RESEARCH PAPER

Bhasma as Nanomedicine in Rasashastra: A Comprehensive, Critical Evaluation

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ABSTRACT

Background: Bhasma formulations in Rasashastra practice the metal and mineral processing of Shodhana and Maraṇa to produce nanostructured, biocompatible formulations with rejuvenating and carrier properties that resemble contemporary drug ideas.

Methods: Narrative synthesis of literature from classical texts, pharmacopeial and current standards in PubMed, Scopus, ScienceDirect, and AYUSH databases using keywords such as "Bhasma," "Rasashastra," "Swarna/JasadaBhasma," "nanoparticles," and "quality control." The literature studies given preference were those involving characterization, pharmacology, toxicology, and GMP of important Bhasmas.

Results: Authentic Bhasmas (particles sized 10-200 nm with a herbal matrix) exhibit increased bioavailability, immunomodulatory, antidiabetic, and neuroprotective properties based on preclinical and clinical trials. The safety of proper preparation is acknowledged, but there are still general safety loopholes and unsatisfactory product toxicity.

Conclusions: Bhasma is a traditional nanomedicine that needs an integrated quality control system, validated studies, and a globally integrated regulatory system-oriented approach while maintaining Ayurvedic principles.

Keywords: Ayurveda, Bhasma, Nanomedicine

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INTRODUCTION

Rasashastra has been developed to enhance the pharmacological properties of metals and minerals through a series of elaborate procedures aimed at developing drugs that are light, subtle, rejuvenating, and able to magnify the effects of other drugs given along with them. In the classical literature, concepts of extreme subtlety, rejuvenation, magnification of effects, and the search for more subtle pathways would relate to the modern concepts of nanoscale delivery, selective targeting, bioenhancement, and improved bioavailability. Bhasma is considered to be a nanocomposite in the current literature. In this context, Rasashastra can be placed in the context of nanomedicine. [1-9]

METHODS

We undertook a comprehensive survey, collecting robust evidence from traditional Ayurvedic literature, pharmacopeial standards, and contemporary research on Bhasma nanomedicine. To provide a wide perspective, we searched the PubMed, Scopus, ScienceDirect, and AYUSH databases using keywords such as "Bhasma," "Rasaśāstra," "Swarna Bhasma," "JasadaBhasma," "nanoparticles," and "quality control." The research papers selected provided a deeper insight into the subject—they covered everything from the preparation of Bhasma to the methods employed for its analysis, including XRD, SEM/TEM, DLS, and FTIR analysis. We analyzed pharmacological and toxicological information, as well as GMP procedures for Swarna, Rasa-Sindura, Abhraka, Lauha, Tamra, and JasadaBhasma. To maintain a balanced perspective, we divided the information into categories such as classical preparation procedures, connection to nanoscience, pharmacology, clinical evidence, standardization, safety, and areas requiring further research.

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CLASSICAL FRAMEWORK OF BHASMA KALPANĀ

Traditionally, a Bhasma Kalpana involves Shodhana (detoxification/purification), Jaraṇa (calcination/roasting), Maraṇa (incineration), and Amṛtikaraṇa (rendering non-toxic and Rasayana), and is often based on practical tests such as Rekhapurṇata, Varitara, Nischandrata, and Apunarbhava [6, 7, 10]. Shodhana, besides the removal of physical and chemical impurities, is also intended to impart desired properties through repeated processing with herbal juices, decoctions, or media such as ghee, Kanji, Gomutra, and plant extracts [7, 10, 11]. Maraṇa involves repeated incineration with defined Puṭa systems (Gajapuṭa,

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Kukkutapuṭa) that regulate temperature and duration, which in turn influence particle size, crystallinity, and phase transformation of the final Bhasma [6, 7, 11, 12].

