

Research / engineering disclosure (not clinical use). This manuscript describes a validator-governed, deterministic radiographic reporting and analytics architecture and related optional research-tier modules. The described methods, outputs, and examples are provided for research, technical documentation, and scholarly discussion only and are not intended for clinical decision-making, diagnosis, treatment guidance, or patient-specific management. .

Sustained Structural Stability in Seropositive Rheumatoid Arthritis With Overlap Features Under JAK Inhibition:

A 4.5-Year Longitudinal Radiographic Case Using RheumaView™ Clinical and Research Outputs

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Keywords: rheumatoid arthritis; longitudinal radiography; deterministic workflow; structural stability; clinical–research separation; reproducibility; trial endpoints; hand/wrist imaging; real-world evidence

Related Publications: This case illustration complements three prior Zenodo publications: (1) *Deterministic Radiographic Scoring in Inflammatory Arthritis* (DOI: 10.5281/zenodo.14538029); (2) *Validator-Governed Deterministic Radiographic Pipelines: The RheumaView™ Architecture* (DOI: 10.5281/zenodo.18002981); and (3) *Longitudinal Structural Stability in Overlapping Spondyloarthritis* (DOI: 10.5281/zenodo.18014565). This document demonstrates peripheral (hand/wrist) application.

Abstract

Background: In inflammatory arthritis, symptomatic activity and musculoskeletal comorbidity can obscure whether structural damage is progressing. Longitudinal radiography remains central for progression assessment but is often limited by variability in acquisition, narrative reporting, and lack of reproducible structured exports.

Case: A woman in her mid-50s with seropositive inflammatory arthritis and overlap features (Raynaud phenotype, ANA positivity, sicca symptoms) was initially treated with hydroxychloroquine and chronic low-dose glucocorticoids due to reluctance to initiate advanced therapy. Upadacitinib was started in 2023, producing rapid clinical improvement and steroid tapering. A mild chest wall herpes zoster episode required temporary treatment hold, followed by restoration of disease control. Across serial hand/wrist radiographs from 2021–2025, no erosive conversion occurred, and structural change was minimal and predominantly distal/age-aligned.

RheumaView Outputs: The platform generated (1) a clinician-facing Structured Clinical Report and (2) a de-identified Research Analytics Addendum including regional ordinal scores, longitudinal delta tables, symmetry metrics, and stability indices.

Conclusion: This case demonstrates how a governed longitudinal workflow can document "structure-stable" disease over multiple years while clinical symptoms fluctuate, producing endpoint-relevant signals and audit-ready exports for real-world evidence and research use.

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1. Introduction

Rheumatoid arthritis management increasingly emphasizes treat-to-target strategies, yet clinical symptom trajectories do not always track with structural outcomes. Patients may experience intermittent pain from periarticular or degenerative sources even when inflammatory disease is controlled. For clinical care, documenting absence of new structural damage supports medication continuity decisions and risk-benefit discussions. For research and pharmaceutical stakeholders, reproducible structural stability over time is an endpoint-relevant signal for registries, pragmatic trials, and real-world evidence programs.

Conventional radiography of hands and wrists remains widely used to assess erosions and joint space narrowing (JSN). However, routine reporting is frequently narrative, varies across sites and readers, and rarely yields structured exports suitable for longitudinal analytics. This creates a fundamental gap: clinicians cannot easily defend "no progression" across timepoints when acquisition differs and descriptions vary, while researchers cannot aggregate data without extensive manual harmonization.

RheumaView™ is a workflow designed to address this gap by producing (a) clinician-ready structured radiology reporting and (b) a separate research analytics layer that summarizes longitudinal structural change with standardized, audit-friendly outputs. This case illustration demonstrates the workflow using a real-world scenario: a patient with seropositive RA and overlap features followed over 4.5 years with serial bilateral hand/wrist radiographs.

2. Case Presentation

2.1 Initial Presentation and Serologic Profile

A woman in her mid-50s presented in 2021 with inflammatory hand pain (MCP/PIP distribution), intermittent wrist symptoms, Raynaud-type color changes, sicca symptoms, and left carpal tunnel syndrome confirmed by EMG. Early imaging (2021) showed no erosions. Serologies included mildly elevated rheumatoid factor and low-titer ANA (centrosome/mitotic pattern), with low complement C3. Clinical concern included seropositive RA with overlap features ("rhumus" considered clinically). Family history was notable for Sjögren syndrome.

2.2 Treatment Course

Initial therapy included hydroxychloroquine (escalated to 200 mg twice daily) and chronic low-dose prednisone (~5 mg/day) due to patient reluctance to start advanced therapy; steroid taper attempts were not tolerated. Left carpal tunnel release was performed in 2021, with mild postoperative wound infection resolving with antibiotics. By 2022 she remained steroid-dependent with persistent symptoms.

In 2023, upadacitinib 15 mg daily was initiated following examination demonstrating active wrist synovitis (right greater than left). Within weeks, she reported marked clinical improvement with reduction of inflammatory findings and began structured prednisone taper. A mild chest wall herpes zoster episode in mid-2023 led to temporary treatment hold during antiviral therapy, followed by brief flare and subsequent re-establishment of disease control.

From 2024–2025, RA remained clinically stable on hydroxychloroquine plus upadacitinib; residual symptoms were largely myofascial/postural pain and intermittent overuse-type

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thumb/knee discomfort (including infrapatellar bursitis noted in 2025). Hypogammaglobulinemia was documented and monitored. Through 2025 follow-up, she continued to show low inflammatory disease activity without examination evidence of synovitis or deformity.

