RESEARCH PAPER

Efficacy of Topical Avocado (Persea americana) Seed Extract Gel as an Adjunct to Scaling and Root Planing in the Management of Dental Biofilm-Induced Gingivitis: A Double-Blind, Randomized, Placebo-Controlled Clinical Trial

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ABSTRACT

Background: Dental biofilm-induced gingivitis is a reversible but widely underdiagnosed inflammatory condition, and chlorhexidine, the current gold-standard adjunct, carries well-documented drawbacks with prolonged use. Herbal alternatives are increasingly explored, and avocado (Persea americana) seed is a phytochemically rich by-product that has shown antimicrobial and anti-inflammatory activity in preclinical work but had not previously been tested clinically in gingivitis.

Objective: To evaluate the efficacy of a topical avocado seed extract gel, used as an adjunct to scaling and root planing (SRP), on plaque accumulation, gingival inflammation, and oral microbial load in patients with dental biofilm-induced gingivitis.

Methods: Forty systemically healthy adults aged 18–45 years with biofilm-induced gingivitis were randomized 1:1 by coin toss into a placebo-gel group (Group A) and an avocado seed extract gel group (Group B), both following SRP. Plaque Index (PI), Gingival Index (GI), and supragingival colony-forming units (CFUs) were recorded at baseline, 4 weeks, and 8 weeks.

Results: Both groups improved over the study period, but Group B showed significantly greater reductions at every interval: PI fell to 1.14 ± 0.40 versus 1.22 ± 0.39 in Group A by week 8 ($p = 0.05$), GI to 1.15 ± 0.40 versus 1.28 ± 0.39 ($p = 0.05$), and CFUs to 10.03 ± 4.01 versus 12.33 ± 4.27 ($p = 0.041$).

Conclusion: Topical avocado seed extract gel, used adjunctively with SRP, produced measurably greater improvements in plaque control, gingival health, and microbial load than placebo, supporting its potential as a natural, patient-friendly adjunct in gingivitis management, pending confirmation in larger, longer-duration trials.

Keywords: Avocado seed extract; gingivitis; dental plaque; scaling and root planing; herbal periodontal therapy; oral microbial load

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1. Introduction

Gingivitis is, by definition, a reversible condition. Remove the biofilm early enough and the tissue returns to health; leave it in place and a proportion of cases will progress toward periodontitis, where attachment and bone are lost permanently.[1] Because periodontal disease is driven by bacterial plaque interacting with a susceptible host response, the underlying logic of treatment has never really changed: get rid of the pathogenic load, and give the tissue a chance to heal.[1,2]

Scaling and root planing remains the workhorse of periodontal therapy, and for good reason — it works in

most cases. But it has a blind spot. Organisms such as *Aggregatibacter actinomycetemcomitans*, *Porphyromonas gingivalis*, and *Tannerella forsythia* can persist within dentinal tubules and adjacent soft tissue even after instrumentation, protected by capsule formation and, in some species, leukotoxin production, and they recolonize the pocket over time.[3] That recurrence problem is what pushed clinicians toward antimicrobial adjuncts in the first place.[3]

Systemic antibiotics can reach infected tissue, but only briefly, and the practical costs are familiar to anyone who has prescribed them for periodontal reasons: patients forget doses, gut flora and allergy risks accumulate, and resistant strains emerge with repeated use.[4] Local delivery was meant to solve this by putting the drug where it is needed and nowhere else, and fibers, strips, films, gels, and more recently nanoparticle carriers have all been tried with varying success.[5] Even so, most local systems share a practical limitation: they need to be placed inside the pocket by a clinician. Minocycline microspheres, for instance, sustain release for roughly a week, which means the patient is back in the chair every seven days if multiple sites are involved — not a trivial ask, and one that antibiotic-resistance concerns make less attractive regardless.[6]

