IJAYUSH
International Journal of AYUSH
AYURVEDA, YOGA, UNANI, SIDDHA AND HOMEOPATHY
http://internationaljournal.org.in/journal/index.php/ijayush/

International Journal
Panacea
Research library
ISSN: 2349 7025

Review Article | Volume 15 Issue 05 | May 2026

PHYTOCONSTITUENTS AND ANTI-ARTHRITIC EFFECTS OF BOSWELLIA SERRATA: A SCOPING REVIEW

***Leena Girish[1], Aadya S.S[1], Subhadra K T[2]**

[1]Shree Vidyadhiraja Homoeopathic Medical College, Tvm.

[2]Kerala University of Health Sciences, Thrissur.

*Corresponding Author's Email ID: leenagirish72@gmail.com

Abstract

Background: *Boswellia serrata*, a resinous plant of the Burseraceae family, is traditionally used in both Ayurvedic and Homoeopathic systems of medicine to man-age inflammatory joint conditions such as osteoarthritis and rheumatoid arthritis. Its key active constituents, particularly acetyl-11-keto-β -boswellic acid (AKBA) and β - boswellic acid, exhibit anti-inflammatory properties through inhibition of the 5- lipoxygenase pathway and downregulation of pro-inflammatory cytokines. In Homoeopathy, Boswellia serrata has been used in various potencies and mother tincture form to alleviate chronic musculoskeletal inflammation.

Objectives: This scoping review aimed to (i) map existing in vitro, in vivo, and clinical evidence on the anti-arthritic effects of Boswellia serrata; (ii) examine its key phytoconstituents and pharmacological mechanisms; (iii) evaluate formulation strategies to enhance bioavailability; (iv) summarize therapeutic outcomes and safety; and

(v) identify research gaps requiring further study.

Methods: The review followed PRISMA-ScR guidelines. A structured search was conducted in PubMed and Google Scholar up to January 2026 using the keywords "Boswellia serrata" AND (arthritis OR anti-inflammatory OR "boswellic acids"). A total of 206 records were retrieved—113 from PubMed and 93 from Google Scholar. After deduplication and applying eligibility criteria, 38 studies were included: 13 clinical trials, 10 animal studies, 11 in vitro studies and 4 formulation-based studies. As per the scoping review methodology, a formal risk-of-bias assessment was not undertaken. The focus of this review was to broadly map available evidence on the anti-arthritic potential of

Boswellia serrata, in line with established frameworks such as Arksey and O'Malley and the PRISMA-ScR guidelines.

Results: AKBA and β-boswellic acid were reported in over 70 % of studies. Among clinical trials, 75% demonstrated significant improvements in pain, stiffness, and function. Over 85% of preclinical studies showed anti-inflammatory or cartilage-protective effects. Formulations such as phytosomes, micelles, and piperine-based enhancers were used to improve bioavailability.

Conclusion: *Boswellia serrata* demonstrates promising anti-arthritic potential, with consistent preclinical support and encouraging clinical outcomes. However, methodological variability and the absence of formal quality assessment limit definitive conclusions. Further high-quality trials are needed to establish its long-term efficacy and safety, including within the Homoeopathic framework.

Keywords: *Boswellia Serrata*, *AKBA*, *Osteoarthritis*, *Phytoconstituents*, *Anti-Arthritic Activity*.

1 Introduction

The Burseraceae family, comprising resin-producing trees and shrubs, is known for its aromatic gum resins and essential oils, historically used in traditional medicine and spiritual rituals. Within this family, the genus *Boswellia* includes species such as *Boswellia serrata*,

B. sacra, and *B. carterii*, which are primary sources of frankincense.

Among them, *Boswellia serrata*, native to India, has gained attention for its anti-inflammatory and anti-arthritic properties. Its active constituents—particularly acetyl-11-keto-β-boswellic acid (AKBA) and β-boswellic acid exert pharmacological effects by inhibiting 5-lipoxygenase

and modulating pro-inflammatory cytokines. These actions support its potential role in managing degenerative and autoimmune joint diseases such as osteoarthritis and rheumatoid arthritis.

In Homoeopathic practice, *Boswellia serrata* is used in the form of mother tincture and higher potencies to manage joint inflammation, synovitis, gout, and chronic rheumatic conditions [1]. Given the increasing acceptance of integrative approaches combining con-ventional, phytotherapeutic, and Homoeopathic interventions, *Boswellia serrata* stands out as a promising candidate for evidence-based complementary care. Despite this, existing research is fragmented and inconsistent, especially regarding formulation, standardization, dosing, and reported outcomes.

