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CLINICAL APPLICATION OF THE MODJAW DIGITAL SYSTEM IN FUNCTIONAL DENTAL REHABILITATION

КЛІНІЧНЕ ЗАСТОСУВАННЯ ЦИФРОВОЇ СИСТЕМИ MODJAW У ФУНКЦІОНАЛЬНІЙ СТОМАТОЛОГІЧНІЙ РЕАБІЛІТАЦІЇ

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Abstracts

The **aim** of this narrative review was to analyze current evidence on the clinical application of the MODJAW digital jaw-tracking system and related dynamic technologies, with a focus on their diagnostic value, accuracy, limitations, and perspectives for integration into contemporary dental practice.

Materials and Methods. A narrative review of the literature published between 2013 and 2025 was conducted using PubMed, MDPI, DOAJ, Ovid, and Google Scholar databases. The search strategy included the following keywords: *MODJAW*, *jaw tracking system dentistry*, *mandibular kinematics*, *digital occlusion movement tracker*, *virtual articulator movement*, and *4D dentistry*. Eligible publications included clinical studies, in vitro accuracy assessments, comparative analyses with conventional articulators, and review articles addressing dynamic jaw tracking and virtual articulation systems.

Results. The analysis demonstrated that the implementation of dynamic jaw-tracking systems represents a paradigm shift from static occlusal analysis toward functional evaluation of mandibular kinematics. The MODJAW system showed high precision and repeatability in recording mandibular movements, with accuracy comparable to industrial-grade three-dimensional scanning systems when standardized calibration protocols were applied. Multiple studies confirmed reliable hinge-axis identification and reproducible condylar pathway registration, independent of bite registration materials.

Clinically, dynamic jaw tracking enabled improved assessment of excursive movements, condylar guidance, and occlusal contact distribution during functional activities such as mastication. Compared with conventional mechanical and static virtual articulators, MODJAW provided superior visualization of complex mandibular trajectories and facilitated early identification of functional disturbances, including eccentric bruxism and temporomandibular joint dysfunction. In orthodontics, measurable differences in mandibular kinematics across skeletal classes supported individualized treatment planning. In prosthodontics, enhanced accuracy of virtual articulation was associated with a reduced risk of occlusal discrepancies and improved communication with CAD/CAM workflows through direct data export.

Conclusions. The MODJAW system represents a promising tool for digital functional dental rehabilitation, offering objective real-time assessment of mandibular kinematics beyond static articulation. Current evidence suggests that dynamic digital articulators enhance diagnostic accuracy and support personalized treatment planning. However, successful clinical implementation requires further standardization, validation, and clinician training to ensure consistent and reliable use in daily practice.

Keywords: digital articulator, mandibular kinematics, functional occlusion, jaw tracking, temporomandibular joint, bruxism.

Метою цього оглядового дослідження було проаналізувати сучасні наукові дані щодо клінічного застосування цифрової системи динамічного відстеження рухів щелепи MODJAW та споріднених динамічних технологій із фокусом на їх діагностичну цінність, точність, обмеження та перспективи інтеграції в сучасну стоматологічну практику.

Матеріали та методи. Проведено наративний огляд наукової літератури, опублікованої в період з 2013 по 2025 роки, з використанням баз даних PubMed, MDPI, DOAJ, Ovid та Google Scholar. Пошук здійснювали за такими ключовими словами: MODJAW, jaw tracking system dentistry, mandibular kinematics, digital occlusion movement tracker, virtual articulator movement, 4D dentistry. До аналізу було включено клінічні дослідження, лабораторні in vitro оцінки точності, порівняльні дослідження з традиційними артикуляторами, а також оглядові публікації, присвячені динамічному відстеженню рухів щелепи та системам віртуальної артикуляції.