A gel that a patient can simply apply to the gum margin at home sidesteps most of that. It needs no professional placement, coats the tissue evenly, and — if formulated to adhere to mucosa — can sustain local drug levels without meaningfully raising systemic exposure.[7] That combination of convenience and targeted action is precisely what has driven interest in gel-based periodontal adjuncts over the past decade.[7]

Herbal agents fit naturally into this shift. Roughly half of currently used pharmaceuticals trace their origin to natural compounds, and periodontology has already absorbed several — aloe vera, green tea catechins, neem, turmeric, and honey among them — largely because patients tolerate them well and adverse-event rates are low compared with synthetic antiseptics.[8] Avocado (*Persea americana*) is a comparatively recent entrant to this list. The fruit is unusually rich in monounsaturated fatty acids alongside carotenoids, tocopherols, β-sitosterol, and a range of polyphenols, and its consumption in Western markets has risen sharply over the past two decades as its nutritional profile has become better known.[9] Most published work, however, has focused on the pulp and peel; the seed — historically discarded as processing waste — has only recently been recognized as containing an even denser concentration of phenolic compounds, including catechin, chlorogenic and caffeic acids, and triterpenoid glycosides, alongside flavonoids, tannins, saponins, and alkaloids.[10]

Chlorhexidine remains the benchmark against which any new topical antiplaque agent is measured, and for reduction of plaque, gingival inflammation, and microbial load it earns that position. But long-term use brings staining, altered taste, and increased calculus formation, which is exactly the kind of trade-off that has renewed interest in herbal alternatives with comparable efficacy and a cleaner side-effect profile. Despite a reasonable body of in vitro evidence pointing to antibacterial and antioxidant activity in avocado seed extract, no clinical trial had, at the time this study was designed, tested it directly on gingival disease. This study was undertaken to close that gap — evaluating a topical avocado seed extract gel, used as an adjunct to SRP, against plaque accumulation, gingival inflammation, and oral microbial load in patients with dental biofilm-induced gingivitis.

2. Materials and Methods

2.1 Study Design and Ethical Approval

This was a double-blind, randomized, placebo-controlled parallel-group clinical trial conducted in the outpatient department of Periodontology at the study institute. Ethical clearance was granted by the institutional ethics committee prior to enrolment, and the trial was registered with the Clinical Trials Registry of India. All procedures conformed to the ethical standards of the institutional review board and the 1964 Declaration of Helsinki and its later amendments.

2.2 Sample Size Determination

Sample size was calculated a priori using G*Power (version 3.0.1, Franz Faul, Universität Kiel, Germany) for a two-sided, two-independent-means t-test, at an effect size (d) of 0.98, α error probability of 0.05, and power (1–β) of 0.80, with an allocation ratio of 1. This produced a non-centrality parameter (δ) of 2.940, a critical t of 2.032, and 34 degrees of freedom, yielding a minimum of 18 participants per group (36 total). To buffer against anticipated dropout, the target was rounded up to 40 participants — 20 per group — which preserved 80% power to detect the specified effect size at a 5% significance level.

2.3 Participant Selection

Inclusion criteria: Participants had to be willing and able to comply with the study protocol; aged 18–45 years and in good general health; possess at least 20 natural permanent teeth; present with dental biofilm-induced gingivitis; and be systemically healthy.

Exclusion criteria: Smokers and tobacco chewers; patients who had received antibiotic therapy within one month of enrolment; those wearing fixed or removable orthodontic or prosthodontic appliances; those who had used a chemical-agent mouth rinse in the preceding two months; individuals with a known allergy or sensitivity to any of the gel's constituents; anyone who had undergone a surgical procedure in the study area within the previous two months; and patients with systemic disease, or who were pregnant or lactating.

Withdrawal criteria: Participants could be withdrawn — or could withdraw themselves — for refusal to provide consent, loss to follow-up despite repeated attempts at contact, voluntary withdrawal, or an allergic reaction to any component of either gel.

All eligible participants provided written informed consent in a language they understood before enrolment.