3. Imaging and Methods

3.1 Radiographic Timepoints

Bilateral hands and wrists were evaluated longitudinally at four timepoints. Table 1 summarizes the projection inventory and quality assessment for each examination.

Table 1. Projection Inventory and Quality Notes by Timepoint

Date	Projections Available	Quality Notes
2021-xxxx (Baseline)	R: PA hand, PA hand (collimated), 2× PA oblique L: PA hand, 2× PA oblique/semilateral No lateral views	Detector-edge banding; partial collimation of distal phalanges; one left view with motion artifact
2023-xxxx	R: PA hand, PA oblique L: PA hand, PA oblique No wrist-only or lateral views	Adequate PA/oblique coverage; limited view set constrains detailed carpal assessment
2024-xxxx	R: PA hand, 2× PA oblique, PA wrist L: PA hand, 2× PA oblique, PA wrist No lateral views	Adequate exposure and coverage; no lateral limits dorsal/volar assessment
2025-xxxx (Reference)	R: PA hand, PA oblique, PA wrist, oblique wrist, lateral L: PA hand, PA oblique, PA wrist, oblique wrist, lateral	Most complete projection set; lateral views with digit overlap but acceptable for carpal alignment

The variable projection availability across timepoints is characteristic of real-world clinical practice. The workflow explicitly documents these limitations and constrains confidence levels appropriately rather than proceeding with assumptions about unavailable data.

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Representative montages for each timepoint are shown in Figure 1A–D.

Fig 1A: 2021 (baseline)