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Результати. Аналіз показав, що впровадження динамічних систем відстеження рухів щелепи є парадигмальним зсувом від статичного аналізу оклюзії до функціональної оцінки кінематики нижньої щелепи. Система MODJAW продемонструвала високу точність і відтворюваність реєстрації рухів нижньої щелепи, з показниками, порівнянними з промисловими тривимірними системами сканування за умови застосування стандартизованих протоколів калібрування. У низці досліджень підтверджено надійну ідентифікацію шарнірної осі та відтворювану реєстрацію траєкторій руху виросткових відростків, незалежно від використаних матеріалів для реєстрації прикусу. У клінічному аспекті динамічне відстеження рухів щелепи забезпечувало більш точну оцінку екскурсійних рухів, напрямку виросткового ведення та розподілу оклюзійних контактів під час функціональних актів, зокрема жування. Порівняно з традиційними механічними та статичними віртуальними артикуляторами, система MODJAW забезпечувала кращу візуалізацію складних траєкторій рухів нижньої щелепи та сприяла ранньому виявленню функціональних порушень, включаючи ексцентричний бруксизм і дисфункцію скронево-нижньощелепного суглоба. В ортодонтії виявлені вимірювані відмінності кінематики нижньої щелепи між різними скелетними класами, що підтверджує доцільність індивідуалізованого планування лікування. В ортопедичній стоматології підвищена точність віртуальної артикуляції асоціювалася зі зниженням ризику оклюзійних неточностей і покращенням комунікації з CAD/CAM-лабораторіями завдяки прямому експорту даних.

Висновки. Система MODJAW є перспективним інструментом цифрової функціональної стоматологічної реабілітації, що забезпечує об'єктивну оцінку кінематики нижньої щелепи в режимі реального часу за межами статичної артикуляції. Наявні наукові дані свідчать, що динамічні цифрові артикулятори підвищують точність функціональної діагностики та підтримують персоналізоване планування лікування. Водночас успішне клінічне впровадження таких систем потребує подальшої стандартизації, валідації та належної підготовки лікарів для забезпечення стабільних і відтворюваних результатів у повсякденній практиці.

Ключові слова: цифровий артикулятор, кінематика нижньої щелепи, функціональна оклюзія, відстеження рухів щелепи, скронево-нижньощелепний суглоб, бруксизм.

Introduction. In contemporary dental practice, the rapid development of digital technologies – such as intraoral scanning, CAD/CAM modeling, digital occlusal analysis, and dynamic recording of mandibular movements – has significantly improved prosthetic outcomes and the overall accuracy of functional diagnostics. Particular attention in clinical research is directed toward the identification of occlusal interferences, which are defined as undesirable or premature contacts between occlusal surfaces during functional mandibular movements.

It has been established that a significant majority of patients exhibit at least one type of occlusal interference during laterotrusive or protrusive movements [7, 12]. Such interferences are considered multifaceted clinical factors, acting both as a primary cause and a potential consequence of functional disturbances, particularly in individuals with parafunctional habits [13].

Recent evidence further supports the strong association between occlusal interferences, bruxism, and temporomandibular joint (TMJ) dysfunction. Clinical data indicate a significantly higher prevalence of occlusal interferences in patients with bruxism (reaching 46%) compared to asymptomatic controls (14%), often correlating with increased reports of TMJ pain and masticatory muscle fatigue [10]. Consequently, occlusion remains a critical factor in the multifactorial pathogenesis of functional dental disorders.

Given the clinical relevance of these conditions, the demand for precise diagnostic tools is increasing. Conventional methods, such as articulating paper and wax records, often present limitations in terms of objectivity and reproducibility. Dynamic digital jaw-tracking systems, represented by the MODJAW system, address these challenges by enabling real-time visualization and quantitative assessment of mandibular kinematics and occlusal contacts during functional activity.

Aim of the study. The aim of this review is to analyze current evidence on the clinical application of the MODJAW digital jaw-tracking system and related technologies, focusing on their diagnostic value, limitations, and perspectives for implementation in dental practice.