PARALLELS BETWEEN BHASMA AND NANOSCIENCE

Contemporary research on Swarna, Rasa Sindura, Abhraka, Lauha, Tamra, and JasadaBhasma has confirmed that nanoparticles/nanocrystalline masses in the 10-200 nm range, often in an organic matrix derived from herbal media, are produced by the ancient methods [1, 2, 5, 9, 13]. The nanoparticles have high surface area, changed redox properties, and increased reactivity, which can account for the rapid action, reduced dose, and wide spectrum of activity reported in the Ayurvedic texts [1, 4, 13, 14]. The herbal decoction and organic ligand-based Bhavana and Maraṇa process in the ancient methods serves as an in situ "green" synthesis, similar to phyto-mediated nanoparticle synthesis in contemporary nanotechnology [2, 5, 8, 15]

PHARMACEUTICO-ANALYTICAL CHARACTERIZATION

The structure, size, and composition of Bhasma have been recently analyzed using X ray diffraction (XRD), scanning and transmission electron microscopy (SEM/TEM), dynamic light scattering (DLS), energy dispersive X ray spectroscopy (EDX), FTIR, and surface area analysis [5, 13, 15, 16]. Swarna Bhasma has been described to be made from gold nanoparticles ranging from 20-70 nm in size, which are mostly carbon or herbal coated, while JasadaBhasma is known to contain zinc oxide or its zinc counterparts in the nano to submicron scale [1, 9, 13, 16]. These studies have shown that properly made Bhasma is not only the ash of metals but also a nano aggregate consisting of inorganic crystalline cores and organic or inorganic surface corona with primary pharmacological properties and safety [1, 4, 5, 13, 15, 16].

PHARMACODYNAMICS, PHARMACOKINETICS, AND MECHANISTIC INSIGHTS

Preclinical studies have also shown that Bhasmas affect oxidative stress, inflammation, and immune systems and act as Rasayana by promoting tissue regeneration and homeostasis [1, 4, 11, 14, 17]. Swarna Bhasma is known to affect macrophage function, cytokine levels, and antioxidant status, providing a rationale for its use in immune modulation, chronic inflammatory conditions, and as a general tonic [11, 14, 17, 18]. Nano zinc forms have shown efficacy in diabetic models of insulin mimetic and insulin sensitization as nano zinc can affect insulin signaling and pancreatic β-cell protection in diabetic models as done by the current zinc nanocarriers [9, 17, 19].

EXPERIMENTAL AND CLINICAL EVIDENCE

Experimental models indicate that Bhasmas such as Swarna, Rasa Sindura, Lauha, Abhraka, and Jasada have antidiabetic, cardioprotective, nephroprotective, neuroprotective, hepatoprotective, and immunomodulatory properties, often at very low concentrations compared to the conventional salts [1, 4, 9, 11, 17]. Clinical experiences and small scale clinical trials, although varied in methodology, have demonstrated the effectiveness of Bhasma-based preparations in different conditions (such as Prameha, Sthoulya, Hridroga, Rajayakṣma, and Apasmara) and in patients with different chronic musculoskeletal and degenerative diseases [11, 14, 18–20]. However, despite the general recommendation of Bhasmas, a considerable number of clinical trials were restricted to a small population size, and lack blinding and randomization, inadequate documentation of analytical characterization, short-term follow-up, which precludes any firm conclusion about long-term efficacy and safety [4, 18-21].

QUALITY CONTROL AND STANDARDIZATION ISSUES

One of the main hurdles is that the raw material, process variables, and traditional practices may vary from pharmacy to pharmacy, resulting in varied products with the same name Bhasma [4, 12, 15, 16]. And some of the most important analytical variables are yet to be unofficially demanded or stated: particle size distribution, crystal phase, lattice defects, elemental composition, and the presence of organic moieties, and there are some gaps in the pharmacopeial standards as compared to their market standards [15, 16, 21, 22]. The integration of classical analysis (Rekhāpūrṇatā, Varitaratva, etc.) has been suggested recently along with modern characterization, monographs for common Bhasmas, and multi-tier quality assurance to reduce batch-to-batch variations [10, 15, 21, 22].

