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Neuroprotective Potential of *Ginkgo biloba* Extracts: A Pharmacognostic Review

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ABSTRACT

This review explores the neuroprotective potential of *Ginkgo biloba* extracts, particularly the standardized formulation EGb 761, through a pharmacognostic lens. With the global rise in neurodegenerative disorders such as Alzheimer's, Parkinson's, and ischemic stroke, there is an urgent need for safe, effective, and multi-targeted therapeutic options. The review begins by outlining the botanical characteristics, traditional uses, and global cultivation patterns of Ginkgo biloba, establishing its importance as a medicinal plant. It then examines a range of preclinical (in vitro and in vivo) and clinical studies, which collectively highlight the extract's ability to enhance memory, reduce oxidative stress, lower inflammatory markers, and improve mitochondrial function. These effects are largely attributed to its active constituents—flavonoids (quercetin, kaempferol) and terpenoids (ginkgolides, bilobalide)—which exhibit antioxidant, anti-inflammatory, anti-apoptotic, and neurovascular actions. The review also presents key mechanisms of action, discusses findings from behavioural and biochemical assessments, and synthesizes the therapeutic relevance of Ginkgo biloba in both early and moderate stages of cognitive impairment. Despite promising results, challenges such as inconsistent clinical trial methodologies, limited long-term data, and a lack of head-to-head comparisons with conventional drugs are noted.

Key Words:

Ginkgo biloba, EGb 761, Neuroprotection, Alzheimer's disease, Parkinson's disease

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1. INTRODUCTION

Neurodegeneration-related illnesses have become a growing concern to the global healthcare system as they remain one of the biggest challenges to date. Diseases like Alzheimer, Parkinson, and other types of dementia are diseases where nerve cells degenerate and die due to the continuous degeneration of nerve cells, cognitive capacity, functional movement disorder, and eventually independence along with the quality of life are in jeopardy. As life expectancy grows and population ages, the incidence of such diseases is seen to dramatically increase in the following decades, and this will further put a strain on the healthcare system[1]. Although tremendous endeavours to find cures have been developed, at the moment there exist still no unambiguous cure to these diseases, and known pharma-based therapies serve mainly to alleviate contrast to cure the diseases and their progress. In this respect, the complementary and alternative

medicine of dealing with neurological disorders has gained increased attention especially when based on traditional medicine.

