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Measurement properties of CADIAX computerized axiography for hinge axis and condylar path assessment: A systematic review of technical accuracy, reliability, agreement with optical and ultrasonic jaw tracking systems, and diagnostic validity

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Abstract

INTRODUCTION. Computerized axiography with the CADIAX family of devices (Gamma Dental, Austria) is widely used to locate the kinematic transverse horizontal axis and to derive sagittal condylar inclination (SCI) and Bennett angle (BA) for articulator programming and temporomandibular joint diagnostics. This review appraised the measurement properties of CADIAX devices: technical accuracy, reliability, agreement with alternative recording methods, and diagnostic or discriminative validity.

MATERIALS AND METHODS. The review followed PRISMA 2020. PubMed (four search strings), Consensus and Google Scholar were searched from 1 January 2000 to 2 September 2026, supplemented by citation searching. Eligible studies used any CADIAX-family axiograph (Cadiax III, Compact, Compact 2, Diagnostic, Cadiax 4) and reported at least one measurement property. Risk of bias was assessed with QUADAS-2 for diagnostic accuracy studies, the COSMIN reliability and criterion validity standards for reliability and agreement studies, and a QUIN-adapted checklist for in vitro studies. Findings were synthesized narratively because of heterogeneity in designs, parameters and reference standards.

RESULTS. Of 562 records, 29 studies (30 reports) were included: 4 in vitro accuracy studies, 8 reliability studies, 9 agreement studies and 8 diagnostic or known-groups validity studies. On articulators with pre-set values the mean error of Cadiax Compact devices was about 1.2° (maximum 2.5° to 3.4°). Test-retest reliability of SCI was consistently excellent (ICC 0.97 to 0.98 at 3 and 5 mm), BA reliability was lower but still above 0.90 in recent studies, whereas transverse parameters showed poor reliability in one multilevel analysis. Mounting method changed mean SCI by up to 10°. Compared with MODJAW, SCI recorded by CADIAX was systematically lower (mean difference 5.9°, 95% CI 3.9 to 8.2), with wider discrepancies at 3 mm than at 5 mm. Compared with Zebris JMA, SCI was comparable once the reference plane was harmonized, whereas BA differed. Against MRI, the sensitivity for disc displacement ranged from 27% to 85% and specificity was 95% in the only study with a prospective reference standard. Case-control studies showed that qualitative kinematic abnormalities, not ranges of motion, separated patients with myogenous TMD or migraine from controls.

CONCLUSION. CADIAX axiography is a technically accurate and highly repeatable method for recording SCI and the kinematic hinge axis, provided a paraocclusal mounting is used. Its numerical outputs are not interchangeable with those of optical or ultrasonic systems without device-specific correction, and its diagnostic accuracy for internal derangement is insufficient to replace MRI. The evidence base consists of small single-center studies with heterogeneous protocols; multicenter studies with blinded reference standards and standardized reference planes are needed.

Keywords: computerized axiography, CADIAX, hinge axis, sagittal condylar inclination, Bennett angle, jaw tracking, MODJAW, Zebris, temporomandibular disorders, systematic review

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Измерительные характеристики компьютеризированной аксиографии CADIAX для оценки шарнирной оси и траектории движения мышцелка: систематический обзор технической точности, надежности, согласованности с оптическими и ультразвуковыми системами регистрации движений нижней челюсти и диагностической валидности

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Резюме

ВВЕДЕНИЕ. Компьютеризированная аксиография с использованием устройств семейства CADIAX (Gamma Dental, Австрия) широко применяется для определения кинематической поперечной горизонтальной оси, а также для определения сагиттального наклона суставного пути (SCI) и угла Беннета (BA) при программировании артикуляторов и диагностике заболеваний височно-нижнечелюстного сустава. В настоящем обзоре проведена оценка измерительных характеристик устройств CADIAX, включая техническую точность, надежность, согласованность с альтернативными методами регистрации, а также диагностическую и дискриминантную валидность.

МАТЕРИАЛЫ И МЕТОДЫ. Обзор выполнен в соответствии с рекомендациями PRISMA 2020. Поиск в базах PubMed (по четырем поисковым стратегиям), Consensus и Google Scholar проводился с 1 января 2000 г. по 2 сентября 2026 г. и был дополнен поиском по библиографическим ссылкам. В обзор включены исследования, в которых использовался любой аксиограф семейства CADIAX (Cadiax III, Compact, Compact 2, Diagnostic, Cadiax 4) и оценивалось как минимум одно измерительное свойство. Риск систематической ошибки оценивали с использованием инструмента QUADAS-2 для исследований диагностической точности, стандартов COSMIN для оценки надежности и критериальной валидности в исследованиях надежности и согласованности, а также адаптированного контрольного перечня QUIN для исследований in vitro. Результаты были обобщены описательно в связи с неоднородностью дизайна исследований, оцениваемых параметров и референтных стандартов.

РЕЗУЛЬТАТЫ. Из 562 выявленных записей в обзор были включены 29 исследований (30 публикаций): 4 исследования технической точности in vitro, 8 исследований надежности, 9 исследований согласованности и 8 исследований диагностической или валидности известных групп. При использовании артикуляторов с заданными референтными значениями средняя погрешность устройств Cadiax Compact составляла около 1,2°, а максимальная погрешность – от 2,5° до 3,4°. Тест-ретестовая надежность определения SCI была стабильно высокой (ICC 0,97–0,98 при 3 и 5 мм), тогда как надежность определения BA была ниже, но в недавних исследованиях оставалась выше 0,90. В одном многоуровневом анализе для поперечных параметров была выявлена низкая надежность. Метод фиксации приводил к изменению среднего значения SCI до 10°. По сравнению с MODJAW значения SCI, зарегистрированные с помощью CADIAX, систематически были ниже (средняя разница 5,9°; 95% ДИ 3,9–8,2°), причем расхождения были более выраженными при 3 мм, чем при 5 мм. При сравнении с Zebris JMA значения SCI были сопоставимыми после стандартизации референтной плоскости, тогда как значения BA различались. При сравнении с MPT чувствительность метода в отношении выявления смещения суставного диска варьировала от 27 до 85 %, а специфичность составила 95 % в единственном исследовании с проспективным референтным стандартом. Исследования типа «случай–контроль» показали, что пациентами с миогенными височно-нижнечелюстными расстройствами или мигренью от контрольной группы отличали качественные кинематические нарушения, а не диапазоны движений.

ЗАКЛЮЧЕНИЕ. Аксиография CADIAX является технически точным и высокоповторяемым методом регистрации SCI и кинематической шарнирной оси, при условии использования параокклюзионной фиксации. Однако числовые показатели, полученные с помощью CADIAX, нельзя непосредственно сопоставлять с результатами оптических или ультразвуковых систем регистрации движений нижней челюсти без специальной коррекции для конкретного устройства; кроме того, диагностическая точность метода при внутренних нарушениях ВНЧС недостаточна для замены MPT. Доказательная база представлена преимущественно небольшими одноцентровыми исследованиями с неоднородными протоколами; необходимы многоцентровые исследования с использованием ослепленных референтных стандартов и стандартизированных референтных плоскостей.

