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(REVIEW ARTICLE)

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From coir to cleaner smiles: A Novel Coconut-Fiber coated VCO Micro brush for eco-conscious oral hygiene

Evelyn Nathania Prasetyo [1, *], Rafael Gerrard [1], Nirvana Sabathani [2], Feodora Davina Aloysia Christy [3] and Maria Puspita Ayu [4]

[1] *Undergraduate student, Faculty of Dental Medicine, Universitas Airlangga, Surabaya, East Java 60131, Indonesia.*
[2] *Undergraduate student, Faculty of Pharmacy, Universitas Gadjah Mada, Yogyakarta, Special Region of Yogyakarta 55281, Indonesia.*
[3] *Undergraduate student, Faculty of Agricultural Technology, Universitas Gadjah Mada, Yogyakarta, Special Region of Yogyakarta 55281, Indonesia.*
[4] *Undergraduate student, Faculty of Law, Universitas Diponegoro, Semarang, Central Java 50275, Indonesia.*

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Abstract

Background: Periodontitis is a chronic, multifactorial inflammatory disease driven by dysbiosis subgingival biofilms that progressively destroy gingival tissues, periodontal ligament, and alveolar bone. Conventional mechanical debridement and single-use plastic interdental applicators contribute to residual disease activity and environmental burden.

Objective: To evaluate the physicochemical properties, antimicrobial efficacy, biodegradability, and user acceptability of a novel, fully biodegradable interdental micro brush composed of coconut coir fibers coated with virgin coconut oil (VCO), and to compare its performance with conventional plastic micro brushes.

Methods: Review search (2019–2025) of PubMed, ScienceDirect, and Google Scholar was conducted using Boolean keywords related to "micro brush," "coconut fiber," "coconut oil," "biomaterials," and "eco-friendly." *In vitro*, *ex vivo*, and clinical studies assessing coir tensile strength, Young's modulus, density, oil adsorption/release kinetics, antimicrobial activity against key oral pathogens (e.g., *Streptococcus mutans*, *Porphyromonas gingivalis*, *Candida albicans*), biodegradability, and user acceptability were included.

Results: Coconut coir fibers demonstrated tensile strengths of 105–593 MPa, Young's moduli of 2–8 GA, and densities of 1.1–1.5 g/cm^3, providing abrasive cleaning efficacy compare with nylon bristles. VCO's lauric acid and monolaurin exhibited broad-spectrum antimicrobial activity by disrupting microbial membranes, with sustained release over 4–6 hours. Preliminary clinical trials reported significant reductions in plaque indices and inflammatory markers (IL-6, TNF-α) comparable to chlorhexidine, without adverse effects. Coir micro brushes fully biodegraded within 60 days under composting conditions, versus centuries for plastic counterparts. User surveys indicated high acceptability in terms of ease of use, comfort, and perceived cleanliness.

Conclusion: Coconut coir–VCO micro brushes combine mechanical plaque removal and targeted antimicrobial delivery in a biodegradable format, offering an eco-friendly alternative to plastic interdental applicators. Further randomized controlled trials and standardized testing protocols are recommended to validate long-term clinical efficacy and environmental impact.

* Corresponding author: Evelyn Nathania Prasetyo

Keywords: Periodontitis; Coconut Coir; Virgin Coconut Oil; Biodegradable Microbrush; Antimicrobial Delivery

1. Introduction

Periodontitis is a chronic, multifactorial inflammatory disease in which dysbiosis subgingival biofilms provoke a host-mediated response that progressively destroys the gingiva, periodontal ligament, and alveolar bone, ultimately leading to irreversible attachment loss and, in advanced cases, tooth mobility or loss of dentition [2]. Clinically, patients present with gingival inflammation, bleeding on probing, pocket formation, gingival recession, halitosis, suppuration, even in severe forms such as necrotizing ulcerative lesions accompanied by pain and systemic symptoms [1]. With a global prevalence of approximately 11% affecting some 743 million people, severe periodontitis thus represents a significant public health burden [2]. Although mechanical debridement supplemented by antimicrobials can reduce inflammation, these approaches seldom achieve full tissue regeneration [3], which underscores the urgent need for innovative therapies such as host-modulation agents, targeted antimicrobial delivery systems, and oral hygiene maintenance. Moreover, recent work has explored the use of biodegradable micro brushes fabricated from coconut coir as a sustainable interdental delivery device, capable of precisely applying antimicrobial agents into periodontal pockets while minimizing environmental impact.