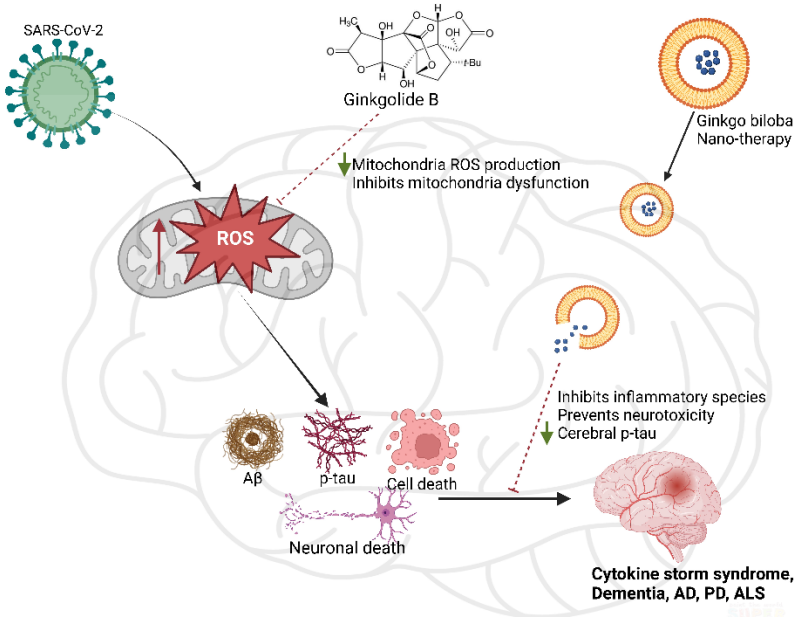

Figure 1: *Ginkgo biloba*: In Vivo And In Vitro Model

Ginkgo biloba takes centre stage among other herbal medicines that have been researched on because it has been evolving as a very unique herb in terms of phylogeny, its tradition of use as a medicine and its wide pharmacological window. Known commonly as a living fossil *Ginkgo biloba* is the only extant species of the ancient Ginkgoaceae family, and has had a botanical history of over 200 million years[2]. Traditional Chinese medicine has used it as a foundation; it was effective in treating respiratory diseases, vascular diseases and cognitive impairment. Over the past few decades, *Ginkgo biloba* has been given immense publicity in the Western medical herbal treatments especially because of its purported qualities such as memory improvement, focus, and general optimization of the brain. The scientific confirmation of its therapeutic action especially in the standardized extracts like EGb 761 has added to the popularity of its use as a natural neuroprotecting agent all over the world. *Ginkgo biloba* still remains an interesting candidate of complementary intervention in the prevention and treatment of neurodegenerative diseases due to its historical importance and current pharmacological potential.

1.1 Background information and context.

Alzheimer disease, Parkinson disease and other dementias are neurodegenerative disorders that are gaining great popularity in the face of aging populations in the world. The conditions are characterized by the gradual destruction of the structure and functioning of neurons resulting in problems with cognition and movement[3]. Existing pharmacologic therapies provide symptomatic management only, and are commonly linked to both small doses of efficacy and side effects hence there exist a need of other forms of therapy. Herbal medicine especially those that are formulated using traditional systems such as Ayurvedic and Traditional Chinese Medicine has arisen as a field

of potential interest. As one of the oldest existing trees in nature, *Ginkgo biloba* has been practiced traditionally because of its mental and cardiovascular advantages. Standardized extracts high content of flavonoids and terpenoids with antioxidant, anti-inflammatory and neuroprotective activities, like EGb 761 have been the centre of modern pharmacological interest. Nonetheless, clinical effect on *Ginkgo biloba* is still debatable as research design and standardization have been considerably inconsistent. To this end, there is a need to conduct a focussed pharmacognostic review to assess its therapeutic potential along with clarifying its role towards the management of neurodegenerative diseases.

1.2 Objectives of the Review

- To determine the pharmacognostic profile of *Ginkgo biloba*.
- To also examine studies that have been done preclinically and clinically regarding its neuroprotective effect.
- To study the cellular and molecular mode of action.
- To underline its prospect in dealing with cognitive and neurodegenerative disorders.
- To determine the limitations and propose the way of future research.

1.3 Importance of the Topic

- **Rising Prevalence of Neurodegenerative Diseases**: Diseases like Alzheimer and Parkinson are increasingly becoming prevalent particularly in older populations, and they are yet to be curably countered[4].
- **Burden on Healthcare Systems**: These diseases cause a heavy emotional, physical, and financial toll on patients, families and healthcare system.
- **Need for Alternative Therapies**: Safe, convenient, and accessible (low-cost) treatments are in demand because of the restrictions of the available pharmacological tools.
- **Interest in Plant-Based Medicine**: Traditional medicine in the form of herbal therapies is education to the rest of the world because they usually lack side effects of synthetic drug usage.
- **Prominence of *Ginkgo biloba***: *Ginkgo biloba* is one of the herbal supplements with the greatest level of research and usage in the support of cognitive performance and neurological wellbeing.
- **Neuroprotective Constituents**: Its activities are mostly credited to flavonoids and terpenoids that are reported to have antioxidant, anti-inflammatory, and anti-apoptotic properties.
- **Mechanism of Action**: They are antioxidants, which avoid degeneration of neurons, act as anti-inflammatories, and counter oxidative stress.
- **Scientific and Clinical Relevance**: The use of *Ginkgo biloba* by clinicians should be informed and evidence-based, and therefore assessment of therapeutic value, safety and limitations of *Ginkgo biloba* must take place.

- **Multidisciplinary Importance**: The subject is widely pertinent in other scientific fields, including pharmacognosy, neuroscience, and integrative medicine and because of its therapeutical potential and its long-standing historical base.

2. Pharmacognostic Profile and Botanical Characteristics of *Ginkgo biloba*

There is a special place of *Ginkgo biloba* both in traditional medicine and in modern medicine because of characteristics related to its botanical properties, and the time of its therapeutic use. It is the only living representative of a very ancient family of plants the Ginkgoaceae, and therefore an actual survivor of the prehistoric flora. Its unsurpassedian morphology, life span and indomitableness have not alone elicited scientific attention but also a global range of cultivation. To identify, control in quality and make it effectively medically useful, knowledge about the pharmacognostic and botanical aspects of *Ginkgo biloba*, i.e., the plant structure, the morphology of leaves, and reproductive characteristics are of paramount significance. This part describes the main characteristic features of *Ginkgo biloba* and condition its pharmacological value[5].