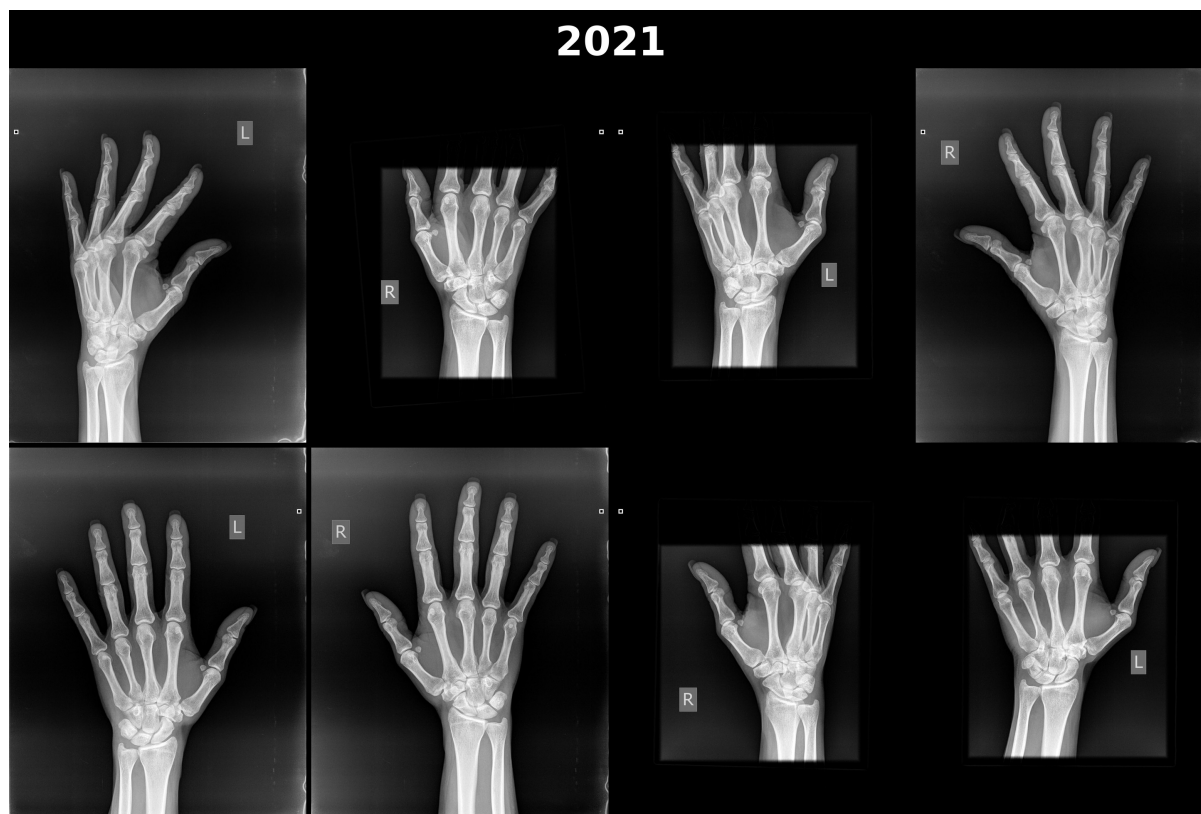


Fig 1B: 2023

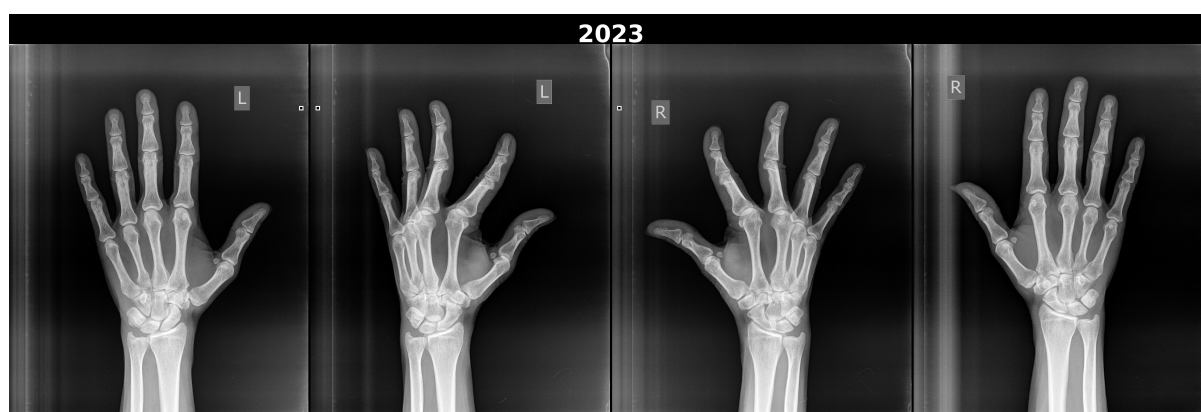


Fig 1C: 2024

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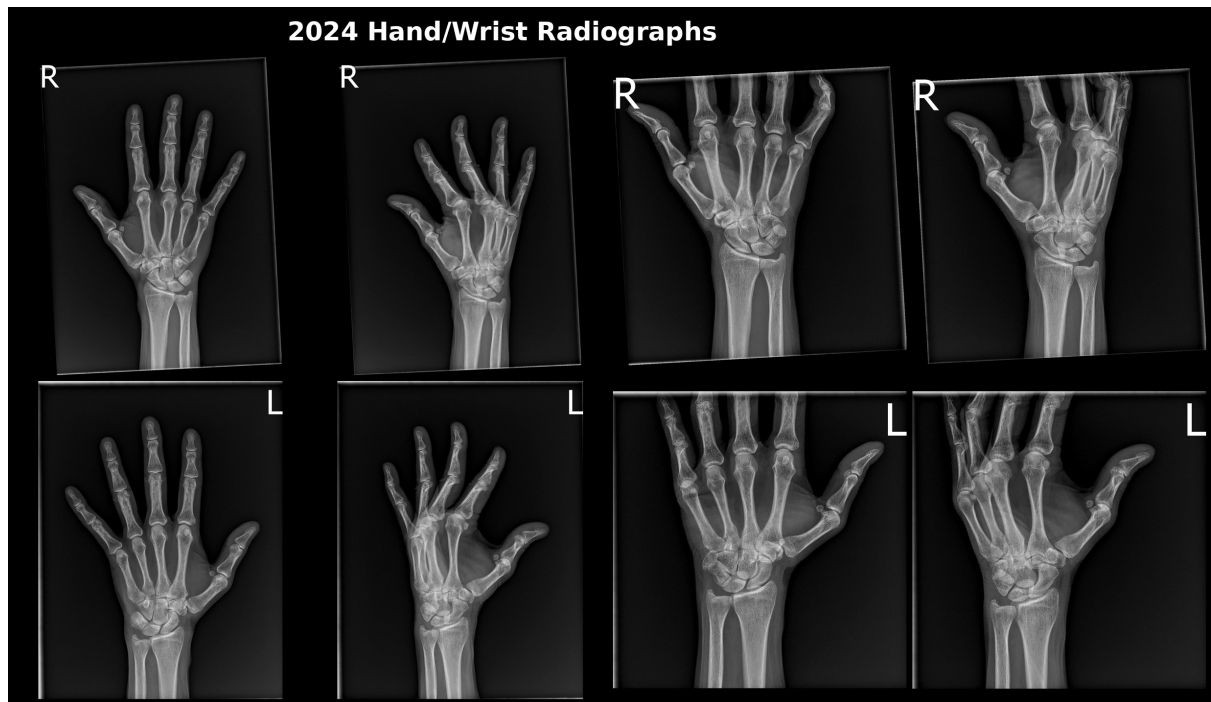
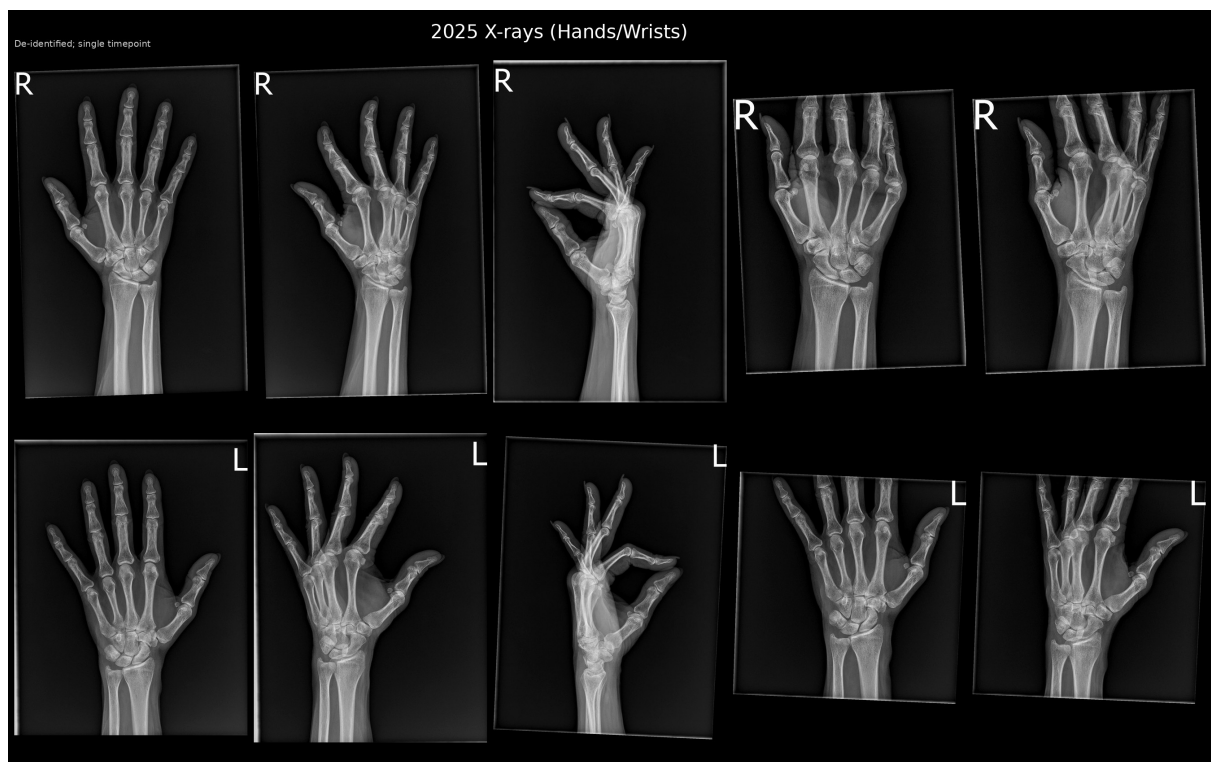


