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REVIEW ARTICLE **OPEN ACCESS**

Herbal Approaches to Arthritis Management: Focus on *Boswellia serrata*

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ABSTRACT

Arthritis is a progressive musculoskeletal disorder characterized by chronic inflammation, pain, joint stiffness, and functional impairment, affecting millions of individuals worldwide. Despite substantial advances in pharmacological therapy, the long-term use of conventional anti-arthritic agents remains limited by adverse effects, high treatment costs, and incomplete disease control. These challenges have accelerated interest in plant-derived therapeutics as complementary and alternative approaches for arthritis management. Among medicinal plants, Boswellia serrata (Indian frankincense) has gained considerable scientific attention because of its well-documented anti-inflammatory and immunomodulatory properties. The therapeutic efficacy of B. serrata is mainly attributed to boswellic acids, particularly 3-O-acetyl-11-keto-β-boswellic acid (AKBA), which regulate multiple inflammatory pathways by inhibiting 5-lipoxygenase (5-LOX), nuclear factor-kappa B (NF-κB), pro-inflammatory cytokines, and oxidative stress. Experimental and clinical studies have demonstrated that B. serrata effectively reduces joint inflammation, alleviates pain, improves physical function, and exhibits a favorable safety profile. This review provides a comprehensive overview of the pathophysiology of arthritis, current therapeutic strategies, ethnomedicinal significance, phytochemistry, pharmacological mechanisms, and preclinical and clinical evidence supporting the use of Boswellia serrata in arthritis management. In addition, recent advances, safety considerations, and future research perspectives are discussed. Collectively, the available evidence highlights B. serrata as a promising herbal therapeutic for arthritis; however, further large-scale, well-designed clinical studies are required to validate its long-term efficacy and facilitate its integration into evidence-based clinical practice.

Keywords: Arthritis; Herbal medicines; *Boswellia serrata*; Therapeutic efficacy

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INTRODUCTION

Arthritis, a highly prevalent autoimmune disorder, is a musculoskeletal disorder and a major cause of pain, disability, and reduced quality of life worldwide. Among the various forms of arthritis, osteoarthritis (OA) and rheumatoid arthritis (RA) are the most prevalent. OA is characterized by progressive cartilage degeneration and joint remodelling, whereas RA represents a persistent inflammatory condition caused by immune system dysregulation, leading to persistent synovial inflammation and progressive destruction of cartilage and bone. The global prevalence of arthritis continues to rise due to population ageing, obesity, and sedentary lifestyles, imposing a significant healthcare and socioeconomic burden [1-4]. Current pharmacological management primarily involves non-steroidal anti-inflammatory drugs (NSAIDs), corticosteroids, disease-modifying anti-rheumatic drugs (DMARDs), biologics, and Janus kinase (JAK) inhibitors. Although these therapies effectively relieve pain and suppress inflammation, their long-term use is frequently associated with gastrointestinal, hepatic, renal, cardiovascular, and immunological adverse effects. Moreover, oral administration is limited by first-pass metabolism, fluctuating plasma drug concentrations, and poor patient adherence, reflecting the need to explore other therapeutic management strategies [5-6].

Herbal resources have experienced growing acceptance in scientific and pharmaceutical research as safer alternatives because of their multitarget pharmacological actions and favourable safety profiles. Among various medicinal plants, *Boswellia serrata* (Indian frankincense) has attracted attention as a versatile anti-arthritic agent. Its therapeutic activity is primarily attributed to boswellic acids, particularly 3-O-acetyl-11-

keto-β-boswellic acid (AKBA), which inhibits 5-lipoxygenase (5-LOX), suppresses NF-κB activation, and diminishes the production of pro-inflammatory cytokines such as TNF-α, IL-1β, and IL-6 [15-22]. However, the poor oral bioavailability of boswellic acids has encouraged the development of *Boswellia serrata*-loaded transdermal formulations. Therefore, this review summarizes the pathophysiology of arthritis and the pharmacological potential of *Boswellia serrata* in arthritis management [7-9].

