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Neuroprotective and *Medhya Rasayana* Potential of *Rajata Bhasma* (Incinerated Silver): A Translational Review of Cognitive Enhancement and Neurological Therapeutics

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Abstract

Background: Cognitive decline, neurodegenerative disorders, and stress-induced neuropsychiatric conditions represent a rapidly escalating global health burden with limited disease-modifying pharmacological interventions. Within Ayurveda, *Medhya Rasayana* therapy offers a specialized rejuvenation strategy aimed at enhancing intellect (*Dhi*), retention (*Dhriti*), and recall (*Smriti*) while protecting neural parenchyma from age-related and pathological degeneration. Among the metallic *Rasayanas* described in *Rasashastra*, *Rajata Bhasma* (incinerated silver) is classically revered as a premier *Medhya* (nootropic), *Majja Dhatu* (nervous tissue) nutrient, and cost-effective therapeutic counterpart to *Swarna Bhasma* (incinerated gold). *Objective:* This review synthesizes classical Ayurvedic textual evidence alongside contemporary physicochemical, preclinical, and clinical research to elucidate the neuroprotective mechanisms, memory-enhancing efficacy, and clinical applications of *Rajata Bhasma* in neurological and neuropsychiatric disorders.

Methods: Classical *Rasashastra* compendia—including *Rasa Tarangini*, *Rasaratna Samuchaya*, *Ayurveda Prakasha*, and *Bhaishajya Ratnavali*—were analyzed alongside peer-reviewed literature retrieved from PubMed, Scopus, and the AYUSH Research Portal.

Results and Discussion: Rigorous pharmaceutical processing via *Shodhana* (purification) and *Marana* (incineration) transforms raw silver into biocompatible, phytochemical-capped silver sulfide nanoparticles (10 to 100 nanometers) capable of crossing the blood-brain barrier without eliciting ionic silver toxicity. Preclinical neurobehavioral studies demonstrate that *Rajata Bhasma* significantly reverses scopolamine-induced amnesia, accelerates spatial learning acquisition, exerts anxiolytic and antidepressant-like effects, and modulates central monoaminergic and cholinergic neurotransmission. Biochemically, it attenuates cerebral lipid peroxidation, suppresses neuroinflammatory cytokines, and upregulates endogenous antioxidant enzymes. Clinically, both standalone *Rajata Bhasma* and *Rajata*-fortified formulations improve remote and recent memory scores and support recovery in *Manovaha Srotas* and *Vatavyadhi* disorders such as *Apasmara* (epilepsy), *Unmada* (psychosis), *Smritinasha* (dementia), and *Pakshaghata* (hemiplegia).

Conclusion: Rajata Bhasma operates as a multi-target nanomedicine and *Medhya Rasayana* that bridges classical Ayurvedic neuro-therapeutics with modern neuropharmacology. Standardized clinical trials and mechanistic neuroimaging studies are warranted to establish its role in integrative neurology.

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1. Introduction

Neurodegenerative and neurocognitive disorders—encompassing Alzheimer's disease, vascular dementia, Parkinson's disease, post-stroke cognitive impairment, and chronic stress-related neuropsychiatric illnesses—pose profound clinical and socioeconomic challenges worldwide [1]. Despite significant advances in molecular neuroscience, conventional pharmacotherapies largely offer transient symptomatic relief by modulating isolated neurotransmitter pathways, such as acetylcholinesterase inhibition or N-methyl-D-aspartate receptor antagonism, without halting underlying neuronal apoptosis, oxidative stress, or neuroinflammation [1, 2]. Consequently, there is growing scientific interest in multi-target neuroprotective agents capable of preserving synaptic plasticity and promoting long-term cognitive resilience [2].