Materials and methods. This narrative review is based on a comprehensive narrative review of publications retrieved from PubMed, MDPI, DOAJ, Ovid, and Google Scholar using the following keywords: *MODJAW*, *jaw tracking system dentistry*, *mandibular kinematics*, *digital occlusion movement tracker*, *virtual articulator movement*, *4D dentistry*. Studies published between 2013 and 2025 were considered. Inclusion criteria comprised investigations involving MODJAW or comparable dynamic systems, clinical applications, laboratory assessments of accuracy, and review articles addressing digital articulators and mandibular kinematics.

Results. The integration of dynamic jaw-tracking systems into the dental workflow has shifted the focus from static occlusion to functional kinematics. The analysis of current literature (2013-2025) reveals several key domains regarding the clinical performance and diagnostic value of the MODJAW system.

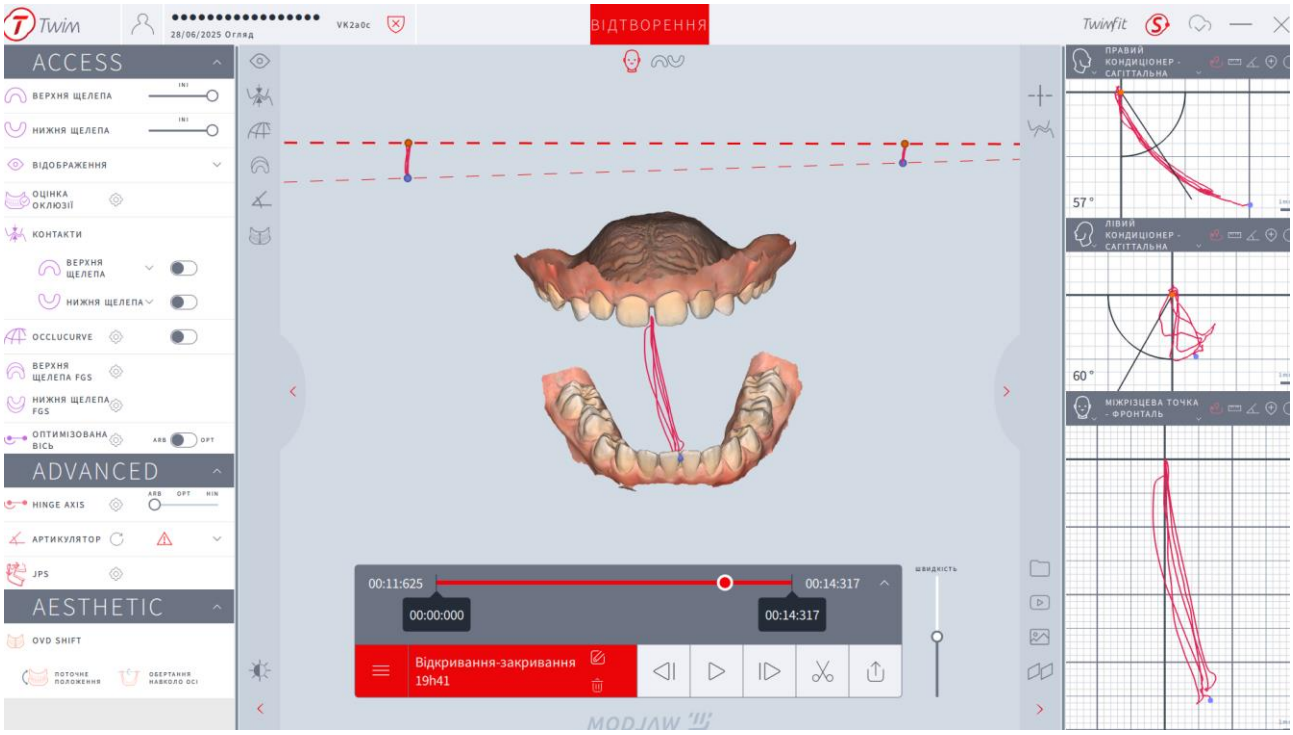

Figure 1. Representative visualization of mandibular kinematics recorded with the Modjaw system, including 3D jaw models, incisal point trajectory, and sagittal condylar movement graphs during opening and closing movements