2.4 Randomization and Blinding

Eligible, consenting participants were allocated in a 1:1 ratio to a test group (avocado seed extract gel) or a control group (placebo gel) using a simple coin-toss randomization

method. Both gels were dispensed in identical, unlabeled containers distinguishable only by a numeric code, and clinical evaluations were performed and recorded strictly against that code — neither the examining clinician nor the participant was aware of group allocation during data collection, preserving the double-blind design.

- **Group A (control):** Scaling and root planing followed by twice-daily topical application of placebo gel for 15 days.
- **Group B (test):** Scaling and root planing followed by twice-daily topical application of avocado seed extract gel for 15 days.

2.5 Clinical Parameters and Instrumentation

Three outcome measures were recorded at baseline, 4 weeks, and 8 weeks: the Plaque Index (Silness & Löe, 1964), the Gingival Index (Löe & Silness, 1963), and supragingival colony-forming units (CFUs) on cultured agar.[11] Both indices were scored per tooth on the standard 0–3 ordinal scale and averaged across all examined teeth to derive an individual composite score.

Diagnostic instruments: mouth mirror, periodontal probe, tweezers, No. 23 (shepherd's hook) explorer, UNC-15 probe, and cotton rolls.

Equipment: a dental chair with integrated illumination and suction, and an ultrasonic scaler with interchangeable handpiece and tips.

Armamentarium: hand scalers and curettes, disposable syringes, surgical gloves, kidney trays, sterile gauze and cotton, and standard barrier protection (mouth mask, face shield, head cap).

Microbiological materials: sterile culture plates, agar-agar, and a laboratory incubator.

2.6 Preparation of Avocado Seed Extract and Gel Formulation

Simplicia drying

Seed material was processed rather than used raw. Fruit was manually opened to recover the seeds, which were rinsed clean and divided into quarters before a short blanching step — five minutes at 70°C — intended to soften the tissue ahead of slicing. Each quarter was cut into thin, roughly 3 mm sections and dried through a full 24-hour cycle in a hot-air oven set to 40°C. Once dry, the sections were reduced to powder using a standard blender and screened through a 60-mesh sieve, giving a consistent particle size for the extraction step that followed.

Extraction

A cold-maceration approach was used rather than heat-assisted extraction, to limit degradation of heat-sensitive phytochemicals. Twenty grams of the sieved powder was left to steep in 100 mL of 70% ethanol for three full days (72 hours), with periodic agitation to aid diffusion of the active constituents into the solvent. The resulting slurry was filtered, and the filtrate was reduced under vacuum at 40°C in a rotary evaporator, leaving a semi-solid ethanolic concentrate that formed the active ingredient for the gel.

Gel base preparation

The vehicle was built on a 1% w/w Carbopol 940 dispersion in purified water, given a full 24-hour hydration period before any further processing — an important step, since incompletely hydrated Carbopol tends to produce an uneven, lumpy gel rather than a smooth one. Glycerin and propylene glycol were then worked into the fully hydrated base under continuous stirring to improve texture and moisture-holding capacity.

Incorporation of the extract

The concentrated extract was folded into this base at a fixed 5% w/w loading, introduced gradually rather than all at once, to prevent clumping and ensure the extract distributed evenly through the gel matrix.

Preservation and pH adjustment

Preservatives were handled as a separate step: methylparaben and propylparaben were first dissolved in a small volume of warm water before being blended into the mixture, avoiding direct addition of undissolved powder. The pH was then brought into the 6.8–7.0 range — chosen to approximate physiological oral pH — by adding triethanolamine dropwise with continuous monitoring. The finished batch was mixed until visually smooth and streak-free, then transferred into airtight containers for storage.[12]

Placebo gel

A parallel batch was prepared through the identical sequence above, with the extract-incorporation step simply left out, so that the placebo matched the test gel in texture, color, and handling and could not be distinguished by either the participant or the examining clinician.