In Ayurveda, cognitive health and neurological integrity are governed by the dynamic equilibrium of *Vata Dosha* (specifically *Prana*, *Udana*, and *Vyana Vata*), *Sadhaka Pitta*, and *Tarpaka Kapha*, alongside the nourishment of *Majja Dhatu* (bone marrow and central nervous tissue) and *Ojas* (the subtle essence of systemic vitality and immunity) [3]. To sustain these physiological pillars, classical texts describe *Medhya Rasayana*—a specialized branch of rejuvenation therapy designed to optimize cognitive faculties, namely *Dhi* (acquisition and comprehension), *Dhriti* (retention and processing), and *Smriti* (memory recall) [3, 4]. While botanical *Medhya Rasayanas* such as *Mandukaparni* (*Centella asiatica*), *Shankhapushpi* (*Convolvulus pluricaulis*), *Guduchi* (*Tinospora cordifolia*), and *Yashtimadhu* (*Glycyrrhiza glabra*) are widely recognized [4, 5], *Rasashastra* (the iatrochemical branch of Ayurveda) elevates metallic and herbo-mineral *Rasayanas* for their rapid action, minute dosage, deep tissue penetration (*Yogavahitva*), and sustained rejuvenative potency [6, 7].

Among the noble metals (*Shuddha Lohas*), *Rajata* (silver) holds an esteemed position in Ayurvedic neurology [8, 9]. Classical compendia such as *Rasa Tarangini* and *Rasaratna Samuchaya* describe *Rajata Bhasma* (incinerated silver) as possessing *Medhya* (nootropic), *Rasayana* (rejuvenative), *Balya* (neuro-muscular strengthening), and *Vayasthapana* (anti-aging) attributes comparable to *Swarna Bhasma* (incinerated gold), while offering a substantially more accessible and cost-effective therapeutic option for chronic neurological care [8, 10, 11]. This review critically examines the classical foundations, nanostructural characteristics, neuropharmacological mechanisms, and clinical applications of *Rajata Bhasma* as a *Medhya Rasayana* and neuroprotective agent.

2. Classical Ayurvedic Perspective on *Rajata Bhasma* in Neurological Health

2.1. Pharmacodynamic Attributes (*Rasapanchaka*) and Neuro-Tropism

In Ayurvedic pharmacology, the therapeutic action of a drug is determined by its *Rasapanchaka* (five core pharmacodynamic properties). Classical *Rasashastra* texts ascribe the following attributes to properly incinerated *Rajata Bhasma* [8, 9, 12]:

- ***Rasa* (Taste):** *Kashaya* (astringent), *Amla* (sour), and *Madhura* (sweet)

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- ***Guna* (Qualities):** *Snigdha* (unctuous and demulcent), *Sara* (mobile and channel-clearing), and *Laghu* (light and easily assimilable)
- ***Virya* (Potency):** *Sheeta* (cooling)
- ***Vipaka* (Post-digestive metabolic effect):** *Madhura* (sweet and tissue-building)
- ***Doshaghnata* (Effect on Doshas):** *Vata-Pittahara* (pacifies aggravated *Vata* and *Pitta* without provoking *Kapha*)

This specific combination of *Guna-Karma* explains *Rajata Bhasma*'s targeted affinity for the central nervous system (*Majja Dhatu* and *Manovaha Srotas*). In Ayurvedic pathophysiology, cognitive decline, anxiety, insomnia, and neurodegeneration are driven predominantly by *Vata* aggravation (manifesting as neuronal hyper-excitability, dryness, and axonal degeneration) and *Pitta* excess (manifesting as neuroinflammation and oxidative cellular injury). The *Snigdha Guna* and *Madhura Vipaka* of *Rajata Bhasma* directly nourish *Majja Dhatu* and support *Tarpaka Kapha* (the protective cerebrospinal and myelin microenvironment), whereas its *Sheeta Virya* pacifies *Sadhaka Pitta* and prevents inflammatory neurotoxicity [8, 11]. Simultaneously, its *Kashaya Rasa* and *Sara Guna* keep the subtle channels of the mind (*Manovaha Srotas*) clear of *Tamas* and metabolic stagnation, facilitating sharp cognitive reception and recall [13].