Fig 1D: 2025 (reference)



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3.2 RheumaView Dual-Layer Outputs

Two outputs were generated from the same longitudinal series:

- **Structured Clinical Report (clinician-facing):** Region-by-region findings with confidence tiers, longitudinal comparison narrative, clinical impression, and EMR-compatible summary. No research metrics appear in this layer.
- **Research Analytics Addendum (de-identified):** Standardized ordinal region scores, longitudinal deltas, symmetry and internal consistency metrics, and unitless stability indices summarizing progression patterns. Indices are reported as outputs; computation details are not disclosed.

3.3 Governance Principles

Key governance behaviors demonstrated in this case:

- **Layer separation:** Clinical narrative is rendered identically regardless of whether research analytics are enabled. Research content never modifies clinical text.
- **Explicit gating for absent inputs:** When required data is unavailable (e.g., no DEXA), metrics are suppressed with explicit "Insufficient data" notation rather than estimated.
- **Projection-aware confidence:** Findings limited by absent views are documented with constrained confidence rather than stated with unwarranted certainty.

4. Results

4.1 Structured Clinical Report Findings (2025-12-22)

Key findings from the clinician-facing report:

- **No erosions** identified in MCPs, wrists, PIPs, or DIPs.
- **Mild degenerative features** confined primarily to distal and thumb joints: DIP joints with mild JSN, small osteophytes, and mild subchondral change (bilateral); thumb IP and first CMC with mild degenerative change (bilateral, symmetric).
- **Wrists and MCPs:** Preserved joint spaces without erosions or inflammatory-pattern narrowing.

Clinical Impression: Predominantly mild distal/thumb osteoarthritic change with no radiographic evidence of erosive RA and no inflammatory-pattern progression across the longitudinal series.

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4.2 Longitudinal Structural Change (Baseline 2021 → Reference 2025)

The Research Analytics Addendum summarized baseline-to-latest change:

Table 2. Baseline-to-Latest Longitudinal Delta Summary (Hands/Wrists)

Domain / Region	Baseline	Latest	Δ	Longitudinal Class
RA erosive burden (MCPs + wrist)	0.0	0.0	0.0	No erosive conversion
JSN — DIP row (avg bilateral)	0.8	1.0	+0.2	Minimal distal OA drift
JSN — thumb IP + 1st CMC	0.8	1.0	+0.2	Minimal OA drift
JSN — MCP row	0.0	0.0	0.0	Stable
JSN — wrists (RC + DRUJ)	0.0	0.0	0.0	Stable
Osteophytes — distal/thumb	0.8	1.0	+0.2	Slight osteophyte sharpening
Subchondral change — distal/thumb	0.8	1.0	+0.2	Mild increase, low burden

Values are unitless outputs from the analytics layer; thresholds and implementation are not disclosed.

4.3 Stability and Symmetry Indices

The analytics layer further characterized phenotype and progression pattern:

Table 3. Selected Stability and Reproducibility Outputs

Metric (unitless)	Value	Interpretation
Overall longitudinal stability index	0.1	Very high structural stability (minimal change)
Progression magnitude (aggregate)	0.05	Very low net structural drift
Bilateral symmetry indices (erosion/JSN)	~0.0	Near-perfect symmetry
Degenerative-pattern signal	Low	Distal-predominant; no inflammatory progression
Quantitative concordance index	0.95	High intra-study pattern coherence
Composite-region quality index	0.94	High regional quality and consistency

4.4 Densitometric Linkage (Governed Behavior Demonstration)

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The analytics layer includes densitometric-radiographic correlation modules. When DEXA is unavailable, outputs are explicitly suppressed:

Table 4. Densitometric Linkage (Requires DEXA Input)

Metric	Value	Note
Bone Area Density Alignment	<i>Not computed</i>	Insufficient data (no DEXA input)
Normalized BMD Delta	<i>Not computed</i>	Insufficient data (no DEXA input)
Densitometric–Radiographic Index	<i>Not computed</i>	Insufficient data (no DEXA input)

This explicit "Not computed" behavior demonstrates governed data handling—outputs are suppressed with reason codes rather than estimated or silently omitted. When DEXA data is provided, the full densitometric-radiographic correlation engine activates.