Micro brush refers to a type of applicator with micro bristles, commonly used in adhesive dentistry to apply priming-adhesive solutions. It is often preferred over standard brushes because it allows for a more uniform and micromechanically stable adhesive bond [4]. In recent years, the majority of commercially available micro brushes have been manufactured using plastic-based materials, raising growing concerns regarding their environmental impact. As single-use applicators, micro brushes contribute significantly to plastic waste accumulation, particularly within high-volume clinical settings where adhesive procedures are routinely performed. This disposable nature, while advantageous in terms of cross-contamination control, presents a critical sustainability challenge, especially given the increasing global emphasis on eco-friendly healthcare practices. Consequently, there is a pressing need to explore alternative materials or reusable designs that can maintain clinical efficacy while minimizing ecological burden.

Coconut (*Cocos nucifera L.*) is a versatile tropical crop whose coarse coir fiber composed of 36–43 % cellulose, 32 % lignin, and 15 % hemicellulose exhibit high tensile strength, and fully biodegradable [5]. Meanwhile, virgin coconut oil, comprised primarily of medium-chain fatty acids (≈92 % saturated, with 45–53 % lauric acid), yields monolaurin; a potent antimicrobial agent shown to disrupt *Streptococcus mutans* and *Candida albicans* biofilms by *in vitro* study [6,7]. By coating coconut coir micro-fibers with coconut oil, one can exploit both the mechanical plaque-removal capacity of the fibers and the chemical antibacterial action of the oil, creating an interdental micro brush that is not only effective but also fully biodegradable. This eco-friendly micro brush has the potential to replace conventional plastic interdental brushes, thereby reducing single-use plastic waste while maintaining or improving oral hygiene efficacy [5].

In this review paper, we will critically examine the physicochemical properties of coconut coir and coconut oil as they pertain to interdental cleaning, compare their performance against traditional plastic micro brushes, and assess current evidence on antimicrobial efficacy, biocompatibility, and user acceptability. We will synthesize data on fiber morphology, oil adsorption and release kinetics, and clinical or *in vitro* cleaning outcomes, before outlining key research gaps and proposing standardized testing protocols for future development of sustainable interdental micro brushes. Ultimately, this work aims to establish a comprehensive framework for evaluating and optimizing coconut-based micro brush designs as a green alternative in oral care.

2. Methods

Systematic search was conducted in PubMed, ScienceDirect, and Google Scholar databases to identify relevant studies published between 2019-2025 using *Boolean* strategy with the following method ("micro brush" OR "brush") AND ("coconut" OR "coconut fiber" OR "coconut oil") AND ("biomaterials" OR "natural materials" OR "eco-friendly") AND ("manufacturing" OR "fabrication") AND ("application" OR "usage" OR "function"). Titles and abstracts were screened based on its relevance to interdental micro brush sustainability and functionality layered with coconut oil in minimizing plaque accumulation. Full texts of eligible articles – including *in vitro*, *ex vivo*, and clinical investigations of coconut fiber tensile strength and biodegradability, and coconut oil antimicrobial efficacy were retrieved for detailed review. Only those meeting all inclusion criteria in addressing utilization of coconut fiber incorporating coconut oil layer as interdental micro brush, were included in the final synthesis