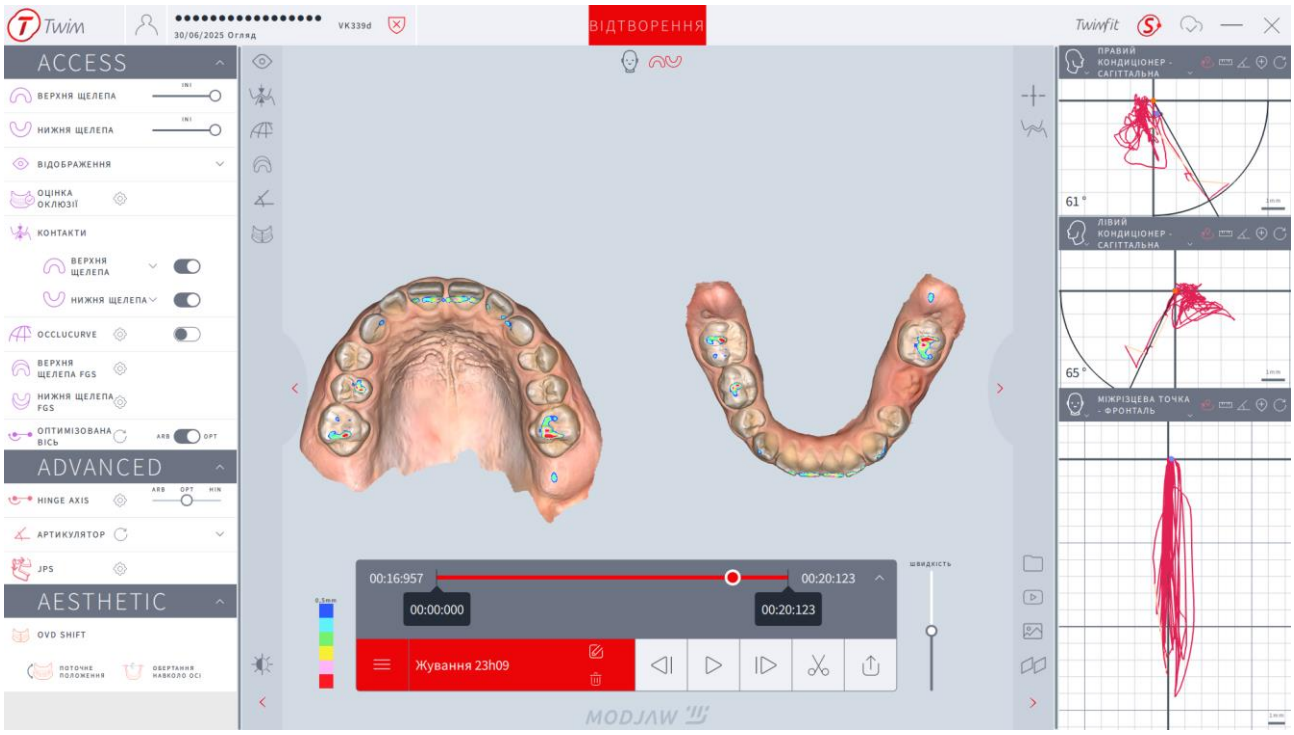

Figure 2. Representative visualization of masticatory function recorded with the Modjaw digital system. The image demonstrates synchronized three-dimensional maxillary and mandibular models with occlusal contact mapping, incisal point trajectory, and bilateral sagittal condylar movement curves during a chewing cycle

1. Reproducibility and Accuracy of Digital Jaw-Tracking

The MODJAW system demonstrates high precision and reliability in recording mandibular kinematics, providing a digital alternative to traditional methods [3]. To ensure clinical relevance, the implementation of standardized digital protocols is essential for consistency in data interpretation [15]. Laboratory *in vitro* studies confirm that the accuracy of these recordings is comparable to industrial 3D scanning systems, with precision values reaching the micrometer range [17]. While digital systems offer high repeatability, absolute functional parameters may occasionally differ from those obtained using traditional mechanical devices, necessitating precise calibration [9]. Furthermore, the reproducibility of digital articulators remains high regardless of the bite-registration materials used [1].