5. Discussion

This case illustrates a clinically common but operationally difficult scenario: symptoms and musculoskeletal complaints fluctuate over time, while radiographic structural outcomes remain stable. The patient experienced early steroid dependence and delayed initiation of advanced therapy due to adverse effect concerns, followed by rapid clinical response after starting a JAK inhibitor. A mild chest wall herpes zoster episode required temporary treatment interruption; symptoms flared briefly but disease control returned. Across 2021–2025, the longitudinal radiographic signal remained stable with no erosive conversion, and only minimal distal/thumb degenerative drift.

5.1 Why the Workflow Is Useful Clinically

Routine narrative reporting can make "no progression" difficult to defend across timepoints, especially when acquisition differs and descriptions vary. The Structured Clinical Report in this case:

- Preserved projection and adequacy context for interpretability
- Reported region-specific findings without conflating degenerative distal changes with inflammatory erosive disease
- Produced consistent impression supporting longitudinal decision-making: therapy continuation, steroid-sparing justification, and documentation for medical necessity

This separation is particularly valuable in overlap syndromes where multiple disease processes may contribute to symptoms. The patient's clinical course included persistent inflammatory symptoms

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requiring JAK inhibitor therapy, yet her radiographic trajectory remained non-erosive—a dissociation that would be difficult to communicate clearly without structured comparison.

5.2 Why the Outputs Are Useful for Research and Pharmaceutical Stakeholders

For real-world evidence, registries, and trial-adjacent programs, the Research Analytics Addendum demonstrates several high-value properties:

- **Endpoint relevance:** Separate tracking of erosive conversion vs JSN drift helps align imaging outcomes to commonly used structural constructs (erosion/JSN domains), while remaining audit-friendly.
- **Longitudinal comparability:** Baseline-to-latest delta tables provide a reproducible "change signature" rather than single-timepoint snapshots.
- **Phenotype labeling:** Distal/thumb-predominant degenerative drift can be separated from inflammatory progression, enabling cleaner cohort definitions for outcomes research.
- **Reproducibility signals:** Symmetry and internal consistency metrics provide additional confidence signals for multi-site and longitudinal use.
- **Reduced sample size potential:** Deterministic, reproducible endpoints with eliminated inter-reader variability can improve statistical power, potentially enabling smaller, more efficient trials.
- **Dual data products:** The same imaging series yields both a clinical document and a de-identified analytic export suitable for aggregation across cohorts.

5.3 Expanded Platform Capabilities

Note: The analytics demonstrated in this case represent a subset of the platform's capabilities, constrained by the available input data (bilateral hand/wrist radiographs without DEXA or advanced imaging). The RheumaView™ research engine supports substantially broader analytic domains including but not limited to:

- Axial spine and sacroiliac joint analytics
- Multi-modal fusion (radiograph–DEXA–MRI correlation)
- Metabolic bone and mineralization modeling
- Immunotherapy response trajectory tracking
- Autoimmune drift detection
- Pediatric developmental normalization
- Neuro-structural concordance mapping (EMG/NCS correlation)
- Harmonized multi-center trial export schemas

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6. Limitations

- Radiographs lacked lateral views at most timepoints, limiting some alignment assessment. Nonetheless, erosions and JSN in MCP/wrist rows—the primary inflammatory progression concerns—were well assessed on available projections.
- No DEXA correlation was available; densitometric linkage metrics were appropriately suppressed.
- Single-patient observational narrative does not establish population-level reproducibility. Generalizability requires systematic evaluation across diverse acquisition conditions and disease phenotypes.
- The patient's structural stability occurred in context of multiple treatment transitions; attributing outcome to any single intervention is not possible from radiographic data alone.
-

7. Conclusion

In a seropositive inflammatory arthritis case with overlap features treated with hydroxychloroquine and upadacitinib, serial hand/wrist radiographs over 4.5 years showed no erosive conversion and minimal structural drift limited to distal/thumb joints consistent with mild osteoarthritic change. RheumaView produced a clinician-facing Structured Clinical Report plus a separate de-identified Research Analytics Addendum that summarized longitudinal stability, symmetry, and phenotype patterning—generating endpoint-relevant and audit-ready signals suitable for clinical documentation and research/pharmaceutical utilization.

Collaboration Opportunities

RheumaView™ is positioned for collaboration with academic research groups, pharmaceutical sponsors, CROs, and registry initiatives seeking reproducible, audit-ready radiographic endpoints. The platform's capabilities extend substantially beyond what is demonstrated in this single-case illustration. Inquiries regarding research partnerships, trial integration, or licensing discussions are welcomed at contact_us@rheumaview.com.