A consolidated synthesis of current evidence is lacking. Therefore, this scoping review was undertaken to map the breadth and nature of existing research on *Boswellia serrata*, with a focus on its phytoconstituents, pharmacokinetics, therapeutic efficacy, safety, and formulation strategies across in vitro, in vivo, and clinical studies.

2 Rationale of the Study

Arthritis, particularly inflammatory forms such as rheumatoid arthritis and osteoarthritis, poses a significant global health burden, affecting millions of individuals and diminishing their quality of life. According to the Global Burden of Disease (GBD) 2019, knee OA is one of the top contributors to musculoskeletal disability, especially in low- and middle-income countries. The global prevalence of knee OA among individuals aged 40 and above is estimated to be 22.9%, with a significantly higher incidence among women and those with obesity, joint injuries, or occupational joint strain [2]. Community-based epidemiological studies report that the prevalence of radiographic knee OA ranges from 28% to 35% in adults aged over 50 years, and it may reach up to 60% to 70% in elderly populations [3].

Given its high prevalence and the chronic pain and functional limitations it causes, knee OA represents a significant public health challenge. While conventional therapies such as NSAIDs and intra-articular corticosteroids provide symptomatic relief, their long-term use is often associated with adverse effects. This has driven interest in safer, plant-based alternatives with anti-inflammatory and disease-modifying potential. Among these, *Boswellia serrata*, a resin-producing tree used traditionally in Ayurvedic medicine, has gained attention for its promising anti-arthritic properties. *Boswellia serrata*, a tree native to India and belonging to the Burseraceae family, has been traditionally used in Ayurvedic medicine for its anti-inflammatory, analgesic, and immune-modulating properties. Its resin, commonly known as Indian frankincense, contains active compounds such as boswellic acids, which have demonstrated promising anti-arthritic effects in preclinical and clinical studies.

Despite a growing body of literature, the evidence surrounding the anti-arthritic efficacy of *Boswellia serrata* remains scattered and diverse in terms of study design, population, dosage, and outcomes measured. A scoping review is warranted to systematically map the existing research, identify knowledge gaps, and provide an overview of the current evidence on the therapeutic potential of *Boswellia serrata* in the context of arthritis.

This study aims to synthesize and categorize the available literature, offering a

comprehensive resource for researchers, clinicians, and policy-makers interested in the integration of herbal medicine into arthritis management strategies.

3 Objectives of the Study

This scoping review aims to:

- Map the existing *in vitro*, *in vivo*, and clinical evidence on *Boswellia serrata* in the context of anti-arthritic activity.
- Analyze key phytoconstituents, particularly boswellic acids, and their pharmacological roles.
- Evaluate various formulations and strategies developed to enhance the bioavailability of active constituents.
- Identify research gaps and areas requiring further scientific exploration.

4 Materials and Methods

4.1 Study Design

This scoping review was conducted in accordance with the framework proposed by Arksey and O'Malley [4], further refined by Levac et al. [5], and adheres to the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) guidelines.

4.2 Objectives

The primary objective was to map the existing literature related to the anti-arthritic potential of *Boswellia serrata*, identify research gaps, and provide an overview of study types, mechanisms of action, and therapeutic efficacy reported across different models.

4.3 Eligibility Criteria

Inclusion Criteria:

- Studies evaluating the anti-arthritic effects of *Boswellia serrata* in its extract, resin, or in formulation.
- *In vitro*, *in vivo* animal models and clinical studies.
- Articles published in English, with full text availability.
- Peer-reviewed journal articles, theses, and dissertations.

- **Exclusion Criteria:**
  - Studies not related to arthritis or joint inflammation.
  - Studies relating to other members of the Burseraceae family.
- **Information Sources and Search Strategy**

A systematic and comprehensive literature search was carried out to identify relevant studies. Electronic databases including *PubMed* and *Google Scholar* were primarily used, while additional sources such as conference proceedings and the reference lists of eligible articles were also manually screened to minimize the chance of missing important studies.

The search method was created by combining Medical Subject Headings (MeSH) and free-text keywords with Boolean operators like (and, or). For example, the terms "Boswellia serrata," "Indian frankincense," and "Olibanum" were coupled with outcome-related terms including "arthritis," "osteoarthritis," "rheumatism," "joint disease," and "anti-inflammatory."

Filters were used to limit the search to publications written in English and published till January 2026. The search also had to include studies on both humans and animals. All kinds of relevant study designs, such as clinical trials, observational studies, preclinical studies, and reviews were studied.

The initial search identified 206 records. After removal of duplicates, 160 unique articles were screened for eligibility. Following a detailed evaluation against predefined inclusion and exclusion criteria, 122 articles were excluded. Ultimately, 38 studies were found eligible and were included in the final review. The selection process has been summarized.