Ключевые слова: компьютеризированная аксиография, CADIAX, шарнирная ось, сагиттальный наклон суставного пути, угол Беннета, регистрация движений нижней челюсти, MODJAW, Zebris, височно-нижнечелюстные расстройства, систематический обзор

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INTRODUCTION

The transverse horizontal axis of the mandible, also called the terminal hinge axis, is a construct that underpins mechanical and virtual articulation. It is defined as the imaginary line through both condyles around which the mandible rotates during the initial phase of opening, and its position is used to transfer the maxillary cast, to program the condylar elements of an articulator and to register the reference position of the joints [1; 2]. Errors in axis location propagate into occlusal errors that grow with the distance between the axis and the incisal edge, and they become clinically relevant whenever the vertical dimension is changed on the articulator [3]. Whether a pure rotation around a fixed axis exists at all has been questioned by kinematic modeling and, more recently, by in vivo tracking registered to computed tomography [2; 4]. This debate does not remove the practical need for a reproducible reference axis, but it does set limits on what any recording device can claim to measure.

Computerized axiography was introduced in the late 1980s as the electronic successor of mechanical pantography. The CADIAX system (Gamma Dental, Klosterneuburg, Austria) records the movement of styli attached to a mandibular facebow relative to measuring flags fixed to a cranial bow. The system locates the kinematic hinge axis through small opening and closing movements, then records border and functional movements of both condyles with six degrees of freedom [5]. Over three decades the hardware has evolved from Cadiax III through Cadiax Compact, Cadiax Compact 2 and Cadiax Diagnostic to the current Cadiax 4, while the software has remained centred on the same parameters: sagittal condylar inclination (SCI), transversal condylar inclination or Bennett angle (BA), condylar path length, symmetry and time curves. Because the styli sit near the joint, CADIAX is often treated as the reference instrument when newer optical (MODJAW, Modjaw SAS, France) or ultrasonic and optical (Jaw Motion Analyser, Zebris Medical, Germany) trackers are validated [6; 7].

Recent systematic reviews have addressed jaw tracking technologies broadly [8–10], the methods available for measuring the sagittal condylar guidance angle [11], and the value of kinesiography relative to MRI [12]. None of them appraised the CADIAX family as a distinct index instrument across its measurement properties, and none reported search strategies that combined the device name with the older terms “computerized axiography” and “electronic axiography” used before 2010. As a result, evidence on the technical accuracy of the device on articulators, on its test-

retest reliability in patients with different dentitions, on the influence of mounting and clutch design, and on its agreement with optical systems is scattered across prosthodontic, orthodontic and craniomandibular journals.

PURPOSE

The aim of this systematic review was to synthesize the evidence on four measurement properties of CADIAX computerized axiography: (i) technical accuracy on articulators with known settings, (ii) reliability of SCI, BA and qualitative tracing evaluation in vivo, (iii) agreement of CADIAX parameters with mechanical, interocclusal, radiographic, optical and ultrasonic methods, and (iv) diagnostic accuracy against MRI and discriminative validity between patients with temporomandibular disorders (TMD) and healthy controls.

MATERIALS AND METHODS

Protocol and Reporting

The review was conducted and reported according to the PRISMA 2020 statement [13]. The protocol was drafted before the searches and is available from the corresponding author; it was not registered in PROSPERO. The review question was framed in PICO terms: population, human participants (any age, dentate or edentulous, with or without TMD) or articulator-based in vitro models; index instrument, any CADIAX-family computerized axiograph; comparators, repeated CADIAX recordings, other recording methods (mechanical pantography, interocclusal records, panoramic radiography, CBCT, optical or ultrasonic trackers) or a reference standard (MRI, clinical diagnosis); outcomes, measurement error, intraclass correlation coefficients (ICC), kappa statistics, mean differences with limits of agreement, correlation coefficients, sensitivity and specificity, or between-group differences in kinematic parameters.

Eligibility Criteria

Primary studies published between 1 January 2000 and 2 September 2026 were eligible if they used a CADIAX-family device as the index instrument or as the reference for another device, and reported at least one of the four measurement properties. In vitro studies were eligible when the device was tested against an articulator with preset condylar values. Case-control studies were eligible when a CADIAX-derived parameter was compared between a clinically defined patient group and controls, because such comparisons constitute known-groups validity. Studies were excluded if

the recording device was another system (SAM Axio-tron or Axiocomp, ARCUSdigma, Zebris, MODJAW, kinesiographs) without a CADIAX arm; if they were purely descriptive or normative reports of SCI and BA in healthy subjects; if they used CADIAX only as an outcome measure of treatment without repeated or comparative measurement; or if they were case reports, reviews, theses or conference abstracts. No language restriction was applied at the search stage; non-English records with an English abstract were assessed on the abstract.

Information Sources and Search Strategy

PubMed was searched on 2 September 2026 with four strings combining title and abstract terms for the device and for computerized, electronic or generic axiography (string 1); for jaw motion tracking systems combined with hinge axis, condylar inclination, Bennett angle and measurement-property terms (string 2); for the hinge axis or transverse horizontal axis with kinematic, digital or electronic determination (string 3); and for SCI or BA with digital, electronic, optical or ultrasonic recording (string 4). All strings were limited to the publication years 2000 to 2026. The full strings and the number of records retrieved by each are given in Supplementary Table S1. The AI-assisted engine Consensus (consensus.app) was queried in its full-review mode with two natural-language questions covering device agreement and diagnostic accuracy, and the reference lists generated by the engine were screened. Google Scholar was searched for the term “Cadiax” combined with reliability, accuracy, agreement, MODJAW, Zebris or MRI, restricted to 2015 onward, and the first 50 records were screened. The reference lists of four key studies published after 2021 were hand-searched.

Study Selection and Data Extraction

Records were de-duplicated and screened on title and abstract against the eligibility criteria. Reports that passed screening were assessed on the full abstract and, where the article was open access, on the full text obtained through Europe PMC. For every included study the following data were extracted into a predefined table: first author and year, country, device model, sample size and population, comparator or reference standard, recording protocol (clutch type, reference plane, condylar displacement at which SCI and BA were read), statistical approach, main quantitative results and a verbatim anchor sentence supporting each extracted result. Where the device model was not stated in the abstract and the full text was unavailable, the study was retained only if the research group is documented to have used CADIAX in contemporaneous publications; otherwise, it was excluded and listed as “device not confirmable”.

Risk of Bias Assessment

Risk of bias was appraised with instruments matched to design. Diagnostic accuracy studies were assessed with QUADAS-2 across patient selection, index test, reference standard, and flow and timing [14]. Reliability and agreement studies were rated with the

COSMIN standards for reliability and criterion validity, which grade the design as very good, adequate, doubtful or inadequate depending on sample size, interval between measurements, stability of subjects and the statistics used [15]. In vitro studies were appraised with a checklist adapted from the QUIN tool for in vitro dental research [16], covering the definition of the reference values, the number of repetitions, operator blinding and the statistical analysis. Ratings were made by one reviewer and checked by a second; disagreements were resolved by discussion.

