

Temporomandibular Joint Disc Exploration, and Its Pathologies diagnosis by using Artificial Intelligence: A Systematic Review

Exploration du disque de l'articulation temporo-mandibulaire et diagnostic de ses pathologies par intelligence artificielle: Une revue systématique

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ABSTRACT

Artificial intelligence is invading almost every field, including health. Scientific publications concerning the medical field and AI have been increasing steadily in recent years, covering almost all medical specialties. This literature review aims to systematically synthesize current research on the development and validation of multimodal machine and deep learning models for automating TMJ disc displacement diagnosis. It highlights how integrating automatic MRI segmentation with clinical data correlation can significantly reduce diagnostic errors. Several databases (PubMed, Web of Science, Scopus, Science Direct, Springer, and ResearchGates) were consulted for articles on the subject of « articular disc and AI », from 2003 to 2025. One thousand eight hundred seventy-six (1876) studies were identified, of which eighteen (27) were included, totaling more than 6869 patients between controls and patients with articular disc displacement and more than 44000 images. Most of the studies used MRI imaging (considered the gold standard) alone or in combination with other types of data to explore the articular disc. To achieve this goal, various artificial intelligence models were used, including Machine Learning (Random forest, XG Boost, KNN, SVM...), and Deep Learning (ANN, CNN, U-Net, Seg-Net, RestNet 34...). Artificial intelligence can help in this sense by determining the condition of the disc in order to avoid not only the serious stages of disc displacements (ADD without Reduction), but also disc perforations.

Keywords: Temporomandibular Joint-Articular Disc-Artificial Intelligence-Systematic Review

RÉSUMÉ

L'intelligence artificielle s'immisce dans presque tous les domaines, y compris la santé. Les publications scientifiques concernant le domaine médical et l'IA ont connu une croissance constante ces dernières années, couvrant la quasi-totalité des spécialités médicales. Cette revue de la littérature vise à synthétiser systématiquement les recherches actuelles sur le développement et la validation de modèles multimodaux d'apprentissage automatique et d'apprentissage profond pour l'automatisation du diagnostic des déplacements discaux de l'articulation temporo-mandibulaire. Elle met en évidence comment l'intégration de la segmentation automatique des images IRM à la corrélation des données cliniques peut réduire significativement les erreurs de diagnostic. Plusieurs bases de données (PubMed, Web of Science, Scopus, Science Direct, Springer, et ResearchGates) ont été consultées pour identifier les articles portant sur le thème « disque articulaire et IA », publiés entre 2003 et 2025. Mille huit cent soixante-seize (1876) études ont été recensées, dont 27 (18) ont été incluses, portant sur un total de plus de 6 869 patients (groupes témoins et patients présentant un déplacement discal) et plus de 44 000 images. La plupart des études ont utilisé l'imagerie IRM (considérée comme la méthode de référence) seule ou en combinaison avec d'autres types de données pour explorer le disque articulaire. Pour atteindre cet objectif, différents modèles d'intelligence artificielle ont été utilisés, notamment l'apprentissage automatique (forêts aléatoires, XGBoost, KNN, SVM...) et l'apprentissage profond (réseaux de neurones artificiels, réseaux de neurones convolutifs, U-Net, Seg-Net, RestNet...). L'intelligence artificielle peut s'avérer utile en déterminant l'état du disque afin d'éviter non seulement les stades graves de déplacement discal (agénésie discale sans réduction), mais aussi les perforations discales.

Mots clés: Articulation temporo-mandibulaire-Disque articulaire-Intelligence artificielle-Revue systématique.

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INTRODUCTION

Temporomandibular joint (TMJ) is the joint between the mandibular condyle and mandibular fossa of temporal bone. This joint is the most functional parts of the head, which allows numerous and complex jaw functionality including but not limited to opening and closing jaw and digestion related movements (1).

Temporomandibular joint (TMJ) disorders are the second most common chronic musculoskeletal disorders in the world after lower back pain, affecting 1,8%-33,4% of the global population and are estimated to cost healthcare an approximate \$4 billion per year. TMJ disorders include joint- associated disorders (disc displacement and mobility), joint diseases (most commonly arthritis, condylitis, osteonecrosis, synovial chondromatosis), joint fracture, developmental disorders and masticatory muscle disorders (muscle pain, contracture, hypertrophy, impaired movement) (2).