Table 1: Botanical Characteristics of *Ginkgo biloba*[6]

Feature	Description
Botanical Name	*Ginkgo biloba* L.
Family	Ginkgoaceae
Common Names	Maidenhair tree, Fossil tree
Plant Type	Deciduous gymnosperm tree
Height	20–35 meters
Leaf Shape	Fan-shaped, often bilobed
Venation	Dichotomous (parallel-like)
Reproduction	Dioecious (separate male and female trees)
Bark	Rough, grayish-brown, deeply fissured

2.1 Pharmacognostic Overview of *Ginkgo biloba*

Ginkgo biloba is a special species of deciduous trees that is special in terms of its botanical characteristics and evolutionary importance. It is also called the living fossil as it is the only surviving species in the Ginkgoaceae family because the fossils are found much earlier than 200 million years. The plant can reach a maximum height of 20-35 meters and has a very long-life span which is usually over 1000 years[7].

- **Morphology of the Plant**

It is a pyramidal shaped tree in young trees but grows irregularly with age and its trunk is straight. It also has rough deeply cracked bark, and long skinny trunks. Ginkgo is dioecious that is, on

separate trees male and female reproductive organs are present. The male trees cannot produce any flower where the small pollen cones are produced unlike the female tree which contains ovules that grows into a seed which has a fleshy outer part[8].

- **Leaf Structure and Identification Features**

Ginkgo biloba is one of the most distinguishable ways of looking at plant foliage because the leaf resembles a distinct bilobed fan shape that makes the plant acquire the Latin name of the species; biloba. These leaves are bright green when in the growing season and bright yellow in autumn before fall. Their venation is parallel, which is unusual in any broad-leaved plant, and the leathery and peculiar appearance enable them to be distinguished with ease[9]. Such morphological characteristics are significant in taxonomic identification of the plant as well as in its ornamental and medicinal purpose.

2.2 Geographical Distribution and Cultivation

World distribution and use of *Ginkgo biloba* are attributed to its availability and quality of medicines as well its worldwide outreach. Although it is indigenous to China, this is an ancient species of trees whose species has moved beyond its natural environment to be a well-grown medicinal and ornamental plant in almost every part of the globe. Its ability to quickly adjust to the varying environmental conditions and sustain urban stress factors has helped it to distribute itself worldwide[10]. Knowing about not only its indigenous source but also the contemporary farming also plays a critical role in determining the sustainability and standardization of *Ginkgo biloba* utilized in pharmacognostic endeavours.

- **Native Habitat**

Ginkgo biloba originated in China, where it has been grown since the very ancient time, especially in temple gardens and monastic landscapes. It is also thought to have escaped natural extinction sometime during cultivation by humans and thus is one of the longest cultivated trees species by humans[11]. Wild populations are very few, a small number existing in remote mountain valleys of Zhejiang and Guizhou Province, China, though there is a disagreement that these valleys may consist of long-naturalized rather than wild distribution.

- **Global Cultivation Patterns**

Ginkgo biloba is currently grown in all parts of the globe due to its high level of resistance, flexibility, and cultural conservation. It grows well in temperate regions; it is usually cultivated in North America, Europe, Korea and Japan. It has a high pollution, pest, and poor soil tolerance and is therefore commonly used in urban landscape and an especially common city street tree. Significant commercial production occurs in China, South Korea and the United States, where large scale production occurs, almost solely in order to collect leaves to make standardized extracts like EGb 761. These developed plantations are commonly grown in controlled agricultural systems in order to maintain the dependence and quality of the medicinal raw substance[12].

