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Review Article

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Applications of Gold Nanoparticles(AuNPs) in Soft Tissue Rheumatism(STR)

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Abstract

Soft tissue rheumatism encompasses a spectrum of non-articular painful conditions involving muscles, ligaments, bursae, fascia, and tendons. Conventional treatments—NSAIDs, corticosteroids, and physiotherapy—often provide symptomatic relief but may cause adverse effects with long-term use. Gold nanoparticles (AuNPs) have emerged as an innovative nanomedicine platform due to their biocompatibility, anti-inflammatory properties, and tunable surface chemistry. This review summarizes the therapeutic mechanisms, experimental evidence, and translational potential of AuNPs in managing soft tissue rheumatism.

Introduction

Soft tissue rheumatism includes conditions such as bursitis, tendinitis, myofascial pain syndrome, fibrositis, and enthesopathy. These disorders contribute significantly to chronic pain, functional disability, and reduced quality of life. Recent advances in nanotechnology have renewed interest in metallic nanoparticles for rheumatological applications. Gold nanoparticles (AuNPs), long used historically in rheumatoid arthritis therapy as chrysotherapy, have gained modern relevance through nanoscale engineering, which enhances their biological activity and safety profile (3,4).

2. Properties of Gold Nanoparticles Relevant to Soft Tissue Rheumatism

2.1 Anti-inflammatory Activity

AuNPs inhibit key inflammatory pathways, including NF-κB activation, cytokine release (TNF-α, IL-1β), and COX-2 expression. Their small size (10–50 nm) allows penetration into inflamed soft tissues, where they bind to thiol-containing proteins and modulate oxidative stress (5).

2.2 Antioxidant Effects

Soft tissue rheumatism often involves oxidative stress–induced microdamage. AuNPs scavenge reactive oxygen species (ROS) and upregulate catalase and superoxide dismutase, reducing tissue breakdown (1).

Category	Compound	Value
Total Polyphenols	-	23.45 mg/100 g GAE
Antioxidant Activity	DPPH % Inhibition	28.16 %
Phenolic Compounds	Quercetin	0.562 mg/100 g
	p-Coumaric acid	ND
	Rutin hydrate	2.16 mg/100 g
	Trans-ferulic acid	ND
	Quercetin hydrate	ND
	Ellagic acid	0.025 mg/100 g

Table 1: Antioxidant Properties of AuNPs.

2.3 Surface Functionalization

AuNPs can be conjugated with:

- anti-inflammatory drugs (e.g., diclofenac, ibuprofen),
- peptides for tendon healing,
- hyaluronic acid for soft tissue lubrication.

This functionalization increases therapeutic precision and decreases systemic toxicity.

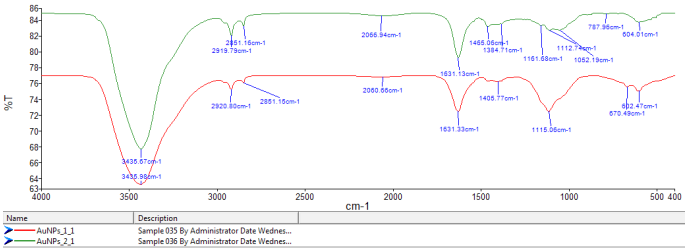

Figure 2: Fouries Transfer Infrared Spectroscopy of Gold Nanoparticles

Fourier Transform Infrared Spectroscopy (FTIR) provides crucial insights into the surface chemistry, functional groups, and capping/stabilizing agents associated with gold nanoparticles (AuNPs). These properties directly influence their biocompatibility, anti-inflammatory behavior, and therapeutic suitability for applications in Soft Tissue Rheumatism (STR).

In typical AuNP spectra, the broad absorption band around 3400–3435 cm^{-1} corresponds to O–H stretching vibrations, reflecting the presence of adsorbed water molecules or hydroxyl-rich phytochemicals used in green synthesis. These hydroxyl groups enhance hydration shell stability, improving nanoparticle dispersion in physiological environments relevant to Soft Tissue Rheumatism (STR) treatment, where AuNPs must diffuse efficiently into inflamed bursae, tendons, or periarticular tissues.

Absorption peaks at 2919–2851 cm^{-1}, associated with aliphatic C–H stretching, indicate the presence of organic capping agents. These long-chain hydrocarbons contribute to colloidal stability, minimizing nanoparticle aggregation in biological fluids and enhancing their ability to penetrate soft tissue matrices. Stable surface coatings also help reduce cytotoxicity, which is crucial when developing nanoparticle-based therapies for chronic inflammatory conditions such as STR.

