

A STUDY OF VARIOUS SPECIES AND TRANS-DISCIPLINARY PROMISE OF CALLISTEMON GENUS

Abstract

The present studies showed significant trans-disciplinary promise of Callistemon genus. Callistemon plant shows its presence as a star in the garden. The plant needs little care once fully grown. Weekly water is enough and can tolerate drought conditions. It is not picky about the soil type and doesn't require lots of fertilizers. It is easy to grow and an excellent attractor of bees or butterflies. Various species of the plant have been explained for a wide category of medicinal properties. Its essential oil has possessed various anti-microbial, fungi toxic, antinociceptive, anti-inflammatory activities. Not only is its medical value, but the plant is also known for the production of natural dye and acts as a natural polymer.

Significant Statement: This review aims to showcase the overall contribution of Callistemon genus to natural product chemistry. Here the author has summed up the information of various species of Callistemon in detail and their phytoconstituents, its activity as a dye, polymer, biological activity with the production of nano-sized material.

Keywords: Callistemon, polymer, dye, bioactivity, nanosized materials.

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I. INTRODUCTION

Callistemon is an evergreen tree or shrub and is commonly known as "Bottle-brush. It is a beautiful ornamental tree that belongs to the family Myrtaceae. The characteristics of the family Myrtaceae is having woody shrubs to tall trees. The leaves of trees are aromatic and containing oil glands and flowers are generally very attractive. The genus Callistemon has around 34 species out of which 10 species are grown in India. The plant has long, dense tufts of red stamen called filament which emerges from the flower. In 1789, the crimson bottle-brush was imported from Australia to Britain which increases its popularity. The plant is native to Australia [1-3] and well known for its graceful, drooping branches and cheerful, bright red or yellow stamen in the flower which forms a tufted cluster that having s shape that resembles a round brush. ". The genus Callistemon means 'Beautiful stamen' [4]. In Australia, bottle-brush trees acts as the host for cossid moth larvae called witchetty grubs which is a popular food for Australian peoples. The average height of bottle-brush species is 5 to 12 feet and tress can reach more than 30 feet in height. The wood of larger and taller species can be used as fuel or to make fence posts. In 19th century handbook of Australian plant, bottle-brush are mentioned as a source of lumber and one of the species of bottle-brush namely Callistemon pallidus is used for shipbuilding, wheelwright's work, and mallet handles. Initially, the tree was planted for ornamental purposes [5] and weed control [6, 7]. Its weed control property makes it a bio-indicators for the proper management of the environment. Traditionally bottle-brush flowers have been used for bed-wetting, urinary tract problems, constipation, and as diuretics. Earlier this genus was investigated by various medical properties like anti-microbial, larvicidal, and pupicidal activity [12]. Later on, various species of Callistemon are used for the treatment of skin disease, gastroenteritis, and diarrhea [13]. The species of Callistemon were used as traditional Chinese medicine for curing hemorrhoids [14]. Research has been revealed that the presence of phenolic derivatives, aliphatic acid, and steroids are present in almost all parts of the plants such as flowers, fruits, leaves, stem barks, and seeds [15-23]. Researchers have proved that some species of Callistemon built our immune system towards the heart, brain, and other organs of the body [24].

II. VARIOUS SPECIES OF CALLISTEMON

1. Common Name

Prickly Bottle-brush (Figure 1)

Botanical Name

Callistemon brachyandrus

Description



Figure 1

This species grows to about 9 feet and in hot and dry areas. The tips of red flower spikes are covered with yellow pollen.

2. Common Name

Crimson Bottle-brush (Figure 2)

Botanical Name

Callistemon citrinus

Description



Figure 2

This species grows is widely cultivated and the best-known bottle-brush. The height of crimson bottlebrush is about 13 feet and require wet soil condition.

3. Common Name

Kingaroy Bottle-brush(Figure 3)

Botanical Name

Callistemon formosus

Description



Figure 3

These species are grown in a tropical and frost-free areas. Its graceful and drooping branches go up to 9 feet. The flower spikes are yellow and evergreen throughout

the year. It grows along the street in Kingaroy, Australia that's why its common name is Kingaroy Bottle-brush.