The TMJ discs between the bones, located between the superior and inferior joint spaces, have a high collagen content for durability and rigidity, which helps the mandible to rotate and translate and serves as a cushion for occlusal force. TMJ displacement, also known as internal disc derangement, is an abnormal relationship among the articular disc, mandibular condyle, and mandibular fossa. While the most frequent displacement of the disc is anterior to the mandibular condyle, it can also occur posteriorly. Therefore, research has mainly been conducted on anterior disc displacement (ADD) of the TMJ. Uniquely, TMJ discs do not have direct nerve distribution or vascularization owing to their complex anatomic features. Alternatively, various blood vessels and nerves that are critical for pathophysiological processes characterize retrodiscal tissue, which is the posterior attachment of the TMJ disc. However, changes in the position or shape of the TMJ disc can further promote TMD development (3).

Artificial intelligence is a field of computer science dedicated to the development of computer algorithms to perform tasks traditionally associated with human intelligence such as the ability to learn and solve problems. This includes Machine Learning (ML), representational learning and Deep Learning. Many researchers are currently in-terested in artificial intelligence, which has been used extensively in a wide range of industries recently. This trend also applies to the dental industry, and applications of artificial intelligence in the field of oral and maxillofacial radiography are particularly exciting. Recent research on artificial intelligence in oral and maxillofacial radiology has mainly used convolutional neural networks capable of image classification, detection, segmentation, recording, generation and enhancement. The use of artificial intelligence has many advantages, especially in the field of oral and maxillofacial radiology. To improve the radiology department's work-flow through precision programming, identify patients most at risk of missing appointments and create personalized exam protocols, artificial intelligence that processes directly with medical data can help prevent errors from cognitive bias (4).

METHODS

This literature review aims to systematically synthesize current research on the development and validation of multimodal machine and deep learning models for automating TMJ disc displacement diagnosis. It highlights how integrating automatic MRI segmentation with clinical data correlation can significantly reduce diagnostic errors. This systematic review of the literature was carried out according to the PRISMA search criteria. Artificial intelligence (AI) is promise to transform many fields, including medicine. By combining various techniques such as language processing, data mining and Machine Learning. AI helps to improve the quality of care, for example by facilitating assisted operations, remote patient tracking, the design of intelligent prostheses and the personalization of treatments thanks to massive data (big data). The text distinguishes two approaches: on the one hand, the so-called «strong» AI, which aims to reproduce human, thought and potentially create a superior intelligence, and on the other hand, the numerical approach which is based on data analysis to detect regularities without a predefined model. In medicine, such as through language models (LLM), these techniques are used to automatically extract information from large sets of clinical data. Although these models are being tested for various uses, such as entity recognition, automatic report completion or patient. Finally, the text highlights the importance of studying the TMJ anatomy parts specially the articular disc.

Precise question

How can artificial intelligence improve the diagnosis of TMJ disc disorders through medical imaging and multimodal data analysis?

Research strategy

A search was carried out on articles published in the different electronic databases (PubMed, Web of Science, Science Direct, Scopus, Springer, and Reaserch Gates). Whatever the year of publication: the search was conducted on January the 10th 2025 until March the 31th 2025 in Oujda Morocco.

Data were retrieved from the following databases through the Mohamed First University Institutional Access: PubMed (PM), Web of Science (WS), Scopus, Science Direct (SD), Springer, and Research Gates (RG).

The keywords and Boolean operators used to search the PubMed, Web of Science, Springer, Scopus, Science Direct, and Research Gtaes were, in the titles and abstracts, indicated as follows: "Temporomandibular Disc and Artificial Intelligence".

The filters "articles concerning the human species" were applied.

Eligibility criteria

To be included in this review, articles should focus on the contribution of AI in the study of TMJ disc.

Inclusion criteria were as follows:

- Articles (research article, conference paper, book chapter...) that address the segmentation, detection, localization of joint disc, and its exploration by using artificial intelligence.
- Articles (research article, conference paper, book chapter...) that address the detection of articular disc damage (perforation, displacement) by using artificial intelligence.
- Articles (research article, conference paper, book chapter...) that address the TMJ exploration including the exploration of TMJ disc by using artificial intelligence.
- Articles (research article, conference paper, book chapter...) that address the TMJ damage or TMD including the TMJ disc damage (perforation, displacement) by using artificial intelligence.
- Human articles.