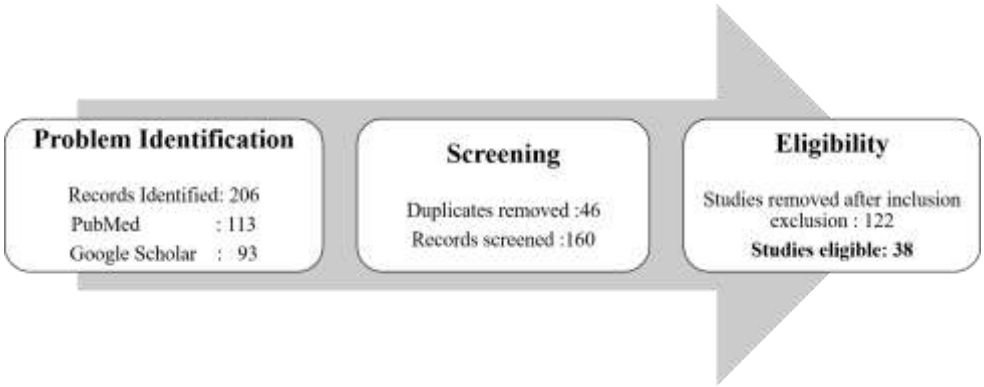

Figure 1: PRISMA-ScR Diagram

4.4 Study Selection and Data Extraction

The research selection and data extraction processes were conducted systematically and rigorously. Two reviewers, the principal researcher and a student collaborator,

independently evaluated all titles and abstracts obtained from the search to identify possibly eligible studies. The complete texts of the shortlisted papers were subsequently evaluated according to the established inclusion and exclusion criteria. The same two reviewers independently conducted data extraction utilizing a standardized data collecting form that included study details including author, year, design, interventions, outcomes, and major results. Dis-agreements that emerged during the selection or extraction of data were addressed through discussion and, when necessary, with the assistance of a third reviewer (the research guide), to ensure correctness, transparency, and methodological rigor throughout the review process.

5 Boswellia Serrata

Boswellia Serrata is widely distributed across India, particularly in Rajasthan, Madhya Pradesh, Maharashtra, Gujarat, Bihar, Assam, Odisha, and the central peninsular regions of Andhra Pradesh. Commonly known as *Kundru* or *Shallaki*, it is referred to as Indian frankincense, a term derived from Old French meaning "pure incense." Since ancient times,

three species have been recognized as the primary sources of true Frankincense. The genus *Boswellia* is named in honor of Johan Boswell, who identified certain species within this group [6]. For centuries, the gum resin extracted from *Boswellia serrata* has been traditionally utilized in treating inflammatory conditions, including arthritis. Additionally, it serves as a key raw material in various industries such as pharmaceuticals, food, bever-ages, flavoring, liqueurs, cosmetics, detergents, creams, perfumes, paints, adhesives, and dye manufacturing [7]. Given its long history of traditional use, Boswellia serrata has been the subject of extensive modern pharmacological and clinical investigation, particularly for inflammatory and arthritic conditions.

5.1 Historical and Traditional Background

Incense has been known to ancient civilizations and was widely used in rituals and prayers to deities. The Babylonians, Hindus, Buddhists, Chinese, Greeks, and Romans all incorporated incense into their ceremonial practices. One of the earliest recorded mentions of frankincense as a medicinal substance appears in the Ebers Papyrus. Ayurvedic texts also describe the use of the oleogum resin derived from *Boswellia serrata* (BS), commonly known as *salaiguggal*. Preparations containing either the bark or the oleogum resin were traditionally used to treat various ailments, including respiratory conditions such as cough and other lung-related issues, as well as digestive problems like diarrhea, constipation, and

flatulence. Additionally, these formulations were used for arthritic conditions and central nervous system disorders. Olibanum, another name for frankincense, remained a recognized remedy in Europe until the early 20th century and was included in the supplement to the 6th edition of the German Pharmacopoeia in 1926. However, it gradually fell out of medical use due to the absence of sufficient pharmacological and clinical evidence. The scientific revival of interest in *Boswellia serrata* began when researchers at the Regional Research Laboratory in Jammu, India, identified its anti-inflammatory properties in animal models by 1986. In 1991, the discovery of its inhibitory effect on leukotriene synthesis further sparked scientific curiosity, leading to extensive research on its medicinal potential [8]. Scientific interests in Bosellia serrata accelerated in the late 22nd century following the identification of its anti-inflammatory activity and leukotriene-inhibiting properties, laying the foundation for contemporary clinical research.