4. Common Name

Lemon Bottle-brush(Figure 4)

Botanical Name

Callistemon pallidus

Description



Figure 4

This species grows well in almost all soil conditions that's why it is tough and frost-tolerant species. Its flower spikes are yellow and emerge in summer so it is commonly known as lemon Bottle-brush.

5. Common Name

Alpine Bottle-brush(Figure 5)

Botanical Name

Callistemon pityoides

Description



Figure 5

This species is very hardy and attractive. The height of this plant is 6 feet and its yellow flower spikes emerge in the spring and summer seasons.

6. Common Name

Willow Bottle-brush(Figure 6)

Botanical Name

Callistemon salignus

Description



Figure 6

The height of this species is 15 and 30 feet long. Its bark is white and papery and the species is drought resistant and has attractive narrow foliage. The flower spikes are white, cream, light, green, pink, and red are found.

7. Common Name

Dwarf Bottle-brush(Figure 7)

Botanical Name

Callistemon subulatus

Description



Figure 7

This species has a very small height of 3 to 9 feet and able to grow in wet soil conditions. Its flower spikes are bright red.

8. Common Name

Weeping Bottle-brush (Figure 8)

Botanical Name

Callistemon viminalis

Description



Figure 8

This species is 15 to 30 feet and widely cultivated for gardens. This species having bright red flower spikes and rich in nectar and attract birds. This variety needs enough water to keep the soil consistently moist.

III. CHEMICAL CONSTITUENTS PRESENT IN A DIFFERENT PARTS OF THE CALLISTEMON [8-11]

Table 1: Various possible major components present in the plant

S.R	Chemical Constituent	Plant part	Percentage %
2.	2-Hexanol	leaf	0.1
3.	α -Pinene	leaf	2.9
4	β -Pinene	leaf	0.2
5.	1,8-cineole	leaf	52.1
6.	γ -Terpinene	leaf	0.1
7.	Geranylacetate	leaf	0.2
8.	(E)-Caryophyllene	leaf	2.1
10.	(E)-Cinnamylacetate	leaf	1.7
11.	α -Humulene	leaf	0.5
14.	Geranylisobutanoate	leaf	0.1
15.	Dihydroxydurene	leaf	1.6
16.	Eugenol acetate	leaf	0.1
17.	β -Thujaplicinol	leaf	0.2
18.	Flavesone	leaf	1.3
19.	Spathulenol	leaf	0.5
20.	Caryophyllene oxide	leaf	0.5
22.	Methyl eugenol	leaf	0.1

24.	Leptospermone	leaf	0.2
25.	iso-Spathulenol	leaf	0.1
26.	Selin-11-en-4 α -ol	leaf	0.1
29.	Viridiflorene	leaf	0.1
30.	Linalool	leaf	1.5
32.	<i>Cis-p</i> -Menth-2-en-1-ol	leaf	0.1
33.	trans-Pinocarveol	leaf	0.5
34.	δ -Terpineol	leaf	0.3
35.	Terpinen-4-ol	leaf	0.8
36.	α -Terpineol	leaf	14.7
39.	trans-Carveol	leaf	0.1
40.	<i>Cis-p</i> -Mentha-1(7),8-dien-2-ol	leaf	0.1
41.	Geraniol	leaf	1.9
43.	Eugenol	leaf	14.2
44.	Neryl acetate	leaf	0.3
45.	Hydrocinnamyl acetate	leaf	0.1
46.	α -Copaene	leaf	0.3
47.	α -Thujene	flower	0.10
48.	α -Pinene	flower	16.0
49.	β -Pinene	flower	0.58
50.	1,8-Cineole	flower	66.93
51.	Limonene	flower	10.04
52.	γ -Terpinene	flower	0.42
53.	Linalool	flower	0.09
54.	endo-Fenchol	flower	0.15
55.	Borneol	flower	66.93
56.	Terpinen-4-ol	flower	10.04
57.	Spathulenol	flower	0.13
58.	1,8-cineol	fruit	38.8
59.	α -terpineol	fruit	15.7