Available Data Products

For research and trial applications, RheumaView can provide (details available upon request):

- **Structured Clinical Report:** PDF/document output for clinical documentation

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- **De-identified Longitudinal Export:** Structured data schema with region scores, deltas, stability indices, and quality metadata
- **Audit Provenance Fields:** Version identifiers and reconstruction metadata for regulatory traceability

Proprietary implementation details, thresholds, and algorithmic logic are not disclosed in these outputs.

Ethics, Consent, and Disclosures

Ethics/Consent: This report uses de-identified data in accordance with HIPAA Safe Harbor guidelines. Dates have been shifted and identifying details removed or generalized.

Disclosures: The author developed RheumaView™ and has filed patent applications covering related methods and systems. No external funding was received.

Data Availability: De-identified, non-proprietary excerpts may be shared upon reasonable request; proprietary implementation details are not disclosed.

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Related Publications

1. Goodman O. Deterministic Radiographic Scoring in Inflammatory Arthritis. Zenodo. 2024. DOI: [10.5281/zenodo.14538029](https://doi.org/10.5281/zenodo.14538029)
2. Goodman O. Validator-Governed Deterministic Radiographic Pipelines: The RheumaView™ Architecture. Zenodo. 2025. DOI: [10.5281/zenodo.18002981](https://doi.org/10.5281/zenodo.18002981)
3. Goodman O. Longitudinal Structural Stability in Overlapping Spondyloarthritis. Zenodo. 2025. DOI: [10.5281/zenodo.18014565](https://doi.org/10.5281/zenodo.18014565)

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Appendices:

1) APPENDIX: CLINICAL REPORT (DEIDENTIFIED)

- **2025-XXXX(reference exam)**
 - Right: PA hand, PA oblique hand, PA wrist, PA oblique wrist, lateral hand/wrist (overlapping digits).
 - Left: PA hand, PA oblique hand, PA wrist, PA oblique wrist, lateral hand/wrist (overlapping digits).
- **2024-XXXX**
 - Right: PA hand, two PA oblique hand/wrist, PA wrist (no lateral).
 - Left: PA hand, two PA oblique hand/wrist, PA wrist (no lateral).
- **2023-XXXX**
 - Right: PA hand, PA oblique hand/wrist (no wrist-only or lateral views).
 - Left: PA hand, PA oblique hand/wrist (no wrist-only or lateral views).
- **2021-XXXX (baseline)**
 - Right: PA hand, PA hand (collimated), two PA oblique hand/wrist (no lateral).
 - Left: PA hand, PA hand (collimated), two PA oblique/semilateral hand/wrist (motion overlap), no lateral.

Comparison: 2021-XXXX 2023-XXXX, 2024-XXXX.
XXXX.

Current reference exam: 2025-XXXX.

Technique and image quality

- Multi-year bilateral hand/wrist series with varying equipment and collimation.
- **2025-XXXX:** Adequate exposure and coverage bilaterally. Lateral views show substantial overlap and some motion of digits, limiting detailed sagittal assessment of individual IP/MCP joints but acceptable for gross carpal alignment.
- **2024-XXXX, 2023-XXXX:** PA and oblique views only; no true lateral projections.
- **2021-XXXX:** PA and oblique/semilateral views; some detector-edge banding and partial collimation of distal phalanges; one semilateral left view with motion/double contours of digits.
- Overall: Adequate for longitudinal structural assessment of hands and wrists in the coronal plane. Sagittal alignment and very subtle dorsal/volar erosions are less confidently assessed due to absence or limitation of lateral views.

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FINDINGS – CURRENT EXAM (2025-XXXX) WITH STRUCTURAL CONTEXT

RIGHT hand and wrist

1. Phalanges / DIP and PIP joints

- **Definite**
 - DIP 2–5: Mild joint-space narrowing with small marginal osteophytes, most pronounced at DIP 2–3.
 - Thumb IP: Mild joint-space narrowing with small marginal osteophytes.
- **Probable**
 - Small, smooth subchondral lucencies at some DIP joints compatible with degenerative cysts.
- **Low-confidence / negative screen**
 - No definite marginal or central erosions identified at DIP or PIP joints.
 - No gross subluxations.

2. Metacarpophalangeal joints (MCP 1–5)

- **Definite**
 - MCP 2–5: Joint spaces preserved; articular margins smooth.
 - No ulnar drift, no MCP subluxation.
- **Probable**
 - MCP1: Very mild joint-space narrowing with a small marginal osteophyte and mild subchondral sclerosis.
- **Low-confidence / negative screen**
 - No definite marginal erosions at MCP 2–5.
 - No marked periarticular osteopenia beyond possible mild diffuse demineralization.

3. First ray and 1st CMC joint

- **Definite**
 - 1st CMC: Mild joint-space narrowing with small osteophytes and mild subchondral sclerosis.
 - Small, well-corticated ossicle/sesamoid at volar aspect of 1st MCP region, benign.
- **Low-confidence**

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- No visible 1st CMC subluxation or collapse on current projections.

4. Carpal bones, intercarpal and carpometacarpal (CMC) joints

- **Definite**
 - Carpal alignment preserved; no perilunate malalignment or carpal collapse.
 - Intercarpal and CMC joint spaces largely maintained.
- **Probable**
 - Mild subchondral sclerosis and marginal irregularity at selected CMC joints, compatible with low-grade osteoarthritic change.
- **Low-confidence / negative screen**
 - No definite erosions of the carpal bones or metacarpal bases.
 - No chondrocalcinosis identified.

