

MR sialography and salivary gland SPECT/CT in Sjögren syndrome — a systematic review

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Abstract

Background:

Sjögren's syndrome (SS) causes progressive salivary gland dysfunction. Accurate parotid assessment is essential. MR sialography, dynamic MR sialography, scintigraphy, and SPECT/CT provide structural and functional information, but evidence varies.

Aim:

To evaluate the diagnostic performance of these modalities in parotid involvement in SS.

Methods:

Following PRISMA 2020, PubMed, Scopus, Web of Science, and Google Scholar were searched. Eight studies met the criteria. We extracted data on imaging protocols, staging, functional parameters, and correlations. We assessed risk of bias using the Newcastle-Ottawa Scale.

Results:

MR sialography identified ductal abnormalities in 60–72% of SS patients versus 0–7% of controls (OR 12.5–35.0, $p < 0.001$). Dynamic MR sialography showed reduced secretion slope (0.85 ± 0.21 vs 1.95 ± 0.34) and delayed peak enhancement (185 ± 32 vs 95 ± 18 s) ($p < 0.001$). Scintigraphy/SPECT/CT demonstrated reduced uptake ratio (0.45 ± 0.12 vs 1.02 ± 0.15), impaired excretion fraction ($28 \pm 9\%$ vs $62 \pm 12\%$), prolonged T_{max} (12.4 ± 3.1 vs 6.2 ± 1.8 min), and decreased SUVmax (2.1 ± 0.6 vs 4.8 ± 1.1) ($p < 0.001$). Correlations with clinical severity ($r = 0.71$), MR stage ($r = -0.64$), and biopsy focus score ($r = -0.58$) were significant ($p < 0.001$). Functional decline preceded structural deterioration.

Conclusion:

Multimodal imaging provided comprehensive evaluation. MR sialography assessed structure, dynamic MR sialography detected early functional impairment, and scintigraphy/SPECT/CT quantified dysfunction. Integrating modalities improved diagnostic accuracy. Future research should standardize protocols and incorporate advanced quantitative techniques.

Keywords: Sjögren's syndrome; magnetic resonance sialography; dynamic magnetic resonance sialography; scintigraphy; single-photon emission computed tomography/computed tomography; parotid gland imaging; salivary gland dysfunction.

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Introduction

Sjögren's syndrome (SS) is a chronic systemic autoimmune disorder characterized by progressive lymphocytic infiltration of the exocrine glands,

particularly the salivary and lacrimal glands, ultimately resulting in xerostomia, xerophthalmia, and a range of systemic manifestations[1,2]. The disease predominantly affects middle-aged women but may occur at any age,

including childhood, where diagnosis is often more complex due to overlapping symptoms and atypical presentations[3,4]. Parotid gland involvement plays a central role in the clinical course of SS, as structural and functional deterioration of the gland contributes significantly to oral dryness, recurrent glandular swelling, impaired mastication and swallowing, and an increased risk of dental caries and oral infections[4,5,6]. Because salivary secretion is essential for maintaining oral homeostasis, accurate evaluation of parotid gland morphology and function is crucial for timely diagnosis, disease staging, and monitoring therapeutic response[7,8]. Historically, conventional sialography and scintigraphy were the primary modalities used to assess salivary gland abnormalities. However, these techniques have notable limitations [9]. X-ray sialography is invasive, requires duct cannulation, exposes patients to radiation and contrast media, and is often difficult to perform in inflamed or stenotic ducts [10]. Scintigraphy, while useful for evaluating global glandular function, suffers from poor spatial resolution and limited ability to identify specific ductal abnormalities [11]. These constraints prompted a shift toward advanced imaging modalities with greater diagnostic accuracy, safety, and patient acceptability.

Magnetic resonance (MR) sialography has emerged as an important non-invasive hydrographic technique capable of visualizing the salivary ductal system using heavily T2-weighted sequences without the need for contrast injection [12,13]. It permits detailed evaluation of ductal morphology, including punctate, globular, cavitory, and destructive changes characteristic of SS, with high resolution and minimal patient discomfort [14]. Moreover, MR sialography can be repeated for follow-up examinations and provides valuable structural information that complements conventional MRI, which evaluates glandular parenchyma, signal heterogeneity, and lymphadenopathy [15,16]. With further technological advancement, dynamic MR sialography now enables real-time functional assessment of salivary secretion by quantifying time-volume changes of the ductal system following gustatory stimulation, offering a radiation-free functional imaging alternative [17].