Exclusion criteria were as follows:

- Letters, abstracts of oral or written communication, review, systematic review, letters, editorials.
- Non-human articles.
- Articles that address the TMJ in general or any other component of TMJ other of the articular disc.
- Articles that address segmentation, detection, exploration, and disc damages without mentioning artificial intelligence.

Selection of articles

After deleting duplicates, the three reviewers (Oussama Abali, Pr. Aissa El Miad Kerkour, and Pr. Abdelkrim Daoudi) independently checked the titles and abstracts of the articles to ensure that they corresponded to the various inclusion criteria. The full texts of eligible articles available according to the three reviewers were collected and read in their integrity. The final selection of articles for this literature review was made by consensus between the three reviewers.

Correlation of data/information

All articles have been sorted according to several themes: Country of origin of the article, artificial intelligence algorithms and architecture used, task performed by the AI, type of features used and/or any other features, number of images used, AI reference standard, year of publication.

Risk of bias assessment

All three reviews strictly applied the inclusion and exclusion criteria to avoid any risk of bias when studying the various articles included using a sensitivity analysis method.

The study was based on the consultation of several databases, including articles from all languages, over a sufficiently long period.

For this study, the authors used the ROBIS tool to assess risk of bias in systematic reviews by following the checklist

that will be corrected by experts from the Department of Epidemiology and Community Medicine of Faculty of Medicine and Pharmacy, Mohamed First University. The evaluation showed a low risk of bias.

RESULTS**Articles selection**

A total of 1876 references from different databases were obtained by searching and using the previously cited keywords according to the following distribution:

- PubMed (PM): 33 from 2011 to 2025,
- Web of Science (WS): 15 from 2021 to 2025,
- Scopus: 16 from 2018 to 2025,
- Science Direct (SD): 154 from 2000 to 2025,
- Springer: 161 from 1974 to 2025,
- ReasearchGates (RG) : 1497 from 2003 to 2025.

Literature systematic reviews, Letters, abstracts of oral or written communication, case report, conferences review, correspondences (n= 179) were removed, giving a total of 1697 references analyzed.

After reading the titles and abstracts, 1648 references were excluded, as they did not meet the inclusion criteria, not being interested in both TMJ articular disc and artificial intelligence. The full-text versions of the 49 articles were collected and checked for suitability for inclusion in the study. After reading the full texts, 22 articles were excluded as duplicates.

In total, we have 27 articles were included in this review by consensus between the three reviewers and studied in detail. The FLOW diagram as shown in Fig 1 explains the selection of the retained articles.

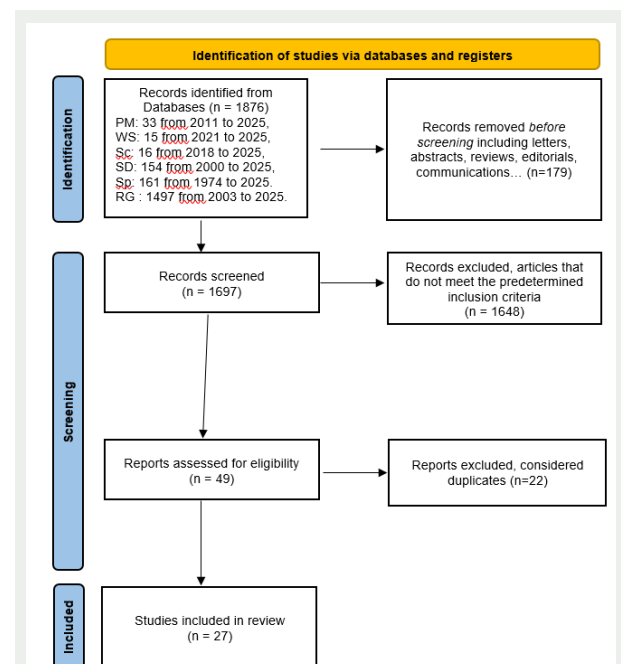


Figure 1. Diagram of FLOW.

Classifying articles by theme

After reading and analysis, the articles were classified in a

table, according to year of publication, author, country of origin and artificial intelligence model used, type of data base used, number of features, and reference standard used.

Study features

The 27 studies from different databases aforementioned reporting the application of Machine Learning models covered the period from 2003 to 2025.