2.2. Classical Neurological and Neuropsychiatric Indications

Classical treatises—including *Rasa Tarangini*, *Ayurveda Prakasha*, *Rasendra Chintamani*, and *Bhaishajya Ratnavali*—prescribe *Rajata Bhasma* across a broad spectrum of neurological, psychiatric, and psychosomatic conditions [8, 9, 14, 15]:

- ***Smritinasha* and *Buddhi Mandya* (Memory Loss and Cognitive Impairment):** Administered with *Ghrita* (clarified butter), *Madhu* (honey), or *Shankhapushpi* juice to restore memory retention and intellectual acuity [13, 14].
- ***Apasmara* (Epilepsy and Convulsive Disorders):** Used as a *Medhya* and *Vatashamaka* stabilizer to reduce seizure frequency and post-ictal cognitive exhaustion [14, 15].
- ***Unmada* and *Chittodwega* (Psychiatric Disorders, Mania, and Severe Anxiety):** Prescribed with cooling adjuvants such as *Brahmi* (*Bacopa monnieri*) or *Kusmanda* (*Benincasa hispida*) to calm agitated *Prana Vata* and *Sadhaka Pitta* [14, 15].
- ***Mastishka Dourbalya* and *Anidra* (Cerebral Debility and Insomnia):** Utilized in chronic mental fatigue, burnout, and sleep disturbances to replenish *Ojas* and restore circadian neuro-regulation [14].
- ***Vatavyadhi* and *Nadivikara* (Neuromuscular and Neuropathic Disorders):** Indicated in *Pakshaghata* (hemiplegia), *Ardita* (facial paralysis), *Gridhrasi* (sciatica), and *Nadishula* (neuralgia) to support nerve conduction and tissue repair [15, 16].

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3. Pharmaceutical Transformation and Nanostructural Basis of Blood-Brain Barrier Permeability

A critical question in modern neuropharmacology is how a metallic preparation traverses the tightly regulated blood-brain barrier without inducing neurotoxicity or argyria. The answer lies in the traditional unit operations of *Shodhana* and *Marana*, which engineer *Rajata Bhasma* into a biocompatible organo-metallic nanomedicine [6, 17].

3.1. *Shodhana* and *Marana* Processing

Raw silver undergoes *Samanya Shodhana* (general purification) via seven cycles of red-hot heating and quenching in five liquid media—sesame oil (*Tila Taila*), buttermilk (*Takra*), cow's urine (*Gomutra*), fermented gruel (*Kanji*), and horse gram decoction (*Kulattha Kwatha*)—followed by *Vishesha Shodhana* (specific purification) in herbal juices such as *Agastya Patra Swarasa* or *Nimbu Swarasa* (lemon juice) [8, 17]. This repeated thermal cycling removes trace base-metal impurities and induces intergranular micro-fractures.

During *Marana*, purified silver is triturated with intermediate sulfur- or mercury-based catalysts (*Kajjali* or *Gandhaka*) and levigated (*Bhavana*) with botanical juices such as *Kumari Swarasa* (aloe vera) or *Nimbu Swarasa*, then subjected to 10 to 15 controlled incineration cycles (*Putapaka*) until classical quality benchmarks—*Varitara* (floating on water), *Rekhapurnatva* (filling skin furrows), *Nishchandratva* (loss of metallic luster), and *Apunarbhava* (irreversibility to elemental silver)—are achieved [8, 17, 18].

3.2. Physicochemical Properties Facilitating Neuro-Delivery

Modern characterization studies utilizing X-ray diffraction, scanning and transmission electron microscopy, and Fourier transform infrared spectroscopy reveal three structural features that govern *Rajata Bhasma*'s central nervous system bioavailability:

1. **Nanoscale Particle Dimensions:** Properly prepared *Rajata Bhasma* consists of spherical and polyhedral nanoparticles ranging from 10 to 100 nanometers (with average crystallite sizes near 68 nanometers), well within the size threshold required for receptor-mediated endocytosis and transcytosis across cerebral microvascular endothelial cells [10, 18].
2. **Thermodynamically Stable Silver Sulfide Core:** X-ray diffraction confirms that elemental metallic silver is converted into polycrystalline silver sulfide (acanthite phase) accompanied by minor silver silicate phases [10, 18]. Unlike synthetic silver nanoparticles or soluble silver salts (such as silver nitrate) that rapidly release cytotoxic silver ions, silver sulfide possesses ultra-low aqueous solubility, providing a sustained, non-toxic biological release profile [19].
3. **Phytochemical Surface Functionalization:** Infrared spectroscopy demonstrates an organic corona of hydroxyl, carbonyl, phenolic, and amine functional groups derived from the herbal *Bhavana* media [18, 19]. Combined with lipophilic lipid adjuvants (*Anupanas*) like *Ghrita* (cow ghee) or *Brahmi Ghrita* during clinical administration, this organo-mineral surface facilitates lipid-raft transport across the blood-brain barrier while acting as a *Yogavahi* (targeted bio-enhancer) [19].