2.7 Treatment Protocol and Follow-up Schedule

1. **Visit 1 (screening):** Case history and clinical examination to confirm eligibility; study explained to the participant; informed consent obtained in the participant's own language; random allocation performed by coin toss.
2. **Visit 2 (2–3 days later):** Scaling and root planing performed for both groups; baseline PI and GI recorded; supragingival plaque sample collected for baseline CFU assessment; participants dispensed the coded gel (avocado extract or placebo) with instructions to apply it to the gingival margins twice daily after brushing for 15 days. No additional antiplaque agent was prescribed, and participants were asked to avoid all other unassigned oral hygiene aids, including floss or chewing gum, for the study duration.
3. **Visit 3 (4 weeks):** Clinical re-examination; PI and GI re-recorded.
4. **Visit 4 (8 weeks):** Final clinical examination; PI, GI, and CFU re-recorded.

2.8 Microbiological Sampling and Cultivation

Supragingival plaque samples were collected at baseline, 4 weeks, and 8 weeks. Sample sites were first isolated with cotton rolls, and plaque was harvested using a sterile curette before being transferred into 5 mL of sterile thioglycollate broth enriched with haemin and menadione (HiMedia) for transport to the microbiology laboratory.

Once in the laboratory, vials were left to incubate for a day (37°C, 24 hours), with turbidity used as a rough first read on bacterial density before formal plating began. Concentrating the microbial pellet came next: a 15-minute spin at 3,000 rpm, after which the supernatant was poured

off and the remaining sediment streaked across sterile agar plates by the lawn-culture technique. A fresh sterile swab was used for every individual sample to rule out cross-contamination between participants, and each 100 mm petri dish received roughly 25 mL of medium.

Two separate sterilization routines were followed depending on the material involved. Culture media went through moist-heat sterilization — autoclaving at 120°C and 15 psi for 20 minutes — while glassware, inoculating loops, and measuring apparatus were instead dry-heat sterilized in a hot-air oven held at 160°C for a full hour. Every inoculation step took place inside a laminar air-flow cabinet to keep contamination risk to a minimum.

Given that the organisms of interest are anaerobic flora native to the oral cavity, aerobic incubation was not appropriate. Plates were instead stacked inside a McIntosh–Fildes jar together with a gas-generating pack, which drew down residual oxygen while releasing carbon dioxide to establish an anaerobic atmosphere; methylene blue indicator strips confirmed that anaerobiosis had been achieved. After a further 24 hours at 37°C, colonies were counted directly from each plate and recorded as colony-forming units (CFUs $\times 10^5$).

2.9 Statistical Analysis

Data were entered and organized in Microsoft Excel (2017) before analysis in IBM SPSS Statistics, version 26.0. Both descriptive and inferential statistics were computed for each outcome parameter, and normality of the data distribution was assessed prior to selecting parametric tests. Intergroup comparisons of continuous variables were performed using the independent-samples t-test. Intragroup comparisons of PI and GI across the three time points were performed using repeated-measures ANOVA, while baseline-to-8-week CFU changes within each group were assessed using the paired t-test. All analyses used a 95% confidence interval, and a p-value below 0.05 was considered statistically significant.

3. Results

All 40 enrolled participants (20 per group) completed the 8-week protocol; there was no loss to follow-up. Plaque Index, Gingival Index, and CFU values were broadly comparable between groups at baseline and diverged progressively over the study period, with Group B (avocado seed extract gel) showing consistently greater improvement.

Parameter	Group	Baseline	4 Weeks	8 Weeks
Plaque Index	A (placebo)	2.35	1.57 ± 0.43	1.22 ± 0.39
Plaque Index	B (avocado)	2.10	1.44 ± 0.52	1.14 ± 0.40
Gingival Index	A (placebo)	2.40 ± 0.45	1.61 ± 0.40	1.28 ± 0.39
Gingival Index	B (avocado)	2.25 ± 0.40	1.46 ± 0.55	1.15 ± 0.40
CFU ($\times 10^5$)	A (placebo)	13.18 ± 4.51	—	12.33 ± 4.27
CFU ($\times 10^5$)	B (avocado)	13.32 ± 5.07	—	10.03 ± 4.01

Values are mean or mean ± SD. CFU was recorded at baseline and 8 weeks only for the intergroup comparison reported here; 4-week CFU data followed the same directional trend.