2. Clinical Applications in Orthodontics and Prosthodontics

The integration of dynamic tracking enables the differentiation of kinematic parameters across various skeletal classes, supporting individualized orthodontic planning. Recent studies using optical jaw-tracking systems have demonstrated measurable differences in mandibular kinematics across orthodontic patient groups, supporting the clinical relevance of dynamic functional analysis beyond static occlusal assessment [16]. In prosthetic dentistry, the increased accuracy of digital articulators is associated with a reduced risk of occlusal errors [5]. Furthermore, the ability to export kinematic data facilitates seamless collaboration between clinicians and CAD/CAM laboratories [6]. Functional analysis of TMJ movements is also significantly improved compared to conventional approaches [14].

3. Diagnostic Value and Functional Evaluation

The potential for early identification of functional disorders, including eccentric bruxism, underscores the diagnostic value of dynamic jaw-tracking [4]. Compared to static CBCT-based assessments, dynamic systems provide a more accurate reproduction of condylar pathways [8]. Additionally, digital occlusal records offer superior accuracy over conventional mechanical methods, particularly in cases with restricted mandibular mobility [2]. Systematic evaluations also indicate that dynamic digital systems outperform static virtual models in recording complex excursive movements [11]. Representative examples of occlusal contact visualization during mastication before and after occlusal adjustment are shown in Figures 3, 4 and 5.