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4. Neuropharmacological Mechanisms and Experimental Evidence

Contemporary preclinical studies across rodent behavioral models and biochemical assays have provided substantial experimental validation for the *Medhya Rasayana* and neuroprotective effects of *Rajata Bhasma*.

Table 1: Summary of Preclinical and Clinical Evidence on the Neurocognitive and Neuroprotective Effects of *Rajata Bhasma*

Study Domain / Model	Intervention & Dosage	Key Behavioral, Biochemical, or Clinical Outcomes	Reference
Neuropsychobehavioral & Scopolamine Amnesia Model (Rodents)	Calcined silver preparations (*Rajata Bhasma*), oral administration	Significant reduction in scopolamine-induced amnesic latency (up to 82 percent); marked anxiolytic, antidepressant, and mild central nervous system stimulant effects without motor impairment.	Nadeem et al., 1999 [20]; Agey et al., 2024 [10]
Morris Water Maze Acquisition Memory Model (Wistar albino rats)	*Rajata Bhasma* (11.25 milligrams per kilogram per day, oral) vs. Piracetam (100 milligrams per kilogram)	Decreased escape latency and improved spatial learning and acquisition memory across quadrant trials, demonstrating nootropic activity comparable to standard piracetam.	Experimental SDM Study [21]
Pain Modulation & Central Analgesia Model (Experimental rodents)	*Rajata Bhasma* combined with *Ashwagandha* (*Withania somnifera*)	Significant central and peripheral analgesic activity; confirmed wide safety margin with no neurotoxicity or organ pathology.	Inder et al., 2012 [22]
Sub-Chronic Safety & Dose-Escalation Toxicity Study	*Rajata Bhasma* up to 5 times human therapeutic equivalent dose	Complete absence of hepatic, renal, or cerebral histopathology; markedly safer profile than synthetic elemental silver nanoparticles.	Agey et al., 2024 [10]; Safety Reviews [19]
Clinical Memory Evaluation in Young Adults (Open-label clinical trial)	*Rajata Bhasma* with *Shankhapushpi* syrup	Statistically significant improvement in remote memory (17.02 percent increase) and recent memory (13.63 percent increase) on standardized PGI Memory Scale subtests.	Clinical Evaluation Study [13]
Aging-Associated Mild Neurocognitive Disorder	*Medhasagar Rasa* (containing *Rajata*	Significant improvements in learning, attention, processing	Clinical Trial, 2024 [23]

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(Clinical trial)	*Bhasma*, *Abhraka Bhasma*, and *Medhya* herbs)	speed, working memory, and stress reduction in elderly subjects with mild cognitive impairment.	

4.1. Enhancement of Learning Acquisition, Memory Consolidation, and Recall

In classic neuropsychobehavioral investigations conducted by Nadeem et al., traditional calcined silver preparations (*Rajata Bhasma*) demonstrated pronounced nootropic activity in experimental animals, reversing scopolamine-induced memory deficits by up to 82 percent and enhancing passive avoidance retention [10, 20]. Complementary studies evaluating spatial learning in the Morris water maze confirmed that oral administration of *Rajata Bhasma* (11.25 milligrams per kilogram) reduces escape latency and strengthens spatial acquisition memory [21].

Clinically, evaluating *Rajata Bhasma* alongside *Shankhapushpi* syrup in human subjects revealed statistically significant gains in both remote memory (17.02 percent improvement) and recent memory (13.63 percent improvement) as measured by validated neuropsychological memory scales [13]. In Ayurvedic terms, this dual enhancement corresponds directly to the restoration of *Dhriti* (long-term retention supported by *Sheeta Virya* and *Tarpaka Kapha* nourishment) and *Smriti* (active recall facilitated by *Kashaya Rasa* and balanced *Udana Vata*) [13].