- As a Source of Dye:** Synthetic dye creates various types of environmental and health hazards so awareness about the natural dye increased at the international level. Natural dyes have very good biodegradability and compatibility with the environment. Callistemon plant is a good source of dye [25]. The boiling method was adopted for extracting the dye from the plant flower. Some part of the extract was autoclave. Both autoclave and non-autoclave part of the extract of the flower was used for dyeing the cotton cloth by using copper sulfate and ferrous sulfate as mordants. Results have shown that the color strength of dye is more fastness, rub fastness and wash fastness with FeSO₄ mordanted. Exploration of Callistemon flower-based natural dye has been investigated by Singh et. al. [26]. Purple color dye is obtained by Callistemon citrinus for dyeing cotton. This study concluded that natural dye obtained from the plant shows non-toxic, non-allergic effects with less pollution and fewer side effects. The dye extracted from the bottlebrush was used on goat crust leather [27]. This study was carried out in the central and Northern Punjab (India). To give the fastness in the color pre-mordanting method was employed by using oxalic acid. This study reveals that *C. citrinus* gave a high dye yield

with good color fastness properties in terms of rubbing and light. The working of dye-sensitized solar cells (DSSC), a new class of low-cost solar cells depends upon the dye that is used as a sensitizer on it. The dye obtained from the flower of the crimson bottlebrush plant is largely used in it to make it eco-friendly and less expensive. The advantage of using natural dye as a sensitizer is that first, the extraction process is very easy and optimum absorption coefficients are also obtained [28]. Carotenoids and Anthocyanin, natural pigments used as a sensitizer in DSSC shown low to moderate solar energy conversion efficiencies [29-31].

- As a Source of Polymer:** Bulk and interfacial properties are the novel characteristics of bottlebrush polymers. The dense crowding of the polymeric side chain makes bottlebrush polymer for the interfacial active material. This property of bottlebrush can be utilized in the drug delivery for the development of new nanomaterial [32-34], responsive surface coating [35], organic electronics [36], and surfactant [37]. Poly (N-isopropylacrylamide) (PNIPAAm), a thermo-responsive polymer which shows a lower critical solution temperature (LCST) of 32°C [38-39]. By using a "grafting-through" technique PNIPAAm bottlebrush polymers with controlled side-chain length and side-chain end group structures were synthesized [40]. Below the LCST, PNIPAAm bottlebrush polymers show a temperature-dependent conformation with 9 kg mol⁻¹ side-chain and lyotropic liquid crystal ordering above the LCST. PNIPAAm bottlebrush polymers decrease the interfacial tension between water and chloroform and the stability of the formation of micro-emulsion was not seen. So, PNIPAAm-bottlebrush polymers are proven to have the properties of interfacial and macroscopic flexibility.

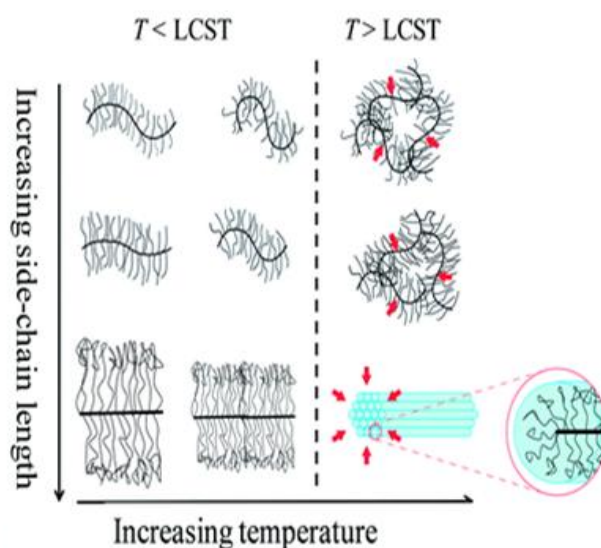


Figure 9: Schematic for changing bottlebrush polymer conformation with temperature. For short side-chains, the side-chain length is invariant with temperature. Above the LCST, bottlebrush polymers form disordered aggregates. For long side-chains, the side-chain length decreases with temperature, and above the LCST bottlebrush polymers exhibit lyotropic liquid crystal ordering due to the formation of structured aggregates [40].

Application of bottlebrush copolymer with their structure, function and self-assembly was investigated by Verduzco et. al. [41]. They reported the vast properties and functions of bottlebrush co-polymer in solution, films and melts. The application was also seen in drug-delivery, tumor detection and imaging and as a film for lithographic patterning. Redox-responsive branched-bottlebrush polymers was reported by Sower et. al. [42] for *in vivo* MRI and fluorescence imaging scientist investigated a new class of branched-bottlebrush polymer called organic radical contrast agent (ORCAFluors) in the field of *in vivo* MRI and IR fluorescence imaging. These materials shows a unique and novel compensatory redox response.

