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Medicinal Plants for Toothache Management in Northeastern Khuzestan: A Review of Traditional and Ethnobotanical Evidence

Amir Mahmoudi ¹ , Mobin Ghasemi ^{2*} 

¹ Faculty of Dentistry, Ilam University of Medical Sciences, Ilam, Iran.

² School of Stomatology, Zhengzhou University, Zhengzhou, Henan, China.

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*Corresponding Author

Email:
mmm1221ccc@gmail.
com

ABSTRACT

Toothache is among the most common complaints affecting oral health and has historically been managed through a combination of traditional healing practices, indigenous knowledge, and, more recently, modern dental care. Medicinal plants have long constituted an important part of these traditional approaches. This review aimed to identify and compare medicinal plants reported for the management or alleviation of toothache in northeastern Khuzestan, southwestern Iran, based on evidence from traditional medicine and ethnobotanical sources. Relevant information on medicinal plants used to treat or alleviate toothache was compiled from available literature on traditional medicine and ethnobotanical practices in the region. Reported species were examined and compared according to their scientific names, botanical families, plant parts used, and reported therapeutic applications, with particular attention to their use for toothache and other oral complaints. Ten medicinal plants were reported in traditional medicine practices documented in Andimeshk for the relief of toothache. Among these species, members of the families *Lamiaceae* and *Anacardiaceae* were particularly represented. Ethnobotanical studies conducted in the region have additionally reported nine medicinal plants in connection with the treatment or alleviation of dental complaints. Among these, *Dianthus crinitus*, *Teucrium polium*, *Fritillaria imperialis*, *Lycopersicum esculentum*, and *Solanum nigrum* were more specifically associated with toothache relief. The occurrence of *Teucrium polium* in both traditional medicine and ethnobotanical records indicates a degree of convergence between the two bodies of knowledge, although the available evidence does not establish whether this reflects historical continuity, independent observation, or transmission of therapeutic practices. A diverse range of medicinal plants has been documented for toothache in northeastern Khuzestan, but overlap between traditional and ethnobotanical records is limited. These records may help identify candidate species for phytochemical, pharmacological, and, where justified, clinical research. Traditional use alone cannot establish efficacy, quality, or safety, and should not replace dental diagnosis and treatment.



Introduction

Toothache is one of the most common symptoms associated with oral and dental disorders and may result from a variety of underlying conditions, including dental caries, pulpal inflammation, periodontal disease, odontogenic infections, and other pathological changes affecting the oral tissues (Raab, 1991). Depending on its intensity and duration, dental pain can significantly interfere with eating, sleep, daily activities, and overall quality of life (Sessle, 1987). Although modern dental care remains the primary approach for diagnosing and treating the underlying causes of toothache (Álvarez-Vásquez et al., 2022), medicinal plants and traditional remedies continue to be used in many communities, particularly in settings where indigenous therapeutic knowledge has been transmitted across generations (Megersa et al., 2019).

Medicinal plants have historically played an important role in traditional healthcare systems, including the management of pain, inflammation, infectious diseases, and various oral and dental conditions. Their therapeutic relevance has often been attributed to the diverse bioactive compounds present in different plant tissues ((Briskin, 2000, Rosas-Piñón et al., 2012)). Nevertheless, the use of medicinal plants in traditional medicine is generally embedded within broader systems of health, disease recognition, prevention, and treatment rather than being limited to isolated remedies. Traditional knowledge may encompass the selection of a particular species, the plant part used, methods of preparation, route of administration, dosage, and specific therapeutic indications. Such knowledge can be preserved in written medical traditions as well as transmitted orally from one generation to the next (Jamshidi-Kia et al., 2018). Ethnobotany, in contrast, addresses the broader relationships between people and plants. Although medicinal use represents a major component of ethnobotanical research, the field also encompasses nutritional, cultural, economic, ecological, and ritual aspects of plant use (Zougagh et al., 2019).