Table 2: Native Habitat vs Global Cultivation[13]

Region	Cultivation Status	Notes
China	Native + Commercial Cultivation	Naturalized in mountain valleys; large-scale leaf plantations
South Korea	Commercial Cultivation	Major exporter of Ginkgo leaf extract
United States	Ornamental + Commercial Use	Extensively used in landscaping; farms for pharmaceutical leaves
Europe (Germany, France)	Ornamental + Supplement Market	Used in memory-enhancing supplements
Japan	Ornamental	Highly symbolic in culture; planted near temples and shrines
India	Limited Cultivation	Mostly ornamental, research-based use in Ayurvedic formulations

3. METHODOLOGY AND FINDINGS

The neuroprotective capability of *Ginkgo biloba*, a broad set of research methods with the use of both preclinical and clinical research of both human subjects and laboratory animals and animal experiments. All these methodologies have helped to develop the knowledge with regards to the pharmacological actions and therapeutic importance of *Ginkgo biloba* with the neurodegenerative illnesses like Alzheimer, Parkinson and comedy. It has been the subjects of these studies, where standardized extracts such as EGb 761 have shown consistent results in matters of antioxidant, anti-inflammatory and anti-apoptotic effects[14]. Whereas in vitro experiments demonstrate the cellular interactions of the bioactive compounds in Ginkgo, in vivo conditions provide relevance in regard to the cognitive and behavioural performances. Clinical trials also further advance this awareness in showing the conversion of these effects into actual health advantages. This section summarizes the results of all these different methodological backgrounds and underlines the biological procedure in which *Ginkgo biloba* may uphold the well-being of the neuron and how this may be the probable therapeutic treatment.

Table 3: Summary of Literature on Neuroprotective Role of Plant-Based Compounds

Author Name	Topic Covered	Research Study Title
Shoaib et al. (2023)[15]	Role of plant-derived bioactive compounds in neuroprotection	Plant-derived bioactive compounds in the management of neurodegenerative disorders: challenges, future directions...
Kulić, Lehner, & Dietz (2022)[16]	EGb 761 standardization and its efficacy in neurodegeneration	*Ginkgo biloba* leaf extract EGb 761® as a paragon of the product by process concept

Saleh et al. (2025)[17]	Neuroprotective potential of Moringa oleifera	The Miracle Moringa Oleifera Tree: A Bibliometric Review of Its Neuroprotective Properties
Das et al. (2024)[18]	Use of phytochemicals in Parkinson's disease and personalized medicine	Phytochemicals in Parkinson's Disease: A Pathway to Neuroprotection and Personalized Medicine
Abdolmaleki et al. (2020)[19]	Historical overview of herbal neuroprotective agents in humans and animals	Herbal medicine as neuroprotective potential agent in human and animal models: A historical overview
Wadood (2024)[20]	Pharmacognosy, antioxidants, and nutritional approaches in stroke prevention and recovery	Pharmacognosy, Antioxidants, Natural. Nutrition and Stroke: Current State and Future Perspectives

3.1 Clinical and Preclinical Evidence of Neuroprotective Effects

This part is a review of major scientific studies that examined the neuroprotective effect of *Ginkgo biloba* through preclinical (laboratory and animal) and clinical (human based) investigations. The preclinical studies are based and they determine the underlying cellular and molecular mechanisms of action and the clinical studies assess the effectiveness under routine conditions of standardized *Ginkgo biloba* formulations, such as EGb 761. In combination, these study methods are certain to outline the validity of *Ginkgo biloba* as a possible treatment alternative in the management of neurodegenerative diseases[21].

3.1.1 In Vitro Studies and Cellular Mechanisms

Isolated cells are used in in vitro experiments occurring under laboratory settings. Such models are particularly helpful when ascertaining interdependence of extracts of *Ginkgo biloba* at the cellular and the biochemical level.

- Cultured studies of neurons indicate that EGb 761 enables the preservation of the viability of the neurons when the cells are exposed to oxidative or chemical stresses. These investigations emulate pathological situation such as Alzheimer or Parkinson disease.
- The extract has demonstrated to be protective to oxidative stress and apoptosis which are considered major neurodegenerative processes. *Ginkgo biloba* prevents the death of neurons by decreasing the generations of reactive oxygen species (ROS) and modulating the apoptotic pathways.
- It can also enhance mitochondrial performance and cut down the levels of ROS, which are indispensable in the provision of energy as well as the wellbeing of the cell in the neurons. The dynamics of healthy mitochondria are directly associated with the enhanced brain performance and lower rates of aging[22].

3.1.2 In Vivo Evidence from Animal Models

In vivo involves the use of live animals (usually rodents) and in it, effects of *Ginkgo biloba* on the brain of a living organism are sought. The models recreate that which happens on the human neurodoxafy to evaluate the treatment value of plant-derived compounds[23].