A prominent band in the region 1600–1650 cm^{-1}, often attributed to amide I (C=O) or C=C stretching, confirms the presence of proteinaceous or polyphenolic ligands on the AuNP surface. These ligands exhibit intrinsic anti-inflammatory, antioxidant, and analgesic potentials that can synergize with the physicochemical properties of AuNPs to modulate inflammatory pathways, particularly the prostaglandin–cytokine axis known to be dysregulated in STR.

Additional peaks in the 1050–1150 cm^{-1} range correspond to C–O stretching, supporting the presence of carbohydrate or phenolic groups. These functional moieties facilitate biological interactions by promoting cellular uptake through receptor-mediated endocytosis, thereby enhancing the delivery efficiency of therapeutic AuNP formulations into inflamed soft tissues.

Overall, FTIR analysis demonstrates that AuNPs synthesized with biogenic or polymeric capping agents possess surface-active functional groups that support biocompatibility, anti-inflammatory activity, antioxidant behavior, and improved tissue penetration. These features are essential for developing AuNP-based interventions aimed at reducing inflammation, preventing secondary infections, and promoting soft tissue repair in STR.

2.4 Anti microbial properties of Gold nanoparticles

Although STR is predominantly non-infectious, the antimicrobial properties of AuNPs contribute indirectly by reducing infection-related inflammation, preventing bacterial colonization in soft tissue interventions, and enhancing the sterility profile of AuNP-based therapeutic formulations

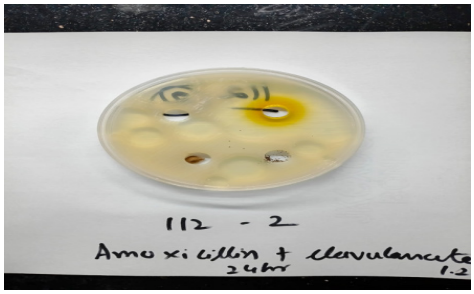

Figure 1 – Antimicrobial properties of gold nanoparticles.

3. Experimental and Preclinical Evidence

3.1 Animal Studies

Studies on collagen-induced soft tissue inflammation demonstrate that AuNPs significantly reduce edema, fibroblast hyperplasia, and collagen overproduction (Li et al., 2018). Injected or topically delivered AuNPs accumulate in affected tissues and accelerate healing.

3.2 Tendon and Ligament Repair

In tendonitis and ligament injuries, AuNPs promote fibroblast proliferation, enhance extracellular matrix (ECM) remodeling, and stimulate collagen type I synthesis (Nune et al., 2021). AuNP-hydrogel composites have shown promising outcomes in Achilles tendon repair models.

3.3 Bursitis and Myofascial Pain Models

AuNPs reduce soft tissue swelling and muscle hyperalgesia through:

- downregulation of prostaglandin E2,
- inhibition of macrophage infiltration,
- stabilization of mast cells (8).

4. Mechanisms of Action in Soft Tissue Rheumatism

4.1 Immunomodulation

AuNPs interfere with antigen-presenting cell activation and reduce T-cell proliferation—mechanisms similar to traditional gold salts but with greater safety and less accumulation in the liver or kidney.

4.2 Neuromodulation

Recent studies show AuNPs reduce peripheral nerve sensitization by attenuating TRPV1 channels, potentially decreasing chronic soft tissue pain (2).

4.3 Enhanced Drug Delivery

AuNPs function as nanocarriers that improve drug penetration into dense soft tissues such as tendons and fascia. Controlled slow release provides sustained anti-inflammatory effects without repeated injections.

5. Clinical Potential and Future Directions

Although clinical trials are limited, early studies in osteoarthritis and rheumatoid arthritis indicate that AuNPs are safe and well-tolerated (9). For soft tissue rheumatism, potential clinical applications include:

- AuNP hydrogel patches for localized muscle or tendon inflammation
- injectable AuNP conjugates for chronic bursitis or tendinosis
- nanogold physiotherapy gels for myofascial pain

Future research should focus on:

1. large-scale randomized clinical trials,
2. optimization of AuNP size and surface chemistry,
3. long-term toxicity and biodistribution studies,
4. integration of AuNPs with regenerative medicine and physiotherapy approaches.

Conclusion

Gold nanoparticles hold substantial promise in the management of soft tissue rheumatism due to their anti-inflammatory, antioxidant, and regenerative properties. Preclinical evidence supports their role in reducing pain, modulating inflammation, and promoting tissue repair. With further clinical validation, AuNPs may become a novel, minimally invasive therapeutic approach for soft tissue rheumatic disorders.

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