



(RESEARCH ARTICLE)



USAGE OF ARTIFICIAL INTELLIGENCE IN THE DIGITAL PROTOCOL OF DESIGNING AND MANUFACTURING STABILIZATION OCCLUSAL SPLINTS

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ABSTRACT

Background: Conservative treatment strategies for temporomandibular disorders (TMD) and sleep bruxism emphasize non-invasive stabilization, typically utilizing occlusal splints. Traditional analog fabrication, involving physical impressions and laboratory acrylic processing, is prone to volumetric errors and patient discomfort. Advanced intraoral scanning, cloud computing, and Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM) workflows have transformed splint manufacturing.

Purpose: This study evaluates the direct involvement of Artificial Intelligence (AI) paired with digital dental systems to streamline the digital design and 3D printing fabrication of occlusal splints.

Material and Methods: A digital workflow was established at the PHI UDCC St. Panteleimon – Skopje, involving patients diagnosed with temporomandibular dysfunction. Digital workflows utilizing intraoral scanning, cloud-based design software powered by AI automation (*SprintRay Cloud Design*), and NextGen biocompatible polymers (*SprintRay NightGuard Flex*) were utilized.

Results: The AI automated boundary alignment and undercut calculations, facilitate high-precision designs. Utilizing advanced 3D printers (*SprintRay Pro 2*), print preparation times were minimized, decreasing potential laboratory structural discrepancies and optimizing clinical workflow timelines.

Conclusion: Incorporating AI algorithms into digital dental manufacturing facilitates same-day splint delivery, providing anatomical precision and predictable biomechanical adaptation. Meticulous long-term tracking remains mandatory to firmly evaluate the exact clinical accuracy across emerging printing systems.

Keywords: Occlusal Splint, Artificial Intelligence (AI), Digital Workflow, Temporomandibular Disorders (TMD), 3D Printing.

1 INTRODUCTION

Conservative therapeutic interventions for temporomandibular disorders (TMD) and sleep bruxism are clinically established as the primary line of patient management. Historically, research spanning over a century has aimed to distinguish between the abstract etiology of bruxism and its structural clinical consequences, such as severe attrition, muscle hypertrophy, or joint clicking.¹

Historically treated through varied behavioral and physical perspectives, modern clinical consensus establishes that occlusal appliances or stabilization splints serve as a crucial biomechanical barrier. They effectively protect teeth surfaces, distribute load, and alleviate pressure within the temporomandibular joint (TMJ) apparatus.²

The traditional manufacturing of stabilization splints heavily relies on dental stone pouring from alginate or elastomeric dental impressions, followed by manual wax-ups or flasking with cold- or heat-cured acrylic resins. These analog laboratory steps introduce a cumulative risk of material shrinkage, linear distortions, and requiring prolonged chairside adjustments during delivery.³

Recent breakthroughs in digital technologies—most notably high-resolution intraoral scanners and modern dental CAD software—allow clinicians to construct an entirely virtual design environment. The recent integration of Artificial Intelligence (AI) further optimizes this transition, automating critical, technically demanding stages like the detection of margins, blockade of undercut path-of-insertions, and distribution of simulated occlusal contact points. Paired with additive manufacturing (3D printing), fully digital workflows eliminate traditional errors, reduce turnaround times, and ideally enable same-day splint delivery directly within clinical or institutional settings.⁴

1.1 Purpose

The purpose of this study is to represent the precise involvement and clinical implementation of AI systems coupled with digital dental infrastructure in the field of digitally designing and manufacturing optimized occlusal splints for TMD patients.

2 MATERIAL AND METHODS

The clinical study was conducted at the Public Health Institution University Dental Clinic Center (PHI UDCC) St. Panteleimon in Skopje, North Macedonia, utilizing patients demonstrating various degrees of temporomandibular dysfunction. Institutional and informed patient consents were thoroughly obtained from all participants prior to their clinical intake.

The overall diagnostic and therapeutic framework involved a parallel assessment, evaluating how the implementation of an advanced digital dental workflow compares to traditional, analog prosthodontic methodologies.