5. Radiocarpal and distal radioulnar joints

- **Definite**
 - Radiocarpal joint: Preserved joint space without focal collapse or step-off.
 - Distal radioulnar joint: Congruent articular surfaces; no erosive change.
- **Probable**
 - Ulnar variance approximately neutral to mildly positive; estimation limited by projection.
- **Low-confidence / negative screen**
 - No large osteophytes or cysts clearly visualized at distal radius/ulna articular margins.

6. Metacarpal shafts, distal radius and ulna

- **Definite**
 - No acute fracture, deformity, or focal lytic/blastic lesion.
- **Probable**
 - Bone mineralization subjectively within normal to mildly decreased range (non-quantitative).

7. Soft tissues (right)

- **Definite**
 - No radiopaque foreign body; no calcified tophi.
- **Probable**
 - No focal soft-tissue mass or marked periarticular swelling; subtle synovitis, if present, is below confident radiographic detection.

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LEFT hand and wrist

1. Phalanges / DIP and PIP joints

- **Definite**
 - DIP 2–5: Mild joint-space narrowing with small marginal osteophytes, most evident at DIP 2–3.
 - Thumb IP: Mild joint-space narrowing with small osteophytes.
- **Probable**
 - Small subchondral cystic lucencies at some DIP joints.
- **Low-confidence / negative screen**
 - No definite erosions at DIP/PIP joints.
 - No gross subluxations.

2. Metacarpophalangeal joints (MCP 1–5)

- **Definite**
 - MCP 2–5: Joint spaces preserved; smooth cortical margins.
 - No ulnar drift or subluxation.
- **Probable**
 - MCP1: Very mild joint-space narrowing and small marginal osteophyte with mild subchondral sclerosis.
- **Low-confidence / negative screen**
 - No definite marginal erosions at MCP 2–5.
 - No pronounced periarticular osteopenia.

3. First ray and 1st CMC joint

- **Definite**
 - 1st CMC: Mild joint-space narrowing with small osteophytes and mild subchondral sclerosis.
 - Small, well-corticated ossicle/sesamoid at volar 1st MCP region, symmetric to right, benign.
- **Low-confidence**
 - No visible 1st CMC subluxation or collapse.

4. Carpal bones, intercarpal and carpometacarpal joints

- **Definite**
 - Carpal alignment preserved; no collapse or perilunate pattern.
 - Intercarpal and CMC joint spaces overall maintained.

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- **Probable**
 - Mild subchondral sclerosis and marginal irregularity at selected CMC joints, compatible with early osteoarthritis.
- **Low-confidence / negative screen**
 - No definite erosions of carpal bones or metacarpal bases.
 - No chondrocalcinosis.

5. Radiocarpal and distal radioulnar joints

- **Definite**
 - Radiocarpal joint: Preserved joint space without focal narrowing or collapse.
 - Distal radioulnar joint: Congruent, non-erosive articular surfaces.
- **Probable**
 - Ulnar variance near-neutral; measurement limited by projection.
- **Low-confidence / negative screen**
 - No large osteophytes or cysts clearly visible at distal radius/ulna articular surfaces.

6. Metacarpal shafts, distal radius and ulna

- **Definite**
 - No acute fracture, cortical break, or focal destructive lesion.
- **Probable**
 - Bone mineralization within normal to mildly reduced range, subjectively stable.

7. Soft tissues (left)

- **Definite**
 - No radiopaque foreign body; no calcified tophus.
- **Probable**
 - No distinct soft-tissue mass or marked swelling; subtle synovitis not radiographically apparent.

LONGITUDINAL STRUCTURAL COMPARISON (Baseline 2021-XXXX → 2023-XXXX → 2024-XXXX → 2025-XXXX)

Global pattern

- **Definite**

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- Symmetric, mild osteoarthritic changes at DIP joints and 1st IP/CMC joints are present from baseline and remain mild.
- MCP joints, carpal bones, radiocarpal and distal radioulnar joints remain structurally preserved and non-erosive at all time points.
- No development of rheumatoid-type marginal erosions, carpal collapse, or classic deformities (ulnar drift, Z-thumb, swan-neck, boutonnière).
- **Probable**
 - Bone mineralization is qualitatively within normal-to-mildly-reduced range throughout, without focal progressive loss.

Interval change by region

1. DIP and PIP joints (bilateral)

- From 2021 to 2025:
 - Definite: Mild DIP osteoarthritis visible at baseline with at most slight osteophyte enlargement over time, still within mild range.
 - Definite: PIP joints show stable minimal degenerative change without erosions.
 - No interval development of erosive change.

2. MCP joints (bilateral)

- Definite: MCP joint spaces and contours remain stable and non-erosive over the entire series.
- No new narrowing, erosions, or subluxations.

3. Thumb IP and 1st CMC joints

- Definite: Mild osteoarthritic changes present from early exams; minimal gradual increase in osteophyte definition but no functional deformity or subluxation.

4. Carpus / intercarpal / CMC joints

- Definite: Carpal alignment and joint-space configuration remain stable.
- Probable: Mild CMC/intercarpal degenerative changes remain low grade without clear structural progression.

5. Radiocarpal and distal radioulnar joints

- Definite: Radiocarpal and DRUJ joint spaces, alignment, and cortical margins remain unchanged and non-erosive across all exams.