SAFETY, TOXICITY, AND REGULATORY CONCERNS

Issues of heavy metal toxicity and contamination continue to be at the forefront of international criticism of Bhasma-based therapies, especially when these are not prepared according to genuine Shodhana-Maraṇa processes or when they are adulterated [3, 4, 20, 23]. Scientific studies of acute and subchronic toxicity of authentically processed Swarna, Rasa Sindura, JasadaBhasma, and other Rasa aushadhis have shown acceptable safety profiles with minimal organ toxicity and lack of significant accumulation upon administration under controlled conditions [1, 9, 20, 23, 24]. However, spontaneous reports and surveys suggest adverse events related to poorly standardized or counterfeit preparations, emphasizing the need for strict regulation and pharmacovigilance related to Rasa aushadhis [3, 4, 23-25].

COMPARATIVE PERSPECTIVE: BHASMA VERSUS CONTEMPORARY NANOMEDICINE

Comparative assessments indicate that Bhasmas and engineered nanoparticles have overlapping regions of nano size, targeted delivery, altered pharmacokinetics, and ability to traverse biological barriers such as the gut epithelium and blood-brain barrier [1, 5, 6, 13, 26]. However, Bhasma formulations can be differentiated based on the following aspects: (a) "green" step-by-step synthesis with herbal and animal-based media, (b) complex multi-component

matrices as opposed to single-component nanoparticles, and (c) Ayurvedic systems of practice that take into account Agni, Doṣa, Dhātu, and Ojas [2, 6, 8, 15, 26]. Compared to synthetic nanocarriers such as liposomes, polymeric nanoparticles, and metallic nanoparticles, Bhasmas have potential advantages in terms of cost-effectiveness, cultural acceptability, and compatibility with other Rasayana and AushadhaKalpanas, but are lacking in terms of global regulatory standards, patenting, and documented clinical evidence [4, 5, 6, 26, 27].

ETHICAL, REGULATORY, AND PUBLIC HEALTH DIMENSIONS

From an ethical perspective, the principles of informed consent, disclosure of metal/mineral content, and open communication about potential risks are critical in the prescription of Bhasma formulations, particularly in non-traditional environments [23, 25, 27]. Government bodies and AYUSH-related councils are increasingly promoting Good Manufacturing Practices (GMP), scientifically proven Shodhana-Maraṇa processes, and the incorporation of modern analytical certification for Bhasma-containing formulations [21, 22, 25, 28]. The convergence of Ayurvedic medicine and conventional nanomedicine also requires inter-disciplinary approaches to ethics, including considerations of environmental sustainability of mining, sustainability of raw materials, and fair access to quality Rasaushadhi [6, 22, 27, 28].

FUTURE DIRECTIONS AND RESEARCH PRIORITIES

Future research should focus on well-designed, properly powered clinical trials of analytically defined Bhasmas with well-defined formulations, dosages, and outcome measures relevant to both Ayurvedic and biomedical models [4, 18, 20, 27, 29]. Mechanistic research employing omics, imaging, and systems biology approaches can help to elucidate the mechanisms by which nanostructured metals and minerals affect cellular signaling, microbiome, immune systems, and related phenomena such as Vyadhikṣhamatva and Dhatuposhana in Rasayana [1, 5, 13, 17, 29]. Collaborative initiatives involving Vaidyas, Rasashastra specialists, pharmaceutical scientists, toxicologists, and regulatory bodies will play a pivotal role in positioning Bhasma as a credible, safe, and innovative contribution to the global nanomedicine community while staying true to the Ayurvedic paradigm [3, 6, 21, 27-29].

CONCLUSION

Bhasma Kalpana is a complex traditional nanotechnology process that turns potentially toxic metals and minerals into highly potent, nano-sized, and biocompatible drugs with specific Rasayana and disease properties. Although new evidence from the pharmaceutico-analytical and experimental sciences is increasingly validating the scientific basis of Bhasma as nanomedicine, there are still challenges to be overcome before the global community can fully accept this ancient nanotechnology. A balanced approach that critically assesses the evidence while staying grounded in Rasa Shastra can help MD Ayurveda experts and practitioners take the lead in integrating Bhasma-based nanomedicine into evidence-informed and patient-centered practices..

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