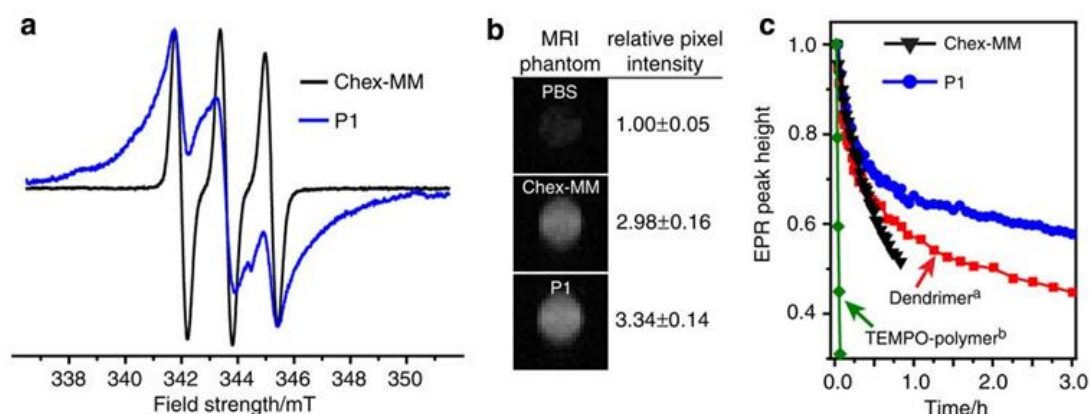


Figure: 10 (a) EPR spectra of chex-MM compared with $n=54$ bottlebrush polymer P1. (b) MRI phantoms and relative contrast enhancements (compared with PBS buffer) of chex-MM and P1. (c) Analysis of nitroxide reduction in response to ascorbate. a ‘dendrimer’ refers to previously reported fourth generation spirocyclohexyl nitroxide-functionalized poly(propyleneimine) dendrimer³¹. b ‘TEMPO-polymer’ refers to previously reported 2,2,6,6-tetramethyl-1-piperidinyloxy (TEMPO)-functionalized branched-bottlebrush polymers⁵³.

Cylindrical molecular brushes of Poly (2-oxazoline) on glassy carbon were prepared by Zhang et. al. [43]. A high side chain grafting density and quantitative reactions were proved by the characterization of the prepared bottlebrush brushes. Kinetics studies proved a linear enhancement in thickness with the polymerization time and it was reproducible. This study proves that bottlebrush brushes side chain end groups were fictionalizing with the molecule of sterical demand. Bottlebrush polymer shows a unique combinatory of molecular and particulate properties with important implications in cartilage and ultrasoft elastomer. Sidechain length and rigidity property of bottlebrush act as a melt of flexible filaments. This study providing a platform for the design of novel material without disturbing the chemical composition for architectural tuning in their characteristics [44].

IV. AS A BIOLOGICAL ACTIVE MATERIAL

Various species of *Callistemon* are known for their medicinal values such as antioxidant activity, antimicrobial activity, insecticidal properties, and other pharmaceutical activities. The extract and essential oil (EO's) of the *Callistemon* species is also a good medium for the preparation of nanoparticles. The EO of two species of *Callistemon* i.e. *C. citrinus* and *C. viminalis* from South Africa have been investigated for their antibacterial activity [45]. The invitro antibacterial activity was investigated against 12 bacterial strain. The results have shown that the strong zone of inhibition is shown by *S. faecalis*, *S. aureus*, *B. cereus* and *S. macrescens*. Zubair et. al. [46] reported the antioxidant activity and oil composition of *Callistemon viminalis* leaves. The plant leaves are extract and their antioxidant activity was studied as an oxidative substrate using sunflower oil. From the above investigation, the plant can be studied as a potential antioxidant source of the natural region. Cytotoxicity of plant extracts was in safe range against human erythrocytes so the plant can be used for natural and pharmaceutical therapies. From the time of ancient Egyptians, the *Callistemon citrinus* is used as a antimicrobial herb for the treatment of cough, bronchitis, inflammation, inhibition of bacterial growth and prevention of decay. Analysis of the essential oil of both the leaves and flowers of *Callistemon citrinus* for the antibacterial activities were examined and were found to have good antibacterial property. It has been concluded that the presence of phenolic compounds and cyclic ethers in bottlebrush are responsible for good pharmacological activity [47]. *Callistemon viminalis* essential oil was investigated as fumigant powder for two bruchids having insecticidal activities [48]. Plant aromatized clay power (ACP) was studied against the Bruchidae (*Acanthoscelides obtectus* and *Callosobruchus maculatus*).