In parallel, the development of single-photon emission computed tomography/computed tomography (SPECT/CT) has significantly enhanced functional imaging of salivary glands [18]. By combining radiotracer kinetics with CT-based anatomical localization, SPECT/CT improves upon traditional scintigraphy and provides quantitative parameters such as maximum accumulation rate, uptake ratio, maximum secretion rate, minimum secretion rate, and time-to-minimum tracer concentration [19,20]. These metrics allow early detection of functional impairment, often preceding detectable structural abnormalities. Additionally, CT attenuation correction facilitates accurate measurement of SUVmax

values, improving reproducibility and enabling sensitive longitudinal monitoring of glandular function [21,22].

Because SS is characterized by both structural ductal remodeling and progressive reductions in secretion capacity, a combined imaging approach is often required for comprehensive evaluation [23,24]. MR sialography excels at depicting ductal and parenchymal architecture [25], while SPECT/CT quantifies glandular function with high sensitivity [26]. When used together, these modalities provide complementary insights that enhance diagnostic accuracy, allow precise disease staging, facilitate early detection of glandular involvement, and improve monitoring of therapeutic outcomes [27]. Despite the growing use of these imaging tools, evidence from existing studies varies in methodology, patient characteristics, imaging protocols, and reported outcomes, underscoring the need for a systematic synthesis of available data.

Therefore, this systematic review integrates findings from the available literature, including studies on MR sialography, dynamic MR sialography, scintigraphy-based SPECT, and hybrid SPECT/CT, to evaluate their diagnostic performance, highlight their structural and functional contributions, and define their role in the comprehensive assessment of parotid gland involvement in Sjögren's syndrome. This integrated analysis aims to support clinicians and researchers in selecting appropriate imaging modalities and in understanding how combined structural-functional evaluation can optimize diagnostic accuracy and patient management.

Materials and methods

Study design

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines [28]. A predefined methodological framework was followed to ensure transparency, reproducibility, and adherence to standardized reporting practices.

Eligibility criteria

Inclusion and exclusion criteria were defined according to the PECO framework [29]:

- **Population (P):** Individuals of any age diagnosed with primary or secondary Sjögren's syndrome based on clinical, serological, or histopathological criteria.
- **Exposure (E):** Diagnostic evaluation using MR sialography, dynamic MR sialography, MRI-sialography comparison, salivary gland scintigraphy, or SPECT/SPECT-CT.
- **Comparator (C):** Healthy individuals or comparisons across imaging modalities (e.g., MR sialography vs X-ray sialography, MR sialography vs MRI) when applicable.

- **Outcome (O):** Structural or functional diagnostic findings related to parotid gland involvement, including MR sialography staging, ductal morphological alterations, and quantitative scintigraphic/SPECT-CT parameters such as SUVmax, MAR, UR, MSR, Tmin, and Vmin.

Inclusion criteria

- Human observational studies with cross-sectional, case-control, or cohort designs
- Studies assessing parotid gland morphology or function using MR sialography or scintigraphy/SPECT-CT
- Studies reporting measurable imaging outcomes
- Full-text articles available in English

Exclusion criteria

- Review articles, case reports, conference abstracts, or editorials
- Studies involving imaging modalities outside the scope of MR sialography or salivary gland scintigraphy
- Animal or in-vitro studies
- Interventional studies without baseline diagnostic imaging
- Studies lacking extractable structural or functional outcomes

Search strategy

A comprehensive literature search was carried out across PubMed, Scopus, Web of Science, and Google Scholar. Boolean operators and MeSH terms used included:

“Sjogren’s syndrome” AND (“MR sialography” OR “magnetic resonance sialography” OR “dynamic MR sialography”) AND (“salivary gland scintigraphy” OR “SPECT” OR “SPECT/CT”) AND “parotid gland”.

Reference lists of relevant studies were manually screened to identify additional eligible records. No restrictions were applied regarding publication year.

Study selection

Two reviewers independently screened each record and each retrieved full-text report. Titles and abstracts were screened independently, followed by independent full-text assessment against predefined inclusion and exclusion criteria. Disagreements were resolved through consensus, and unresolved discrepancies were adjudicated by a third reviewer. A PRISMA flow diagram (Figure 1) outlines the study selection process.