Synthesis

Meta-analysis was not undertaken. The included studies measured different parameters (SCI at 3, 5 or 10 mm, BA, path lengths, qualitative scores), used different reference planes (axis-orbital versus Frankfort horizontal) and different comparators, and several reported only p values. Results were therefore grouped into the four measurement-property domains and summarized in tables with the original point estimates and, where available, confidence intervals or limits of agreement.

RESULTS

Study Selection

The PubMed strings retrieved 490 records (422 after internal de-duplication), Consensus produced 22 references and Google Scholar 50; citation searching yielded no additional records. After removal of duplicates, 423 records were screened and 354 were excluded on title and abstract, mostly because they concerned radiotherapy jaw tracking, gait or spine analysis with Zebris platforms, or clinical series without measurement-property data. Sixty-nine reports were assessed in detail and 39 were excluded, principally because no CADIAX device was used or the model could not be confirmed (26 reports), because the study was descriptive, normative or a treatment outcome series without a measurement property (12 reports), or because the report was a case report (1 report). Twenty-nine studies published in 30 reports met the criteria (Fig. 1). The list of reports excluded at this stage with reasons is provided in Supplementary Table S2.

Characteristics of Included Studies

The included studies were published between 2002 and 2026, with 13 published in 2020 or later. They originated from Austria, Germany, Poland, Romania, Italy, Greece, Croatia, Iran, Saudi Arabia, India, Turkey, China, Korea and the United States. Sample sizes in vivo ranged from 10 to 173 participants; the four in vitro studies used one to five articulators. The device model was Cadiax Compact or Compact 2 in 17 studies, Cadiax 4 or Cadiax Diagnostic in 4, and an earlier Cadiax or unspecified CADIAX in 8. Four studies were rated as having a device model that could not be confirmed from the abstract and were excluded; two further studies from the Vienna and Turin groups were retained because the same groups documented CADIAX use in adjacent publications [17; 18]. Table 1 summarizes the included studies by domain.

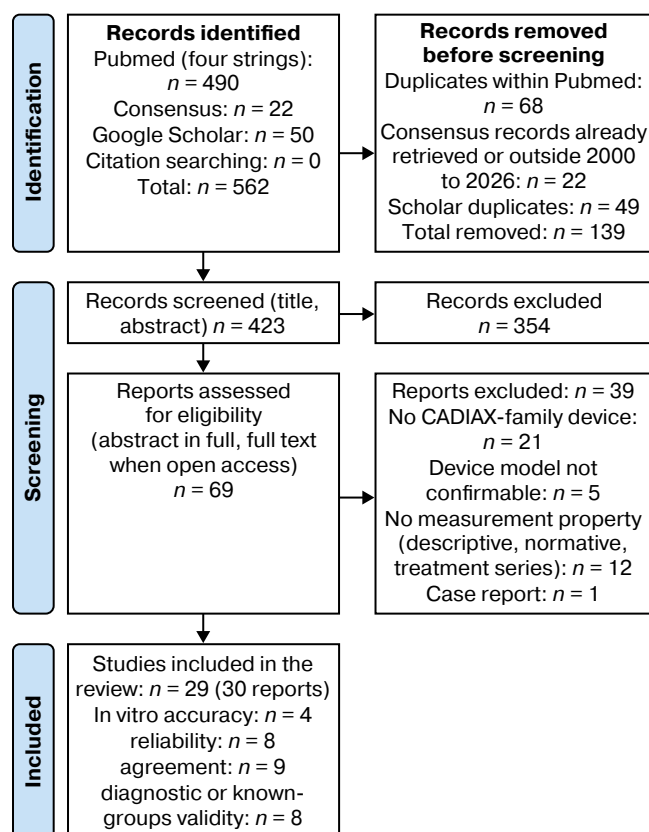


Fig. 1. PRISMA 2020 flow diagram of study selection

Technical Accuracy on Articulators

Four studies tested Cadiax Compact devices on fully adjustable articulators with preset condylar guidance (Table 2). Celar and Tamaki mounted the Cadiax compact on an articulator with horizontal condylar inclination (HCI) set at 20°, 40° and 60° and BA at 0° to 20° and reported maximum errors between 0° and 3.4° with a mean of 1.2°; the differences from the presets were statistically significant except for HCI 40° and BA 0° [19]. Chang et al. tested the same device on five articulators and observed that both the dispersion of readings and the deviation from preset values decreased from the 3 mm to the 10 mm condylotrack distance, with the smallest deviations obtained on the Denar Mark II [20]. Ahangari et al. found that most comparisons between Cadiax Compact II readings and the settings of a Reference SL articulator were statistically different, but the maximum discrepancy was approximately 2.5° [21]. Balch et al. compared the Cadiax Compact 2 with an optoelectronic pantograph (Freecorder Bluefox) on a Denar D5A with mock-patient settings; most predicted condylar values were statistically inaccurate for both instruments, although lateral condylar inclination and progressive lateral translation fell within 5° of the known values [22]. Taken together, the in vitro evidence indicates a systematic but small measurement error of the order of 1° to 3° for SCI and BA, with better accuracy when the parameter is read at a longer condylar excursion.

Table 1. Included studies by measurement-property domain (n = 29 studies, 30 reports)

Study (author(s), year)	Country	Device	Sample	Design / Comparator	Domain
Celar & Tamaki, 2002	Austria	Cadiax Compact	Articulator, preset HCI 20/40/60°, BA 0 to 20°	In vitro accuracy	A
Chang et al., 2004	USA	Cadiax Compact	5 articulators, 3/5/10 mm condylotrack	In vitro accuracy	A
Ahangari et al., 2012	Iran	Cadiax Compact II	Reference SL articulator	In vitro accuracy	A
Balch et al., 2017	USA	Cadiax Compact 2	Denar D5A, mock-patient settings	In vitro accuracy vs Freecorder Bluefox	A
Bernhardt et al., 2003	Germany	Cadiax Compact; Gamma Cadiax	30 adults (subset 10)	Test-retest, 2 days; kinematic vs arbitrary axis	B
Petrie et al., 2003	USA	Cadiax Compact	10 adults	Test-retest 2 weeks to 1 month; vs Denar pantograph	B, C
Han et al., 2010	China	CADIAX	10 adults	Functional occlusal clutch vs tray clutch	B
Schierz et al., 2014	Germany	Cadiax Compact 2	65 patients (19 dentate, 27 partially dentate, 19 edentulous)	Two sessions x 3 repetitions; multilevel models	B
Schierz et al., 2019	Germany	Cadiax Compact 2	27 adults	Three mounting methods; inter-session reliability	B
Ahlert et al., 2023	Germany	Cadiax compact II	20 TMD patients, 4 examiners	Inter-examiner reproducibility of standardized evaluation	B
Buduru et al., 2024	Romania	Cadiax 2 vs Modjaw	25 adults, 22 to 27 y	Test-retest 1 week; Bland-Altman between devices	B, C
Manziuc et al., 2025	Romania	Cadiax Compact 2 vs MODJAW	17 adults, 20 to 30 y	Three sessions; ICC; Bland-Altman	B, C

Table 1 (end)