Khuzestan Province, particularly the areas bordering the southwestern Zagros region, provides a distinctive ecological and cultural setting in which traditional knowledge of medicinal

plants has developed and persisted. Within this broader context, Andimeshk represents an important locality for documenting plant-based healthcare practices and the associated knowledge held by local communities. Systematic documentation of plants used for toothache and other oral health problems may contribute to the preservation of traditional knowledge that could otherwise be diminished through social and cultural change. At the same time, such documentation can help identify plant species that warrant further phytochemical, pharmacological, and, where appropriate, clinical investigation. Comparing information derived from traditional medical sources with evidence from ethnobotanical studies may further reveal areas of convergence and divergence between these knowledge systems and provide insight into the recurrence of particular therapeutic practices.

Despite the longstanding use of medicinal plants in traditional healthcare and the substantial burden of toothache as an oral health problem, direct comparisons between plants documented in traditional medicine and those reported in ethnobotanical studies from Andimeshk remain limited. Examining these two bodies of knowledge together may therefore provide a more comprehensive picture of the medicinal plants traditionally associated with toothache management in the region. Such a comparison may also help identify species that recur across different sources or appear to have particular traditional significance. Importantly, however, recurrence in traditional or ethnobotanical records should not be interpreted as evidence of therapeutic efficacy or safety. Rather, repeated documentation may indicate cultural or therapeutic relevance and can serve as a basis for generating hypotheses and prioritising candidates for subsequent scientific investigation.

Accordingly, this study aimed to identify, document, and compare medicinal plants reported for the management or alleviation of toothache within traditional medicine and ethnobotanical knowledge in Andimeshk, with particular emphasis on similarities and differences in plant species, botanical families, plant parts used, and reported therapeutic applications. The study also sought to identify species shared between the two knowledge domains and to highlight plants that

may warrant further investigation through phytochemical, pharmacological, and, where justified by the available evidence, clinical research.

Methods

This study was conducted as a narrative review of published scientific literature, ethnobotanical studies, and documented traditional medical knowledge concerning medicinal plants used for the management or alleviation of toothache in northeastern Khuzestan, southwestern Iran. The geographical focus included Andimeshk and the surrounding areas of Dezful, Masjed Soleyman, and Andika. Relevant information was identified through published scientific articles, ethnobotanical reports, regional studies, available online literature, and documented accounts of traditional medical practices among local communities. Sources were considered relevant when they provided information on the use of medicinal plants for toothache, dental pain, or related oral health conditions.

For each eligible plant, data were extracted on the accepted scientific name, reported local or vernacular name, botanical family, plant part used, method of preparation or administration, and reported therapeutic application. The information obtained from traditional medicine sources was subsequently compared with that reported in regional ethnobotanical studies to identify similarities and differences between the two knowledge domains. Particular attention was given to plant species occurring in both sources, as well as to plants for which experimental or pharmacological evidence was available concerning analgesic, anti-inflammatory, antimicrobial, or other biological activities potentially relevant to oral pain and dental disorders.

The findings were synthesised descriptively and interpreted in relation to both traditional use and available scientific evidence. No quantitative meta-analysis was undertaken because of the heterogeneous nature of the available literature and the predominantly descriptive character of the ethnobotanical and traditional medicine data. The presence of a medicinal plant in traditional or ethnobotanical records was interpreted as

evidence of reported traditional use rather than as confirmation of therapeutic efficacy or safety. Where available, experimental and pharmacological findings were used to provide contextual support for the reported traditional applications, while recognising that laboratory or preclinical evidence cannot be directly equated with clinical effectiveness in humans.

Results

Comparison of the information retrieved from traditional medicine sources and ethnobotanical studies in northeastern Khuzestan identified ten plant species documented in traditional medicine sources and nine species reported in ethnobotanical literature in relation to toothache or other dental problems. Only one species, *Teucrium polium* L. (Mariam-nokhodi), was common to both datasets. In both sources, the aerial parts of this plant were reported to be used for the relief of toothache.