ARTHRITIS: AN OVERVIEW

Arthritis is a group of more than 100 musculoskeletal disorders characterized by joint inflammation, degeneration, or structural abnormalities, leading to chronic pain, disability, and reduced quality of life. Although commonly associated with ageing, certain forms, particularly autoimmune arthritis, can affect individuals of all ages and impose a substantial healthcare and socioeconomic burden [10-12]. Arthritis is broadly classified into degenerative, inflammatory, autoimmune, crystal-induced, and infectious types. Osteoarthritis (OA) and rheumatoid arthritis (RA) are the most prevalent forms, with OA characterized by progressive cartilage degeneration and RA by chronic autoimmune-mediated synovial inflammation. Other important types include gout, psoriatic arthritis, ankylosing spondylitis, juvenile idiopathic arthritis, and septic arthritis [13,14] (Table 1).

Table 1. Classification of Arthritis

Type	Etiology	Major Features
Osteoarthritis	Degenerative	Cartilage degradation, osteophytes
Rheumatoid arthritis	Autoimmune	Synovitis, bone erosion
Gout	Hyperuricemia	Urate crystal deposition
Psoriatic arthritis	Autoimmune	Skin lesions with joint inflammation
Ankylosing spondylitis	Autoimmune	Axial skeleton involvement
Septic arthritis	Infection	Bacterial joint infection

Global Incidence of Rheumatoid Arthritis

The occurrence of rheumatoid arthritis varies across regions, with the highest rates reported in Western Europe. Estimates for data-deficient regions were generated using the DisMod-MR model, emphasizing the need for better epidemiological surveillance.

Pathophysiology of Arthritis

RA represents a persistent inflammatory condition caused by immune system dysfunction that primarily affects synovial joints. The disease begins with immune system activation, leading to infiltration of macrophages, T cells, B cells, and neutrophils into the synovial membrane. These immune cells release pro-inflammatory cytokines such as tumor necrosis factor-alpha (TNF-α), interleukin-1 (IL-1), and interleukin-6 (IL-6), which sustain chronic inflammation. Persistent inflammation causes synovial hyperplasia and formation of pannus, an invasive inflammatory tissue that spreads over the articular cartilage. Activated synovial fibroblasts produce matrix metalloproteinases (MMPs) and prostaglandin E2 (PGE2), resulting in progressive cartilage degradation. Inflammatory mediators also stimulate osteoclast differentiation, leading to bone erosion and joint destruction. Increased vascularization further facilitates the recruitment of inflammatory cells into the joint, amplifying the inflammatory response. Over time, continuous cartilage and bone damage result in joint swelling, pain, stiffness, deformity, and loss of function. If left untreated, RA progresses to irreversible structural damage and significant disability [15] (Figure 1).

Risk Factors

The development of arthritis is multifactorial and influenced by both genetic and environmental factors. Advanced age remains the strongest predictor for osteoarthritis because of progressive cartilage degeneration and diminished regenerative capacity. Obesity significantly elevates mechanical strain in weight-supporting joints while contributing to widespread inflammation by secreting adipokines [16,17]. Genetic susceptibility, particularly HLA-DRB1 alleles, plays a key role in RA. Additional contributing factors include cigarette smoking, occupational joint overuse, previous trauma, metabolic syndrome, hormonal changes, physical inactivity, and alterations in gut microbiota. These factors collectively contribute to immune dysregulation, chronic inflammation, and progressive joint deterioration [18-20].

Diagnosis of Arthritis

Accurate diagnosis requires comprehensive clinical assessment supported by laboratory investigations and imaging techniques. Conventional radiography remains the standard method for detecting joint-space narrowing, osteophyte formation, and bone erosion. Magnetic resonance imaging (MRI) and ultrasonography enable early detection of synovitis, cartilage defects, and soft tissue abnormalities before radiographic changes become apparent [21,22]. Laboratory investigations such as rheumatoid factor (RF), anti-cyclic citrullinated peptide (anti-CCP) antibodies, erythrocyte sedimentation rate (ESR), C-reactive

protein (CRP), serum uric acid, and synovial fluid analysis assist in differential diagnosis and disease monitoring.