5.2 Bioactive Compounds and Phytochemistry

The oleo gum resin is obtained by making an incision in the tree trunk, after which it is collected in specially designed bamboo baskets to allow the removal of oil content and solidification of the resin. Following processing, the resin is graded based on its flavor, color, shape, and size. Oleo gum resin contains several important phytochemicals, including 30–60% resin, 5–10% essential oils soluble in organic solvents and polysaccharides making up the remainder. The composition and content of oleo gum resin vary between species, influenced by factors such as resin quality, tree age, and geographical conditions.

Extracts from *Boswellia serrata* gum-resin have been traditionally utilized in folk medicine for centuries to treat chronic inflammatory diseases. The resinous fraction of *Boswellia ser-rata* is rich in bioactive compounds, including monoterpenes, diterpenes, triterpenes, tetra-cyclic triterpenic acids, and four key pentacyclic triterpenic acids: β -boswellic acid, acetyl-β -boswellic acid, 11-keto-β -boswellic acid, and acetyl-11-keto-β -boswellic acid. These compounds inhibit pro-inflammatory enzymes, with acetyl-11-keto-β -boswellic acid identified as the most effective inhibitor of 5-lipoxygenase, a key enzyme in inflammation [6].

Boswellic acids have been extensively studied for their therapeutic potential in treating acute and chronic inflammatory diseases. These compounds exhibit anti-arthritic, anti-rheumatic, anticancer, antimicrobial, hepatoprotective, and immunomodulatory properties [9]. The major Phytoconstituents and Mechanism of Action of *Boswellia serrata* is listed in Table .1

Table 1: Phytoconstituents and Mechanisms of Action of *Boswellia serrata* [8]

Compound/ Constituent	Class	Mechanism of Action	Therapeutic Relevance
AKBA (Acetyl-11-keto-β-boswellic acid)	Boswellic acid	5-LOX inhibition, MMP suppression	Anti-inflammatory, Cartilage protection
KBA (11-keto-β-boswellic acid)	Boswellic acid	Leukotriene synthesis inhibition	Pain, inflammation reduction
Incensole acetate	Diterpenoid	Neuroprotective Anti-inflammatory	Potential CNS-related relief
Boswellic Resin Oil	Mixed terpenoids	Modulates COX-2 and oxidative stress	General anti-inflammatory

5.3 Pharmacokinetic Challenges of Boswellic Acids

Boswellic acids (BAs), the principal active constituents of *Boswellia serrata*, exhibit poor oral bioavailability due to their high molecular weight, low aqueous solubility, and extensive first-pass metabolism, as noted by Siddiqui [6]. Among the various BAs, acetyl-11-keto-β-boswellic acid (AKBA) and 11-keto-β-boswellic acid (KBA) are especially noted for their potent pharmacological activity, but they are also among the least bioavailable forms due to poor intestinal absorption and limited plasma concentrations following oral administration.

Due to their lipophilic nature, the absorption of boswellic acids can be significantly enhanced when co-administered with high-fat meals. This dietary fat improves their solubilization in the gastrointestinal tract and facilitates uptake via lipid-mediated pathways, as demonstrated by Krüger et al. [10]. However, this dependency on dietary fat can lead to inconsistencies in therapeutic outcomes.

5.4 Delivery Systems of Boswellic Acid

To overcome these pharmacokinetic limitations, various formulation strategies have been developed. One such approach includes the use of phospholipid-based delivery systems like phytosomes, which form molecular complexes with phosphatidylcholine to enhance membrane permeability [6]. In addition, advanced drug delivery systems such as nano formulations, micelles, solid lipid nanoparticles, and self-emulsifying drug delivery systems (SEDDS) have shown promise in improving the dissolution rate, systemic absorption, and bioavailability of boswellic acids [11].

Moreover, combining *Boswellia serrata* with other herbal extracts such as *Curcuma longa* (turmeric) or *Piper nigrum* (black pepper) has been explored to facilitate synergistic absorption and enhance bioactivity. Piperine, the active component of black pepper, is particularly effective in inhibiting hepatic and intestinal glucuronidation, thereby increasing the systemic availability of boswellic acids, as reported by Ammon [12].

Despite these advancements, clinical translation remains limited, and further pharmacokinetic studies in human subjects are needed to establish standardized, effective dosing regimens.

5.5 Evidence-Based Strategies to Enhance Bioavailability of Boswellic Acid

Boswellic acids (BAs), the primary anti-inflammatory constituents of *Boswellia serrata*, exhibit poor water solubility and high lipophilicity, which limits their oral bioavailability and therapeutic potential. Consequently, several experimental and computational studies have explored strategies to enhance the systemic absorption and efficacy of BAs.