The table 1 shows the distribution of items according to country of origin.

The country of origin was determined according to the location of the structure (university or hospital) where the data collection was carried out.

If the location of the structure is not mentioned, we use the country of origin of the structures (hospital or university) to which the authors belong.

If the structures to which the authors of the article belong have a different country of origin, this will be mentioned in the table as "country of mixed origin".

The twenty-seven paper were included in this review by consensus between the three reviewers and studied in detail.

Twenty-one (21) studies adopted Deep Learning algorithms for TMJ disc exploration (3,5,6,7,8,9,10,11,12, 13,14,15,16,17,18,19,20,21,22,23, 24).

Table 1. Number of articles published by country of origin.

Country origin	Number of Articles
S.Korea	08
Japan	05
China	04
Turkey	03
Canada	02
USA	01
Brazil	01
Taiwan	01
Romania	01
Mixed origin	01

Three studies adopted Machine Learning models to explore TMJ articular disc (25, 26, 27).

The rest adopted both Deep Learning/Machine Learning models or AI algorithms in general (28, 29, 30)

The table 2 shows the distribution of articles using artificial intelligence (Machine Learning and Deep Learning algorithms) used for TMJ disc detection and exploration over the years.

Table 2. Breakdown of studies included from 2003 to 2025 according to the AI model used.

Model AI used	2003	2012	2015	2021	2022	2023	2024	2025
Deep Learning	01	01	00	01	07	05	03	03
Machine Learning	00	00	00	01	00	00	01	01
Combination between DL/ML algorithms	00	00	01	01	01	00	00	00

The table 3 shows the distribution of articles using artificial intelligence algorithms (Deep Learning and Machine Learning) according to the different tasks

carried out (TMJ disc exploration, TMJ disc displacement, etc.) over the years.

Table 3. Breakdown of studies included from 2003 to 2025 according to the Task done by Artificial Intelligence model used.

Task done	2003	2012	2015	2021	2022	2023	2024	2025
TMJ disc segmenta-tion/detection	00	00	00	01	02	01	02	03
TMJ disc displace-ment/perforation	01	01	01	03	04	04	03	01

We can see in the figure 2 that 33.33% of the articles selected addressed the exploration of the TMJ disc (segmentation, detection, measurement...), while 66.66% were interested of TMJ disc damage (perforation, displacement...).

The table 4 shows the different types of dataset used for training and testing the different algorithms by number of articles retained.

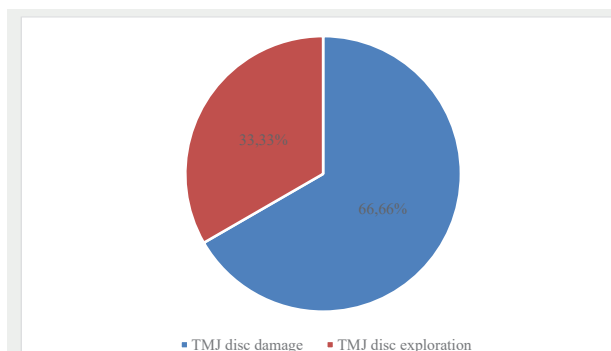


Figure 2. Graph showing the percentage of different tasks performed by AI models concerning the study of the articular disc in the selected articles.

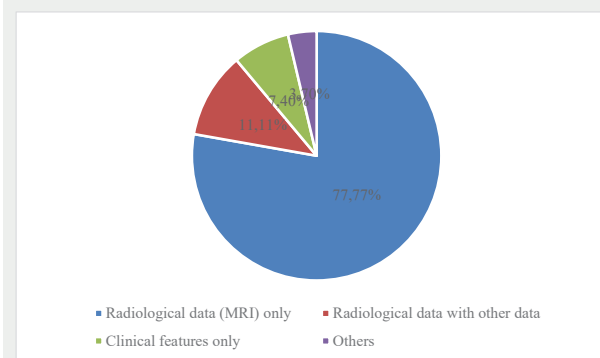
Table 4. Number of articles by type of data analyzed.

Data Types	Number of Articles
Radiological data only (MRI images)	21
Radiological data with other data (clinical, biological, radiomic features....)	03
Clinical features only	02
Other features (camera videos...)	01

Twenty one of selected paper (n=21) 77,77% of total articles retained used radiological images (MRI) only as dataset for training and testing of Deep Learning/ Machine Learning algorithms.