- To test effectiveness of EGb 761, rodent models of Alzhiemer, Parkinson, and ischemic stroke have been employed. Such animals are made either chemically or genetically altered to express symptoms of disease.
- Results include such behavioural improvements, as enhanced memory performance and learning ability and reduced anxiety-like behaviour, usually measured with such tools as the Morris water maze or Y-maze, after applying *Ginkgo biloba* extracts.
- Molecularly, the administration of EGb 761 brings about a decline in the number of inflammatory markers like IL-6 and TNF-a, and a considerable decline in the build-up of amyloid plaque, which is typical of Alzheimer pathophysiology. Such transformations imply cognitive as well as physiological levels of improvements.

3.2 Pharmacological Mechanisms and Therapeutic Evidence

The major biological mechanisms discussed in this section depict how *Ginkgo biloba* acts as neuroprotective. EGb 761 is the standardized extract licensed with active ingredients including the flavonoids and the terpenoids, which react with the multiple brain aging and neurodegenerative molecular pathways[24]. This knowledge of the mechanisms also explains the effectiveness of *Ginkgo biloba* but also defends its therapeutic potential in diseases such as Alzheimer, Parkinson and age-dependent decline of cognitive functions.

Table 4: Major Active Constituents in EGb 761

Class	Compounds	Pharmacological Role
Flavonoids	Quercetin, Kaempferol, Isorhamnetin	Antioxidant, anti-inflammatory
Terpenoids	Ginkgolide A, B, C, J; Bilobalide	Neuroprotective, anti-platelet
Organic acids	Shikimic acid, Vanillic acid	Modulate free radicals
Other compounds	Proanthocyanidins, Sitosterol	Cardioprotective, anti-aging effects

3.2.1 Antioxidant Activity

Neurodegenerative diseases the development of neurodegenerative diseases is closely linked to neuronal loss and aging through oxidative stress. *Ginkgo biloba* is a very potent antioxidant:

- It aids in neutralizing reactive oxygen species (ROS) very harmful products of cellular metabolism that include protein breakdown, genomic and membrane destruction[25].

- Flavonoids in Ginkgo like; quercetin and kaempferol have been shown to have the ability to scavenge directly free radicals in the body and directly stimulates the own system of antioxidant enzymes in the body thus providing protection against oxidative stress.
- *Ginkgo biloba* suppresses lipid peroxidation, during which free radicals oxidize fatty acids in cell membranes, which causes the aging of cells and neurodegeneration. This helps in maintenance of structure and functions of neurons.

3.2.2 Anti-inflammatory Effects

Most devastating neurodegenerative diseases such as Alzheimer are strongly linked to chronic inflammation in the brain, which hastens the destruction of the neurons.

- *Ginkgo biloba* has the possibility to suppress pro-inflammatory cytokines, such as tumor necrosis factors-alpha (TNF-alpha), and interleukin-6 (IL-6), which are raised in neurodegenerative disorders[26].
- It is, also, useful in inhibiting microglial activation. The immune cells of the brain are microglia; they are vital in defense but in excess, they cause inflammation and harm the neurons.
- Down regulation of such inflammatory responses, therefore ensures that Ginkgo attenuates neuroinflammation that contributes significantly in the pathology of Alzheimer disease. These anti-inflammatory impacts play a major role in making the neuronal environment healthier.

3.2.3 Anti-apoptotic Mechanisms

Programmed cell death (apoptosis) is the regulated loss of neurons that is over-compensated in case of their dysregulation.

- *Ginkgo biloba* supplements help in inhibition of neuronal apoptosis by mediating with G-protein signaling pathway, in turn inhibiting the stress-induced neuronal apoptosis and tissue injury[27].
- It regulates the mitochondrial membrane potential, vital in production of energy and survival of the cell. The dysfunction of mitochondrial is an early occurrence in neurodegenerative disorders and this stabilization ensures the health of brain cells.
- *Ginkgo biloba* also ensures that mitochondria are defended and fewer apoptotic signals are created thus enhancing the survival of neurons in the long-term and this factor plays a critical role in preventing a brain disorder s development.