Table 1 Key Methodological Studies

Author(s)	Year	Country	Study Design	Scientific Findings
Nitbani *et al.* [8]	2022	Indonesia	Review study (literature-based)	Lauric acid and monolaurin from VCO exhibit broad-spectrum antimicrobial activity against Gram-positive bacteria (*S. aureus*), fungi (*C. albicans*), and viruses (HSV, VSV). The main mechanism involves disruption of microbial cell membranes.
Loung *et al*. [9]	2014	Indonesia	Experimental (*in vitro*, agar diffusion)	Enzymatic hydrolysis of VCO and PKO showed significantly higher antibacterial activity compared to untreated oils. Stronger effect against *S. aureus* than against *E. coli* and *S. typhi.*
Elysa *et al.* [10]	2014	Indonesia	Experimental (*in vitro* & *in vivo*)	Enzymatic hydrolysis of VCO produced lauric acid and monolaurin with potent antibacterial activity against *Salmonella typhi* and *S. typhimurium*. In vivo tests in mice showed significant reduction of bacterial colonies and milder tissue damage compared to untreated controls.
Yoon BK *et al.* [11]	2018	Singapore & USA	Review study	Monoglycerides and fatty acids such as monolaurin and lauric acid are highly effective against a wide range of pathogens. Monoglycerides have stronger effects and lower risk of resistance development, making them promising for therapeutic use.
Woolley *et al.* [6]	2020	UK	Systematic review of 4 RCTs	Coconut oil pulling showed reductions in plaque and bacterial counts; comparable to chlorhexidine with fewer side effects, but more rigorous trials needed.
Cevanti *et al.* [12]	2021	Indonesia	Descriptive experimental laboratory study	Cellulose from coconut coir exhibited antibacterial effects against *S. mutans* and had a porous, fibrous morphology suitable for use in dental composites.
López *et al.* [13]	2025	Spain & USA	Triple-blind randomized controlled trial	Coconut oil significantly reduced pathogenic bacteria (*T. forsythia*, *T. denticola*) and inflammatory markers (IL-6, TNF-α), improving periodontal health.

3. Discussion

Coconut coir exhibits highly promising mechanical properties for use in interdental micro brushes. Its tensile strength ranges from 105 to 593 MPa and its Young's modulus sits between 2 and 8 GA, all while maintaining a low density of just 1.1–1.5 g/cm^3 [5]. Although nylon fibers in commercial micro brushes can achieve slightly higher peak strengths, coir's rigid, coarse structure provides exceptional abrasive action against dental plaque, ensuring more through removal in interdental spaces compared to smoother plastic bristles [4, 14]. This rougher fiber morphology translates to cleaning performance on par with synthetic micro brushes while leveraging a naturally derived material. Consequently, coconut coir can match the efficacy of commercial products and simultaneously reduce reliance on petroleum-based plastics.

Beyond its mechanical robustness, coconut coir delivers significant sustainability advantages. With roughly 32% lignin content, these fibers resist premature degradation during use yet break down far more readily than single-use plastics once disposed of [5]. Their porous architecture also enhances grip and evenly distributes brushing forces, reducing the risk of fiber breakage under flexural stress [15]. In contrast, disposable nylon micro brushes contribute to mounting clinical plastic waste despite their dimensional stability and uniform bristle arrangement [16]. By leveraging coir's near-industry-standard strength and inherent biodegradability, developers can create an eco-friendly interdental micro brush that rivals commercial alternatives in both durability and cleaning efficacy.

Coconut oil is known to be rich in lauric acid, a medium-chain fatty acid that can naturally be converted into monolaurin (glycerol monolaurate) through two main mechanisms: esterification or partial hydrolysis of the triglycerides in coconut oil by lipase enzymes. This process produces a monoglyceride, monolaurin, which has higher antimicrobial activity than pure lauric acid [8, 9, 10]. Both lauric acid and monolaurin have an amphipathic structure, which consists of a hydrophilic group (polar head) and a hydrophobic group (nonpolar tail). This structure allows them to insert into the lipid bilayer of the bacterial cell membrane, which is the main target of monolaurin as an antibacterial. The hydrophilic part interacts with the polar surface of the membrane and the hydrophobic part integrates into the lipid core [11].