Study (author(s), year)	Country	Device	Sample	Design / Comparator	Domain
Wagner et al., 2003	Austria	Conventional axiograph (Vienna group)	10 subjects, 100 tracing pairs	vs optoelectronic axiography	C
Torabi et al., 2014	Iran	Cadiax Compact II	Dentate adults	vs wax and silicone protrusive records	C
Naqash et al., 2020	Saudi Arabia	Cadiax Compact	23 adults, 18 to 30 y	vs protrusive records and CBCT	C
Franklin et al., 2010	UK	Cadiax	20 subjects	Programmed vs unprogrammed articulator; excursive contacts	C
Erden & Karakis, 2026	Turkey	Cadiax Compact 2	15 dentate adults	vs wax records and panoramic tracing	C
Lepidi et al., 2023	Italy	Cadiax Diagnostic 4	10 patients x 5 records	vs Zebris JMA+ Optic; linear mixed model	C
Gu et al., 2025	China	CADIAX 4	26 adults, 23 to 35 y	vs Zebris JMA (ultrasonic); comfort rating	C
Nigam et al., 2025	USA	Cadiax Compact 2	15 dentate adults	vs MODJAW; SCI 3/5 mm, BA 3 mm	C
Cheong et al., 2025	USA	Cadiax compact 2	12 dentate adults	vs MODJAW and average values; appliance fit	C
Sadat-Khonsari et al., 2003	Germany	CADIAX	10 dysfunction, 20 asymptomatic	Known groups; instantaneous centres of rotation	D
Kraljević et al., 2003	Croatia	Gamma Cadiax	51 TMD, 43 controls	Known groups; movement lengths	D
Schmid-Schwap et al., 2005	Austria	Electronic axiography (Vienna group)	33 patients, 45 TMJs	vs MRI disc morphology	D
Piancino et al., 2012	Italy	Computed axiography (Turin group)	173 TMD patients	vs MRI; sensitivity, kappa	D
Buduru et al., 2020	Romania	Cadiax Compact 2	50 patients, 21 to 62 y	vs clinical diagnosis; retrospective	D
Talmaceanu et al., 2022	Romania	Cadiax Compact II	33 patients, 66 TMJs	vs MRI 1.5 T; prospective	D
Zokaris et al., 2024	Greece	Cadiax 4	50 migraine, 50 controls	Known groups; qualitative and quantitative tracing features	D
Surowiecki et al., 2025	Poland	Cadiax Diagnostic / Cadiax 4	26 myogenous TMD (DC/TMD), 26 matched controls	Known groups; ranges and qualitative deviations	D

Note. A – technical accuracy; B – reliability; C – agreement with other methods; D – diagnostic accuracy or known-groups validity. HCI – horizontal condylar inclination; BA – Bennett angle; SCI – sagittal condylar inclination; TMD – temporomandibular disorders.

Table 2. Technical accuracy of CADIAX devices on articulators with preset condylar values

Study (author(s), year)	Device	Reference values	Main result	Authors' conclusion
Celar & Tamaki, 2002	Cadiax Compact	HCI 20°, 40°, 60°; BA 0°, 5°, 10°, 15°, 20°	Maximum error 0 to 3.4°, mean 1.2°; significant differences from pre-sets except HCI 40° and BA 0°	Reasonable accuracy for anterior guidance restorations
Chang et al., 2004	Cadiax Compact	HCI, immediate and progressive lateral translation, top and rear wall on 5 articulators	Dispersion and deviation smallest at 10 mm, largest at 3 mm; smallest deviations with Denar Mark II	Reliable and valid
Ahangari et al., 2012	Cadiax Compact II	Preset HCI and BA on Reference SL	Most comparisons statistically different; maximum difference about 2.5°	Accurate and reliable, technique-sensitive
Balch et al., 2017	Cadiax Compact 2 (and Freecorder Bluefox)	Mock-patient settings on Denar D5A	Majority of predicted condylar values statistically inaccurate; LCI and PMLT within 5°	Both electronic pantographs statistically inaccurate for most settings

Note. LCI – lateral condylar inclination; PMLT – progressive mandibular lateral translation.

Reliability in Vivo

Eight studies addressed reliability (Table 3). The earliest, by Bernhardt et al., repeated recordings on two days in 30 young adults and found ICC values above 0.8 for SCI and transversal condylar inclination with both the Cadiax Compact and the older Gamma Cadiax, regardless of whether the axis was located kinematically or arbitrarily [23]. Two recent Romanian studies that compared Cadiax with MODJAW provide the most detailed repeatability data. Buduru et al. recorded 25 participants one week apart and reported ICC values for Cadiax 2 of 0.974 and 0.976 for right and left SCI at 3 mm, 0.972 and 0.982 at 5 mm, and 0.926 to 0.950 for BA [24]. Manziuc et al. obtained intrarater ICC values above 0.90 for all SCI and BA readings across three sessions in 17 participants [25].

Reliability was not uniform across parameters and protocols. Schierz et al. analysed two sessions with three repetitions each in 65 prosthodontic patients with multilevel models; subject-specific variance accounted for 75% of the total variance for the sagittal condylar path angle but only 38% for the transverse angle, and dentition status (dentate, partially dentate, edentulous) had no effect [26]. In a later study the same group tested three mounting methods in 27 adults and found that mean HCI differed by up to 10° between paraocclusal and periocclusal tray adapters; intersession reliability of HCI was fair to good only with the paraocclusal adapter, whereas BA reliability was independent of mounting [27]. Han et al. compared a functional occlusal clutch with a tray clutch in ten subjects and observed more regular and congruent tracings with the occlusal clutch, although the differences did not reach

significance [28]. Petrie et al. using pantographic reproducibility index scores rather than raw angles, reported a coefficient of stability of -0.06 for the Cadiax compact between sessions two weeks to one month apart, against 0.91 for a mechanical pantograph [29]; this outlier is discussed below. Finally, Ahlers et al. examined the reproducibility of the interpretation rather than of the recording: four calibrated examiners evaluated the Cadiax compact II recordings of 20 TMD patients with a standardized scheme and reached a Fleiss kappa of 0.88 [30].

Agreement with other Recording Methods

Nine studies compared CADIAX parameters with other methods in vivo (Table 4). Against mechanical or interocclusal methods, CADIAX consistently produced higher SCI values and lower BA values. Torabi et al. found significant differences between Cadiax Compact II and wax or silicone protrusive records for all parameters, with closer correlation to silicone [31]. Naqash et al. recorded 23 participants with the Cadiax Compact, protrusive records and CBCT; mean SCI was 34° with pantographic tracing, 32° with protrusive records and 38° to 39° on CBCT, with Pearson coefficients between 0.84 and 0.93 [32]. Erden and Karakis reported the highest correlation between panoramic tracing and Cadiax Compact 2, with wax records yielding the lowest and Cadiax the highest SCI in 15 dentate adults [33]. Franklin et al. demonstrated a functional consequence: the proportion of excursive contacts reproduced on a Denar D5a articulator improved significantly when the articulator was programmed with Cadiax data rather than left at average settings [34].