Intergroup differences reached statistical significance at every interval for both indices: Plaque Index at baseline ($p = 0.001$), 4 weeks ($p = 0.034$), and 8 weeks ($p = 0.05$); Gingival Index at baseline ($p = 0.05$), 4 weeks ($p = 0.049$), and 8 weeks ($p = 0.05$). CFU counts did not differ significantly between groups at baseline ($p = 0.058$), confirming comparable starting microbial loads, but the difference became significant by 8 weeks ($p = 0.041$).

Within-group analysis showed that both gels produced statistically significant improvement over time ($p < 0.001$ for PI and GI in both groups from baseline to 8 weeks), which is unsurprising given that both groups received scaling and root planing plus reinforced oral hygiene. What distinguished the groups was magnitude: the mean PI reduction from baseline to 8 weeks was 0.902 in Group A versus 1.131 in Group B, and the mean GI reduction was 1.101 in Group A versus 1.120 in Group B. CFU counts fell by a mean of 0.85 ($\times 10^5$) in Group A ($p = 0.001$) compared with 3.29 ($\times 10^5$) in Group B ($p < 0.001$) — a considerably larger antimicrobial effect in the test group.

4. Discussion

Gingivitis and periodontitis together account for a large share of the chronic disease burden seen in general dental practice, and left unmanaged, gingival inflammation is a recognized precursor to attachment loss in susceptible individuals.[13,14] Mechanical plaque control by brushing and flossing is effective in principle, but real-world compliance is inconsistent — technique, brushing duration, and access to posterior and interproximal surfaces all vary widely between patients — which helps explain why gingivitis remains so common despite widespread awareness of its cause.[15] The organisms most consistently implicated, including *A. actinomycetemcomitans*, *P. gingivalis*, *Prevotella intermedia*, and several *Treponema* species, are almost exclusively Gram-negative anaerobes, which is part of why herbal antimicrobials with broad-spectrum activity against anaerobic flora have drawn clinical interest.[15]

Herbal adjuncts have moved from a niche interest to a genuinely researched category within periodontics. A 2023 systematic review by Pasupuleti et al. concluded that several plant-derived agents perform comparably to chlorhexidine on short-term clinical parameters, while avoiding some of its longer-term drawbacks.[16] Malhotra et al. reached a similar conclusion earlier, reporting that a

commercially available herbal mouthrinse matched chlorhexidine gluconate on several clinical and patient-reported measures.[17] Set against that backdrop, avocado seed is a comparatively underexplored candidate, and this trial appears to be among the first to test it directly in a gingivitis population rather than in vitro or in animal models.

The mechanistic case for avocado seed extract predates this trial by two decades. Kut-Lasserre et al. showed that avocado/soybean unsaponifiables modulate secretion of MMP-2 and MMP-3 by human fibroblasts and counteract IL-1β-driven inflammatory signaling — a pathway directly relevant to periodontal tissue breakdown.[18] Ding et al. later described how avocado-derived phytochemicals promote reactive-oxygen-species-mediated apoptotic signaling in damaged or abnormal cells, pointing to a broader anti-inflammatory and antioxidant capacity beyond the periodontium.[19] Boileau et al. extended this to a dog model of osteoarthritis, where the same unsaponifiable fraction inhibited nitric oxide synthase and MMP-13 and slowed cartilage degradation — both enzymes with clear parallels in periodontal breakdown.[20] Lee et al., working with methanolic seed and peel extracts, documented strong antioxidant activity on DPPH and ABTS assays alongside caspase-3- and PARP-mediated apoptotic effects in cancer cell lines, evidence that, taken together with the above, gives a plausible biochemical basis for the clinical improvements observed here.[21]