4.2. Neuromodulation: Cholinergic, Monoaminergic, and GABAergic Pathways

Neurocognitive performance and emotional stability depend on balanced synaptic transmission across cholinergic, monoaminergic, and inhibitory amino acid networks:

- **Cholinergic Preservation:** Scopolamine induces amnesia by blocking central muscarinic acetylcholine receptors. The robust reversal of scopolamine-induced cognitive deficits by *Rajata Bhasma* indicates preservation of central cholinergic tone and attenuation of excessive acetylcholinesterase activity [10, 20].
- **Monoaminergic Stabilization (Antidepressant and Anxiolytic Actions):** Experimental neurobehavioral screening demonstrates that *Rajata Bhasma* exerts significant antidepressant-like effects in forced swim and tail suspension paradigms alongside anxiolytic activity in elevated plus-maze tests [10, 20]. These behavioral outcomes correlate with the stabilization of synaptic serotonin, dopamine, and norepinephrine levels in the hippocampus and prefrontal cortex—mechanisms further corroborated when *Rajata Bhasma* is administered within neuroprotective compound formulations such as *Vasantakusumakara Rasa* [24].
- **Inhibitory Tone in Convulsive States:** Classical use of *Rajata Bhasma* in *Apasmara* (epilepsy) and *Apatanaka* (convulsions) aligns with suppression of glutamate-mediated excitotoxicity and stabilization of neuronal membrane resting potentials [14].

4.3. Antioxidant Defense and Anti-Neuroinflammatory Protection

The human brain is exceptionally vulnerable to oxidative stress due to its high oxygen consumption, abundant polyunsaturated fatty acids, and relatively modest baseline antioxidant enzyme reserves. Chronic

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oxidative damage drives lipid peroxidation, mitochondrial dysfunction, amyloid-beta aggregation, and dopaminergic neuronal loss [2].

Rajata Bhasma exhibits potent free-radical scavenging and endogenous antioxidant-upregulating properties [10, 18]. Experimental models demonstrate that *Rajata Bhasma* reduces cerebral malondialdehyde (a marker of lipid peroxidation) while elevating superoxide dismutase, catalase, and reduced glutathione levels [18, 24]. Simultaneously, it downregulates pro-inflammatory cytokines—including tumor necrosis factor alpha, interleukin 1 beta, and interleukin 6—thereby protecting hippocampal neurons and retinal-neural microvasculature from chronic neuroinflammation [24, 25].

5. Clinical Applications: Standalone Therapy vs. Compound Formulations

In clinical Ayurvedic practice, *Rajata Bhasma* is utilized both as a targeted single mineral drug and as a synergistic core ingredient in classical neuro-active *Rasaushadhis* [15, 26].

5.1. Standalone Administration and *Anupana* Selection

For adult patients, the classical therapeutic dose of *Rajata Bhasma* ranges from 30 to 125 milligrams per day in divided doses, typically administered with tailored *Anupanas* (vehicles) that direct its *Yogavahi* action toward specific neuro-pathologies [8, 14, 15]:

- **Cognitive Enhancement and Memory Loss (*Smritinasha*):** Administered with *Brahmi Swarasa* (*Bacopa monnieri*), *Shankhapushpi* syrup, or cow's *Ghrita* and honey to facilitate blood-brain barrier transport and *Medhya* nourishment [13, 14].
- **Anxiety, Insomnia, and *Chittodwega*:** Combined with *Kusmanda Swarasa* or warm milk with nutmeg (*Jatiphala*) to pacify agitated *Prana Vata* and *Sadhaka Pitta* [14].
- **Neuropathic Pain and Neuralgia (*Nadishula*):** Paired with *Ashwagandha* powder or *Dashamoola* decoction to soothe *Vata* and promote peripheral nerve repair [15, 22].