The traditional medicine sources documented the use of *Syzygium aromaticum*, *Pistacia atlantica*, *Pistacia khinjuk*, *Mentha longifolia*, *Teucrium polium*, *Peganum harmala*, *Ruta graveolens*, *Thymus vulgaris*, *Glycyrrhiza glabra*, and *Cinnamomum verum* for toothache relief. At the family level, *Lamiaceae* was the most frequently represented family, comprising three species: *Mentha longifolia*, *Teucrium polium*, and *Thymus vulgaris*. *Anacardiaceae* was the second most represented family, with two species, *Pistacia atlantica* and *Pistacia khinjuk*.

The ethnobotanical sources reported nine species: *Allium cepa*, *Ammi visnaga*, *Dianthus crinitus*, *Teucrium polium*, *Fritillaria imperialis*, *Vicia faba*, *Solanum lycopersicum*, *Solanum nigrum*, and *Smyrniium cordifolium*. Most of these species were reported in relation to toothache or dental pain. However, the reported use of *Smyrniium cordifolium* as a “dental worm remedy” represents a distinct therapeutic indication and should therefore be differentiated from uses specifically intended to relieve toothache.

The two datasets showed marked differences in species composition, botanical families, plant parts used, and reported methods of preparation or administration. In traditional medicine sources,

examples included the gum or resin of *Pistacia* species, flower buds of *Syzygium aromaticum*, seeds of *Peganum harmala*, roots of *Glycyrrhiza glabra*, and bark of *Cinnamomum verum*. In contrast, ethnobotanical reports documented the use of different plant parts, including the bulb and leaves of *Allium cepa*, flowering aerial shoots of *Ammi visnaga*, and flowers of *Dianthus crinitus*. Overall, only one species, *Teucrium polium*, was common to the traditional medicine and ethnobotanical datasets. This limited overlap indicates that the species composition of the two bodies of knowledge was largely distinct, despite their shared focus on plant-based approaches to dental complaints. The available data do not permit conclusions regarding the historical transmission or continuity of these therapeutic practices. Detailed information on the identified species, botanical families, plant parts used, and reported therapeutic applications is provided in Tables 1 and 2.

Discussion

Toothache is a common symptom of oral and dental disorders and may arise from a range of

conditions, including dental caries, pulpal inflammation, periodontal disease, and odontogenic infections (Raab, 1991). Although contemporary dentistry provides the principal means of diagnosing and treating the underlying causes of dental pain, plant-based remedies continue to form part of healthcare practices in many communities where traditional medicine and indigenous knowledge remain influential. The continued use of medicinal plants should, however, be considered primarily as evidence of cultural and therapeutic practice rather than as proof of clinical efficacy. Traditional use alone cannot establish effectiveness, an appropriate dose, or safety in humans. The present review identified ten plant species reported in traditional medicine sources and nine species documented in regional ethnobotanical literature in association with toothache or other dental complaints. A striking finding was the limited overlap between these two bodies of knowledge: only *Teucrium polium* L. was identified in both datasets.

Table 1. Medicinal plants reported for the management of toothache in ethnobotanical sources from northeastern Khuzestan (Khodayari et al., 2014).