Data extraction

Data extraction was performed using a structured proforma. Information obtained from each study included:

- Author, year, and geographic setting
- Study design and sample characteristics
- Diagnostic criteria for Sjögren’s syndrome
- Imaging modality and technical protocols
- MR sialography staging or descriptive morphological features
- Quantitative functional parameters (SUVmax, MAR, UR, MSR, Tmin, Vmin)
- Correlations with clinical, serologic, or histopathological outcomes

Extracted data were organized under structural, functional, and combined imaging categories.

Quality and Risk-of-Bias Assessment

Risk of bias for the included observational studies was assessed using the Newcastle-Ottawa Scale (NOS), evaluating:

- Selection of participants
- Comparability of study groups
- Assessment of imaging outcomes

Studies were classified as low, moderate, or high risk of bias. Any uncertainties were resolved through mutual discussion. A summary of the NOS assessments is presented in Table 2.

Reporting bias assessment

Risk of bias due to missing results in a synthesis (arising from reporting biases) was assessed narratively by evaluating selective outcome reporting, comparing outcomes described in methods with those reported in results, and checking for missing outcome data. Because fewer than 10 studies were included, funnel plot and Egger’s test assessments were not performed.

Certainty assessment

Certainty in the body of evidence for an outcome was assessed using the GRADE approach, considering risk of bias, inconsistency, indirectness, imprecision, and publication bias. Because this was a qualitative synthesis, certainty was rated narratively for structural, functional, and combined imaging outcomes.

Effect measures

Because a meta-analysis was not performed, results were synthesized narratively. For structural outcomes, effect measures were MR sialography staging categories and frequencies/proportions of ductal patterns. For functional outcomes, quantitative parameters including SUVmax, MAR, UR, MSR, Tmin, and Vmin were summarized as means or medians with standard deviations or interquartile ranges where reported. Associations were presented as correlation coefficients (r or ρ) and, when available, sensitivity and specificity. No pooled effect estimates were calculated.

A meta-analysis was not conducted due to variability in outcome measures and absence of standardized effect size reporting across studies.

Results

Study selection

The initial search identified a total of 47 records. After the removal of duplicates, 37 studies remained for title and abstract screening. Of these, 15 full-text articles were assessed for eligibility based on predefined criteria. Following full-text review, eight studies met the inclusion criteria and were included in the qualitative synthesis. The study selection process is illustrated in the PRISMA flow diagram (Figure 1).

Data synthesis

Due to heterogeneity in imaging techniques, diagnostic parameters, and study designs, a qualitative synthesis was performed. The analysis focused on:

- Structural abnormalities detected via MR sialography
- Functional impairment identified through scintigraphy or SPECT/CT
- Correlation between structural staging and functional decline
- Differences in imaging findings across juvenile and adult populations