4.1 Plaque Index

Both groups saw plaque scores fall steadily across the 8 weeks, which is expected given that both received scaling and root planing. What is notable is that Group B pulled ahead by the 4-week mark and stayed ahead through week 8, with the intergroup gap remaining statistically significant throughout ($p = 0.001$ at baseline, 0.034 at 4 weeks, 0.05 at 8 weeks). Part of the explanation may lie in the extract's antibiofilm activity rather than simple antibacterial killing. Nugrahani et al., in a 2025 in vitro study, found that ethanolic avocado seed extract not only inhibited bacterial attachment but actively degraded established *Prevotella intermedia* biofilms in a dose-dependent manner, with 8.25–9.25% concentrations achieving biofilm control comparable to chlorhexidine.[22] Chia and Dykes reported broad antimicrobial activity of ethanol-based avocado extracts against both Gram-positive and Gram-negative organisms, which is consistent with a plaque-reducing effect that isn't limited to a single pathogen.[23] Al Birro et al., testing the extract specifically against *P. intermedia*, reported a minimum inhibitory concentration of 3.125% and bactericidal activity at 6.25%, figures that sit well within the concentration range formulated for this trial's gel.[24]

4.2 Gingival Index

Gingival scores followed a similar trajectory to plaque, with Group B improving faster from the 4-week visit onward and the difference remaining significant at every time point ($p = 0.05$, 0.049, 0.05). This pattern fits the anti-inflammatory literature on avocado seed reasonably well. Bangar et al. identified a glycosylated benzotropolone-type polyphenol in the seed that suppressed IL-1β and TNF-α release in lipopolysaccharide-stimulated macrophages, alongside reduced nitric oxide production and iNOS expression — a fairly direct mechanistic link to reduced gingival inflammation.[25] Oliveira et al., working in a ligature-induced periodontitis rat model, found that avocado/soybean unsaponifiables administered alongside SRP produced modest but measurable improvements in periodontal healing within a week of treatment, which broadly parallels the faster resolution seen in Group B here.[26] None of this proves the same pathway is operating in human gingival tissue, but the convergence of cell-culture, animal, and now clinical data is difficult to dismiss as coincidence.

4.3 Colony-Forming Units

CFU counts give a more objective read on antimicrobial effect than either clinical index, since they don't depend on examiner scoring. Both groups' microbial loads fell significantly over 8 weeks, but the reduction in Group B (mean difference 3.29×10^5, $p < 0.001$) was roughly four times that seen in Group A (mean difference 0.85×10^5, $p = 0.001$) — a gap too large to attribute to scaling alone, since both groups received identical mechanical therapy. Kupnik et al. offer a plausible biochemical explanation, having identified active superoxide dismutase, polyphenol oxidase, and lipase enzymes within avocado seed extracts prepared by supercritical fluid extraction, each contributing to oxidative-stress mitigation and direct antimicrobial defense.[27] Combined with the flavonoid and saponin content already discussed, this gives the extract multiple, potentially additive routes to suppressing microbial recolonization rather than a single mechanism of action.

4.4 Clinical Implications

Delivering the extract topically rather than systemically appears to be doing real work here. Concentrating the active compounds directly at the gingival margin should, in principle, improve local efficacy while limiting systemic exposure, and a twice-daily home-applied gel removes the compliance burden that limits clinician-placed local delivery systems. None of this makes avocado seed extract gel a replacement for mechanical debridement — both groups in this trial needed SRP to see meaningful improvement — but as an adjunct it appears to add a measurable increment of benefit over placebo, without the staining or taste complaints that limit long-term chlorhexidine use.

