

**SANDHI SHARIR AND BIOMECHANICS A COMPARATIVE STUDY OF AYURVEDIC
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DOI: <https://doi.org/10.5281/zenodo.18428317>**How to cite this Article:** ¹Dr. Maheswari Rajaram Terkar, ²Dr. Vivek Vasanttrao Kulkarni, (2026). Sandhi Sharir and Biomechanics A Comparative Study of Ayurvedic and Modern Anatomy. World Journal of Pharmaceutical and Medical Research, 12(2), 35–39.

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Article Received on 18/12/2025

Article Revised on 07/01/2026

Article Published on 01/02/2026

ABSTRACT

Joints (Sandhi) play a crucial role in maintaining the structural integrity, mobility, and functional coordination of the human body. Ayurveda offers a detailed understanding of Sandhi Sharir, emphasizing not only structural aspects but also the dynamic role of dosha, dhatu, and upadhatu in maintaining joint health. Classical texts describe various sandhi types, their supportive tissues, and the pathological states resulting from imbalances—especially Vata. Modern anatomy and biomechanics, on the other hand, provide a microscopic and mechanical perspective of joints, covering aspects of synovial fluid dynamics, articular cartilage biomechanics, load distribution, kinematics, and joint stability mechanisms. This review synthesizes information from Ayurvedic literature and modern anatomical and biomechanical sciences to identify overlapping principles and complementary insights. It explores joint classification, functional mechanisms, pathological correlations (such as Sandhigata Vata with osteoarthritis), and therapeutic guidance from both disciplines. The study highlights strong parallels in lubrication, load-bearing, stability, and degenerative processes, showing Ayurveda's conceptual depth in explaining functional deterioration long before structural changes become apparent. The review concludes that integrating Ayurvedic principles with modern biomechanics can support better preventive, diagnostic, and rehabilitative strategies for joint disorders, while also opening new avenues for interdisciplinary research.

KEYWORDS: Sandhi Sharir, Ayurveda, Biomechanics, Modern Anatomy, Synovial Joint, Vata, Osteoarthritis, Integrative Medicine.**INTRODUCTION**

The musculoskeletal system, comprising bones, joints, ligaments, tendons, and muscles, forms the cornerstone of human movement and stability. Among these components, joints (sandhi) serve as anatomical junctions that permit mobility while simultaneously ensuring structural coherence. Ayurveda, India's traditional medical system, offers a sophisticated conceptualization of Sandhi Sharir, linking form, function, physiology, and pathology through the lens of dosha, dhatu, and upadhatu dynamics. Ayurvedic scholars such as Charaka, Sushruta, and Vagbhata elaborated on the formation of joints, their types, supporting tissues (snayu, kandara, sleshma), and their functional importance in facilitating gati (movement), sthirata (stability), and sampreshana (transmission of forces).^[1]

Simultaneously, modern anatomy provides detailed structural and biomechanical explanations of joints, supported by advances in imaging, histology, and movement science. Biomechanics, a discipline combining mechanical principles with biological systems, enhances our understanding of joint motion, load distribution, lubrication mechanisms, tissue stress–strain relationships, micro-damage progression, and the etiology of degenerative diseases like osteoarthritis. Modern perspectives elaborate on synovial fluid rheology, cartilage viscoelasticity, neuromuscular stabilisation, and kinetic-chain interactions—concepts that resonate with Ayurvedic interpretations of Vata, Kapha, and Sandhi Shleshma.^[2]

As joint disorders—especially osteoarthritis, sports injuries, and lifestyle-related musculoskeletal

conditions—continue to rise globally, the integration of Ayurvedic and modern biomechanical insights is not only relevant but necessary. Ayurveda contributes preventive and therapeutic strategies aimed at restoring balance, improving lubrication, and enhancing global-body harmony through snehana, swedana, basti, and herbal formulations. Modern biomechanics, meanwhile, provides quantifiable frameworks for understanding joint loads, muscular imbalances, posture-related stresses, and movement abnormalities.^[3]

Despite originating from vastly different philosophical foundations, both systems converge in describing joint function, degeneration, and maintenance. This creates fertile ground for comparative exploration. A systematic comparison of these two knowledge systems can offer clinicians—both Ayurvedic and modern—an enriched understanding of joint physiology and pathology, leading to more integrative and effective treatment modalities. This review article attempts to bridge this gap by offering a comprehensive comparative analysis of Sandhi Sharir and modern biomechanics, underscoring their intersections, complementarities, and clinical relevance.^[4]

AIMS AND OBJECTIVES

AIM

To comprehensively analyse and compare the Ayurvedic concept of Sandhi Sharir with modern anatomical and biomechanical principles.