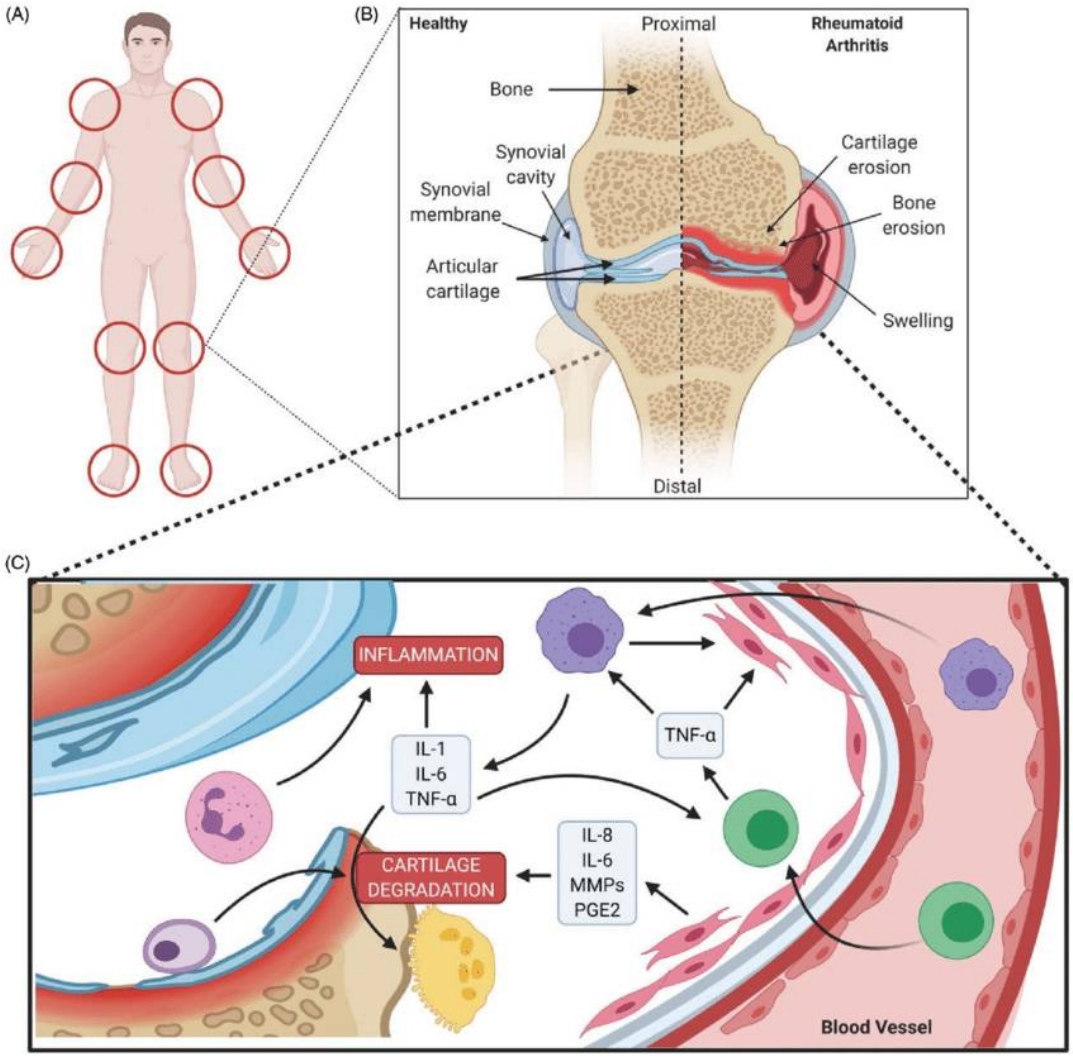

Figure 1. Molecular pathophysiology of arthritis. (A) Locations of impacted areas in rheumatoid arthritis. (B) A healthy synovial joint and the impact of RA — in a healthy joint (left) there is no swelling and cartilage and bone are intact, whereas in RA (right) there is swelling with cartilage and bone erosion. (C) Mechanism of RA within the joint capsule: TNF-α acts on synoviocytes, macrophages/monocytes, and osteoclasts to initiate RA pathogenesis; synoviocytes line the capsule while T-cells infiltrate the synovial membrane, initiating inflammation via TNF-α; joint degradation occurs via recruitment of macrophages and secretion of inflammatory cytokines; bone erosion occurs through osteoclast activity and inhibition of collagen secretion by synoviocytes (Created with BioRender.com) [15].

THERAPEUTIC CHALLENGES AND NEED FOR HERBAL MEDICINES

Despite significant advances in arthritis management, long-term use of conventional therapies, including NSAIDs, corticosteroids, DMARDs, and biologics, is often associated with gastrointestinal, hepatic, renal, cardiovascular, and immunological adverse effects. In addition, prolonged treatment may reduce patient adherence and increase healthcare costs [23-25]. These limitations have led to rising acceptance of plant-based therapeutics as complementary and integrative treatment modalities. Botanical sources possess versatile bioactive phytochemicals with anti-inflammatory, antioxidant, analgesic, chondroprotective, and immunomodulatory properties that act on numerous signaling cascades linked to arthritis. Owing to their multitarget actions, favorable safety profile, and long history of traditional use, herbal medicines have emerged as promising candidates for the long-term management of arthritis [26].

