of building dental structures, additive production, and digital
a platform with integrated artificial intelligence. The technology provides a personalized approach to prosthetics, high accuracy in designing and manufacturing structures, optimization, and automation of processes, making MDR a promising solution for modern dentistry.

The main advantage of MDR is the absence of the need to possess specialized CAD/CAM software. To work with the system, the doctor or laboratory needs to have access to the internet and the ability to download oral scanners. The web platform and built-in artificial intelligence system automatically process data, generate 3D models of frame modules and external anatomical module, and prepare files for printing on compatible equipment. This significantly reduces the entry threshold for implementing the technology in practice.

Due to the modular architecture and the materials used, the structures have minimal weight (2-3 times lighter than classical prostheses), high strength, wear resistance, and thermal stability. MDR allows for minimizing the volume of tooth preparation and ensures the possibility of installing the structure even with minimal number of support teeth.

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The digital component of the solution ensures long-term data storage and the ability to reproduce the external anatomical module multiple times without repeated scanning, which significantly simplifies the process of repeated prosthetics and saves the resources of the doctor and patient.

Thus, MDR forms a new generation of technologies for dental prosthetics, combining modular approach, additive production, and intelligent digital services, and opens up new possibilities for personalized, high-precision, and minimally traumatic dental row restoration.

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