Table 5: Pharmacological Mechanisms of *Ginkgo biloba* Extract[28]

Mechanism	Action
Antioxidant	Scavenges free radicals, prevents lipid peroxidation
Anti-inflammatory	Reduces cytokine release (TNF-α, IL-6), suppresses microglial activity
Anti-apoptotic	Inhibits caspase pathway, preserves mitochondrial function
Neurotransmitter Modulation	Enhances ACh activity; modulates serotonin, dopamine
Improved Blood Flow	Inhibits platelet-activating factor (PAF), vasodilation

4. DISCUSSION

The study of *Ginkgo biloba* as an agent against neuroprotection has become a subject of large-scale interest to various subsets of pharmacology since the herb has a very extensive pharmacological background with an ancient and deep-seated presence in traditional as well as modern medicine. Based on several preclinical and clinical research findings, this review has analysed how successful it is in its therapeutic effects at preventing neurodegenerative processes by antioxidant effects, anti-inflammatory effects, anti-apoptotic effects and neurovascular effects. The results of the previous chapters have given vital information on how the *Ginkgo biloba* (especially, its standardized extract EGb 761) can be used therapeutically in diseases like Alzheimer, Parkinson and vascular dementia. The purpose of the discussion is to interpret and analyse the scientific evidence, point out the wider implications of its usage in the clinical practice and point to current research gaps in relation to which the discussed evidence should be utilised to maximize its therapeutic usage[29].

4.1 Interpretation and Analysis of the Findings

The idea that *Ginkgo biloba* exhibits neuroprotective effects in the brain is corroborated by ample evidence of preclinical and clinical studies of its experiments and experiments, indicating its multifactorial activities of action against neurodegenerative disorders. The standardized extract EGb 761 has been shown to have a potent protective effect in all in vitro studies on cultured neuronal cells through attenuation of oxidative damage and prevention of apoptotic cell death[30]. This is mainly done by regulation of reactive oxygen species (ROS), maintenance of mitochondrial integrity, and stabilization of the cellular redox state, all of which are essential in the maintenance of neuronal viability during stressful conditions. These neuroprotective effects have also been confirmed in animal models of Alzheimer-related dementia, Parkinson disease, and cerebral ischemia by in vivo experiments[31].

These models demonstrated large cognitive improvements, substantial declines in amyloid-beta plaque burden, and the decrement of pro-inflammatory cytokines including interleukin-6 (IL-6) and tumour necrosis factor-alpha (TNF-alpha), which major contributors to neuroinflammatory

mechanisms. In addition, *Ginkgo biloba* showed the potential to regulate neurotransmitter pathways, increase blood flow to the brain, and stimulate synaptic plasticity, thus contributing to neural resilience in general. Despite certain differences in effects according to the design of the studies, dosage, and demographics of the population of patients studied, clinical trials demonstrated an overall positive impact on improving memory, attention, and overall functioning in a population affected by mild to moderate dementia. Such laboratory findings are corroborated by corresponding clinical outcomes and highlight the potential of the extract to exert its effects using a synergistic pharmacological profile[32].

4.2 Implications and Significance

1. ***Ginkgo biloba* as a Multi-Targeted, Plant-Based Therapeutic Option**: The results of the numerous preclinical and clinical researches underline the potential of using *Ginkgo biloba* in plant-based medicine to provide the solutions being able to respond to several facets of neurodegenerative disorders evolution. Unlike the pharmaceutical drugs, that often affect only one single molecular target or pathway, *Ginkgo biloba* can be characterized by the wide range of the biological activity[33].
2. **Role of Active Constituents in Neuroprotection**: *Ginkgo biloba* has a great number of neuroprotective properties that are mostly explained by the presence of bioactive compounds namely flavonoids and terpenoids. Flavonoids include quercetin and kaempferol as having potent antioxidant and anti-inflammatory effects and protect against reactive oxygen species (ROS), reduce lipid peroxidation, and promote mitochondrial health. They have a range name, terpenoids (e.g. ginkgolides and bilobalide), which are important in improving blood flow in the brain, regulating the activities of neurotransmitters as well as safeguarding neuronal structures against excitotoxicity and degeneration[34].
3. **Clinical Relevance in Aging and Integrative Medicine:** The fact that populations around the world are aging, there is a frightening increasing rate in developing cognitive disorders. With regard to it, *Ginkgo biloba* is a rather cheap, natural intervention that may aid in dealing with early-stage cognitive impairment before it is transformed into something harder to cope with as dementia. Its preventive use is of particular value to populations at risk, and its compatibility with the incorporation into comprehensive treatment approaches makes it useful in complementary and integrative medicine[35].