HERBAL THERAPEUTICS AND PHYTOCHEMICALS IN ARTHRITIS MANAGEMENT

Herbal medicine remains an important component of arthritis management worldwide. As per the World Health Organization (WHO), nearly 80% of the global population relies partly on indigenous medicinal

plants as a frontline therapeutic strategy, and the WHO Traditional Medicine Strategy (2025-2034) supports its evidence-based integration into modern healthcare. In India, Ayurveda uses medicinal plants such as *Boswellia serrata, Curcuma longa, Withania somnifera, Tinospora cordifolia, Commiphora mukul,* and *Zingiber officinale*; conversely, classical Chinese medicine applies *Tripterygium wilfordii* and *Sinomenium acutum* for inflammatory joint disorders [27-29] (Figure 2).

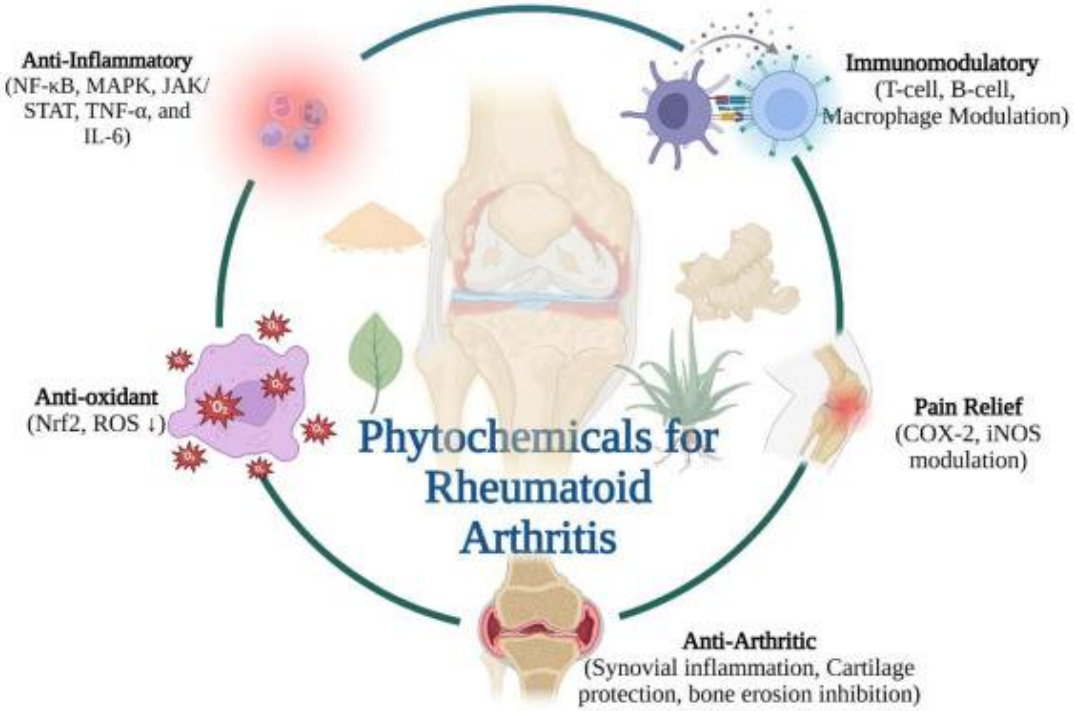

Figure 2. Targets of phytochemicals for arthritis management [33].

The anti-arthritic effects of these botanicals are predominantly related to naturally occurring pharmacologically active plant constituents, such as phenolic compounds, flavones and flavonols, isoprenoid compounds, nitrogen-containing alkaloidal compounds, glycosidic saponins, hydrolyzable and condensed tannins, and hydroxybenzoic and hydroxycinnamic acid derivatives. These compounds regulate key inflammatory mediators and signalling pathways such as COX-2, 5-LOX, TNF-α, IL-1β, IL-6, iNOS, ROS, and NF-κB, thereby reducing inflammation, cartilage degradation, and bone erosion while promoting joint protection [30-33].