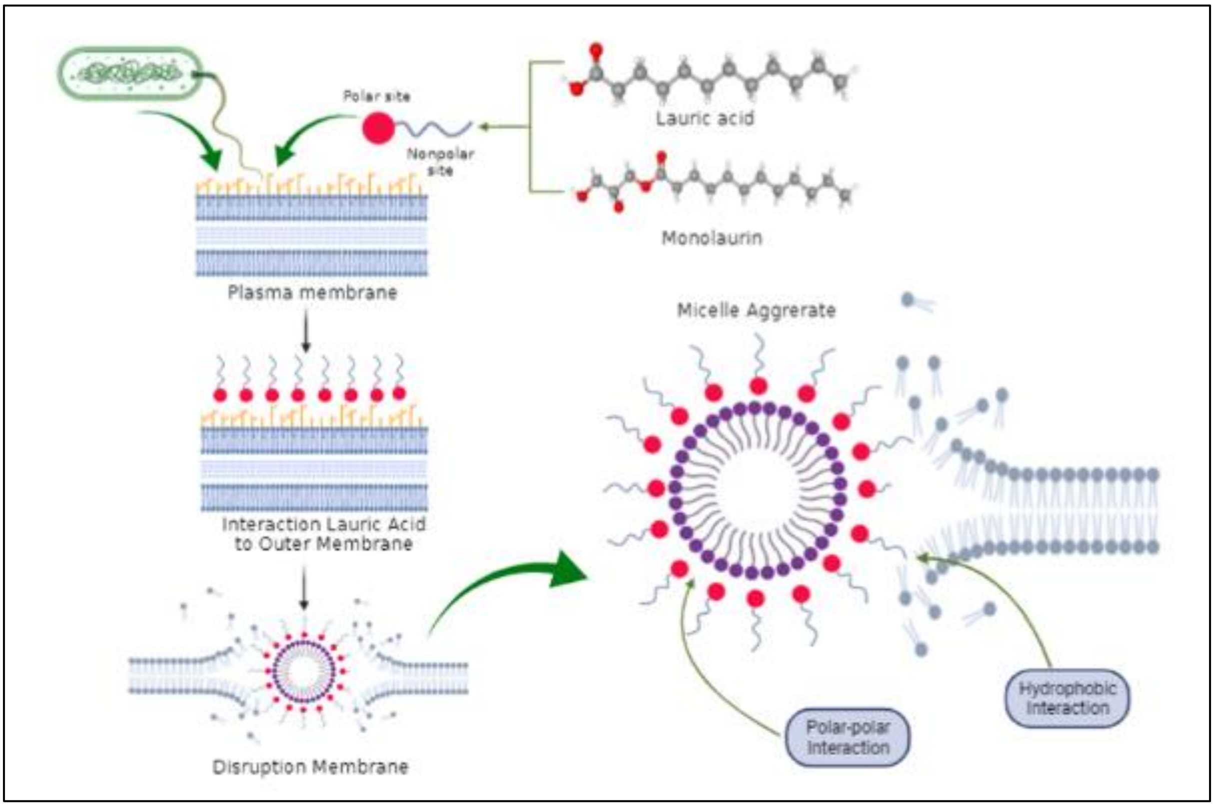

Figure 1 Mechanism of membrane disruption by lauric acid and monolaurin [8]

Nitbani *et al*. (2022) [8] stated that the mechanism of antibacterial action of lauric acid and monolaurin, which are the main components of virgin coconut oil (VCO), is explained as follows:

The ability of lauric acid and monolaurin to insert into the lipid bilayer of the bacterial membrane disrupts the order of the lipid arrangement, increases the fluidity of the membrane, and forms small pores. As a result, the membrane becomes more permeable and loses structural stability. Increased permeability makes it easier for foreign compounds to enter the bacterial cell [8]. This integration triggers the leakage of intracellular contents, including ions, nutrients, and essential molecules, to the external environment of the cell, thus breaking the osmotic balance and disrupting the cell's energy homeostasis. At high concentrations, this leakage can cause cell lysis (bactericidal effect), while at lower concentrations it can inhibit bacterial growth (bacteriostatic effect) [8].

Gram-positive bacteria are a group of bacteria commonly found in the oral cavity, including the interdental area. Against these bacteria, lauric acid and monolaurin can also interact with cell wall components, such as peptidoglycan (NAM/NAG), or even compete with transpeptidase enzymes. In the structure of lauric acid and monolaurin, the carbonyl atom of the carboxylic group serves as an electrophile center that can be attacked by the nucleophilic side of the transpeptidase enzyme, allowing bond formation. This bond potentially closes the active site of the enzyme, which inhibits the formation of cross-links in the peptidoglycan. As a result, the bacterial cell wall loses its rigidity, leading to cell lysis and ultimately resulting in cell death [8]. Lauric acid (LA) and glycerol monolaurate (GML) mechanisms have been observed in various Gram-positive bacteria such as Listeria monocytogenes and Clostridium perfringens [11].