Three articles adopted the association between radiological images (mostly MRI scans) and other features (clinical, radiomics, biological...).

The last three papers used clinical features (02 papers) and one study adopted cam-era videos as dataset.

**Figure 3.** Graph of the distribution of the percentage of features used as dataset in the selected articles.

The table 5 shows the distribution of articles retained (n=27) by the reference standards used.

Most articles (n=20) used the usual single reference standard (expert judgment, AI algorithms comparison, and methods comparison): eleven articles used expert judgement as a reference, eight used AI algorithm comparison, and one paper adopted the method comparison.

Six articles used the combination between AI algorithms comparison and expert judgment (four articles), between AI algorithms comparison and method comparison (one paper), and Combination between expert judgment and method comparison (one article).

Table 5. Number of articles by reference standard used.

Reference standard	Number of Articles
Expert judgement	11
AI algorithm comparison	08
Combination between expert judgment and method comparison	01
Combination between AI algorithms comparison and method comparison	01
Combination between expert judgment and AI algorithms comparison	04
Method comparison	01
Not available	01

DISCUSSION

Interpretation of Diagnostic Accuracy

Analysis of overall performance shows that AI models have reached a threshold of clinical maturity. Deep Learning (DL) models exhibit exceptional results, with AUROCs reaching 0.988 for non-reduced disc displacement (ADsR) (5). The use of ResNet architectures enables an accuracy of 0.970 (11), while AI assistance achieves 100% sensitivity (15). This efficiency relies on the ability of six machine learning algorithms to build this model and identify radiomic features (up to 90 identified, 56 of which can be calculated and associated with features for TMJ disc changes) that the human eye cannot detect or quantify (25).

Diagnostic Performance and Clinical Decision Support

The analyzed literature demonstrates the consistent superiority of Deep Learning (DL) models over conventional methods. Architectures such as ResNet (11), MobileNetV2 (20), and InceptionV3 (16, 20) often exhibit accuracies exceeding 95%. A key finding of this review is the impact of AI assistance on human expertise: the study by Kim et al. (15) shows that an AI-assisted specialist achieves an AUC of 0.995, consistently surpassing isolated human analysis.

However, accuracy varies depending on joint position. While the closed-mouth position allows for an accuracy of 0.97 (20), the open-mouth position proves more complex (Accuracy of 0.84), suggesting that dynamic disc deformations remain a challenge for convolutional neural networks (CNNs).

Anatomical Segmentation: Between Automation and Precision

Segmentation of the articular disc is the most challenging step due to its small size and variable contrast on MRI sequences.

2D vs. 3D models: Although nnU-Net (3D) offers a three-dimensional volumetric view, 2D models such as U-Net++ (22) or DeepLabV3+ (8, 21) exhibit robust Dice similarity scores (0.82 to 0.84).

Image optimization: The contribution of preprocessing techniques such as contrast-limited adaptive histogram equalization CLAHE (14, 24) or Super-Resolution (26) is crucial. Study (26) demonstrates that artificially increasing the resolution (400x400 pixels) allows simple models like Naive Bayes to surpass clinicians by revealing structural details invisible to the naked eye.

Cutting-edge algorithms: The emergence of the YOLOv8 series (24) and GANs (Trans-UNet) (23) opens the way to real-time detection with a structural similarity index measure (SSIM) of 82.28%.

Towards a Multimodal and Predictive Approach

One of the most innovative contributions of this review concerns the integration of extra-radiological data. Isolated analysis of disc shape (AUC of 0.79) is significantly inferior to a multimodal approach (AUC of 0.94) including

effusion and joint space (28).

Bayesian Networks (BBNs) (29) stand out for their near-absolute accuracy (99.6%), illustrating the power of probabilistic models to correlate heterogeneous variables. Finally, the automation of motion tracing (30) links static imaging to dynamic function, offering a novel perspective for holistic diagnosis.

Analysis of Radiomics and Machine Learning (ML)

Unlike deep learning (DL), which learns directly from pixels, radiomics-based machine learning (ML) (25, 27) allows for the extraction of texture biomarkers. The KNN model (27) exhibits 100% specificity, positioning ML as an exceptional triage tool for excluding false positives.