Pharmacological Mechanisms of Herbal Therapies

Herbal therapeutics show anti-arthritic effects via diverse pharmacological responses rather than acting on a single molecular target. Common principal mechanisms involve suppression of inflammatory cytokines like TNF-α, IL-1β, and IL-6, which are key mediators of synovial inflammation and cartilage destruction. Several plant-derived compounds inhibit induction of the NF-κB signalling pathway, thereby reducing transcription of inflammatory DNA-encoded determinants regulating prostaglandin biosynthesis and leukocyte recruitment. Additionally, herbal medicines inhibit cyclooxygenase (COX) and lipoxygenase (LOX) enzymes, resulting in reduced production of prostaglandins and leukotrienes that contribute to pain and inflammation. Their antioxidant properties neutralise reactive oxygen species, protecting chondrocytes from oxidative injury and preserving extracellular matrix integrity. Certain phytochemicals also inhibit matrix metalloproteinases (MMPs), preventing degradation of collagen type II and aggrecan within articular cartilage. Furthermore, immunomodulatory herbs regulate T-cell activation, macrophage polarisation, and B-cell responses, thereby reducing autoimmune-mediated joint damage characteristic of rheumatoid arthritis [34,35].

Major Medicinal Plants Used in Arthritis Management

Several medicinal plants possess significant anti-inflammatory and anti-arthritic properties. Their major bioactive constituents, mechanisms of action, and supporting evidence are summarized in Table 2 [36-37]. Among these medicinal plants, *Boswellia serrata* has received the greatest research attention because of its strong anti-inflammatory activity and substantial preclinical and clinical evidence. Therefore, the following sections primarily focus on its therapeutic potential in arthritis management [38].

Table 2. Major Medicinal Plants Used in Arthritis Management

Medicinal Plant	Major Active Constituents	Mechanism of Action	Evidence
Boswellia serrata (Indian frankincense)	Boswellic acids (AKBA)	Selective 5-LOX inhibition; suppresses inflammatory pathways	Preclinical, Clinical
Curcuma longa (Turmeric)	Curcumin	Inhibits NF-κB, COX-2, LOX, TNF-α, and IL-6	Preclinical, Clinical
Withania somnifera (Ashwagandha)	Withanolides	Anti-inflammatory, antioxidant, and immunomodulatory effects	Preclinical
Tinospora cordifolia (Guduchi)	Diterpenoid lactones, alkaloids	Suppresses inflammatory cytokines and modulates immune responses	Preclinical
Zingiber officinale (Ginger)	Gingerols, shogaols	Inhibits COX/LOX pathway and prostaglandin synthesis	Clinical
Commiphora mukul (Guggul)	Guggulsterones	Inhibits NF-κB activation	Preclinical

BOSWELLIA SERRATA: A PROMISING HERBAL THERAPEUTIC FOR ARTHRITIS MANAGEMENT

Boswellia serrata (Indian frankincense or Shallaki) is a well-characterized herbal species for the management of arthritis because of its potent anti-inflammatory, analgesic, antioxidant, and immunomodulatory properties. Its therapeutic activity is primarily attributed to boswellic acids, a group of pentacyclic triterpenoids that selectively inhibit 5-lipoxygenase (5-LOX) and modulate multiple inflammatory pathways involved in arthritis. Recent phytochemical, preclinical, and clinical investigations have thoroughly evaluated its traditional use and supported the development of standardized extracts and advanced drug delivery systems to improve its therapeutic efficacy [39,40].

Botanical Profile

The botanical characteristics and pharmaceutical relevance of *Boswellia serrata* are illustrated in Table 3 [41-43].

Table 3. Botanical Profile of *Boswellia serrata*

Parameter	Description
Scientific name	*Boswellia serrata* Roxb. ex Colebr.
Family	Burseraceae
Common name	Indian frankincense (Shallaki)
Plant type	Medium-sized deciduous tree (8-15 m)
Distribution	Native to India; distributed in tropical and subtropical regions
Medicinal part	Oleo-gum resin
Key botanical features	Papery bark, imparipinnate serrated leaves, small white-yellow flowers, trigonous fruit
Major phytoconstituents	Boswellic acids, volatile oils, polysaccharides
Pharmaceutical relevance	Major natural source of boswellic acids with anti-inflammatory and anti-arthritic activity

Geographical Distribution

Boswellia serrata originates in India and is widely distributed across the dry deciduous forests of central and western India, particularly in Madhya Pradesh, Rajasthan, Gujarat, Maharashtra, and adjoining states. It grows in tropical climates on dry, rocky, well-drained soils at elevations of 200-1,200 m. Related Boswellia species are also found in East Africa and the Arabian Peninsula. Resin yield and phytochemical composition vary with geographical origin, climatic conditions, and harvesting practices, highlighting the importance of sustainable harvesting for consistent pharmaceutical quality [44].