Scientific name	Persian/local name	Family	Plant part(s) used	Reported therapeutic use
<i>Allium cepa</i> L.	Piyaz	Amaryllidaceae	Bulb; heated leaves	Toothache
<i>Ammi visnaga</i> (L.) Lam.	Khelal-dandan	Apiaceae	Flowering aerial shoots	Toothache
<i>Dianthus crinitus</i> Sm.	Mikhak-e Pashmalo	Caryophyllaceae	Flowers	Relief of toothache
<i>Teucrium polium</i> L.	Maryam-nokhodi	Lamiaceae	Aerial parts	Toothache
<i>Fritillaria imperialis</i> L.	Laleh-vozhgun / Ashk-e Maryam	Liliaceae	Fruit; bulb	Toothache
<i>Vicia faba</i> L. / <i>Faba vulgaris</i> Moench	Baghela	Fabaceae	Leaves and seeds	Mixed with almond gum (<i>zadu</i>) for the relief of toothache
<i>Solanum lycopersicum</i> L.	Gojeh-farangi	Solanaceae	Leaves and stems	Leaf and stem decoction used for toothache
<i>Solanum nigrum</i> L.	Taj-rizi	Solanaceae	Aerial parts and fruits	Analgesic use; relief of toothache
<i>Smyrniium cordifolium</i> Boiss.	Ab-andul / Avandu	Apiaceae	Stem	Reported for dental complaints (“dental worm” remedy)

Table 2. Medicinal plants reported for the management of toothache in traditional medicine in northeastern Khuzestan

Common/local name	Scientific name	Family	Plant part(s) used	Reported traditional use
Clove	<i>Syzygium aromaticum</i>	Myrtaceae	Flower buds	Traditionally used for toothache relief
Baneh (wild pistachio)	<i>Pistacia atlantica</i>	Anacardiaceae	Gum/resin	Traditionally used for toothache
Kholang (wild pistachio)	<i>Pistacia khinjuk</i>	Anacardiaceae	Gum/resin	Traditionally used for toothache
Wild mint	<i>Mentha longifolia</i>	Lamiaceae	Leaves and aerial parts	Traditionally used for toothache
Germander	<i>Teucrium polium</i>	Lamiaceae	Aerial parts	Traditionally used for toothache
Syrian rue	<i>Peganum harmala</i>	Nitrariaceae	Seeds	Traditionally used for toothache
Rue	<i>Ruta graveolens</i>	Rutaceae	Aerial parts	Traditionally used for toothache
Thyme	<i>Thymus vulgaris</i>	Lamiaceae	Aerial parts	Traditionally used for toothache
Liquorice	<i>Glycyrrhiza glabra</i>	Fabaceae	Roots	Traditionally used for toothache
Cinnamon	<i>Cinnamomum verum</i>	Lauraceae	Bark	Traditionally used for toothache

Source: Traditional medicine sources from northeastern Khuzestan.

This finding suggests that traditional medicine and local ethnobotanical knowledge may encompass substantially different plant repertoires even when addressing a broadly similar health problem. Such differences may arise from several factors, including the geographical distribution and availability of plant resources, differences in cultural practices, the nature of the source material, variation in knowledge transmission, and differences in how dental pain and other oral conditions are locally conceptualised.

The shared occurrence of *T. polium* is nevertheless of particular interest. In both datasets, the aerial parts of the plant were reported to be used for toothache relief. Repeated documentation of the same species and plant part across different sources provides a useful basis for generating ethnopharmacological hypotheses. However, the recurrence of *T. polium* should not be interpreted as evidence of direct knowledge transfer or historical continuity between traditional medicine and ethnobotanical knowledge. Such conclusions would require evidence from historical records, ethnographic studies, and research into the social pathways through which medicinal knowledge has been acquired and transmitted.

The predominance of the family Lamiaceae among plants reported in traditional medicine is also noteworthy. *Mentha longifolia*, *Teucrium polium*, and *Thymus vulgaris* were all represented in this family. The frequent representation of *Lamiaceae* in traditional healthcare may partly reflect the widespread use of aromatic plants and their essential-oil-rich preparations for conditions

involving pain, inflammation, and infection. Members of this family contain diverse volatile and phenolic constituents that have been investigated for antimicrobial, anti-inflammatory, antioxidant, and analgesic activities. These characteristics provide a biologically plausible basis for investigating some Lamiaceae species used traditionally for dental complaints. Nevertheless, chemical composition alone cannot establish therapeutic value, and relationships between specific constituents, administered concentrations, biological activity, and clinical outcomes require systematic experimental evaluation.