The formalized digital protocol consisted of the following sequence:

- **Data Acquisition (Intraoral Evaluation):** High-precision extraoral scanning of plaster cast models of the first patient and intraoral scanning of the second patient were performed to register the maxilla and mandible arches alongside the patient's centric relation bite records.
- **AI-Driven CAD Architecture:** The digital mesh data (STL files) were processed using cloud-connected diagnostic software (*Medit/3Shape/SprintRay Cloud Design*). The integrated AI algorithms automatically mapped the precise boundary line of the splint, identified the path of insertion, computed undercuts, and generated optimized parameters for thickness and occlusal relief.
- **Material and Additive Manufacturing (CAM):** Fabrication was processed via the *SprintRay Pro 2* printing ecosystem. The material selected was SprintRay NightGuard Flex (REF: SRI-0202015, Batch: S24K019), a high-strength, biocompatible 3D printing polymer specifically designed for nightguards and splints. The resin activation was set in the wavelength range of 385nm–405nm.

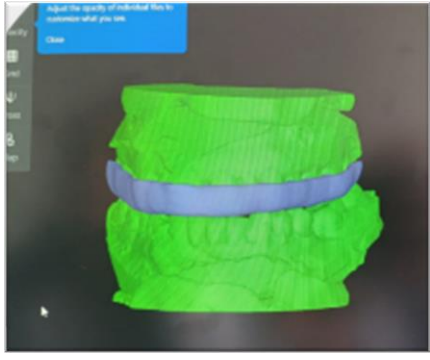
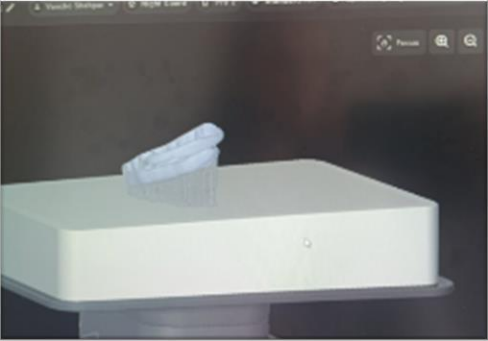
- **Post-Processing Protocol:** The printed objects underwent standardized automated isopropyl alcohol washing followed by post-curing cycles in an automated UV curing chamber (*SprintRay*) to guarantee structural monomer conversion and final material biocompatibility.

3 CASE STUDIES

3.1 Case Study Number 1

A female patient was presented with severe chronic masticatory muscle pain, restricted jaw opening, and secondary sleep bruxism symptoms. Initial diagnostics involved an intraoral evaluation coupled with Cone-Beam Computed Tomography (CBCT) to analyze the structural changes of the condyle within the glenoid fossa and assess joint space distribution.

Following digital jaw scans of the plaster cast models, a maxillary stabilization splint was planned using the *SprintRay Cloud Design* portal. The AI engine processed the automated orientation at a 25-degree preference for dental support structures, calculating a printing configuration at 100 Microns per layer thickness, consuming a precise calculated resin volume of approximately ~9 mL. The digital design was successfully transmitted to the *SprintRay Pro 2* printer with an active printing time of 44 minutes. Following automated washing, curing, and minimal lab finishing, the clear, precise splint was inserted. It demonstrated absolute anatomical retention, uniform flat occlusal contacts, and resulted in immediate alleviation of joint pressure.

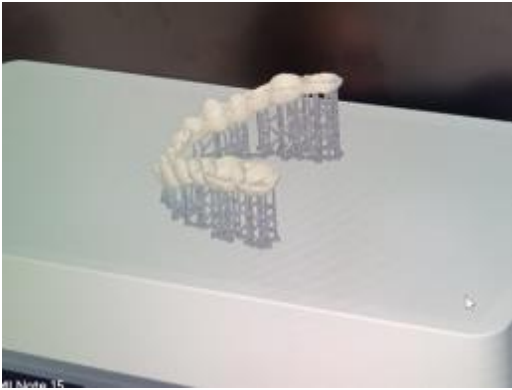
	
Figure 1a) Extraoral scan of a plaster cast of a patient with night bruxism	Figure 1b) Digital planning of stabilization occlusal splint
	
Figure 1c) The process of printing of the stabilization occlusal splint	Figure 1d) Intraoral view of the stabilization occlusal splint

3.2 Case Study Number 2

A male patient exhibited prominent signs of temporomandibular joint clicking, atypical occlusal wear facets, and local joint tenderness. An intraoral scan was captured directly in the dental chair. The digitized maxilla and mandible arches were submitted online for cloud-based design calculation.