Morphological Characteristics

The morphology of *Boswellia serrata* directly influences resin production and phytochemical composition. Mature trees generally possess thick exfoliating bark with multiple resin ducts located within cortical tissues. Resin exudation occurs naturally following injury or artificial tapping, during which specialized epithelial cells secrete oleoresin rich in terpenoids. The plant bears pinnately compound leaves ranging from approximately 20-45 cm in length with pubescent undersurfaces. Flowers are bisexual and exhibit pentamerous symmetry typical of the Burseraceae family. Fruits mature during late summer and release triangular seeds possessing moderate germination capacity. Commercially harvested resin occurs as

irregular translucent masses ranging from pale yellow to golden brown. High-quality resin exhibits characteristic balsamic aroma, brittleness, and minimal contamination by bark fragments or foreign materials. Physicochemical properties, including resin colour, volatile oil content, acid value, and boswellic acid concentration, are routinely applied for quality assessment according to pharmacopoeia standards [45].

Ethnomedicinal Importance

Boswellia serrata (Shallaki) has served as a therapeutic remedy for generations in traditional medicine, particularly Ayurveda, for the management of inflammatory disorders, joint pain, fractures, wounds, and respiratory diseases. In Ayurvedic medicine, it is commonly prescribed for Amavata (rheumatoid arthritis) and Sandhivata (osteoarthritis), either alone or in polyherbal formulations such as Shallaki Guggulu and Yogaraja Guggulu [46]. Beyond Ayurveda, Boswellia is also used in Unani, Traditional Chinese Medicine, and Middle Eastern traditional medicine for inflammatory conditions, pain relief, wound healing, and other chronic disorders. These longstanding ethnomedicinal applications have been supported by modern pharmacological studies demonstrating its significant anti-inflammatory and anti-arthritic potential [47] (Table 4).

Table 4. Traditional Uses of *Boswellia serrata*

Traditional System	Therapeutic Uses
Ayurveda	Arthritis, osteoarthritis, rheumatoid arthritis, fractures, wound healing
Unani	Joint disorders, ulcers, respiratory diseases
Traditional Chinese Medicine	Pain relief, trauma, inflammation
Folk Medicine	Asthma, dysentery, skin diseases, chronic pain

Phytochemistry

The clinical utility of *Boswellia serrata* is predominantly attributable to its chemically diverse oleo-gum resin, which comprises approximately 30-60% resin, 5-10% essential oil, and 20-35% gum. Over 200 bioactive metabolites have been described, including pentacyclic triterpenoids, diterpenoids, monoterpenes, sesquiterpenes, polysaccharides, flavonoids, and sterols. Among these, boswellic acids represent the prominent therapeutic metabolites contributing to the plant's anti-inflammatory and anti-arthritic properties [48] (Table 5).

Table 5. Major Phytoconstituents of *Boswellia serrata*

Phytochemical Class	Major Constituents	Reported Biological Activities
Pentacyclic triterpenoids	AKBA, KBA, β-BA, α-BA	Anti-inflammatory, anti-arthritic
Essential oils	α-Pinene, limonene, myrcene	Antioxidant, antimicrobial
Polysaccharides	Arabinose, galactose	Immunomodulatory
Sterols	β-Sitosterol	Anti-inflammatory
Phenolics	Various polyphenols	Free radical scavenging

The major boswellic acids include β-boswellic acid (β-BA), acetyl-β-boswellic acid (AβBA), 11-keto-β-boswellic acid (KBA), 3-O-acetyl-11-keto-β-boswellic acid (AKBA), α-boswellic acid, and acetyl-α-boswellic acid. Among these constituents, AKBA is considered the most pharmacologically active because of its high affinity for the 5-lipoxygenase enzyme and its ability to suppress inflammatory cytokine production, inhibit matrix metalloproteinases, and modulate NF-κB signalling pathways. In addition to boswellic acids, the volatile oil fraction contains α-pinene, limonene, myrcene, β-caryophyllene, p-cymene, sabinene, and incensole acetate, which contribute to antimicrobial, antioxidant, and analgesic activities. The gum fraction mainly consists of arabinose, galactose, xylose, glucuronic acid, and polysaccharides that exhibit immunomodulatory and wound-healing properties. Minor molecules such as flavonoids, phytosterols, and phenolic elements further enhance the resin's therapeutic action through synergistic interactions [49,50] (Figures 3 and 4).