Table 3. Reliability of CADIAX recordings and of their interpretation in vivo

Study (author(s), year)	Device, n	Interval / Conditions	Statistic	Result
Bernhardt et al., 2003	Cadiax Compact, 30; Gamma Cadiax, 10	Two days; kinematic vs arbitrary axis	ICC; kappa for tracing quality	ICC > 0.8 for SCI and TCI with both systems; kappa 0.46 for protrusion quality
Petrie et al., 2003	Cadiax Compact, 10	2 weeks to 1 month	Coefficient of stability of PRI scores	$r = -0.06$ (axiograph) vs 0.91 (mechanical pantograph)
Han et al., 2010	CADIAX, 10	Functional occlusal clutch vs tray clutch	t test; kappa	Similar contour and dimensions; tray clutch tracings more irregular, not significant
Schierz et al., 2014	Cadiax Compact 2, 65	Two sessions x 3 repetitions, no re-mounting	Share of variance explained by subject	Sagittal CPIA 75%, transverse CPIA 38%; dentition no effect
Schierz et al., 2019	Cadiax Compact 2, 27	Paraocclusal vs periocclusal adapters; intersession	Mean difference; ICC	HCI means differ up to 10° between mountings; HCI reliability fair to good with paraocclusal, poor with periocclusal; BA unaffected
Ahlers et al., 2023	Cadiax Compact II recordings, 20 patients	Four calibrated examiners	Fleiss kappa	0.88 ($p < 0.00001$)
Buduru et al., 2024	Cadiax 2, 25	One week	ICC	SCI 3 mm 0.974 (R), 0.976 (L); 5 mm 0.972, 0.982; BA 3 mm 0.937, 0.950; 5 mm 0.926, 0.926
Manziuc et al., 2025	Cadiax Compact 2, 17	Three sessions	Intrarater ICC	All values > 0.90 for SCI and BA at 3 and 5 mm

Note: CPIA – condylar path inclination angle; PRI – pantographic reproducibility index; TCI – transversal condylar inclination.

Three studies compared CADIAX with Zebris systems. Wagner et al., who developed an optoelectronic axiograph in Vienna, attached its sensors to the conventional axiograph frame in ten subjects and obtained ICC values of 0.978 to 0.991 for condylar pathways and 0.864 to 0.960 for HCI, with 95% confidence intervals for the difference of -3.4° to 1.9° for HCI and -2.8° to 4.8° for BA [17]. Lepidi et al. recorded ten patients five times each with the Cadiax Diagnostic 4 and the Zebris JMA+ Optic system; mean SCI at 3 mm was 55.2° (left) and 49.7° (right) with Cadiax versus 49.8° and 54.5° with Zebris, and a linear mixed model showed no significant difference [35]. Gu et al. compared Cadiax 4 with the ultrasonic JMA in 26 subjects with normal occlusion. Maximal sagittal condylar displacements did not differ, raw SCI was higher with Cadiax because it is referenced to the axis-orbital plane rather than the Frankfort horizontal, and the difference disappeared after a 7° correction; BA, however, was significantly higher with JMA, and patients rated JMA as more comfortable (2.96 versus 2.04 on a five-point scale) [7].

Three studies compared Cadiax Compact 2 with MODJAW. Manziuc et al. found MODJAW SCI higher than Cadiax by 5.9° (95% CI 3.9 to 8.2) on Bland-Altman analysis, with larger discrepancies at 3 mm than at 5 mm and inconsistent BA differences [25]. Buduru et al. reported mean Cadiax minus MODJAW differences of -2.67° for SCI at 3 mm (limits of agreement -16.5° to 11.15°) and 4.47° at 5 mm (limits -14.2° to 23.16°), which indicates that the individual disagreement between devices can exceed 15° even when group means are similar [24]. Nigam et al. found significant differences for right and left SCI at 3 and 5 mm and for BA at 3 mm in 15 participants, with the conventional device generally reading lower [6]. Cheong et al. translated this disagreement into a clinical outcome: occlusal appliances designed from MODJAW values showed fewer contact-point discrepancies at maximal intercuspation (1.83 ± 0.31) than those designed from Cadiax values (4.08 ± 0.76) or average values (4.83 ± 1.39), and no protrusive interferences, although working and non-working side interferences did not differ [36].

Table 4. Agreement between CADIAX and other recording methods in vivo

Study (author(s), year)	CADIAX device, <i>n</i>	Comparator	Statistic	Result
Wagner et al., 2003	Conventional axiograph, 10 (100 tracing pairs)	Optoelectronic axiography on same frame	ICC; 95% CI of differences	Pathways ICC 0.978 to 0.991; HCI ICC 0.864 to 0.960; difference HCI -3.4° to 1.9° , BA -2.8° to 4.8°
Torabi et al., 2014	Cadiax Compact II	Wax and silicone protrusive records	Paired comparison; correlation	All differences significant; Cadiax SCI higher, BA lower; closer correlation with silicone
Naqash et al., 2020	Cadiax Compact, 23	Protrusive records; CBCT	Means; Pearson <i>r</i>	SCI 34.4/33.9° (Cadiax), 32.1/31.8° (records), 39.0/38.1° (CBCT); <i>r</i> 0.84 to 0.93
Franklin et al., 2010	Cadiax, 20	Programmed vs unprogrammed Denar D5a	Proportion of matching contacts	Significantly better with programmed articulator
Erden & Karakis, 2026	Cadiax Compact 2, 15	Wax records; panoramic tracing	Pearson <i>r</i>	Highest correlation panoramic vs Cadiax; wax lowest SCI, Cadiax highest
Lepidi et al., 2023	Cadiax Diagnostic 4, 10 x 5	Zebris JMA+ Optic	Linear mixed model	SCI 3/5 mm: Cadiax L $55.2^{\circ}/52.2^{\circ}$, R $49.7^{\circ}/48.2^{\circ}$; Zebris L $49.8^{\circ}/48.1^{\circ}$, R $54.5^{\circ}/51.9^{\circ}$; no significant difference
Gu et al., 2025	CADIAX 4, 26	Zebris JMA (ultrasonic)	Paired <i>t</i> / Wilcoxon	Sagittal displacements equal; SCI equal after 7° reference-plane correction; BA higher with JMA ($p < 0.05$); comfort 2.96 vs 2.04 favouring JMA
Buduru et al., 2024	Cadiax 2, 25	Modjaw	Bland-Altman (Cadiax minus Modjaw)	SCI 3 mm -2.67° (LoA -16.5 to 11.15); SCI 5 mm 4.47° (LoA -14.2 to 23.16); TCI 3 mm -1.19° (LoA -19.0 to 16.6)
Manziuc et al., 2025	Cadiax Compact 2, 17	MODJAW	Wilcoxon; Bland-Altman	MODJAW SCI higher by 5.9° (95% CI 3.9 to 8.2); larger discrepancy at 3 mm; BA differences inconsistent
Nigam et al., 2025	Cadiax Compact 2, 15	MODJAW	Wilcoxon signed-rank	SCI 3 mm $p = 0.007$ (R), 0.010 (L); 5 mm $p = 0.015$, 0.004; BA 3 mm $p = 0.043$, 0.035; Cadiax lower
Cheong et al., 2025	Cadiax Compact 2, 12	MODJAW; average values	Kruskal-Wallis	Contact discrepancies at MIP 4.08 ± 0.76 (Cadiax) vs 1.83 ± 0.31 (MODJAW) vs 4.83 ± 1.39 (average), $p = 0.047$; protrusive interferences 0.92 vs 0 vs 0.42

Note. LoA – 95% limits of agreement; MIP – maximal intercuspation.