In a pharmacokinetic and computational modeling study, Vijayarani et al. investigated the oral co-administration of *Piper longum* with boswellic acids. Their findings suggest that *Piper longum* may improve the intestinal absorption and systemic availability of boswellic acids, supporting the rationale for combining these herbal agents in clinical use [13].

Jürgen Meins et al. conducted an in vivo study in rats to assess the impact of AquaNova micellation technology on the bioavailability of Boswellia extract. The study demonstrated that micellar solubilization led to significantly enhanced absorption of boswellic acids compared to native forms, highlighting its potential as a delivery strategy for poorly soluble herbal compounds [14].

David Banji et al. investigated the combination therapy of 10% acetyl-11-keto-β -boswellic acid (AKBA) with methotrexate (MTX) in arthritic animal models. The study concluded that this combination not only provided superior anti-arthritic effects compared to either agent alone but also mitigated MTX-induced hepatotoxicity, offering both therapeutic and protective benefits [15].

These studies collectively demonstrate that bioenhancers, micellar delivery systems, and combination therapies can substantially improve the pharmacokinetic and therapeutic profile of boswellic acids.

5.6 Branded Formulations Containing *Boswellia serrata*

Boswellia serrata, traditionally used in religious ceremonies, also serves as a key component

in perfumes, soaps, creams, lotions, and detergents due to its fixative properties. In pharmaceuticals, it is valued for its antiseptic, antiarthritic, and anti-inflammatory effects. Over the past two decades, extensive research has been conducted to explore its medicinal properties and active constituents. Several branded formulations incorporating *Boswellia serrata* include:

- **Shallaki®** – Manufactured by Himalaya Drug Company, Bangalore. Each capsule contains 125 mg of *Boswellia serrata*. Known for anti-inflammatory and analgesic properties, particularly for joint pain relief. Recommended dosage: one capsule twice daily [6].
- **Frankincense Serrata Oil** – A steam-distilled essential oil from *Boswellia serrata* resin, manufactured by Plant Therapy. Used in aromatherapy, skincare, and respiratory blends [12].
- **Boswellin®** – A registered trademark of Sabinsa Corporation, introduced in 1991 in the US and European markets. Available in capsule or tablet form, and as a pain-relieving cream with capsaicin. Each dose contains 150–250 mg of boswellic acids. Recommended dosage: 2–3 times daily [15].
- **Niltan®** – A topical cream from Dr. Reddy's Laboratories, Hyderabad, containing boswellin, arbutin, liquorice extract, and coriander seed oil. It inhibits tyrosinase activity, reducing melanin production [17].
- **Rheumatic-X®** – From Sunrise Herbals, Varanasi, each capsule contains 20 mg of Shallaki (*Boswellia serrata*) with other ingredients. Used in rheumatoid arthritis, gout, OA, and sciatic pain. Dosage: 2 capsules twice daily or as directed [18].
- **Aflapin®** – A novel *Boswellia serrata* extract standardized for AKBA. Demonstrates strong anti-inflammatory effects in osteoarthritis, with good safety profile and rapid onset of action [19].
- **5-Loxin®** – Enriched with 30% AKBA. Reduces osteoarthritis pain by inhibiting 5-LOX and COX-2 enzymes, lowering MMP-3 levels in synovial fluid [20].
- **Colox®** – A polyherbal capsule (901 mg), formulated to inhibit COX-2 and 5-LOX, reducing inflammation and stiffness. Certified vegan and Jain-friendly [21].

The branded formulation containing *Boswellia serrata* is listed in Table 2

Table 2: Branded Formulations Containing *Boswellia serrata* [16]

S. No.	Brand Name	Composition	Form	Reported Benefits
a	Shallaki©	*Boswellia serrata* gum resin extract (125 mg)	Capsule	Anti-inflammatory, used in arthritis and joint pain
b	Frankincense Serrata Oil	Steam-distilled essential oil from *B. serrata* resin	Oil	Aromatherapy, skincare, respiratory benefits
c	Boswellin©	Standardized *Boswellia* extract (65% boswellic acids)	Capsule/ Cream	General inflammation, OA pain relief
d	Niltan©	Boswellin, arbutin, liquorice extract, coriander seed oil	Cream	Inhibits tyrosinase, reduces melanin production
e	Rheumatic-X©	Shallaki (20 mg) with other herbal ingredients	Capsule	Relief in RA, gout, OA, and sciatic pain
f	Aflapin©	AKBA + Non-acidic *Boswellia* fractions	Capsule	Enhanced anti-inflammatory effect in OA
g	5-Loxin©	Enriched AKBA (≥30%) *Boswellia* extract	Capsule	Reduces joint pain, inhibits 5-LOX, COX-2, lowers MMP-3
h	Colox©	Polyherbal (901 mg): inhibits COX-2 and 5-LOX	Capsule	Reduces inflammation, stiffness; vegan and Jain-friendly

5.7 Therapeutic Trials of *Boswellia serrata*

Both *in vivo* and *in vitro* studies provide substantial evidence supporting the anti-arthritic properties of *Boswellia serrata*. A summary of the included studies, categorized by study type clinical, animal, in vitro, and product is presented in Table 3.