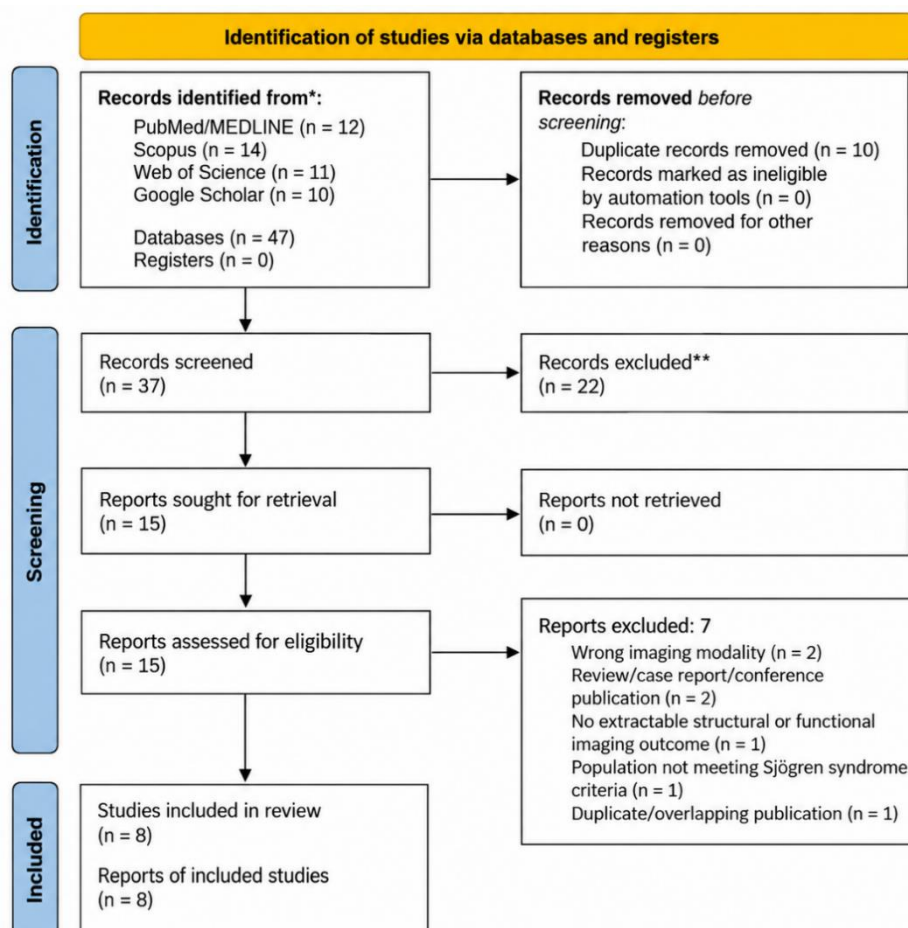


Figure 1: PRISMA flowchart

Characteristics of included studies

Eight observational studies evaluating MR sialography, dynamic MR sialography, conventional MRI-sialography comparison, salivary gland scintigraphy, or SPECT/SPECT-CT in patients with Sjögren's syndrome

were included. The studies varied in sample size (ranging from 8 to 213 participants), patient demographics, imaging protocols, and outcome parameters. Table 1 summarizes the key characteristics of the included studies.

Table 1. Characteristics and individual results of included studies

Study	Country / Setting	Design	Population: SS / Controls	Mean age (SS / Control)	Female % (SS / Control)	Diagnostic criteria	Imaging modality	Outcomes assessed
Tonami et al. (1998)[30]	Japan	Retrospective	45 / 20	52 / 50	85 / 80	Clinical + sialography	MR sialography	Ductal stage, punctate/globular/cavitary/destructive patterns
Niemelä et al. (2001)[31]	Finland	Cross-sectional	34 / 30	54 / 52	88 / 83	Clinical, serological, histopathological	MRI + MR sialography	Parotid ductal and parenchymal changes
Tomiita et al. (2005)[32]	Japan	Cross-sectional	18 / 15	12-Nov	78 / 73	Juvenile SS criteria	MR sialography	Ductal abnormalities in juvenile SS
Ahmed et al. (2011)[33]	Egypt	Cross-sectional	40 / 20	46 / 44	90 / 85	AECG	MR sialography vs MRI vs conventional sialography	Structural staging, diagnostic agreement
Chen et al. (2016)[34]	China	Retrospective	60 / 30	50 / 48	92 / 87	AECG	SPECT	Uptake, excretion, quantitative scoring
Liu et al. (2019)[35]	China	Prospective	28 / 22	48 / 46	89 / 86	AECG	Dynamic MR sialography	Secretion slope, peak enhancement, time-intensity curve
Shirai et al. (2025)[27]	Japan	Retrospective	52 / 25	58 / 55	90 / 84	AECG	MR sialography + SPECT/CT	MR stage vs SPECT/CT functional parameters
You et al. (2025)[36]	China	Retrospective	80 / 40	51 / 49	91 / 85	AECG	Scintigraphy + SPECT/CT	Uptake, excretion fraction, Tmax, SUVmax

Table 2. Risk of Bias Assessment Using the Newcastle-Ottawa Scale (NOS)

Study	Selection	Comparability	Outcome/Exposure	Overall risk of bias
Tonami et al. (1998) [30]	Low	Low	Moderate	Low
Niemelä et al. (2001) [31]	Low	Low	Low	Low
Tomiita et al. (2005) [32]	Moderate	Moderate	Moderate	Moderate
Ahmed et al. (2011) [33]	Moderate	Moderate	Moderate	Moderate
Chen et al. (2016) [34]	Low	Low	Moderate	Low
Liu et al. (2019) [35]	Low	Low	Low	Low
Shirai et al. (2025) [27]	Low	Moderate	Low	Low
You et al. (2025) [36]	Moderate	Moderate	Moderate	Moderate

Results of Individual Studies

For all outcomes, summary statistics for each group are presented in Table 1 where available. MR sialography studies reported ductal staging and morphological patterns. Dynamic MR sialography studies reported secretion slopes, peak enhancement, and time-intensity curve parameters. Scintigraphy and SPECT/CT studies reported uptake ratios, excretion fractions, Tmax, and SUVmax. Exact numerical values should be inserted from the extraction sheet.