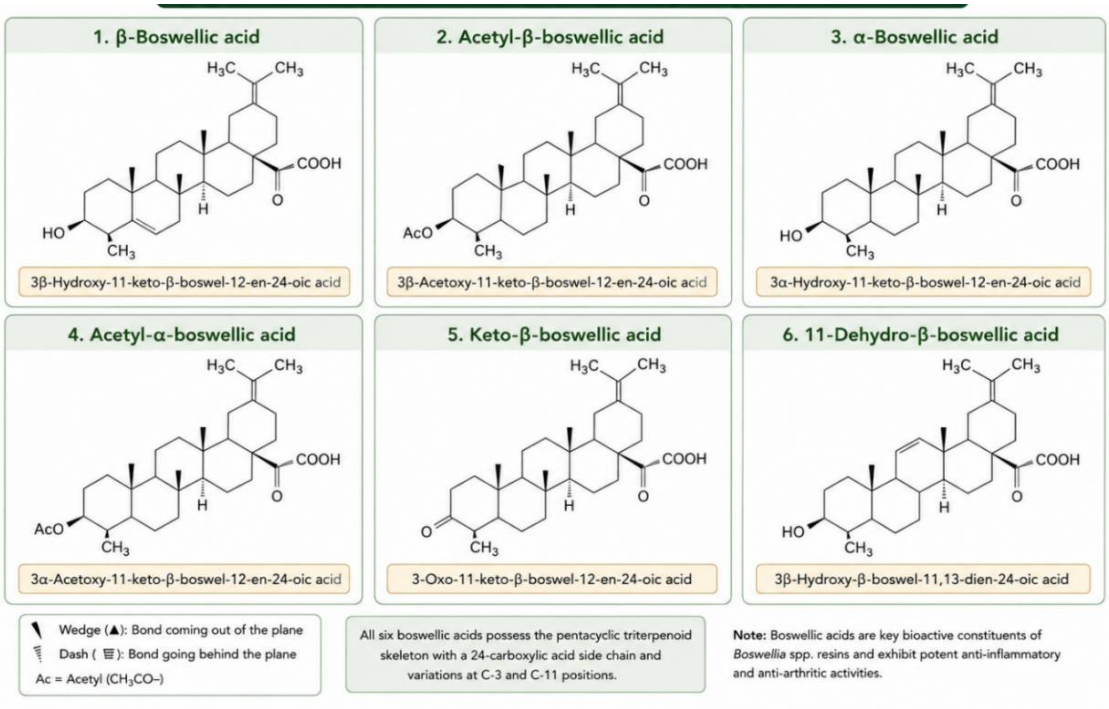

Figure 3. Chemical structures of the six principal boswellic acids.

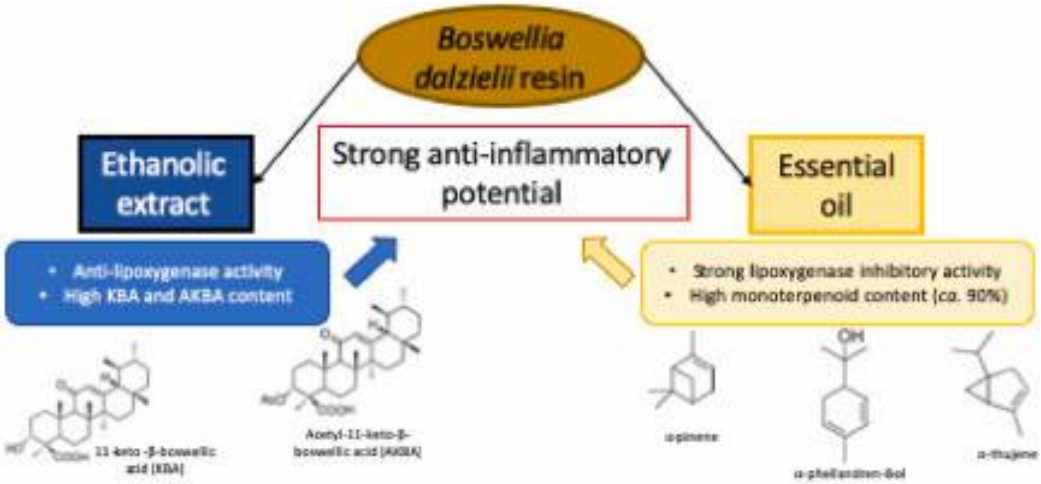

Figure 4. Major phytochemical classes present in *Boswellia serrata* oleo-gum resin [50].