Table 3: Summary of Included Studies on *Boswellia serrata*

Study Type	Number of Studies	Reference Numbers
Clinical (Human)	13	[19, 20, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32]
Animal (Preclinical)	10	[15, 33, 34, 35, 36, 37, 11, 38, 39, 40]
In vitro	11	[8, 9, 10, 11, 12, 13, 14, 16, 41, 40, 38, 39]
Product/Formulation/ Other	4	[17, 18, 21, 42]
Total	**38**	

A. In Vivo Trials

Several clinical trials support the anti-arthritic properties of *Boswellia serrata*. A systematic review of electronic databases, using the search terms *Boswellia serrata* and osteoarthritis (OA) knee joint, includes all relevant clinical trials. By focusing on this area, researchers have the opportunity to conduct new clinical trials to further explore the anti-arthritic effects of *Boswellia serrata*, ultimately benefiting individuals suffering from osteoarthritis.

Vishal et al. [19] conducted a double-blind, randomized, placebo-controlled study with 60 osteoarthritis patients, where Aflapin was found to significantly improve pain and physical function. Sengupta et al. [20] compared a novel synergistic composition of AKBA-enriched *B. serrata* extract and the nonvolatile oil fraction of *B. serrata* (Aflapin) with a standardized extract BE-30 (5-Loxin), concluding that both products exhibit strong anti-inflammatory and anti-arthritic properties, with Aflapin offering superior protection against cartilage degradation.

Similarly, Kimmatkar et al. [22] conducted a randomized, double-blind, placebo-controlled crossover study involving 30 osteoarthritis patients, demonstrating statistically significant and clinically relevant benefits of *B. serrata* extract (BSE).

Abdel-Tawab et al. [16] noted the increasing popularity of BSE and gum resin-based preparations of *Boswellia* in Western countries. Bannuru et al. [23] performed a systematic

re-view and meta-analysis comparing curcuminoid and *Boswellia* formulations with NSAIDs and placebos for knee osteoarthritis, concluding that these formulations could be effective alternatives with lower safety risks.

Majeed et al. [24] conducted a double-blind, placebo-controlled study involving 48 osteoarthritis patients, showing that BSE significantly improved physical function, reduced pain and stiffness, and lowered inflammation markers such as high-sensitive C-reactive protein. Yu et al. [25] analyzed seven trials with 545 participants, demonstrating that *Boswellia* extracts significantly alleviated pain and stiffness while enhancing joint function, recommending a minimum supplementation period of four weeks.

Karlapudi et al. [26] evaluated Aflapin in a randomized controlled trial involving 35 sub-jects, confirming its efficacy in osteoarthritis symptom relief. Anju Majeed et al. [27] conducted a multicentric placebo-controlled study with 105 knee osteoarthritis patients, demonstrating that Boswellin™ Super significantly improved pain scores within five days of supplementation.

Monaco et al. [28] studied the effects of hyaluronic acid and *Boswellia serrata* supplements in patients with mild to moderate knee osteoarthritis, reporting improvements in pain and joint mobility. Dalmonte et al. [29] performed a systematic review of phytoextracts from *Boswellia*, finding overall positive effects despite study heterogeneity.

Dubey et al. [30] conducted a meta-analysis of nine RCTs with 712 participants, confirming the effectiveness of *Boswellia* supplementation in reducing osteoarthritis symptoms and suggesting that Aflapin® might be particularly effective. Kumar et al. [31] used MRI assessments in a randomized controlled trial to evaluate the effects of SN13108F, a standardized *B. serrata* extract, on knee osteoarthritis, concluding that it improved cartilage morphology and musculoskeletal function.

Gayathri et al. [41] reported that a pure compound from *Boswellia serrata* extract exhibits anti-inflammatory properties by inhibiting key inflammatory mediators such as TNF-α, IL-1β, nitric oxide, and MAP kinases.

Ernst [43] performed a systematic review of seven clinical trials assessing *B. serrata* ex-tracts for conditions such as asthma, rheumatoid arthritis, Crohn's disease, osteoarthritis, and collagenous colitis, confirming their clinical efficacy without serious safety concerns.