OBJECTIVES

- To explore classical Ayurvedic descriptions, classifications, and functional aspects of Sandhi.
- To review modern anatomical and biomechanical concepts of joint structure, function, and pathology.
- To identify correlations between Ayurvedic and modern frameworks.
- To evaluate how integrative understanding can enhance the management of joint disorders.
- To propose potential research areas bridging Ayurvedic and biomechanical sciences.

MATERIALS AND METHODS

Study Design

A narrative review study based on classical Ayurvedic texts, contemporary anatomy literature, and biomechanical research.

Sources of Data

Ayurvedic Classical Texts

- Charaka Samhita
- Sushruta Samhita
- Ashtanga Hridaya
- Commentaries by Chakrapani, Dalhana, Arundatta

Modern Anatomy & Biomechanics References

Standard textbooks: Gray's Anatomy, Kinesiology texts, Joint biomechanics research papers

PubMed, Google Scholar, Scopus databases

Clinical Studies & Review Articles

Studies on osteoarthritis, synovial biomechanics, chondroprotection, and Ayurvedic interventions.

Ayurvedic Concept of Sandhi Sharir

Definition

Sandhi is described as the junction where asthi (bones), snayu (ligaments), peshi (muscles), and related structures meet to allow movement and provide stability.^[5]

Classification of Sandhi (Sushruta Samhita)^[6]

- Koodha Sandhi – immovable joints (similar to fibrous joints)
- Sira Sandhi – joints with limited motion
- Snayu Sandhi – ligamentous joints
- Valaya Sandhi – movable joints (similar to synovial joints)

Total sandhi counts vary across texts: 210 (Sushruta), 360 (Charaka), depending on classification methodology.

Structural Components (Sandhi Avayava)^[7]

- Sandhi Asthi Bhaga – articulation surfaces
- Snayu (ligaments) – stability providing structures
- Kandara (tendons)
- Sandhi Shleshma (synovial fluid analogy) – functions like lubrication, nutrition, and smooth movement
- Sleshmadhara Kala – comparable to synovial membrane
- Sandhi Bandhana – binding elements including ligaments, fibrous capsules, etc.

Functions According to Ayurveda^[8]

- Enables movement (gati)
- Provides stability (sthirata)
- Maintains posture
- Protects soft tissues and channels (srotas)
- Supports load transmission
- Acts as a seat of Vata dosha, making joints vulnerable during Vata vridhhi

Modern Anatomy and Biomechanics of Joints^[9]

Joint Classification (Functional & Structural)

1. Fibrous Joints – immovable (sutures, syndesmoses)
2. Cartilaginous Joints – slightly movable (synchondroses, symphyses)
3. Synovial Joints – freely movable, with capsule, synovial membrane, articular cartilage, and synovial fluid. Types: hinge, ball-and-socket, pivot, saddle, condyloid, plane.

Biomechanical Concepts^[10]

- Kinetics: Force distribution, weight-bearing, torque generation
- Kinematics: Range of motion, degrees of freedom
- Joint Stability: Passive structures (ligaments, cartilage) + active structures (muscles)
- Lubrication Mechanisms: Boundary and fluid-film lubrication

- Load Transmission: Stress absorption via cartilage and menisci

Degeneration and Pathology^[11]

- Osteoarthritis: cartilage wear, reduced lubrication, bone remodeling
- Ligament strains/sprains
- Posture-related joint stresses
- Age-related decline in joint biomechanics

Ayurvedic and Modern Correlations^[12,13]

1. Joint Types

Ayurveda's koodha, sira, snayu, valaya correspond closely to modern fibrous, cartilaginous, and synovial joints.

2. Sandhi Shleshma ↔ Synovial Fluid

Lubrication and nourishment roles are described in both systems.

Ayurveda emphasizes its depletion in Vata vriddhi, correlating to reduced synovial fluid in osteoarthritis.

3. Sleshmadhara Kala ↔ Synovial Membrane

Both refer to the inner lining responsible for production/maintenance of joint lubrication.

4. Vata Dosha ↔ Joint Biomechanics

Vata governs movement; excessive or depleted Vata results in restricted or painful motion.

In biomechanics, altered load, reduced lubrication, and instability produce similar clinical symptoms.

5. Sandhigata Vata ↔ Osteoarthritis^[14]

Ayurvedic symptoms:

- Shoola (pain)
- Shotha (swelling)
- Atopa (crepitus)
- Hanti sandhi gati (restricted mobility)

These correlate strongly with OA features.