RECENT ADVANCES IN *BOSWELLIA SERRATA*

Umar et al. evaluated the anti-arthritic efficacy of a *Boswellia serrata* gum resin preparation in collagen-induced arthritic rats. Treatment with BSE (100-200 mg/kg) for 21 days significantly reduced inflammatory cytokines, improved antioxidant defense, and alleviated joint inflammation and tissue damage. Histological analysis confirmed protection against cartilage and bone destruction, demonstrating that *Boswellia serrata* exerts anti-arthritic activity through immunomodulatory and antioxidant mechanisms [51]. A recent review examined the pharmacological mechanisms and clinical evidence of *Boswellia serrata* in osteoarthritis and rheumatoid arthritis. The review reported that boswellic acids, particularly AKBA, reduce inflammation by inhibiting 5-LOX, suppressing NF-κB, and modulating inflammatory cytokines and oxidative stress pathways. Clinical studies showed significant improvements in WOMAC and VAS scores in osteoarthritis, whereas evidence in rheumatoid arthritis remains limited. The authors concluded that *Boswellia serrata* is a promising and well-tolerated adjunct therapy, although expanded multi-site clinical research is necessary [52].

Kimmatkar et al. evaluated the effectiveness of *Boswellia serrata* extract in a randomized, double-blind, placebo-controlled trial involving 30 patients with knee osteoarthritis. After 8 weeks of treatment, patients receiving BSE showed significant reductions in knee pain and swelling, along with improved knee flexion and walking distance compared with placebo. The intervention was well tolerated, with only minor

gastrointestinal adverse effects, supporting the clinical performance and acceptability of *Boswellia serrata* in osteoarthritis [53].

CONCLUSION

Arthritis remains a major cause of chronic pain, joint dysfunction, and disability, highlighting the need for therapeutic strategies that are both effective and safe for long-term use. Although conventional medications provide symptomatic relief and disease control, their prolonged administration is often associated with adverse effects and treatment limitations. Consequently, plant-derived therapeutics have emerged as valuable complementary approaches owing to their multitarget pharmacological activities and improved safety profiles. Among these, *Boswellia serrata* has demonstrated considerable promise because of its boswellic acid-rich phytochemical composition, particularly AKBA, which modulates key inflammatory mediators and signalling pathways involved in arthritis pathogenesis. Recent preclinical studies, clinical investigations, and advances in formulation technologies further support its potential as an adjunctive therapy for arthritis management. Nevertheless, additional well-designed, large-scale clinical studies and standardized formulations are essential to establish its long-term efficacy, safety, optimal dosage, and clinical applicability. Overall, *Boswellia serrata* represents a promising natural therapeutic candidate with the potential to enhance future arthritis treatment strategies.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest, financial or otherwise, related to this work.

AUTHOR'S CONTRIBUTION

Vishal Kumar: Conceptualization, literature search, data collection, manuscript planning, original draft preparation, and coordination of the review.
Dr. Abhishek Bhardwaj: Scientific content organization, critical review of the literature, manuscript editing, and intellectual input.
Ms. Anchal Karwal: Literature search, data extraction, manuscript review, and editing.
Dr. Ashutosh Badola: Literature analysis, interpretation of published findings, and manuscript drafting.
Dr. Amandeep Singh: Supervision, critical review of the manuscript, and final approval.
Dr. Ashok Kumar: Literature review, manuscript editing, formatting, reference verification, and final approval.
Ms. Reetika Gupta: Literature analysis, evidence synthesis, interpretation of published findings, and manuscript drafting.
Dr. Esha Vatsa: Literature analysis, interpretation of published findings, and manuscript drafting.
(All authors have read and approved the final manuscript.)

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ETHICS STATEMENT

This article is a literature-based review and did not involve any new experiments on human participants or animals; therefore, institutional ethics committee approval was not applicable.

INFORMED CONSENT

Not applicable, as this review did not involve human participants.

DATA AVAILABILITY

The data supporting the findings of this study are available within the article. No additional external datasets were generated or analyzed during this study.

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