Pérez-Piñero et al. [32] conducted a randomized controlled trial with four study arms,

evaluating *Boswellia serrata*, an omega-3 supplement, a combination of both, and a placebo in individuals with persistent knee discomfort. The combination of *Boswellia serrata* and AvailOm® significantly improved quality of life and clinical outcomes.

B. In Vitro Trials

Animal-based studies are integral to preclinical research, providing essential data on the safety, efficacy, and pharmacological profiles of therapeutic compounds before they advance to human trials. These studies offer critical insights into biological mechanisms, dosage responses, and potential adverse effects within controlled, living systems. Specifically, in the investigation of *Boswellia serrata*, animal models have been utilized to assess its anti-inflammatory and anti-arthritic properties, demonstrating promising therapeutic potential. Some of the important studies are as follows:

Mi-Rae Shin et al. [35] demonstrated that 5-Loxin® supplementation alleviated osteoarthritis pain by inhibiting inflammatory processes and cartilage degeneration in a rat model.

Banji et al. [15] examined the bioavailability, anti-inflammatory, and anti-arthritic effects of Acetyl Keto Boswellic Acid (AKBA) alone and in combination with methotrexate (MTX) in an arthritic animal model, concluding that AKBA exerts anti-inflammatory effects through 5-LOX inhibition, with the combination of 10% AKBA and MTX effectively suppressing arthritis.

Umar et al. [36] evaluated the antioxidant and antiarthritic effects of *Boswellia serrata* gum resin extract (BSE) in a collagen-induced arthritis model in rats. Administered at doses of 100 and 200 mg/kg body weight daily for 21 days, BSE led to significant improvements

in biochemical and histological parameters of joints, reducing inflammatory mediators and increasing IL-10 levels.

Similarly, Alluri et al. [37] investigated the anti-osteoarthritic efficacy of LI13019F1 (Serratrin®), a unique blend of acidic and non-acidic fractions of *B. serrata* gum resin. The com-position effectively inhibited 5-lipoxygenase (5-LOX) activity, reducing leukotriene B4

and prostaglandin E2 production in human blood-derived cells. It was concluded that LI13019F1 mitigates pain and protects articular cartilage in a rodent model.

Sanchez et al. [38] conducted an *in vitro* study on *Curcuma longa* and *B. serrata* extracts in human osteoarthritic chondrocytes, noting significant gene expression changes after 6 hours

of treatment with *C. longa* at 2 μg/ml, whereas *B. serrata* was effective only after 24 hours, regardless of concentration.

Ammon et al. [39] elucidated that boswellic acids inhibit leukotriene synthesis via 5-LOX without affecting 12-lipoxygenase and cyclooxygenase activities. Additionally, boswellic acids do not impair arachidonic acid peroxidation, suggesting their role as specific, non-redox inhibitors of leukotriene synthesis.

Sharma et al. [40] reported the effects of boswellic acids on bovine serum albumin (BSA)-induced arthritis in rabbits, demonstrating their anti-inflammatory potential.

Choi et al. [44] assessed the comprises -osteoarthritic potential of standardized *B. serrata* gum resin extract (BSRE) in an osteoarthritis-induced model, finding significant mitigation of knee joint swelling, cartilage destruction, and tissue deformation.

Singh et al. [45] studied the anti-inflammatory activity of a boswellic acid mixture, observing a 25–46% inhibition of paw edema in rats and mice.

5.8 Role of *Boswellia serrata* as Herbal Medicine

Boswellia serrata has long been valued in traditional systems of medicine for its ability to treat inflammatory conditions such as arthritis, bronchitis, and colitis. Its medicinal effects are primarily attributed to boswellic acids, which are extracted using methods like hydrodistillation, percolation, solvent-based, and ultraviolet-assisted techniques. These com-pounds exhibit multiple pharmacological actions, including anti-inflammatory, analgesic, and immunomodulatory properties.

Dubey et al.[30] conducted a meta-analysis of randomized controlled trials, confirming the clinical efficacy of *Boswellia serrata* extracts in improving symptoms of osteoarthritis, thereby validating its traditional use as a potent herbal medicine.

5.9 Safety and Tolerability

Boswellia serrata extract is generally considered safe and well-tolerated in clinical settings, particularly for the management of osteoarthritis. Typical daily dosages range from 100 mg to 250 mg, depending on the formulation and severity of symptoms. While no serious ad-verse events or toxicological effects have been reported, mild gastrointestinal symptoms such as diarrhea, nausea, abdominal discomfort, and heartburn have occasionally been ob-served.