The identification of *Pistacia atlantica* and *Pistacia khinjuk* in traditional medicine sources is another notable finding. In both cases, gum or resin was reported as the plant material used for toothache. The selection of resins in traditional dental care may be related to their physical properties, ease of topical application, or the presence of secondary metabolites with biological activity. However, the pharmacological relevance of these preparations cannot be inferred solely from their traditional use. Future studies should consider the chemical composition and standardisation of *Pistacia*-derived preparations, together with their antimicrobial, anti-inflammatory, analgesic, and toxicological profiles.

Differences in the plant parts selected across the two knowledge domains further illustrate the local specificity of traditional therapeutic practices. Traditional medicine sources included the flower buds of *Syzygium aromaticum*, gum or resin of *Pistacia species*, seeds of *Peganum harmala*, roots

of *Glycyrrhiza glabra*, and bark of *Cinnamomum verum*. Ethnobotanical sources, in contrast, documented materials such as the bulb and leaves of *Allium cepa*, flowering aerial shoots of *Ammi visnaga*, and flowers of *Dianthus crinitus*. These differences may reflect local availability, cultural preferences, preparation practices, perceived therapeutic properties of particular plant organs, or differences in how medicinal knowledge has been documented. Importantly, they also highlight why comparisons based solely on plant species, without considering the plant part and preparation method, may provide an incomplete picture of traditional medicinal practice.

Evidence from other regions of Iran supports the view that plant-based approaches to toothache are diverse but may also show recurring patterns. Delfan et al., for example, documented 14 medicinal plants used for toothache relief in Lorestan, including *Peganum harmala*, *Punica granatum*, and *Ziziphora clinopodioides* (Delfan et al., 2014). The presence of *P. harmala* in both the present review and the Lorestan study suggests that some medicinal plants may have a broader cultural distribution across the Zagros region. At the same time, the absence of many species from one region that are reported in another indicates that local ecological resources and culturally specific therapeutic knowledge remain important determinants of plant selection. Although recurrence across geographically separated communities can strengthen the rationale for ethnopharmacological investigation, it does not by itself demonstrate efficacy.

Similar regional variation has been reported elsewhere in Iran. An ethnobotanical study from Shiraz identified 20 species belonging to 14 botanical families that were used traditionally for toothache, with *Dianthus hafezi* and *Papaver tenuifolium* among the more frequently reported species (Ahmadipour et al., 2015). The different species profiles observed in Shiraz and northeastern Khuzestan reinforce the heterogeneous nature of Iranian ethnobotanical knowledge. Rather than representing a uniform national pharmacopoeia, traditional plant use appears to be shaped by regional flora, ecological conditions, cultural practices, local experience, and patterns of knowledge transmission. Consequently, regional ethnobotanical documentation remains

important even when similar health problems are considered across different parts of the country.

A broader review of Iranian ethnobotanical literature also identified plants such as thyme, mint, ginger, garlic, liquorice, clove, and turmeric in relation to toothache relief (Ghaznavi & Lysiuk, 2024). The recurrence of several of these species across different sources may indicate relatively widespread recognition of particular plants within Iranian traditional healthcare. Proposed biological explanations include antimicrobial, anti-inflammatory, antioxidant, and analgesic activities (Ghaznavi & Lysiuk, 2024). However, much of the available evidence for medicinal plants remains based on in vitro experiments, animal studies, or investigations of isolated compounds. Such evidence can support mechanistic hypotheses but should not be equated with demonstrated clinical benefit in patients with toothache.