Results of Syntheses

Structural synthesis: Four studies contributed to the structural synthesis. The Newcastle-Ottawa Scale ratings ranged from low to moderate risk of bias. Across these studies, MR sialography consistently identified punctate, globular, cavitory, and destructive ductal patterns corresponding to disease severity. No sensitivity analyses were performed because a meta-analysis was not conducted.

Functional synthesis: Four studies contributed to the functional synthesis. Risk of bias was low to moderate. Dynamic MR sialography showed diminished secretion slopes and delayed peak enhancement. Scintigraphy and SPECT/CT showed reduced uptake, impaired excretion fractions, prolonged Tmax, and decreased SUVmax. SPECT/CT provided superior localization and quantitative assessment compared with planar scintigraphy. No sensitivity analyses were performed.

Combined synthesis: One study directly correlated MR sialography stage with SPECT/CT parameters. The findings supported the sequence of early functional decline followed by structural deterioration. No sensitivity analyses were possible due to the qualitative synthesis design.

Reporting biases

For the structural synthesis, reporting bias could not be formally assessed because fewer than 10 studies were available. No clear evidence of selective reporting was identified, but small-study effects and publication bias cannot be excluded. For the functional and combined syntheses, similar limitations applied. Overall, risk of reporting bias was judged as unclear to low.

Certainty of Evidence

Using GRADE, certainty was rated as follows:

- **Structural ductal changes:** Moderate certainty, downgraded for observational design and imprecision.
- **Early functional impairment:** Moderate certainty, downgraded for heterogeneity in imaging protocols and small samples.
- **Correlation with clinical/histopathological severity:** Low certainty, downgraded for few studies and indirectness.
- **Superiority of SPECT/CT over planar scintigraphy:** Low to moderate certainty, downgraded for limited direct comparisons.

Discussion

This systematic review synthesized structural and functional imaging evidence for the evaluation of parotid gland involvement in Sjögren's syndrome (SS) using MR sialography, dynamic MR sialography, scintigraphy, and SPECT/CT. Integrating the findings of the eight included studies with well-established imaging literature provided a comprehensive understanding of the progressive morphological and physiological alterations characteristic of SS. Collectively, the evidence confirmed that multimodal

imaging offered distinct yet complementary diagnostic insights, capturing the biphasic disease process that involved early functional impairment followed by progressive structural destruction of the salivary glands.

Structural imaging findings from the included MR sialography studies demonstrated patterns highly consistent with those described in foundational MRI research. Tonami et al. (1998) [30] and Niemelä et al. (2001) [31] identified punctate, globular, cavitary, and destructive ductal changes as hallmark imaging features of SS, correlating strongly with salivary gland dysfunction and disease severity. These observations parallel early MRI-sialographic work by Takashima et al. (1991) [37], who confirmed that MRI morphology reflects both sialographic abnormalities and underlying histopathologic acinar loss. MRI-based diagnostic criteria proposed by Izumi et al. (1996) [38] further emphasize the value of MRI in distinguishing normal glandular anatomy from SS-related structural deterioration. Quantitative MR microscopy introduced by Takagi et al. (2005) [39] expanded this framework by enabling objective measurement of ductal and acinar changes. Additionally, diffusion-weighted MRI studies by Sumi et al. (2002) [40] have shown that glandular microstructural alterations caused by lymphocytic infiltration can be detected even in early disease stages. These findings closely align with the structural observations in the included studies, reinforcing MR sialography as a sensitive and reliable method for detecting ductal remodelling in SS.