Diagnostic Accuracy and Known-Groups Validity

Four studies compared CADIAX findings with MRI or clinical diagnosis and four compared patients with controls (Table 5). Talmaceanu et al. examined 33 patients (66 TMJs) with clinically suspected disc displacement using Cadiax Compact II and MRI within one to seven days; against MRI, axiography reached a sensitivity of 85.1%, a specificity of 94.7%, a positive predictive value of 97.6%, a negative predictive value of 72% and an accuracy of 87.9%, and the six false negatives were attributed to incipient displacement with reduction masked by the vertical opening introduced by the bite fork [37]. Piancino et al., in a larger convenience sample of 173 TMD patients, found much lower sensitivity: 68% for joints without morphological change, 27% for disc displacement and 8% for osteoarthritis, with kappa values between 0.01 and 0.28 [18]. Schmid-Schwap et al. found no correlation between axiographic time curves and disc morphology on MRI in 45 joints [38]. Buduru et al. used the clinical muscular-articular examination as reference and reported a sensitivity of 100%, a specificity of 74% and an accuracy of 88% for the Cadiax Compact 2 in 50 patients [39]; because the reference standard was the clinical diagnosis the axiograph was meant to confirm, this study estimates agreement rather than accuracy.

The known-groups studies converge on one observation: quantitative ranges do not separate groups, qualitative features do. Kraljević et al. found no differences in movement lengths or rotational capacity between 51 TMD patients and 43 controls recorded with the Gamma Cadiax [40]. Sadat-Khonsari et al. described irregular pathways of the instantaneous cen-

tre of rotation in patients with joint dysfunction and harmonious pathways in asymptomatic subjects [41]. Surowiecki et al. compared 26 patients with myogenous TMD diagnosed according to DC/TMD with 26 matched controls recorded with the Cadiax Diagnostic; maximal opening was similar (48.0 ± 6.5 versus 49.5 ± 5.4 mm, $p = 0.40$), but lateral deflections during protrusion and opening occurred in 46.2% of patients versus 23.1% of controls ($\phi \approx 0.24$) and condylar distraction on closing into intercuspation occurred only in patients (19.2% of left condyles) [42]. Zokaris et al. recorded 50 migraine patients and 50 controls with Cadiax 4 and found higher lateral translation in protrusion ($p = 0.001$), transient velocity losses in opening ($p = 0.001$), reduced condylar stability ($p = 0.001$) and more frequent figure-eight opening curves ($p = 0.012$) in migraineurs [43]; in the companion occlusal analysis the retral condylar displacement between reference position and maximal intercuspation was 1.53 versus 0.90 mm ($p = 0.001$) [44].

Risk of Bias

The in vitro studies were rated as raising moderate concern, mainly because operator blinding and the number of repetitions were not described and because one report appeared in a non-indexed journal without full numeric data. Among reliability studies, the designs of Bernhardt et al., Schierz et al. (both studies), Buduru et al. and Manziuc et al. were rated adequate and that of Ahlers et al. very good; the studies by Petrie et al. and Han et al. were rated doubtful because of ten-subject samples and, in the former, the use of an index designed for mechanical pantography.

Table 5. Diagnostic accuracy against MRI or clinical diagnosis, and known-groups validity

Study (author(s), year)	Device, sample	Reference standard or groups	Result
Schmid-Schwap et al., 2005	Electronic axiography, 45 TMJs	MRI disc morphology (4 classes)	No correlation between time curves and disc morphology
Piancino et al., 2012	Computed axiography, 173 TMD patients	MRI	Sensitivity 68% (normal joints), 27% (disc displacement), 8% (osteoarthritis); kappa 0.16, 0.28, 0.10, 0.01
Buduru et al., 2020	Cadiax Compact 2, 50 patients	Clinical muscular-articular examination	Sensitivity 100%, specificity 74%, accuracy 88%
Talmaceanu et al., 2022	Cadiax Compact II, 66 TMJs	MRI 1.5 T within 1 to 7 days	Sensitivity 85.1%, specificity 94.7%, PPV 97.6%, NPV 72%, accuracy 87.9%; 6 false negatives with incipient DDwR
Sadat-Khonsari et al., 2003	CADIAX, 10 vs 20	Clinical dysfunction vs asymptomatic	Irregular ICR pathway with erratic direction changes in dysfunction; harmonious pathway in healthy subjects
Kraljević et al., 2003	Gamma Cadiax, 51 vs 43	Clinical TMD vs controls	No significant difference in movement lengths or rotational capacity
Zokaris et al., 2024	Cadiax 4, 50 vs 50	Migraine vs controls	Higher lateral translation in protrusion ($p = 0.001$) and opening ($p = 0.031$); velocity losses ($p = 0.001$); reduced condylar stability ($p = 0.001$); figure-eight opening ($p = 0.012$); retral condylar displacement 1.53 vs 0.90 mm ($p = 0.001$)
Surowiecki et al., 2025	Cadiax Diagnostic, 26 vs 26	Myogenous TMD (DC/TMD) vs matched controls	Opening 48.0 ± 6.5 vs 49.5 ± 5.4 mm ($p = 0.40$); ΔY deflection in protrusion 46.2% vs 23.1% ($p = 0.08$, $\phi 0.24$); condylar distraction on closing 19.2% (left) vs 0%

Note. DDwR, disc displacement with reduction; ICR, instantaneous centre of rotation; NPV, negative predictive value; PPV, positive predictive value.

Table 6. Risk of bias and methodological quality of included studies

Study (author(s), year)	Tool	Main concerns	Overall
Celar & Tamaki, 2002 Ahangari et al., 2012 Chang et al., 2004	QUIN-adapted	Operator blinding and number of repetitions not reported; single device unit	Moderate
Balch et al., 2017	QUIN-adapted	Non-indexed journal; full numeric results not retrievable	Moderate to high
Bernhardt et al., 2003 Schierz et al., 2014 Schierz et al., 2019 Buduru et al., 2024 Manziuc et al., 2025	COSMIN reliability	Adequate interval and statistics; samples 17 to 65; no blinding of operator	Adequate
Ahlers et al., 2023	COSMIN reliability (inter-rater)	Blinded, calibrated examiners; 20 recordings	Very good
Petrie et al., 2003 Han et al., 2010	COSMIN reliability	n = 10; index not designed for electronic tracings (Petrie)	Doubtful
Wagner et al., 2003 Naqash et al., 2020 Gu et al., 2025	COSMIN criterion validity	Adequate samples or repeated tracings; correlation or p values without limits of agreement (Naqash, Gu)	Adequate
Torabi et al., 2014 Franklin et al., 2010 Erden & Karakis, 2026 Lepidi et al., 2023 Nigam et al., 2025 Cheong et al., 2025	COSMIN criterion validity	n = 10 to 20; correlation or p values only; comparator not blinded	Doubtful
Talmaceanu et al., 2022	QUADAS-2	Patient selection: high (only clinically diagnosed displacement); index test: unclear (criteria not prespecified); reference standard: low; flow and timing: low	Moderate
Piancino et al., 2012	QUADAS-2	Selection: unclear (convenience sample); index test: unclear; reference: low; flow: unclear	Moderate to high
Buduru et al., 2020	QUADAS-2	Reference standard: high (clinical diagnosis); retrospective	High
Schmid-Schwap et al., 2005	QUADAS-2	Retrospective series; selection unclear	Moderate to high
Surowiecki et al., 2025 Zokaris et al., 2024	Known-groups (JBI cross-sectional)	Defined diagnostic criteria, matched or equal groups; examiner blinding not stated	Low to moderate
Sadat-Khonsari et al., 2003 Kraljević et al., 2003	Known-groups (JBI cross-sectional)	Unmatched groups; no inferential statistics (Sadat-Khonsari)	Moderate to high