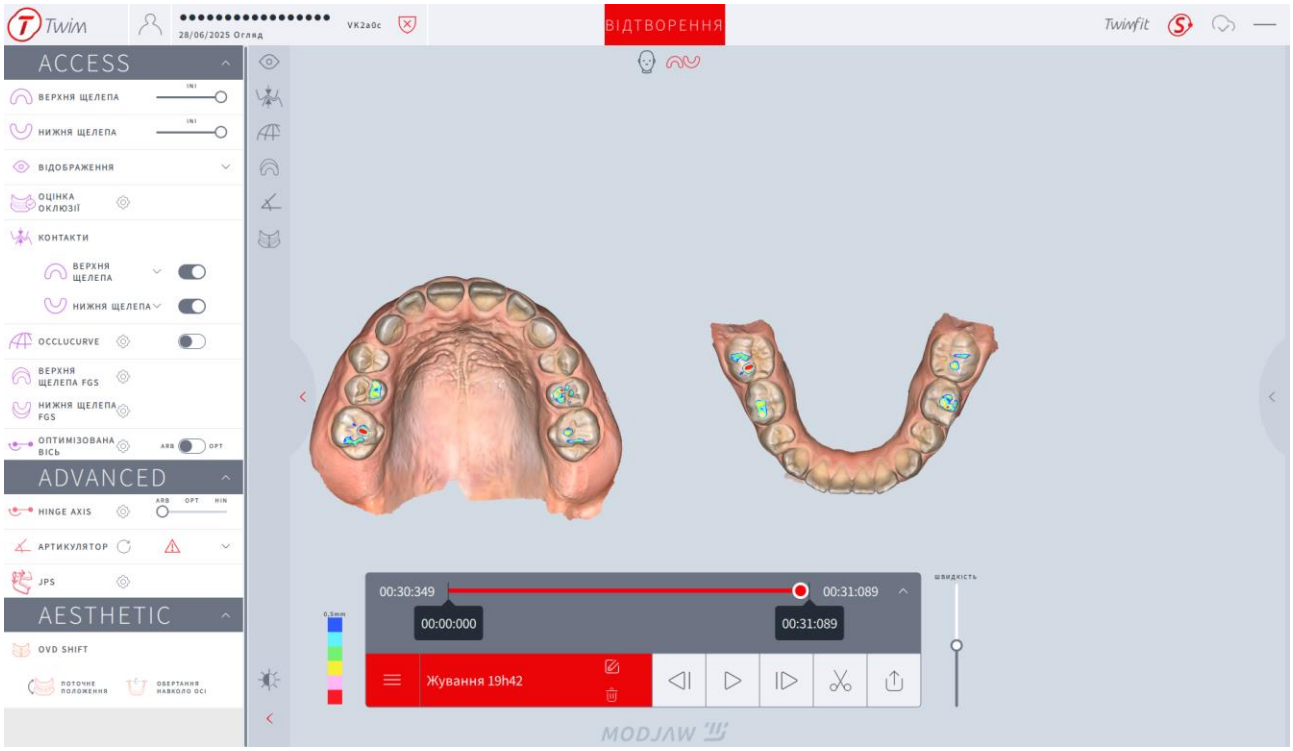

Figure 3. Representative visualization of occlusal contact distribution during mastication in the initial clinical situation recorded with the Modjaw digital system. The image shows synchronized three-dimensional maxillary and mandibular models with color-coded occlusal contact mapping on the occlusal surfaces, illustrating baseline functional occlusal conditions prior to occlusal adjustment

Figure 4. Representative visualization of occlusal contact distribution during mastication after occlusal adjustment recorded with the Modjaw digital system. The image demonstrates synchronized three-dimensional maxillary and mandibular models with color-coded occlusal contact mapping, illustrating changes in contact distribution following occlusal correction during functional mandibular movements

