# Hybrid ZnO-AuDAPT Nanoparticle Coating for Enhanced Antimicrobial Performance of Clear Orthodontic Aligners

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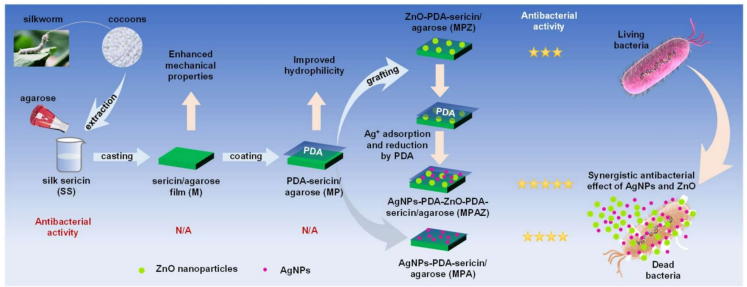
# Introduction

- Clear aligners are vulnerable to bacterial colonization and biofilm formation, potentially causing dental complications like enamel demineralization and gingival inflammation
- Our proposed solution employs **a hybrid antimicrobial coating**, strategically combining **ZnO nanoparticles with low concentrations of AuDAPT** embedded within **a UV-crosslinked acrylic matrix**
- Aim to leverage ZnO's robust antibacterial properties alongside AuDAPT's powerful anti-biofilm capabilities

**Figure 1.** Preparation of AgNPs-PDA-ZnO-PDA-SS/AG (MPAZ) film with enhanced mechanical performance and antibacterial activity.




Li, W., Huang, Z., Cai, R., Yang, W., He, H., & Wang, Y. (2021). Rational Design of Ag/ZnO Hybrid Nanoparticles on Sericin/Agarose Composite Film for Enhanced Antimicrobial Applications. *International Journal of Molecular Sciences*, 22(1), 105. https://doi.org/10.3390/ijms22010105

# Competition/Need

**Current Coatings – Limitations:**

- **ZnO**: Clear but loses effectiveness after 24 hours.
- **MgO**: Antibacterial but causes visible discoloration.
- **Quaternary Ammonium**: Easy to apply but lacks long-term data.
- **AuDAPT**: Strong anti-biofilm but turns aligners purple and may leach thiols.

**Why a New Solution?**

- No current option balances **clarity**, **durability**, and **safety**.
- Patients need a **transparent, long-lasting, and biocompatible** antimicrobial coating.

# Materials:

**Zinc Oxide (ZnO) Nanoparticles**

- Properties:
  - Well-established antibacterial, antifungal, and antiviral properties
  - Inherently transparent, maintaining aesthetic quality
  - Biocompatible

**Low-concentration AuDAPT**

- Properties:
  - Anti-biofilm and antibacterial properties, effective against drug-resistant pathogens
  - Potential to cause discoloration of the aligner
  - Possible leaching of thiol functional groups

**UV Crosslinked Acrylic/Carbon Matrix**

- Properties
  - Anchors nanoparticles securely to the aligner surface
  - Physically entraps AuDAPT, reducing risk of leaching

# Coating Method Overview

## Low-concentration AuDAPT

- Minimizes discoloration
- Maximizes anti-biofilm & antibacterial effects

## Dip-Coating Method

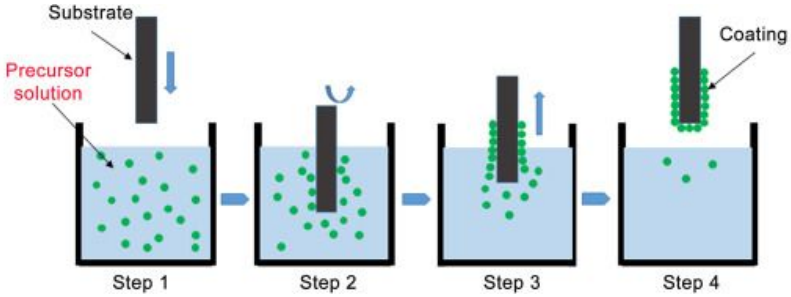
- Ensures **thin, uniform** coating

## UV-Crosslinked Acrylic/Carbon Matrix

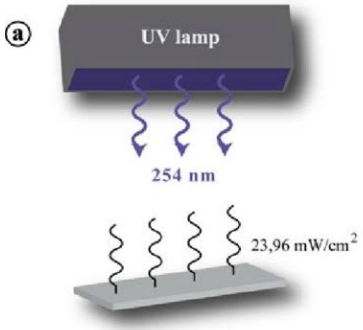
- **Anchors AuDAPT** to aligner surface
- **Enhances wear resistance** and durability
- **Reduces leaching** of gold nanoparticles & thiol groups

## Outcome:

- Clear, **long-lasting**, and **clinically safe** antimicrobial coating for aligners
    - Evaluates coating robustness and substrate bonding.




Dip coating method
(Perovskite Photovoltaics Basic to Advanced Concepts and Implementation
Book • 2018)




Expected process
(UV cross-linking of unmodified DNA on glass surfaces
10.1007/s00216-009-3045-9
Analytical and bioanalytical chemistry)

# Coating Characterization Overview

**Optical Properties: Transparency & Band Gap**

**UV-Vis Spectroscopy & Photoluminescence (PL):**

- Assess transparency, color (e.g., purple hue), and band gap.
- PL identifies defect states or multiple band gaps.

**Thickness & Surface Morphology**

**Alpha-step:** Measures ~100 nm thickness, uniformity.
**AFM:** Nanoscale surface details, localized thickness.
**SEM/TEM (Cross-section):** Structural validation post initial thickness scans.

**Material Uniformity**

**EDX Mapping (SEM/TEM):**

- Elemental distribution of ZnO.
- Detects agglomeration or uneven deposition.

**Adhesion Testing**

**Tape & Scratch Tests:**

- Evaluates coating robustness and substrate bonding.

# Functional Testing & Application Performance

**Crosslinking Efficiency**

**FTIR:** Tracks functional group changes post UV curing.

**Raman & XPS:** Analyzes ZnO-polymer interactions, carbon bonding states.

**Antimicrobial Testing**

**Confocal Microscopy + Fluorescent Labeling:**

- Compares hybrid-coated, ZnO-only, AuDAPT-only, and uncoated samples.

**Ilastik Image Analysis:** Quantifies bacterial colonization.

**Biocompatibility**

**Cytotoxicity Assays (MTT, Live/Dead):**

- Tests on oral cells for viability, morphology, and proliferation.

**Durability & Longevity**

**Mechanical:** Simulated 7-day brushing to test wear resistance.

**Chemical:** 7-day immersion in artificial saliva for leaching & stability.

# Overall Impact & Conclusion

**On Consumers…**

**Health and Comfort:**

- Reduced risk of oral issues like gingivitis
- Maintained transparency and comfort that consumers desire
- Reduced frequency of dental visits

**On the Environment…**

**Long-lasting with minimal waste:**

- UV-crosslinked coating minimizes waste

**Pollutants:**Low concentration of thiols.

**On Manufacturing…**

**Dip-coating:**

- Can be applied directly after the current manufacturing process without intense capital reinvestment

**Potential Hurdles and Areas for Future Research**

**Regulatory Frameworks:** Nanoparticle-coated dental appliances may require robust long-term data

**Adhesion:** Acrylics and TPU may pose an issue

**Next Steps:**

- Optimizing nanoparticle size if needed
- Long-term clinical trials
- Keep a keen eye on the thiol-modified AuDAPT component

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