6. Metacarpal shafts, distal radius and ulna

- Definite: No interval fractures, deformities, or focal bone lesions.

7. Soft tissues

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- Definite: No persistent soft-tissue masses or calcifications; no chronic large effusions identified on any study.

IMPRESSION

1. Inflammatory arthropathy / RA-related structural damage

- Over more than four years of serial bilateral hand and wrist radiographs, there is **no radiographic evidence of erosive rheumatoid arthritis**.
- MCP joints, carpal bones, radiocarpal and distal radioulnar joints remain structurally intact, non-erosive, and free of deformities or carpal collapse.
- The overall pattern is consistent with **non-erosive RA with good structural preservation** over the observation window.

2. Degenerative (osteoarthritic) changes

- Mild, symmetric osteoarthritic changes involving:
 - DIP joints 2–5 bilaterally.
 - Thumb IP joints bilaterally.
 - 1st CMC joints bilaterally, with mild joint-space narrowing and small osteophytes.
- Probable low-grade degenerative change at selected carpometacarpal/intercarpal joints without significant progression.

3. Bone density

- Subjective appearance of bone mineralization is within normal-to-mildly-reduced limits and stable over time; quantitative assessment would require dedicated densitometry.

4. Overall longitudinal conclusion

- From 2021-xxxx through 2025-xxxx, the hands and wrists show **no radiographic progression of inflammatory-type structural damage**.
- Mild osteoarthritic changes at DIP, thumb IP, and 1st CMC joints show at most minimal progression and remain mild.
- In the context of treated seropositive RA, the imaging course supports **stable, non-erosive disease with preservation of joint architecture**.

EMR summary

Serial bilateral hand and wrist radiographs (2021–2025) demonstrate mild, symmetric osteoarthritic changes involving the DIP joints, thumb IP joints, and first CMC joints. MCP joints, carpal bones, radiocarpal and distal radioulnar joints remain non-erosive with preserved joint spaces and no deformity. No fractures or focal bone lesions are identified. Overall, there is no radiographic progression of inflammatory-type structural damage over the 4.5-year interval.

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Supplementary Appendix S1

Projection Inventory and Consolidated Longitudinal Structural Deltas — Bilateral Hands/Wrists (2021–2025)

De-identified case. Imaging-only supplement intended to document projection completeness and longitudinal structural change summaries without proprietary rule text, thresholds, or implementation details.

S1.1 Projection inventory by timepoint (hands/wrists)

Study date	Right side – projections captured	Left side – projections captured	Technical notes / limitations relevant to longitudinal comparability
2025-x (reference)	PA hand; PA oblique hand; PA wrist; PA oblique wrist; lateral hand/wrist	PA hand; PA oblique hand; PA wrist; PA oblique wrist; lateral hand/wrist	Lateral views present but described as overlapping digits (limits fine assessment of some interphalangeal detail on lateral).
2024-x	PA hand; two PA oblique hand/wrist; PA wrist (no lateral)	PA hand; two PA oblique hand/wrist; PA wrist (no lateral)	No lateral views. Oblique series includes hand/wrist combined views rather than wrist-only laterals.
2023-x	PA hand; PA oblique hand/wrist (no wrist-only or lateral)	PA hand; PA oblique hand/wrist (no wrist-only or lateral)	Limited projection set (2 views/side). Reduced ability to adjudicate subtle wrist compartment JSN/erosions vs positioning effects.
2021-x(baseline)	PA hand; PA hand (collimated); two PA oblique hand/wrist (no lateral)	PA hand; PA hand (collimated); two PA oblique/semilateral hand/wrist (motion overlap); no lateral	Left oblique/semilateral noted with motion overlap , increasing uncertainty for very small marginal changes on that view.

Series anchors: baseline **2021-06-17**; latest/reference **2025-12-22**.

S1.2 Consolidated longitudinal structural deltas (baseline → latest)

Single-table summary of region-group metrics spanning distal joints, thumb units, MCP row, and wrists. Values are structural descriptors only (no treatment guidance).

Metric / Region group	Baseline (2021-06-17)	Latest (2025-12-22)	Δ (latest – baseline)	Temporal class
RA-erosive index (MCPs + wrists)	0.0	0.0	0.0	No erosive conversion
JSN index — DIP row (avg bilateral)	0.8	1.0	+0.2	Minimal distal OA drift
JSN index — thumb IP + 1st CMC	0.8	1.0	+0.2	Minimal OA drift

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Metric / Region group	Baseline (2021-06-17)	Latest (2025-12-22)	Δ (latest – baseline)	Temporal class
JSN index — MCP row	0.0	0.0	0.0	Stable
JSN index — wrists (RC + DRUJ)	0.0	0.0	0.0	Stable
Osteophyte index — distal/thumb	0.8	1.0	+0.2	Slight osteophyte sharpening
Osteophyte index — MCP/wrist	0.0	0.0	0.0	No new osteophytes
Subchondral change — distal/thumb	0.8	1.0	+0.2	Mild increase, low burden
Bone density (qualitative index)	0.5	0.5	0.0	Qualitatively stable

Interpretive note for readers (structural-only): Across a ~4.5-year window, the consolidated deltas localize to **minimal distal/thumb OA-aligned drift** while **MCP/wrist erosive and JSN domains remain stable**, supporting a “symptom-active / structure-stable” phenotype framing when paired with clinical course (presented in the main manuscript).

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