The essential oil from the leaves of *C. viminalis* acts as a fumigant agent above two Bruchidae. A very interesting activity, the Allelopathic activity of essential oil from *Callistemon viminalis* has been reported [49]. Allelopathy has been explained as positive or negative interference of any process by which products of secondary metabolism of a plant are liberated into its environment and these products receive by another plant. These products are called allelochemicals. It can benefit or harm the receptor plant in the natural and agricultural systems. Tomato and lettuce are indicators of allelopathic activity. The essential oil from the flower of *C. viminalis* has 1,8-cineole, α -pinene, and limonene and has allelopathic activity at intensities proportional to the concentration of EO and responsible for the reduction in the germination speed index (GSI) in lettuce seeds as of roots and shoots of lettuce seedling. *Callistemon lanceolatus* leaf was investigated for anti-inflammatory activity [50]. The methanolic leaf extract of the plant was tested for anti-inflammatory activity at doses of 200 and 400mg/kg orally in rats and at the dose of 400mg/kg was found to be comparable with the standard drug of diclofenac sodium (50mg/kg). The fruit, bark and leaves ethanol extract of *C. viminalis* was tested for molluscicidal activity against *Biomphalaria alexandrina* Snails [51]. The fruit extracts proved to have the highest molluscicidal activity against the tested snails. The site of action of the tested extract is concentrated in the digestive system and hermaphrodite gland and it was proved by histopathological studies of these extracts. Bottlebrush plants were also evaluated for their anti-diabetic activity. Abdelhady et. al. [52] reported the in-vitro anti-diabetic activity of many *Callistemon* species via the result of the sucrase inhibitory activity test. In this study, an aqueous-alcoholic decoction was used to treat patients. The leaves of five bottlebrush plants were extracted with 80% methanol. Sucrase enzyme inhibitory activity test is used for the dry

residue of the alcoholic extract to measure their antidiabetic activity. The five bottlebrush plant was *C. rigidus*, *C. viminalis*, *C. lanceolatus*, *C. viridiflorus* and *C. comboynensis*. All the plant extract showed significantly inhibited ($p \leq 0.01$) sucrase activity and it is due to the presence of flavonoid diglycosides hydrolyzable tannins. The study has done invitro and invivo toxic tests and concluded that these extracts can be used as complementary drugs to help main medicines in treatments of diabetic patients.

Table 2: Sucrase enzyme activity in different species of Callistemon. [52]

S. No.	Sample	Sucrase I%±SD
1.	<i>C. lanceolatus</i>	54.64±2.34
2.	<i>C. viminalis</i>	61.21±3.65
3.	<i>C. viridiflorus</i>	52.54±2.53
4.	<i>C. comboynensis</i>	45.36±2.86
5.	<i>C. rigidus</i>	63.05±3.43