Kimmatkar et al.[22] conducted a randomized, double-blind, placebo-controlled trial,

demonstrating that *Boswellia serrata* extract (BSE) is safe for use in osteoarthritis patients, with only minor gastrointestinal side effects reported. Similarly, a clinical trial by Majeed et al.[24] confirmed the safety and efficacy of Boswellin® Super, reinforcing its potential as a joint health supplement. A safety assessment study by Singh et al.[45] in rats further established the relative safety of *B. serrata*, with no observed adverse effects at doses up to 500 mg/kg body weight.

Basch et al.[46] compared the tolerability of *B. serrata* extract with NSAIDs, concluding that BSE is associated with better gastrointestinal tolerability. For tincture formulations, the recommended dosage of *Boswellia* is 2–10 ml per day of a 1:5 tincture in 90% alcohol[47].

Discussion and Future Directions

Over the past two decades, *Boswellia serrata* preparations have emerged as promising alternatives to conventional nonsteroidal anti-inflammatory drugs (NSAIDs), which are often associated with gastrointestinal and cardiovascular adverse effects. A substantial body of *in vitro*, *in vivo*, and clinical evidence supports the efficacy of *Boswellia serrata* extracts in the management of inflammatory disorders, particularly osteoarthritis. The present review highlights that *Boswellia* extracts may provide therapeutic benefits comparable to NSAIDs, with a more favorable safety and tolerability profile.

The results section extends beyond the reporting of individual studies by integrating a comparative synthesis to elucidate key variances and trends. The reviewed trials demonstrated marked heterogeneity in dosage, formulation, and intervention duration. *Boswellia ser-rata* was investigated in both crude extracts and standardized formulations, with the latter consistently producing greater improvements in pain and functional outcomes. Reported dosages ranged from modest daily amounts of 100 mg to higher regimens of 500 mg or more, and trials with extended treatment durations (12–24 weeks) generally yielded more sustained benefits than shorter interventions. Only a minority of studies employed rigorous double-blind, randomized designs, whereas several others involved small sample sizes, open-label methodologies, or incomplete reporting, thereby undermining the overall robustness of the evidence. Collectively, standardized formulations, higher dosages within safe limits, and longer treatment durations appear to produce the most reliable therapeutic outcomes. Nevertheless, the variability and methodological constraints of the current body of research necessitate cautious interpretation of these

findings.

Several broader limitations should also be acknowledged. The included studies exhibit considerable variability in sample size, extract composition, and methodological design, which complicates direct comparison of outcomes. Long-term data evaluating chronic use across diverse populations remain limited. Furthermore, this scoping review did not incorporate a formal assessment of methodological quality or risk of bias, thereby precluding the grading of evidence strength.

While the present review adhered to scoping review principles following the PRISMA-ScR framework, it primarily employed a narrative synthesis, which may limit analytical depth. Future systematic reviews should include formal quality appraisal and meta-analytic synthesis to enable more robust comparative insights. Additionally, large-scale, multicenter randomised controlled trials using standardized *Boswellia* formulations are warranted to confirm therapeutic efficacy, assess long-term safety, and explore its role as an adjunct or integrative therapy in arthritis management.

Conclusion

Boswellia serrata, with its long history of traditional use, is increasingly supported by scientific evidence for its significant therapeutic potential, particularly in osteoarthritis and other inflammatory disorders. The primary bioactive compounds, boswellic acids especially 3-*O*-acetyl-11-keto--boswellic acid (AKBA)—exert multimodal anti-inflammatory, analgesic, and immunomodulatory effects by inhibiting pathways such as 5-lipoxygenase (5-LOX) and modulating pro-inflammatory cytokines. While promising outcomes extend to conditions including rheumatoid arthritis, asthma, and inflammatory bowel disease, critical research gaps persist. These include the absence of standardized formulations, limited long-term safety data, and restricted scale and diversity among existing clinical trials.

To fully harness its clinical potential and integrate it into evidence-based practice, a concerted interdisciplinary research effort is essential. Future investigations should prioritize large-scale, multicenter randomized controlled trials employing standardized *Boswellia serrata* extract compositions to ensure reproducibility and regulatory alignment. Com-prehensive longitudinal studies are required to assess chronic safety, pharmacovigilance, and potential drug–herb interactions. Moreover, clinical validation of advanced delivery systems, such as nanoformulations or bioenhancers, is warranted to

optimize bioavailability. Given its favorable safety profile and multimodal mechanisms of action, *Boswellia serrata* represents a compelling candidate for incorporation as a complementary strategy within mainstream arthritis management and broader integrative care frameworks. Continued focused research will be instrumental in establishing *Boswellia serrata* as a rigorously validated, evidence-based botanical in modern clinical practice.

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