5.2. Role in Classical Neuro-Active Compound Formulations

Rajata Bhasma forms a cornerstone of several renowned poly-mineral formulations indicated for complex neurological and neurocognitive disorders:

- ***Smritisagara Rasa*:** A specialized *Medhya* formulation combining *Rajata Bhasma* with *Shuddha Parada*, *Shuddha Gandhaka*, *Haritala*, and *Manahshila*, levigated in *Brahmi*, *Vacha* (*Acorus calamus*), and *Jyotishmati* (*Celastrus paniculatus*) juices, indicated in *Apasmara* and severe memory impairment [23, 27].
- ***Rasaraja Rasa*:** Combines *Rajata Bhasma* with *Rasasindura*, *Swarna Bhasma*, *Abhraka Bhasma*, and *Ashwagandha* for *Pakshaghata* (hemiplegia), *Ardita* (Bell's palsy), and neurodegenerative *Vatavyadhi*, where *Rajata Bhasma*'s cooling, unctuous nature nourishes *Majja Dhatu* and buffers heating co-ingredients [16].

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- ***Vasantakusumakara Rasa*:** Pairs equal proportions of *Rajata Bhasma* and *Swarna Bhasma* with *Mauktika Pishti* and *Vanga Bhasma* to prevent diabetic encephalopathy, peripheral neuropathy, and diabetic retinopathy by suppressing neuroinflammation and restoring cerebral monoamines [24, 25].
- ***Chaturmukha Rasa* and *Yogendra Rasa*:** Classical *Rasayanas* incorporating *Rajata Bhasma* alongside *Swarna* and *Abhraka Bhasmas* to manage *Unmada*, post-stroke motor deficits, and age-related cognitive decline [14, 26].

6. Safety Profile, Toxicological Guardrails, and Future Research Directions

6.1. Safety and Toxicological Margin

Concerns regarding heavy metal toxicity in traditional medicines frequently stem from improperly processed preparations or unregulated adulteration [6, 28]. When manufactured strictly according to classical *Shodhana* and *Marana* protocols, *Rajata Bhasma* exhibits a wide therapeutic index. Sub-acute and chronic oral toxicity studies confirm that *Rajata Bhasma* produces no hematological, hepatic, renal, or neurological toxicity even at doses five times higher than the human therapeutic equivalent [10, 19]. Unlike synthetic elemental silver nanoparticles, which can induce oxidative tissue injury upon dose escalation due to rapid silver ion release, the phytochemical-capped silver sulfide matrix of *Rajata Bhasma* prevents systemic silver accumulation and argyria when used within prescribed therapeutic durations and dosages [10, 19].

6.2. Translational Roadmap for Future Investigations

To integrate *Rajata Bhasma* into mainstream evidence-based neurology, future doctoral and clinical investigations should prioritize:

1. **Standardized Pharmacopoeial Characterization:** Mandatory batch-to-batch verification using X-ray diffraction (confirming acanthite phase purity and absence of free metallic silver), inductively coupled plasma mass spectrometry (for trace elemental profiling), and particle size distribution analysis [17, 18].
2. **Mechanistic Neurobiology:** In vitro and in vivo studies examining the impact of *Rajata Bhasma* on brain-derived neurotrophic factor (BDNF) expression, hippocampal neurogenesis, tau protein phosphorylation, and amyloid-beta clearance in transgenic neurodegeneration models.
3. **Randomized Controlled Clinical Trials:** Well-powered, double-blind clinical trials evaluating *Rajata Bhasma* (standalone and with *Medhya* botanical adjuvants) in mild cognitive impairment, early-stage Alzheimer's disease, and post-stroke neurorehabilitation using standardized cognitive batteries and functional neuroimaging.

7. Conclusion

Rajata Bhasma represents a sophisticated convergence of ancient Ayurvedic pharmaceutics and modern nanomedicine. Guided by its *Sheeta Virya*, *Snigdha Guna*, and *Madhura Vipaka*, incinerated silver nourishes *Majja Dhatu*, pacifies aggravated *Vata* and *Pitta* in *Manovaha Srotas*, and enhances *Dhi*, *Dhriti*, and *Smriti*. Physicochemical transformation via *Shodhana* and *Marana* yields stable, organo-capped silver sulfide nanoparticles capable of crossing the blood-brain barrier safely. Corroborated by preclinical evidence of

cholinergic preservation, monoaminergic stabilization, antioxidant defense, and clinical memory enhancement, *Rajata Bhasma* holds compelling promise as an effective, accessible *Medhya Rasayana* for managing cognitive decline and neurological disorders.

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