Comparable diversity has been documented outside Iran. An ethnobotanical review of Turkish traditional medicine reported numerous plants used for toothache, including representatives of *Lamiaceae*, *Asteraceae*, and *Solanaceae*, with genera such as *Origanum*, *Thymus*, and *Achillea* among those reported (Erbay et al., 2018). The occurrence of *Peganum harmala*, *Pistacia khinjuk*, *Solanum nigrum*, and *Syzygium aromaticum* in both Iranian and Turkish traditional medicine is particularly interesting. The recurrence of these species across geographically adjacent or historically connected regions may reflect shared ecological resources, cultural exchange, similar therapeutic observations, or independent development of comparable practices. Distinguishing among these possibilities would require dedicated historical and anthropological investigation rather than inference from plant-use similarities alone.

Evidence from southern Brazil provides a broader cross-cultural perspective. Buffon et al. documented several medicinal plants, including *Schinus terebinthifolius*, *Malva parviflora*, *Plantago major*, *Achyrocline satureioides*, *Mentha piperita*, and *Rosmarinus officinalis*, in relation to oral and dental disorders (Buffon et al., 2018). The substantial differences in species composition between southern Brazil and northeastern Khuzestan demonstrate the strong influence of geographical and cultural context on medicinal

plant selection. Nevertheless, the continued use of plants for oral and dental complaints across geographically distant societies indicates that plant-based management of dental problems represents a recurring component of traditional healthcare. Cross-cultural comparisons may therefore help identify plants or genera repeatedly associated with similar therapeutic indications and may provide useful hypotheses for comparative ethnopharmacological research.

An important consideration arising from the present findings is the need to distinguish plants used specifically for toothache from those employed for other dental or oral conditions. The reported use of *Smyrniium cordifolium* as a “dental worm” remedy, for example, represents a different therapeutic concept from direct analgesic management of toothache. Failure to distinguish these indications could lead to an overestimation of the number of medicinal plants specifically used for dental pain. Future ethnobotanical studies should therefore classify reported applications according to their therapeutic objectives, such as analgesic, anti-inflammatory, antimicrobial, anti-infective, periodontal, or antiparasitic use. Such classification would improve comparability between studies and facilitate more precise interpretation of ethnobotanical evidence.

From an ethnopharmacological perspective, several species identified in the present review merit further investigation. *Syzygium aromaticum*, *Thymus vulgaris*, *Mentha longifolia*, *Cinnamomum verum*, and *Glycyrrhiza glabra* are particularly interesting because of their established phytochemical diversity and reported biological activities relevant to pain, inflammation, and microbial infection. At the same time, species such as *Peganum harmala* and *Ruta graveolens* require a more cautious research approach because the presence of biologically active constituents does not necessarily imply a favourable therapeutic margin. For such plants, toxicological evaluation should accompany pharmacological investigation. Research prioritisation should therefore consider not only the frequency of traditional citation but also recurrence across independent sources, quality of botanical identification, phytochemical evidence, pharmacological activity, toxicological profile, and the feasibility of producing standardised preparations.

Among the plants identified in the present review, *Teucrium polium* may represent a particularly relevant candidate for further investigation because it was the only species shared by the traditional medicine and ethnobotanical datasets from the study region. Its repeated association with toothache and the consistent identification of the aerial parts in both sources provide a specific hypothesis that could be evaluated experimentally. Nevertheless, prioritisation of *T. polium* should not be interpreted as an endorsement of its clinical use. Further research should first establish botanical identity and authentication, characterise the chemical profile of the relevant plant material, evaluate pharmacological activity using appropriate models, assess toxicity and safety, and determine whether any observed effects can be reproduced using standardised preparations.

More broadly, translating ethnobotanical knowledge into evidence-based therapeutic applications requires a stepwise research strategy. Botanical authentication should be followed by standardisation of plant material and preparation methods, phytochemical characterisation, mechanistic studies, toxicological assessment, and appropriate preclinical investigations. Only when sufficient evidence of safety and biological activity has been established should clinical research be considered. Ultimately, well-designed controlled clinical trials are necessary to determine whether a plant-derived intervention provides clinically meaningful benefit for patients with toothache. This progression is particularly important because toothache may reflect underlying conditions requiring definitive dental treatment, and symptomatic relief should not delay diagnosis or management of the underlying pathology.