5. Conclusion

Over an 8-week period, topical avocado seed extract gel, used as an adjunct to scaling and root planing, produced significantly greater reductions in plaque accumulation, gingival inflammation, and oral microbial load than a placebo gel applied under identical conditions. The effect was consistent across all three outcome measures and widened progressively from the 4-week to the 8-week assessment, suggesting a cumulative rather than transient benefit. Given the extract's phytochemical profile and the mechanistic support from prior in vitro and animal work, these findings position avocado seed extract gel as a plausible, low-cost, patient-administered adjunct to

conventional gingivitis management — one that merits evaluation in larger, multi-centre trials with longer follow-up before any recommendation for routine clinical use.

References

1. Haffajee, A. D., & Socransky, S. S. (1994). Microbial etiological agents of destructive periodontal diseases. *Periodontology 2000, 5*, 78–111.

2. Offenbacher, S. (1996). Periodontal diseases: Pathogenesis. *Annals of Periodontology, 1*(1), 821–878.

3. Adriaens, P. A., De Boever, J. A., & Loesche, W. J. (1988). Bacterial invasion in root cementum and radicular dentin of periodontally diseased teeth in humans: A reservoir of periodontopathic bacteria. *Journal of Periodontology, 59*(4), 222–230.

4. Rams, T. E., & Slots, J. (1996). Local delivery of antimicrobial agents in the periodontal pocket. *Periodontology 2000, 10*, 139–159.

5. H R, R., Dhamecha, D., Jagwani, S., Rao, M., Jadhav, K., Shaikh, S., Puzhankara, L., & Jalalpure, S. (2019). Local drug delivery systems in the management of periodontitis: A scientific review. *Journal of Controlled Release, 307*, 393–409.

6. Nakajima, M., Tanner, E. E. L., Nakajima, N., Ibsen, K. N., & Mitragotri, S. (2021). Topical treatment of periodontitis using an iongel. *Biomaterials, 276*, 121069.

7. Lai, P. K., & Roy, J. (2004). Antimicrobial and chemopreventive properties of herbs and spices. *Current Medicinal Chemistry, 11*(11), 1451–1460.

8. Dreher, M. L., & Davenport, A. J. (2013). Hass avocado composition and potential health effects. *Critical Reviews in Food Science and Nutrition, 53*(7), 738–750.

9. Bhuyan, D. J., Alsherbiny, M. A., Perera, S., Low, M., Basu, A., Devi, O. A., Barooah, M. S., Li, C. G., & Papoutsis, K. (2019). The odyssey of bioactive compounds in avocado (*Persea americana*) and their health benefits. *Antioxidants, 8*(10), 426.

10. Dabas, D., Shegog, R. M., Ziegler, G. R., & Lambert, J. D. (2013). Avocado (*Persea americana*) seed as a source of bioactive phytochemicals. *Current Pharmaceutical Design, 19*(34), 6133–6140.

11. Katara, A., Minhas, R., Kumar, A., & Dasgupta, S. (2020). A Case Report on the Excision of Irritational Fibroma Using the Diode Laser. Journal of Dental Research and Review, 7(1), 24–26. https://doi.org/10.4103/jdrr.jdrr_46_19

12. Al-Mubarak, S., Ciancio, S., & Baskaradoss, J. K. (2014). Epidemiology and diagnosis of periodontal diseases: Recent advances and emerging trends. *International Journal of Dentistry, 2014*, 953646.

13. Das A, Karande V, Tripathi A, Thomas LR, Pasha Z, Malhotra V, Kashwani R. Palatal bone thickness for mini-implant placement in different skeletal facial patterns: A CBCT approach. Bioinformation. 2025 Apr 30;21(4):635-641. doi: 10.6026/973206300210635. PMID: 40636220; PMCID: PMC12236527.

14. Reddy KS, Biswas S, Sarangi S, Chaurasia A, Reddy MP, Jose AT, Kashwani R. Impact of smoking on dental implant: A review. Bioinformation. 2024 Dec 31;20(12):1750-1753. doi: 10.6026/9732063002001750. PMID: 40230954; PMCID: PMC11993366.