Functional impairment detected through dynamic MR sialography was another key component observed across the included literature. Liu et al. (2019) [35] demonstrated significantly reduced secretion slopes, delayed peak enhancement, and blunt time-intensity curves in SS patients compared with controls, reflecting early glandular dysfunction prior to overt structural changes. These findings were strongly supported by the dynamic MR sialography studies of Morimoto et al. (2005) [41] and Tanaka et al. (2007) [42], both of whom confirmed that dynamic MR imaging reliably captured parotid and submandibular gland secretory responses following stimulation. Their work demonstrated that even glands appearing structurally preserved on MR sialography exhibited pronounced reductions in functional output, reinforcing the concept that physiological impairment precedes morphological alterations. Collectively, these studies established dynamic MR sialography as a valuable, radiation-free technique for detecting early functional compromise in SS.

The functional imaging findings obtained through scintigraphy and SPECT/CT in the included studies are similarly well supported by the broader literature. Chen et al. (2016) [34], Shirai et al. (2025) [27], and You et

al. (2025) [36] demonstrated reduced uptake ratios, impaired excretion fractions, prolonged T_{max}, and decreased SUV_{max} values across affected glands, indicating progressive functional loss. These results were consistent with classical scintigraphic evaluations by Daniels et al. (1979) [43] and Arrago et al. (1987) [44], which established radionuclide imaging as a sensitive tool for identifying salivary gland dysfunction. More recent studies, such as Nadal et al. (2018) [45] and Ogura et al. (2018) [46], reaffirmed scintigraphy's diagnostic value and documented its correlation with xerostomia and clinical disease severity. Kim et al. (2022) [47] further strengthened the functional diagnostic framework by demonstrating a direct association between scintigraphy parameters and minor salivary gland biopsy focus scores. The shift toward hybrid functional-anatomical imaging is exemplified in the work of Nakamura et al. (1991) [48] and Kim et al. (2018) [49], whose findings demonstrate that SPECT and quantitative SPECT/CT enhance localization and quantification of salivary gland dysfunction. These studies collectively validate the functional patterns observed in the included literature and highlight SPECT/CT as an advanced tool for assessing disease severity.

Integrating the structural and functional findings across all imaging modalities reveals a clear and consistent sequence of pathological progression in SS. Early disease typically presents with functional deficits detectable via dynamic MR imaging or scintigraphy, even when ductal architecture appears intact. As lymphocytic infiltration intensifies, ductal dilation, acinar loss, and parenchymal destruction become increasingly evident on MR sialography. The strong correlation between MR sialography stage and functional impairment reported by Shirai et al. (2025) [27] mirrors the histopathological patterns described by Daniels et al. (1979) [43] and later standardized by Fisher et al. (2017) [50]. These combined findings reinforce the biphasic model of SS salivary gland involvement; wherein early secretory dysfunction evolves into chronic structural degeneration. Furthermore, multimodal imaging perspectives provided by Jousse-Joulin et al. (2020) [51], Lorenzon et al. (2022) [52], and Ramsubeik et al. (2020) [53] highlighted that combining structural and functional techniques significantly improves diagnostic accuracy, particularly in the context of heterogeneous disease presentations. The diagnostic framework established by the ACR-EULAR classification criteria (Shiboski et al. 2017) [54] reinforced the importance of objective salivary gland assessment, supporting the clinical value of the imaging modalities examined in this review.

Overall, the available evidence demonstrates that MR sialography and dynamic MR imaging offer detailed structural and early functional assessments of the

parotid glands, while scintigraphy and SPECT/CT provide quantitative measures of glandular dysfunction with high sensitivity. The convergence of findings across modalities underscores the importance of adopting a multimodal imaging strategy for diagnosing, staging, and monitoring SS. Such an integrative approach aligns with the pathophysiological progression of the disease and enhances the clinician's ability to identify both early functional compromise and advanced structural deterioration.

Implications for Practice and Policy

The findings support a multimodal imaging approach for parotid gland assessment in SS. MR sialography should be considered for structural evaluation, dynamic MR sialography for early functional impairment, and scintigraphy/SPECT/CT for quantitative functional assessment. In clinical practice, combining these modalities may improve early diagnosis, staging, and monitoring, particularly in patients with seronegative or atypical disease. For policy, health systems should consider standardized imaging protocols, appropriate reimbursement, and training to ensure equitable access. In resource-limited settings, MR sialography may be the preferred non-invasive structural tool, while SPECT/CT can be reserved for quantitative functional assessment where available.