Agreement studies were mostly rated doubtful: samples of 10 to 15 participants, reliance on correlation coefficients or p values without limits of agreement, and absence of blinding between devices were common. Among diagnostic accuracy studies, Talmaceanu et al. met the reference standard and flow criteria but enrolled only patients with clinically diagnosed displacement, which inflates sensitivity estimates; Piancino et al. did not describe index test thresholds; Buduru et al. used an inappropriate reference standard. The known-groups studies by Surowiecki et al. and Zokaris et al. were rated low to moderate concern, whereas the two 2003 studies lacked matched groups or inferential statistics. A summary of ratings is given in Table 6.

DISCUSSION

Principal Findings

The evidence assembled here supports three statements about CADIAX axiography. First, the device measures what it is set to measure with an error of about 1° to 3° on articulators, and its SCI readings are highly repeatable in vivo, with ICC values close to 0.98 when the same clutch and mounting are used. Second, the numbers it produces depend on protocol choices that are often left unreported: the mounting adapter can shift mean SCI by 10°, the reference plane accounts for about 7° of difference relative to Frankfort-based systems, and the condylar displacement at which the angle is read (3, 5 or 10 mm) changes both the value and its precision. Third, the agreement between CADIAX and optical or ultrasonic trackers is good at the group level for SCI and poor for BA, and the individual limits of agreement are wide enough that the values cannot be transferred from one system to another without device-specific calibration.

Interpretation of Reliability Data

The excellent ICC values reported after 2020 should be read alongside the older and less favourable findings. The near-zero coefficient of stability reported by Petrie et al. [29] reflects the use of the pantographic reproducibility index, a score developed for mechanical tracings that penalizes the fine irregularities an electronic system records at high resolution, rather than a failure of the instrument to reproduce angles. The multilevel analysis by Schierz et al. [26] is arguably the most informative reliability study, because it separates subject variance from session and repetition variance in a clinically representative sample including edentulous patients; its conclusion that sagittal parameters are reliable and transverse parameters are not agrees with the lower BA coefficients in the Romanian studies [24; 25] and with the significant BA disagreement between CADIAX and JMA [7]. The BA is derived from a few millimetres of mediotrusive excursion and is sensitive to immediate side shift, clutch play and the definition of the working-side reference; it is therefore the parameter that most needs individual recording and the one least suited to comparison across systems.

The influence of mounting deserves emphasis. A 10° shift of mean SCI between paraocclusal and periocclusal adapters [27] is of the same order as the entire between-device difference reported for

MODJAW [25] and larger than the articulator error of the device itself [19; 21]. Studies that compare devices without stating the clutch type, or that use a tray clutch for CADIAX and a bonded marker for the optical system, confound device technology with mounting. Where a functional occlusal clutch was used, tracings were more regular [28], which suggests that part of the “noise” attributed to electronic axiography in early reports originates from clutch instability.

Agreement with Optical and Ultrasonic Systems

The direction of the disagreement with MODJAW is consistent: CADIAX reads lower SCI, and the gap widens at 3 mm [6; 24; 25]. Several mechanisms can explain this. The optical system tracks markers on the chin or teeth and calculates condylar points from a CBCT or facial scan registration, whereas CADIAX measures at styli placed on the hinge axis; the longer lever arm and the model-based reconstruction of the condylar point in optical systems amplify small rotational components in the first millimetres of protrusion. The two systems also default to different reference planes, and SCI is by definition plane-dependent. Gu et al. showed that a 7° correction for the axis-orbital versus Frankfort horizontal difference eliminated the SCI discrepancy with JMA [7], and Lepidi et al. found no difference once both systems were referred to the same kinematic axis [35]. The reviews by Lassmann [11] and Farook [9] reached similar conclusions for jaw tracking in general: the reference plane and the definition of the condylar point explain most between-method variance. What this review adds is the quantitative scale of the residual disagreement for CADIAX specifically, expressed as limits of agreement of roughly $\pm 15^\circ$ [24], which is far wider than the 2° to 3° device error and wider than the 5° to 7° change in SCI that alters cusp height in a restoration.

The clinical study by Cheong et al. is the only one to test the consequence of these differences on a restoration [36]. Appliances designed from MODJAW values showed fewer static discrepancies and no protrusive interferences, whereas appliances from Cadiax values were intermediate between optical and average values. Two cautions apply. The sample was 12 participants, and the outcome (contacts on a printed appliance) depends on the entire digital chain, including the registration of the intraoral scan to the tracking data, which is native to MODJAW and indirect for CADIAX. The result therefore speaks to workflow integration rather than to the accuracy of axis or angle recording.

Diagnostic Value

The diagnostic accuracy of axiography for internal derangement has been debated since the first MRI comparisons in the 1990s, when a sensitivity of 0.64 was reported against MRI [45], and shorter condylar pathways were described in patients with disc displacement with the same device [46]. The two contemporary studies with MRI as reference give estimates at the two extremes of that range: 85% sensitivity in a prospective sample of clinically suspected displacement [37] and 27% in a large heterogeneous TMD sample [18]. The difference is more

likely explained by spectrum than by device. In the first study, every patient had a clinical diagnosis of displacement, which enriches the sample with advanced, easily detectable cases; in the second, the sample included osteoarthritis and joints without morphological change, for which kinematic signs are subtle. Both studies agree that specificity is high, so an abnormal axiographic tracing is a strong indicator of joint pathology, whereas a normal tracing does not exclude it. This is consistent with the conclusion of the systematic review on kinesiography [12] and with the absence of correlation between time curves and disc morphology [38]. Axiography should therefore be positioned as a functional complement to MRI, useful for documenting condylar translation, stability and symmetry, and for monitoring treatment, rather than as a screening test for disc position.

The known-groups studies clarify where the device is informative. In myogenous TMD and in migraine, ranges of motion were normal and only qualitative features differed [42; 43]. These features, including lateral deflection in protrusion, loss of velocity, condylar distraction on closing and the figure-eight opening curve, are the same features that the standardized evaluation scheme of Ahlers et al. reproduces across examiners with a kappa of 0.88 [30]. The combination of a reliable recording and a reliable reading scheme is what makes qualitative axiographic diagnosis defensible; without the scheme, the interpretation of tracings remains operator-dependent, as several authors have cautioned.