The antihyperglycemic activities of *Callistemon lanceolatus* stem extracts were investigated by Kumar et. al. [53]. This study reported the invitro and invivo antihyperglycemic activity of methanolic and aqueous extracts of stem of *C. lanceolatus*. There was a decrease in blood sugar level within 28 days and also showed improvement in body weight and HDL level in hyperglycemic rate. The three new phytoconstituents were investigated from the various aerial parts of *Callistemon lanceolatus* DC and the phytochemical investigation of the antidiabetic chloroform fraction of the ethanolic extract was reported. These three new constituents are 8-(1''-hydroxyisopranyl)-5,6-dihydroxy-7,4-dimethoxyflavone (a type of flavone) (I), 2,3,4-trihydroxyphenethyl tetracontanoate (a type of phenolic ester) (II), 2,3,4-trihydroxyphenethyl tetraconatanoate-4-β-xylo-pyranoside (a type of phenolic ester) (III). The compound (I) showed a decrease in blood sugar level significantly as compared to standard drugs Pioglitazone and Rosiglitazone in streptozotocin without causing any toxic effect on the pancreas and liver in diabetic rats. Compound (I) exhibited a glide score of -7.89 against PPAR-γ target in molecular docking studies against a reference molecule Rosiglitazone (glide score of -5.77) [54]. *Callistemon rigidus* stem bark showed an inhibitory effect on mouse α-amylase activity. Two constituents piceatannol and scirpusin B were isolated and showed inhibitory effects on α-amylase activity in isolated mouse plasma. These components also tested invivo for α-amylase in mouse gastrointestinal tract. The essential oil of *Callistemon rigidus* has been already investigated against cough, bronchitis and, respiratory infection in Europe. This study proved that the component scirpusin B present in *Callistemon rigidus* mildly suppressed activity in the gastrointestinal tract and found to suitable clinically the gentle improvement of postprandial hyperglycemic in diabetic patients [55]. A species of *Callistemon* (*C. viridiflorus*) is rich in polyphenols and used as folk medicine in anti-nociceptive and anti-schistosomal activities. The aqueous methanolic extract of *C. viridiflorus* leaves was analyzed by direct infusion ESI/MS and NMR. A new component i.e. polyphenol, Quercetin-(3'-O-4'')-3''-O-methyl-kaempferol, and several known other metabolites were also identified. The aqueous methanol extract is showed a significant anti-nociceptive and anti-schistosomal activity and non-toxic to experimental animals [56].

Callistemon flowers were investigated for their acid-base indicator properties. Flowers were extracted for their color pigments by using cold solvent extraction. The stability of the color and wavelength at 450nm was obtained. Volumetric experiments showed that the equivalence points observed by the flower extract coincided with that of the standard indicator. This study concluded that the *C. lanceolatus* flower extract is an excellent alternative in comparison to the synthetic one. This natural indicator is non-toxic, cost-effective, eco-friendly, precise, comprehensible, uncomplicated, and non-toxic [57].

V. ACT AS NANOSIZED BIOLOGICALLY ACTIVE MATERIALS

Green synthesis of nanosized HgO from the flower extract act as a reducing agent as well as a stabilizing agent. The phytoconstituents such as saponins, phenolic compounds, and flavonoids. UV-Vis absorption spectroscopy and FTIR showed the formation of the HgO nanoparticles. This study reported that the size of the nanoparticles can be easily adjusted by using different amounts of extract. This study has proved the potential of Callistemon plant in the field of herbal medicine in nanoscience for biomedical application [58]. Biosynthesis of silver and gold nanoparticles from the leaf extract of Callistemon citrinus was reported by Saad et. al. [59]. The extract was tested for invitro antioxidant, antimicrobial, cytotoxic activities as well as their total phenolic content (TPC). The TEM analysis proved that the sizes of the silver nanoparticles at 450nm were at 8 to 14 nm and gold nanoparticles at 535 nm are of 5.8 to 8.84nm. The TPC was estimated via Folin-Ciocalteu's assay and was found from 548.85 to 123.30mg gallic acid equivalent (GAE)/g dry extract. The extract also showed very good antimicrobial activity. The n-butanol extract (63.09µg/ml) showed the most potent cytotoxic activity followed by EtOAc (100.0µg/ml). The study proved that the leaves of Callistemon citrinus are capable to produce AgNPs and AuNPs which having noticeable antimicrobial, antioxidant and cytotoxic activities.

VI. CONCLUSION

"Blood-coloured Bottle-brush trees create brightness for this devastated world". The plant "Bottle-brush" is a great attractor of pollinators. There are 50 species of Callistemon with different growth patterns and the most eye-catching fluffy cylindrical flower of bottle brush produces the lemonary citrus scent and oil. Its oil is used in various types of aromatherapy. Several phytochemical constituents like fatty acids, tannins, terpenoids, etc. are isolated from its leaves and flower. Till now, various researchers have been reported the plant for its pharmacological value. This review focuses on the therapeutic value as well as some new applications of the plant as a dye, a good source of nano-sized biologically active materials, and as a source of polymer. As a whole, the genus Callistemon is known for its various therapeutic values and acts as a natural polymer and dye which was very well explained in this review.

Conflict of Interest

The author declares that this review content has no conflict of interest.

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Data Availability Statement: All data presented during this study are included and references are given in the article. Requests for material should be made to the corresponding authors.

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