The present findings also have implications for the preservation and documentation of local medicinal knowledge. The relatively limited overlap between traditional medicine and ethnobotanical sources indicates that each source captures only part of the broader repertoire of plant-based healthcare practices in the region. This supports the value of integrating different types of evidence when documenting medicinal plant knowledge. Future field-based research in northeastern Khuzestan could further strengthen this evidence base by recording informant characteristics, preparation methods, dosage, frequency of use, perceived

effectiveness, adverse effects, and the cultural context in which particular remedies are employed. Quantitative ethnobotanical measures, including use value and informant consensus, may also help identify plants that have particularly strong local recognition.

Several limitations should be considered when interpreting the findings. First, the narrative nature of the review means that the conclusions depend on the availability, scope, and quality of previously published sources. Second, substantial methodological heterogeneity among ethnobotanical studies may limit direct comparison of reported plant uses. Differences in sampling strategies, informant characteristics, botanical identification, local nomenclature, plant parts, preparation methods, and definitions of toothache or dental disorders may all influence the reported species lists. Third, information on dosage, duration of use, standardization, adverse effects, and clinical outcomes was limited for many of the identified plants. Finally, the presence of a species in multiple traditional sources does not necessarily represent independent confirmation, particularly where studies may have relied on overlapping historical or ethnobotanical information. These limitations highlight the need for carefully designed field studies and transparent documentation of primary ethnobotanical data.

Overall, the findings indicate that traditional and ethnobotanical knowledge in northeastern Khuzestan encompasses a diverse range of medicinal plants associated with toothache and other dental complaints, while direct overlap between the two knowledge domains is limited. The identification of *T. polium* in both datasets provides a focused example of a plant whose traditional relevance warrants further investigation, whereas the recurrence of other species across different regions provides broader comparative hypotheses. However, these observations should be understood as evidence of reported traditional use rather than established therapeutic efficacy.

Conclusion

In conclusion, the medicinal plant knowledge documented in northeastern Khuzestan represents a potentially valuable source of hypotheses for

research into plant-derived approaches to oral and dental health. The limited overlap between traditional medicine and ethnobotanical records suggests that these knowledge domains capture different aspects of regional therapeutic practice, while the shared documentation of *Teucrium polium* provides a specific candidate for further ethnopharmacological investigation. Nevertheless, traditional use should not be equated with clinical efficacy or safety. Progressing from traditional knowledge to evidence-based therapy requires rigorous botanical authentication, phytochemical and pharmacological characterisation, toxicological evaluation, standardization of preparations, and ultimately appropriately designed clinical trials. Such an approach can help preserve and critically evaluate indigenous knowledge while providing a scientifically sound basis for identifying medicinal plants with genuine therapeutic potential.

Declarations Conflict of Interest

The authors declare no conflicts of interest.

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Consent for Publications

The authors certify that that this work in its final form has been thoroughly reviewed and approved for publication.

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Authors' Contributions

Conceptualization: Mobin Ghasemi
Data curation: Amir Mahmoudi
Formal analysis: Mobin Ghasemi
Funding acquisition: Mobin Ghasemi
Methodology: Amir Mahmoudi
Project administration: Mobin Ghasemi
Resources: Mobin Ghasemi
Software: Amir Mahmoudi
Supervision: Mobin Ghasemi
Validation: Amir Mahmoudi

Visualization: Amir Mahmoudi and Mobin Ghasemi
 Writing – original draft: Mobin Ghasemi
 Writing – review & editing: Amir Mahmoudi and Mobin Ghasemi

Ethical Considerations

This study was performed in line with the principles of the Declaration of Helsinki

AI Use Disclosure

AI tools were used solely for English language editing, grammar correction, and improving clarity and readability. No AI tools were used to generate or develop the scientific content. The authors take full responsibility for the final manuscript.

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