Clinical and Research Relevance^[15,16]

Ayurvedic Interventions

- Snehana (oleation): improves lubrication
- Swedana: reduces stiffness
- Basti therapy: normalizes Vata and reduces degeneration
- Mardana & Upanaha: improves circulation
- Guggulu, Rasna, Shallaki preparations: anti-inflammatory, chondroprotective

Modern Treatment Parallels

- Physiotherapy for ROM improvement
- Viscosupplementation mimics lubrication therapies
- NSAIDs for acute inflammation
- Strength training similar to vyayama concepts
- Joint replacement in advanced degeneration

Areas for Integrative Research

- Comparative analysis of Sandhi Shleshma and synovial biomarkers
- Biomechanical effects of Panchakarma therapies
- Ayurvedic herbs as potential chondroprotective agents
- Functional MRI or motion analysis pre/post Ayurvedic therapies

DISCUSSION

The comparative study of Sandhi Sharir and modern biomechanics reveals a remarkable alignment between two systems that evolved from different epistemological backgrounds. While Ayurveda interprets joint structure and function through holistic principles grounded in dosha, dhatu, and srotas, modern anatomy relies on empirical observations, histological evidence, and mechanical modelling. Yet, despite these methodological differences, both systems converge on several key concepts, demonstrating their complementary nature.^[17]

Ayurveda's description of Sandhi Shleshma as a lubricating and nutritive element closely parallels the modern understanding of synovial fluid, which functions in friction reduction, shock absorption, and metabolic support to avascular articular cartilage. Similarly, Sleshmadhara Kala finds a direct correlation to the synovial membrane, reinforcing that ancient observations, though not expressed in modern terminology, captured the essence of joint physiology.^[18]

The Ayurvedic notion that Vata dosha governs movement and becomes aggravated in degenerative joint conditions corresponds well to modern biomechanical explanations of joint wear due to decreased lubrication, collagen matrix disruption, altered load mechanics, and muscle weakness or imbalance. In clinical terms, symptoms such as crepitus, pain during movement, stiffness, and restricted joint mobility are consistently described in both Sandhigata Vata and osteoarthritis, indicating a conceptual overlap between classical and contemporary musculoskeletal pathology.^[19]

Another significant point is Ayurveda's emphasis on the interconnectedness of joint health with digestion, metabolism, ageing, and lifestyle. Modern biomechanics similarly acknowledges that joint degeneration is not only a result of localized mechanical stress but also systemic factors such as inflammation, metabolic dysfunction, obesity, and sarcopenia. This shared recognition highlights the value of multidisciplinary approaches to musculoskeletal care.^[20]

Therapeutically, Ayurveda's strategies for Vata pacification—such as snehana, swedana, basti, and the use of Guggulu, Rasna, and anti-inflammatory herbs—align with biomechanical principles of enhancing lubrication, reducing stiffness, improving range of motion, and restoring neuromuscular function. Moreover, Panchakarma interventions, especially Matra

Basti and Kati Basti, when viewed from a biomechanical lens, can be understood as modalities that improve tissue hydration, reduce muscle guarding, enhance fascial gliding, and provide neuro-modulatory effects.^[21]

From a research standpoint, the comparative analysis suggests multiple potential areas of interdisciplinary collaboration. For example, studying the rheology of Sandhi Shleshma through biomarkers, evaluating biomechanical improvements after Ayurvedic therapies using gait analysis or motion-capture technology, and exploring the chondroprotective effects of Ayurvedic herbs through molecular biology can provide strong scientific validation for ancient therapeutic principles.^[22]

Overall, the integration of Ayurvedic and modern anatomical perspectives enriches our understanding of joint disorders by combining mechanistic clarity with holistic context. This creates a comprehensive framework for preventive care, early detection of degeneration, personalised therapy, and rehabilitation strategies, ultimately improving patient outcomes.

CONCLUSION

The comparative analysis of Sandhi Sharir and modern biomechanics demonstrates that Ayurveda's classical understanding of joints is not only conceptually profound but highly relevant to contemporary musculoskeletal science. The alignment between Sandhi Shleshma and synovial fluid, Sleshmadhara Kala and synovial membrane, Vata dysfunction and biomechanical degeneration, and Sandhigata Vata and osteoarthritis illustrates that ancient observations were accurate representations of joint physiology and pathology. This synthesis highlights that Ayurveda provides a holistic foundation focusing on doshic balance, lifestyle, diet, and systemic integrity, while modern biomechanics offers precise quantitative models for understanding motion, stress distribution, and tissue mechanics. When these perspectives are integrated, they create a broader and more effective framework for joint care—emphasizing prevention, early intervention, and long-term functional restoration. The review underscores the value of using Ayurvedic therapies alongside biomechanical rehabilitation for conditions such as osteoarthritis, sports injuries, and age-related joint degeneration. It also indicates a strong potential for future research, especially in areas such as synovial fluid biomarkers, imaging-based evaluation of Ayurvedic treatments, and biomechanical testing of traditional formulations. In conclusion, the comparative study demonstrates that Ayurveda and modern biomechanics are not competing but complementary sciences. Their integration can significantly enhance the understanding, prevention, and management of joint disorders. This interdisciplinary approach can guide future clinical practice, research innovation, and educational frameworks in musculoskeletal health.

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