The use of super-resolution (SR) allows models (Naive Bayes and Logistic Regression) to outperform clinicians. This proves that AI can "see" structural details that the human eye misses, especially when the resolution of MRI images is artificially increased (400x400 pixels), which constitutes a key factor in ensuring accurate diagnosis of disc displacements (26).

However, study (25) highlights a major limitation: the difficulty of generalization to small cohorts (n=107), where the AUC drops during external tests, unlike deep learning, which benefits from transfer learning (3).

Sources of Heterogeneity and Bias

Despite these successes, significant variability remains. Generalizing the models remains a challenge: a high-performing model can see its AUC drop to 0.742 when tested on small external samples (25). The acquisition protocol is a major source of bias: accuracy varies drastically between closed (0.97) and open (0.84) mouths (20). Furthermore, the use of pT2 sequences shows massive disagreement rates (85% for ADDwoR), proving that the choice of MRI sequence (PD vs. T2) determines the final reliability (12).

Recent Technological Advances in AI Models

Technological evolution is marked by the shift from 2D to 3D segmentation (nn U-Net) and the use of generative models (GAN / Trans-UNet) (6, 23). The introduction of YOLOv8 and contrast filters such as CLAHE has made it possible to optimize automatic detection, even on images of heterogeneous quality (24). A major advance is Super Resolution (SR), which artificially increases the resolution of MRI scans (400x400 pixels), allowing simple models (Naïve Bayes) to surpass human expertise (26).

AI Model Performance and Clinical Implications

AI integration reduces interpretation time to a few seconds (~4 sec) while offering diagnostic consistency (3). For specific populations, such as children, the U-Net++ model provides an accuracy of 0.927 (22). Clinically, this means a reduction in subjectivity: AI consistently outperforms intermediate-level observers (levels 2 and 3) and matches senior experts (6).

Comparative Diagnostic Performance and Clinical Integration

Traditional machine learning (ML) (e.g., KNN) excels at triage with 100% specificity in identifying healthy cases (27). However, the multimodal approach is the most robust: integrating clinical data (effusion, joint space) increases the AUC from 0.79 to 0.94 (28). Bayesian networks (BBNs) achieve near-absolute accuracy of 99.66% by dynamically correlating these variables (29).

Strengths and Limitations

Strengths:

Ability to process multimodal data (EMG, history, imaging) with 86.8% accuracy (17).

AI offers enhanced vision through radiomics and high resolution (25, 26).

The study encompasses different types of AI models, allowing for better comparison between them.

Limitations:

The risk of overfitting on limited databases (e.g., 20 patients) (7, 29).

The decision-making opacity ("black box") of disc herniation models remains a barrier to clinical explainability (28).

Few articles have adopted machine-learning models in the exploration and study of the articular disc.

The reference standard used in some articles was not always clearly defined.

It is worth mentioning that the study did not include grey literature (thesis dissertations, reports, working papers, newsletters, speeches, white papers, etc.).

Clinical complexity: The diagnosis of bilateral non-reduction (ADDwoR) cases remains less accurate (sensitivity 37% in study 9), suggesting that AI still needs improvement for the most severe pathologies.

Future Directions and Clinical Integration

The future lies in dynamic diagnosis. The integration of automated video analysis of mandibular movement, correlated with MRI data, enables true functional assessment (30). The development of models like Three-Branch Jointed Feature and Topology Decoder (TFTD), providing a precise visual basis for each segmentation (18), is essential to transforming AI into a shared decision-making tool that is transparent and reproducible in routine hospital practice.

CONCLUSION

The articular disc constitutes an integral part of the anatomy of the TMJ articular disc displacements are the main pathologies that can affect this structure.

The results of this systematic review confirm that multimodal and machine learning models generally exhibit high diagnostic accuracy in distinguishing patients with disc displacement from those without, thus

confirming their reliability in diagnostic and screening contexts.

These results support the idea that AI (especially deep learning algorithms) has become a clinically relevant tool for diagnosing disc lesions. By avoiding the limitations already observed, notably the diversification of assessment parameters and the adopted reference standards, the unification of these two parameters will undoubtedly allow for a better evaluation of the different models.

Indeed, heterogeneity in feature selection and training data remains a major concern, highlighting the need for standardized methodologies and validation in diverse populations to ensure consistent and generalizable results.

All of this will allow us to study the articular disc and help clinicians and radiologists diagnose its pathologies, including anterior displacement, which can affect it.

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