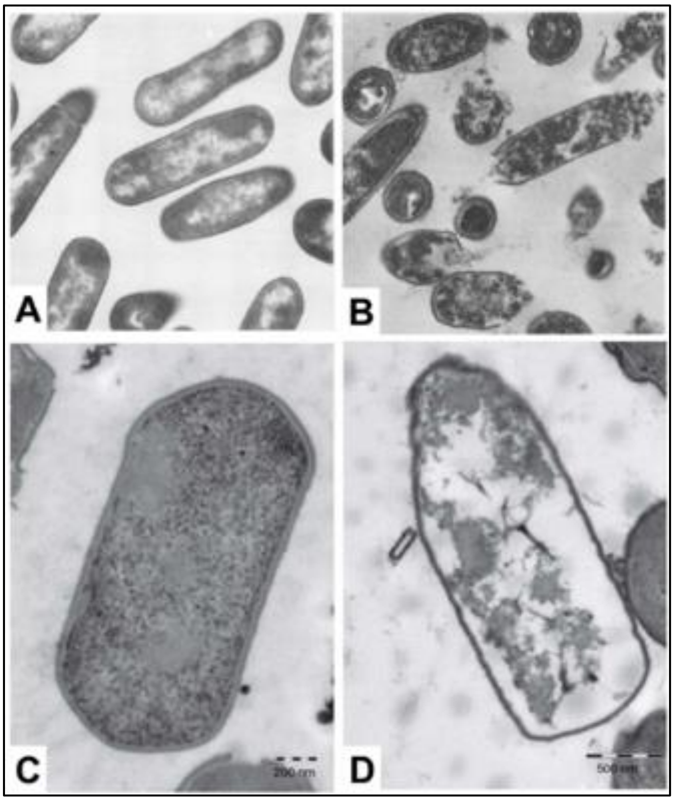

Figure 2 Transmission electron microscopy (TEM) images showing the effects of fatty acid and monoglyceride treatment on bacterial cell ultrastructure. Listeria monocytogenes cells are shown untreated (A) and after treatment with 50 µg/mL glyceryl monolaurate (GML) (B), while Clostridium perfringens cells are shown untreated (C) and after treatment with 1 mg/mL lauric acid (LA) (D). The images reveal significant intracellular disruption and membrane damage in the treated groups [11]

The results of transmission electron microscopy (TEM) observations shown in Figure 2 clearly illustrate the impact of lipid compound treatment on bacterial cell morphology. In Listeria monocytogenes, the untreated cells (panel A) displayed intact, well-organized membranes and clearly defined cytoplasmic structures. However, after treatment with 50 µg/mL GML (panel B), there was significant membrane damage and leakage of cytoplasmic contents, which are typical signs of cell lysis. Something similar was observed in Clostridium perfringens, where control cells (panel C) showed a normal structure. In contrast, treatment with 1 mg/mL LA (panel D) resulted in cytoplasmic disorganization, disruption of internal membrane integrity, and indications of fatal damage to the cell structure. However, the outer cell wall remained intact [11, 17]. Such morphological damage reflects the antibacterial mechanism commonly possessed by medium-chain fatty acids and their derivatives, such as GML and LA. GML in particular has been reported to have very strong bactericidal activity against Gram-positive bacteria, including Staphylococcus aureus and L. monocytogenes, with lower minimum bactericidal concentration (MBC) values than LA [18, 19]. LA and GML are naturally found in virgin coconut oil (VCO). LA makes up about 45-53% of the total fatty acids in VCO, and GML is formed from the enzymatic process or hydrolysis of LA in the body or oral environment. Studies show that VCO and its components are effective against various oral pathogens such as Streptococcus mutans, Porphyromonas gingivalis, and Aggregatibacter actinomycetemcomitans. In fact, VCO in nano emulsion form can enhance the penetration of active compounds and broaden their antibacterial spectrum against periodontopathogen bacteria [11, 20]. The TEM results from Figure 2 reinforce that the observed cell damage is a direct result of the antibacterial activity of GML and LA. Thus, the use of an interdental micro brush made from VCO-treated coconut fibers has potential as a natural alternative in keeping the interdental area clean. This approach not only utilizes the fine abrasive effect of coconut fibers but also incorporates the antibacterial activity of the coconut oil content. Moreover, compared to synthetic chemicals such as chlorhexidine that risk causing mucosal irritation or tooth discoloration, coconut oil is biocompatible and safe for long-term use [21, 11]

4. Conclusion

Coconut coir coated with VCO micro brushes merge the mechanical strength and abrasive morphology of coir fibers (tensile strength 105–593 MPa; Young's modulus 2–8 GA) with the sustained antimicrobial release of lauric acid and monolaurin, yielding plaque reductions and anti-inflammatory effects comparable to chlorhexidine yet without its adverse effects. Their full biodegradability within 60 days and high user acceptability underscore their potential to significantly reduce clinical plastic waste and advance sustainable dental practice.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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