Strengths and Limitations

The search combined a conventional database strategy with an AI-assisted literature engine and Google Scholar, and it deliberately included the older terminology under which CADIAX studies were published before 2010. The Consensus searches retrieved no eligible study that PubMed had missed, which supports the sensitivity of the PubMed strings, but they did surface pre-2000 work useful for context. Scopus and Embase were not searched directly, and grey literature was limited to Google Scholar; one eligible *in vitro* study was found only through Scholar and is published in a journal that is not indexed in PubMed, which illustrates the risk of database-only searching for device-specific topics.

Several limitations concern the primary studies. Most were single-center and small; only three exceeded 60 participants. Reporting of the recording protocol was incomplete, and four otherwise relevant comparisons with sonography and cine MRI had to be excluded because the device could not be identified. Blinding of the operator to the comparator was rarely described. Because many studies reported only *p*-values, pooling was not possible, and the synthesis relies on the few studies that reported ICC values and limits of agreement. A limitation of the review process itself is that screening and risk of bias assessment were performed by one reviewer with verification by a second rather than independently in duplicate, and that full texts were obtained only for open access articles; the device confirmation for two studies rests on the publication history of the research groups rather than on the reports themselves.

Implications for Practice and Research

For clinicians, the data support three practical rules: use a paraocclusal or functional occlusal clutch, read SCI at 5 mm or more rather than at 3 mm when the value is to be used for articulator programming, and record the reference plane with the value. When a case moves between a CADIAX-based diagnostic record and an optical workflow, the SCI should be re-recorded or corrected for the reference plane rather than copied, and the BA should not be transferred at all. For research, the priority is a multicenter agreement study in which CADIAX, an optical and an ultrasonic system are recorded in the same session with a shared clutch and a common reference plane, reported with Bland-Altman limits rather than correlation; a diagnostic accuracy study with consecutive enrolment of patients across the TMD spectrum, blinded MRI reading and prespecified axiographic criteria; and reporting of reliability for the qualitative tracing features that appear to carry the diagnostic information.

CONCLUSION

Within the limits of a heterogeneous and largely small-sample evidence base, CADIAX computerized axiography is a technically accurate and highly repeatable method for locating the kinematic hinge axis and recording sagittal condylar inclination, with mean articulator errors of about 1° and test-retest ICC values near 0.98. Bennett angle and transverse parameters are less reliable, and mounting and reference plane choices alter the recorded values by amounts that exceed the device error. Agreement with MODJAW and Zebris systems is acceptable for SCI at the group level after reference plane harmonization, but individual limits of agreement are wide and Bennett angle values differ systematically, so parameters should not be transferred between systems. Diagnostic accuracy against MRI is characterized by high specificity and variable sensitivity, which confines axiography to a complementary functional role in TMJ diagnostics; its discriminative value in TMD and migraine lies in qualitative tracing features that can be evaluated reproducibly with a standardized scheme.

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AUTHOR'S CONTRIBUTION

All the authors made equal contributions to the publication preparation in terms of the idea and design of the article; data collection; critical revision of the article in terms of significant intellectual content and final approval of the version of the article for publication.

ВКЛАД АВТОРОВ

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SUPPLEMENTARY MATERIAL

Supplementary Table S1. Search strings and records retrieved (2 September 2026)

Source	String	Records
PubMed 1	(cadiax[tiab] OR "computerized axiography"[tiab] OR "computerised axiography"[tiab] OR "electronic axiography"[tiab] OR axiograph*[tiab]) AND 2000:2026[dp]	156
PubMed 2	(modjaw[tiab] OR zebris[tiab] OR "jaw motion analy*" [tiab] OR "jaw tracking"[tiab] OR "jaw motion tracking"[tiab] OR "mandibular movement record*" [tiab] OR "mandibular kinematic*" [tiab] OR "mandibular motion"[tiab]) AND ("hinge axis"[tiab] OR "condylar inclination"[tiab] OR «condylar guidance»[tiab] OR «Bennett angle»[tiab] OR "condylar path*" [tiab] OR reliab*[tiab] OR accura*[tiab] OR agreement[tiab] OR reproducib*[tiab]) AND 2000:2026[dp]	223
PubMed 3	("hinge axis"[tiab] OR "transverse horizontal axis"[tiab]) AND (kinematic*[tiab] OR digital[tiab] OR computer*[tiab] OR electronic[tiab]) AND 2000:2026[dp]	49
PubMed 4	("sagittal condylar inclination"[tiab] OR "condylar inclination"[tiab] OR "Bennett angle"[tiab]) AND (digital[tiab] OR electronic[tiab] OR computer*[tiab] OR optical[tiab] OR ultrasonic[tiab]) AND 2000:2026[dp]	62
Consensus 1	Reliability and accuracy of Cadiax computerized axiography for sagittal condylar inclination, Bennett angle and hinge axis compared with other jaw tracking systems (Modjaw, Zebris JMA, ARCUSdigma) or MRI	12 references
Consensus 2	Diagnostic accuracy of computerized axiography (Cadiax condylography) versus MRI for TMJ disc displacement, and axiographic differences between TMD patients and healthy controls	10 references
Google Scholar	"Cadiax" (reliability OR accuracy OR agreement OR MODJAW OR Zebris OR MRI), 2015 onward, first 50 records	50

Supplementary Table S2. Reports excluded after detailed assessment, with reasons

Reason	Reports
No CADIAX-family device ($n = 21$)	Lassmann, 2023 (Modjaw); Zhu, 2026 (Artex, Zebris JMAlyser+, SDi MatriX); Saygılı, 2025 (Zebris JMAlyser+, Modjaw); Zhao, 2025 (ARCUSdigma, SDiMatriX, Modjaw); Kucukkeles, 2005 (SAM Axiograph, Axiotron); Prasad, 2015 (Axioquick); Wieckiewicz, 2014 (ARCUSdigma II, Gerber); Dragus, 2023 (ultrasonic device); Wang, 2024, Ma, 2023, Zhou, 2024, Shang, 2026 (JMA or unspecified tracker); Kordass, 2019, Nebe, 2026 (Zebris); Hangai, 2008 (MMJI-E); Boulos, 2007, 2008 (Quick-Axis); Hue, 2011, 2016 (Axiocomp); Heiser, 2004 (mechanical axiograph); Mehl, 2025 (optoelectronic)
Device model not confirmable from available text ($n = 5$)	Cimić, 2014; Kondrat, 2021; Landes, 2000; Landes, 2003; Beer, 2004
No measurement property: descriptive, normative or treatment outcome series ($n = 12$)	Wu, 2026; Kostiuik, 2024; Londoño, 2023; Lewandowska, 2022; Alshali, 2013; Alratroot, 2022; Hernandez, 2010; Starikov, 2011; Tymofiyeva, 2007; Hlawitschka, 2002; Ozkan, 2003; Dolgalev, 2008 (no abstract available)
Case report ($n = 1$)	Jiang, 2026