4.3 Gaps and Future Research Directions

The results of the study are encouraging, still, there are a number of gaps in the present research that restraint their higher clinical use[36]:

- Different clinical trial methods: variation in dosage, duration of treatment, cognitive test instruments, and demographics of subjects make results inconsistent and minimize the ability to compare different studies[37].
- Lack of long-term data: Although short term effects have been reported the efficacy and safety in the long run are lacking, particularly in severe cases of neurodegeneration[38].

- Ambiguous synergistic interactions: Although *Ginkgo biloba* affects multiple constituents, the way their interactions work synergistically on the molecular levels requires further studying by using genomics, proteomics, and metabolomics strategies[39].
- Unavailability of comparative studies: There have been hardly any cross-comparative trials where EGb 761 has been put in direct contest against commonly used neuroprotective medications (e.g., donepezil) before it could be focused in the clinical practice as a competing substance[40].

5. CONCLUSION

The increased global prevalence of neurodegenerative diseases and the inefficiency of modern pharmacological medications, the study of plant-based remedies is becoming exceptionally acute. Among them, *Ginkgo biloba* seems to be in a different league since it has a long medicinal history and a big evidence base confirming its role in neurological activity. The purpose of the present review was to offer a detailed pharmacognostic and pharmacological evaluation of *Ginkgo biloba* regarding their usefulness in preventing and treatment of cognitive decline and neurodegenerative disorders.

5.1 Summarize main insights and conclusion

The neuroprotective potential of *Ginkgo biloba* extracts has therefore been subject of critical review and evaluation with respect to the pharmacognostic properties, bioactive constituents, and therapeutic importance in neurodegenerative disorders. A considerable number of preclinical studies provide evidence that standardized *Ginkgo biloba* extract (EGb 761) has a potent antioxidant, anti-inflammatory, anti-apoptotic, and neurovascular profile, which mutually add to neuronal survival and better cognitive performance. Its ability to control reactive oxygen species (ROS) along with stabilizing the activities of the mitochondrion are established in vitro, and proven cognitively-enhancing with respect to lowered amyloid-plaque deposition and inflammatory cytokines in in vivo animal models. There is homogeneity between clinical trials and laboratory results in that patients with mild to moderate dementia have exhibited improvements in their cognitive functions. This confirms the multi-targeted pharmacological properties on this extract and the possibility of acting as a multi-pathway modulator of brain aging and neurodegeneration.

5.2 Reiterate the importance of the revie

This review is important as it includes the integrative methodology that addresses introduction to the pharmacognostic assessment of *Ginkgo biloba* effects, the mechanistic and the clinical details that help to achieve an entire concept of neuroprotective actions of Ginkgo bilober. With the increasing burden of neurodegenerative disease in the world and limited efficacy and tolerability of conventional treatment methods, there has been an increasing interest in safe, natural, and economical substitutes. *Ginkgo biloba* one of the earliest ancient medicinal plants that are very deep in conventional medicines has come out as one of the most researched herbal supplements

dealing with brain health. This makes it more interesting to pharmacognosy, neuroscience and complementary medicine because it has an evidence-based potential to become a neurotherapeutic agent.

5.3 Recommendations

- **Conduct large-scale, well-designed clinical trials**: Tracing the long term trials on the safety and therapeutic effect of *Ginkgo biloba* in different patients is a puzzle that has plagued the research experts in the future to ensure the lasting safety and therapeutic properties of *Ginkgo biloba* especially in the different stages of the neurodegenerative diseases.
- **Standardize *Ginkgo biloba* extracts**: The consistent and high-quality formula, e.g., EGb 761, should be emphasized to achieve reproducibility of results and clinical reliability.
- **Harmonize clinical research protocols**: Consistency in clinical trials design: dose, treatment time, evaluation instruments of cognition is necessary in order to make comparisons and meta-analysis of the study outcome possible.
- **Investigate molecular interactions using advanced techniques**: Omics-base methods (genomics, proteomics, metabolomics) must be used to examine the synergistic action of flavonoids and terpenoids as well as other ingredients on a molecular level.
- **Conduct comparative studies with standard neuroprotective drugs**: Clinical trials comparing *Ginkgo biloba* (e.g., EGb 761) with such conventional drugs as donepezil or memantine will position it better in clinical practice.
- **Use as a supportive therapy in early-stage cognitive decline**: Regarding the existing evidence, *Ginkgo biloba* could be considered as a choice of a complementary and natural therapy in patients with mild cognitive decline as a component of integrative care, preferably with the help of a medical worker.

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