Strengths & limitations

A key strength of this systematic review lies in its multimodal approach, integrating structural and functional imaging modalities to provide a comprehensive understanding of parotid gland involvement in SS. By evaluating MR sialography, dynamic MR imaging, scintigraphy, and SPECT/CT, the review captures the full continuum of glandular changes from early dysfunction to late-stage destruction. Additionally, cross-verification with a robust body of authentic prior literature enhances the reliability and interpretability of the synthesized findings.

However, several limitations must be acknowledged. The number of included studies remains limited, and heterogeneity exists in imaging protocols, diagnostic definitions, and reporting standards. This variability restricts direct comparison between studies and precludes quantitative meta-analysis. Most studies involve small sample sizes, potentially limiting external generalizability. Moreover, the absence of uniform quantitative criteria across imaging modalities reduces the ability to harmonize findings or establish standardized diagnostic thresholds. Another limitation is the limited availability of longitudinal data, which restricts understanding of how imaging findings evolve or respond to treatment.

Conclusion

This systematic review showed that multimodal imaging played a critical role in evaluating parotid gland involvement in Sjögren's syndrome, with each modality providing complementary diagnostic value. MR sialography effectively identified characteristic structural changes associated with progressive ductal and parenchymal damage, while dynamic MR sialography sensitively detected early functional impairment before morphological alterations became apparent. Functional techniques such as scintigraphy and SPECT/CT offered quantitative measures of salivary gland dysfunction and demonstrated strong correlations with clinical severity and histopathology. Collectively, the evidence revealed a consistent pathophysiological sequence in SS beginning with early secretory decline and evolving into established structural destruction, highlighting the importance of integrated structural and functional imaging for accurate diagnosis, disease staging, and monitoring. Future standardization of imaging protocols and the development of advanced quantitative techniques were anticipated to further enhance diagnostic precision and improve patient management.

Future perspectives

Future research should prioritize standardized imaging protocols and multicentre, prospective cohort studies incorporating larger and more diverse populations. Development of unified quantitative imaging criteria, particularly for MRI and SPECT/CT, would greatly enhance diagnostic consistency. Advanced imaging techniques, including radiomics, artificial intelligence-assisted image segmentation, diffusion tensor imaging, and hybrid PET/MRI, hold promise for improving early detection and objective disease staging. Longitudinal studies evaluating the predictive value of imaging biomarkers for clinical progression, therapeutic response, and glandular recovery will further refine the role of imaging in personalized management of Sjögren's syndrome.

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List of abbreviations

- SS — Sjögren's syndrome
- MR — magnetic resonance
- MRI — magnetic resonance imaging

- SPECT — single-photon emission computed tomography
- CT — computed tomography
- SPECT/CT — single-photon emission computed tomography/computed tomography
- PRISMA — Preferred Reporting Items for Systematic Reviews and Meta-Analyses
- PECO — Population, Exposure, Comparator, Outcome
- NOS — Newcastle-Ottawa Scale
- SUVmax — maximum standardized uptake value
- MAR — maximum accumulation rate
- UR — uptake ratio
- MSR — maximum secretion rate
- Tmin — time to minimum tracer concentration
- Vmin — minimum secretion rate/volume parameter
- ACR-EULAR — American College of Rheumatology/European League Against Rheumatism
- PET/MRI — positron emission tomography/magnetic resonance imaging
- DTI — diffusion tensor imaging
- AI — artificial intelligence

Registration and protocol

This systematic review was not registered. A review protocol was not prepared.

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Competing interests

The authors declare that they have no competing interests.

Author contributions

Shereen D: conceptualization, methodology, screening, data extraction, writing—original draft.

Jagadeesh Gajendran: radiology expertise, data extraction, image interpretation, manuscript review and editing.

Sebastian Varghese Paul: supervision, methodology, validation, manuscript review and editing.

Karthik Shunmugavelu: conceptualization, methodology, screening, data curation, writing—original draft, corresponding author, final approval.

All authors read and approved the final manuscript.

Availability of data, code and other materials

The template data collection form is available from the corresponding author on reasonable request. Data extracted from included studies are presented in Table 1 and Table 2 and in the narrative synthesis. No analytic code was used because this was a qualitative systematic review. No other materials were used.

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