The cloud platform processed the request under the designated file profile: *igor_ii_LowerJawRetainer_V1_1779100_046977.stl*. The AI algorithm precisely outlined a mandibular splint, mapping out automatic vertical dimension adjustments. The virtual model was arranged on the print setup dashboard under a "Flat/Fastest Print" structural orientation preference. The object was fabricated using *NightGuard Flex* resin, yielding a highly accurate appliance that

leverages the material's unique elastomeric, smart-flex properties. Upon clinical placement, the splint provided an optimal fit, uniform canine guidance, and stable posterior support without requiring significant chairside corrective trimming.

	
Figure 2a) Image of an intraoral scan of the lower jaw of the patient	Figure 2b) Designing of a stabilization occlusal splint of the patient
	
Figure 2c) Following the process of printing of the stabilization occlusal splint	Figure 2d) Intraoral view of the stabilization occlusal splint

4 RESULTS AND DISCUSSION

Our clinical observations confirm that the addition of AI automation significantly enhances the predictability and reproducibility of splint fabrication compared to classic analog methods. This is strongly supported by recent data in global dental literature.^{5,6}

Taneva *et al.* (2021) emphasize that modern technological advancements have profoundly reshaped the utility of occlusal splints. Their research indicates that combining digital functional diagnostics, like the digital axiograph, with advanced *3Shape Digital Design Software* allows for precise mapping of individual lower jaw trajectories and movement rates. This transforms splint prophylaxis from a hypothetical model into a highly precise, evidence-based therapy.⁷

Furthermore, a comprehensive systematic review published by Saini *et al.* (2026) in *BDJ Open* compiled findings from 2115 initial records comparing digital and traditional bruxism splints. Their data indicated that digital splints machined or 3D-printed from high-strength medical polymers demonstrate a clear clinical tendency toward improved outcomes regarding symptom severity reduction and superior fit.⁸

This is further validated by a randomized controlled clinical trial conducted by Chen *et al.* (2026) in *Head & Face Medicine*. They established that fully digital occlusal splints show significant post-treatment reductions in Visual Analog Scale (VAS) pain indices, Craniomandibular Index (CMI), and Palpation Index (PI) scores.⁹

Their radiographic data via CBCT also verified structural condylar adaptation, proving that digital workflows represent a highly promising, precision-based approach for personalized TMD management. Additionally, alternative therapies, such as wireless biofeedback appliances highlighted by Gu & Yang *et al.* (2015), provide exciting insights into future smart-device integrations.¹⁰

Artistically and conceptually, this profound intersection of human diagnostic skill and artificial automation mirrors Michelangelo's timeless fresco, *The Creation of Adam* (1508-1512) inside the Vatican Museum. On the fresco, God's

finger is fully outstretched in his trial to reach Adam, while Adam's hand remains relaxed. In modern clinical practice, as therapists operating under the progressive slogan "The Future is Now," we are similarly challenged in the race with the machines and digital tools we have created. To maintain pace with these rapidly evolving digital setups, healthcare professionals must commit to continuous, lifelong education. This ongoing educational process is now remarkably magnified, optimized, and supported through the implementation of AI engines.

5 CONCLUSION

The implementation of AI algorithms in the field of digitally designing and manufacturing occlusal splints provides outstanding clinical precision, material optimization, and enhanced logistics. However, this advanced technology must be meticulously followed, practiced, and analyzed in the coming years. Establishing thorough, long-term clinical studies remains essential for providing upcoming dental generations with concrete metrics regarding system accuracy and clinical efficacy. Such research is critical to definitively determining which digital modalities optimize overall healthcare system results.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Disclosure of conflict of interest

The authors declare no conflicts of interest regarding this manuscript.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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