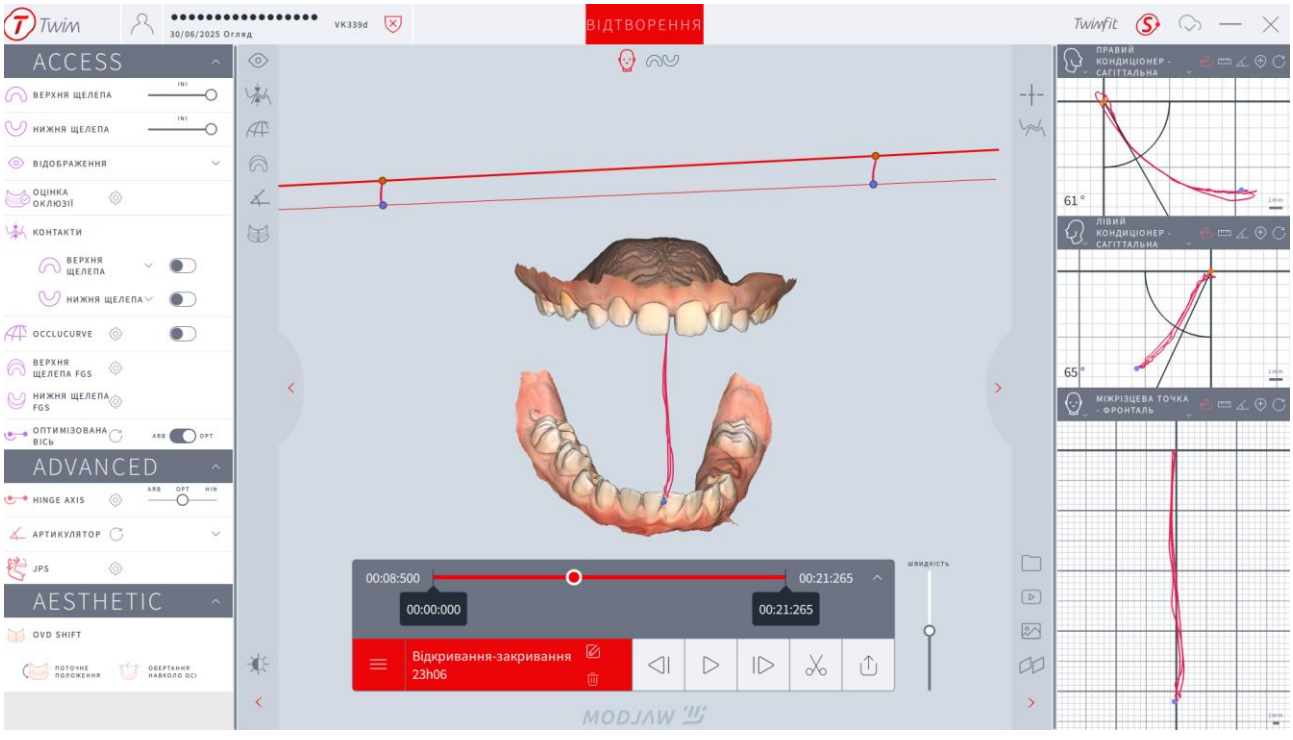

Figure 5. Representative visualization of mandibular opening and closing movements after occlusal adjustment recorded with the Modjaw digital system. The image demonstrates synchronized three-dimensional maxillary and mandibular models, incisal point trajectory, and bilateral sagittal movement curves of the condylar processes during a functional opening-closing cycle following occlusal correction

Discussion. The findings of this review demonstrate that the transition from mechanical to digital dynamic articulation significantly enhances the precision of functional dental diagnostics. As emphasized by the analysis of current protocols, the shift toward standardized digital workflows is essential for maintaining clinical reliability and ensuring the comparability of kinematic data [15]. Our results confirm that dynamic systems provide superior accuracy in recording complex excursive movements compared to static virtual models, which often fail to capture the full range of mandibular trajectories [11].

The primary advantage of the MODJAW system lies in its ability to create a "virtual twin" by integrating real-time kinematic registration with high-resolution 3D intraoral scans. This integration allows for a level of diagnostic depth that was previously unattainable with conventional methods. However, it is important to acknowledge that while MODJAW is a prominent representative of 4D dentistry, it exists within a broader landscape of dynamic tracking technologies. Other established systems, such as Zebris (optoelectronic) and ARCUSdigma (ultrasonic), have long been utilized for recording mandibular kinematics. While these systems provide high-resolution data for electronic axiography, the MODJAW system simplifies the workflow by offering seamless data export to CAD/CAM platforms without the need for manual transfer protocols [6].

Furthermore, the clinical relevance of dynamic tracking extends beyond simple occlusal adjustments. The ability to differentiate condylar pathways and identify functional disturbances, such as eccentric bruxism, provides a foundation for preventive dentistry and complex prosthetic rehabilitation [4, 8]. Despite the high repeatability of digital articulators, clinicians must remain aware that absolute functional values may differ slightly from traditional mechanical recordings, necessitating careful calibration and a thorough understanding of digital parameters [1, 9].

It is important to note that while this review focuses on the MODJAW system as a prominent example of 4D dentistry, it belongs to a broader category of dynamic jaw-tracking technologies. Nevertheless, each technology has specific calibration requirements and learning curves, and the choice of system should be guided by the clinical task, ranging from routine functional assessment to complex full-mouth rehabilitation.

Conclusions. The MODJAW system is a promising tool in digital functional rehabilitation of dental patients, as it enables objective assessment of mandibular kinematics and supports individualized treatment planning. The system demonstrates reliable hinge-axis identification and good to excellent repeatability, which are essential for virtual articulation and individualized restorative procedures. Current evidence suggests that MODJAW and similar dynamic digital articulators may enhance the accuracy of functional analysis and support personalized dental care. However, successful clinical implementation requires further standardization, validation, and development of interoperable digital solutions.

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