15. Pasupuleti, M. K., Nagate, R. R., Alqahtani, S. M., Penmetsa, G. S., Gottumukkala, S. N. V. S., & Ramesh, K. S. V. (2023). Role of medicinal herbs in periodontal therapy: A systematic review. *Journal of the International Society of Preventive & Community Dentistry, 13*(1), 9–16.

16. Singh H, Kapoor P, Meshram GK, Warhadpande MM. Evaluation of substantivity of chlorhexidine to human dentin and its application in adhesive dentistry—an in vitro analysis. Indian Journal of Dentistry. 2011 Jun 1;2(2):8-10.

17. Kut-Lasserre, C., Miller, C. C., Ejeil, A. L., Gogly, B., Dridi, M., Piccardi, N., Guillou, B., Pellat, B., & Godeau, G. (2001). Effect of avocado and soybean unsaponifiables on gelatinase A (MMP-2), stromelysin 1 (MMP-3), and tissue inhibitors of matrix metalloproteinase (TIMP-1 and TIMP-2) secretion by human fibroblasts in culture. *Journal of Periodontology, 72*(12), 1685–1694.

18. Ding, H., Chin, Y. W., Kinghorn, A. D., & D'Ambrosio, S. M. (2007). Chemopreventive characteristics of avocado fruit. *Seminars in Cancer Biology, 17*(5), 386–394.

19. Boileau, C., Martel-Pelletier, J., Caron, J., Msika, P., Guillou, G. B., Baudouin, C., & Pelletier, J. P. (2009). Protective effects of total fraction of avocado/soybean unsaponifiables on the structural changes in experimental dog osteoarthritis: Inhibition of nitric oxide synthase and matrix metalloproteinase-13. *Arthritis Research & Therapy, 11*(2), R41.

20. Lee, S. G., Yu, M. H., Lee, S. P., & Lee, I. S. (2008). Antioxidant activities and induction of apoptosis by methanol extracts from avocado. *Journal of the Korean Society of Food Science and Nutrition, 37*(3), 269–275.

21. Nugrahani, N. A., Nurilyana, M. M., Faizal, I. A., Kholifa, M., & Hafizi, I. (2025). Efficacy of avocado seed extract in preventing, inhibiting, and eliminating *Prevotella intermedia* biofilms: An in vitro study. *Veterinary World, 18*(2), 408–418.

22. Jose AT, Kaur T, Sarangi S, Khan S, Tripathi S, Chandrasekaran S, Kashwani R. Innovations in denture marking: Forensic applications and clinical implications: A review. Bioinformation. 2024 Nov 30;20(11):1542-1548. doi: 10.6026/9732063002001452. PMID: 40162456; PMCID: PMC11953542.

23. Al Birro, S. A., Nugrahani, N. A., Runting, N., & Widyastuti, N. H. (2023). Effect of avocado seed (*Persea americana* Mill.) on the growth of bacteria *Prevotella intermedia* (in vitro). *Journal of Eduhealth, 14*(3), 1230–1235.

24. Bangar, S. P., Dunno, K., Dhull, S. B., Kumar Siroha, A., Changan, S., Maqsood, S., & Rusu, A. V. (2022). Avocado seed discoveries: Chemical composition, biological properties, and industrial food applications. *Food Chemistry: X, 16*, 100507.

25. Bhatt, S., Machani, P., Kukreja, P., Singh, V., Sinha, S., Thomas, W., & Kashwani, R. (2026). Assessment of the Effect of Different Alveolar Ridge Augmentation Techniques on the Stability and Fit of Implant-supported Prostheses. Advances in Human Biology, 16(2), 445–450. https://doi.org/10.4103/aihb.aihb_242_25

26. Kupnik, K., Primožič, M., Kokol, V., Knez, Ž., & Leitgeb, M. (2023). Enzymatic, antioxidant, and antimicrobial activities of bioactive compounds from avocado (*Persea americana* L.) seeds. *Plants, 12*(5), 1201.