

Bacterial Biofilms and Titanium Implants: Current Understanding, Clinical Challenges, and Emerging Surface Modification Strategies

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INTRODUCTION & AIM

Bacterial biofilms are a major factor contributing to chronic and persistent infections, posing a significant challenge in modern medicine due to their high resistance to antimicrobial treatments and host immune responses. This problem is particularly critical in the context of titanium-based implants, which, despite their excellent mechanical properties and biocompatibility, remain susceptible to bacterial adhesion and biofilm formation. The limited effectiveness of conventional therapies has driven the development of alternative strategies, especially those focused on preventing biofilm formation through surface modification of biomaterials.

The aim of this review is to summarize current knowledge on biofilm formation on titanium implants and to evaluate modern strategies for its prevention and control, with particular emphasis on advanced surface modification techniques and antibacterial coatings that can enhance implant performance and long-term reliability.

RESULTS & DISCUSSION

Table 1 Types of infection and etiological agents associated with biofilm formation on biomaterial surfaces

Type of infection	Etiological agent
Surgical site infections (SSI)	Staphylococcus aureus, Staphylococcus epidermidis, Staphylococcus saprophyticus, Echerichia coli
Infections associated with dental implants	Staphylococcus aureus, Staphylococcus epidermidis, Streptococcus spp., Echerichia coli
Infections associated with orthopedic implants	Staphylococcus aureus, Staphylococcus epidermidis, Cutibacterium acnes, Echerichia coli
Infections associated with urinary catheters	Pseudomonas aeruginosa, Staphylococcus saprophyticus, Echerichia coli
Infections associated with artificial heart valves	Staphylococcus epidermidis, Staphylococcus aureus, Enterococci, Echerichia coli.
Infections associated with vascular grafts and catheters	Staphylococcus epidermidis, Staphylococcus aureus, Enterobacteriaceae, Echerichia coli

CONCLUSIONS

Material composition and surface engineering play a critical role in biofilm prevention on implant surfaces. Advanced titanium alloys and multifunctional surface modifications represent promising directions, though further research is required to develop stable, non-toxic, and clinically effective antibacterial solutions.

METHOD

A systematic literature review was conducted focusing on studies investigating biofilm formation on implant materials, including metals, polymers, ceramics, and composites. Bacterial biofilms represent structures that are widely present in both natural and artificial environments, as well as in living organisms. The process of their formation constitutes the bacterial life cycle and includes the following stages.

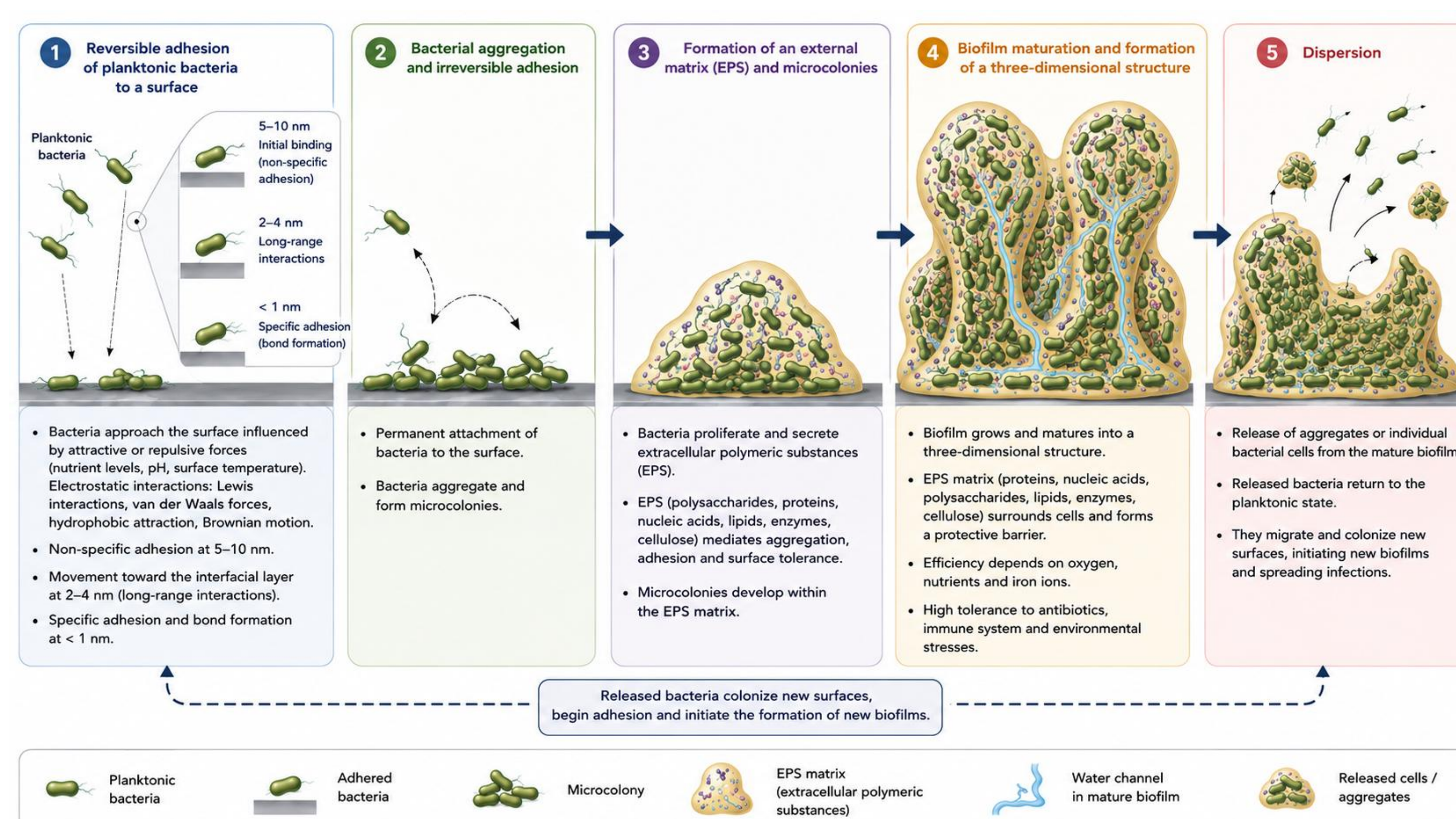


Figure 1 Biofilm formation cycle

Particular attention was given to titanium alloys and surface modification techniques such as micro-arc oxidation and electrophoretic deposition. Key parameters analyzed included surface roughness, wettability, chemical composition, and surface energy

These methods are divided into four main groups:

- physical and mechanical,
- composite,
- chemical.

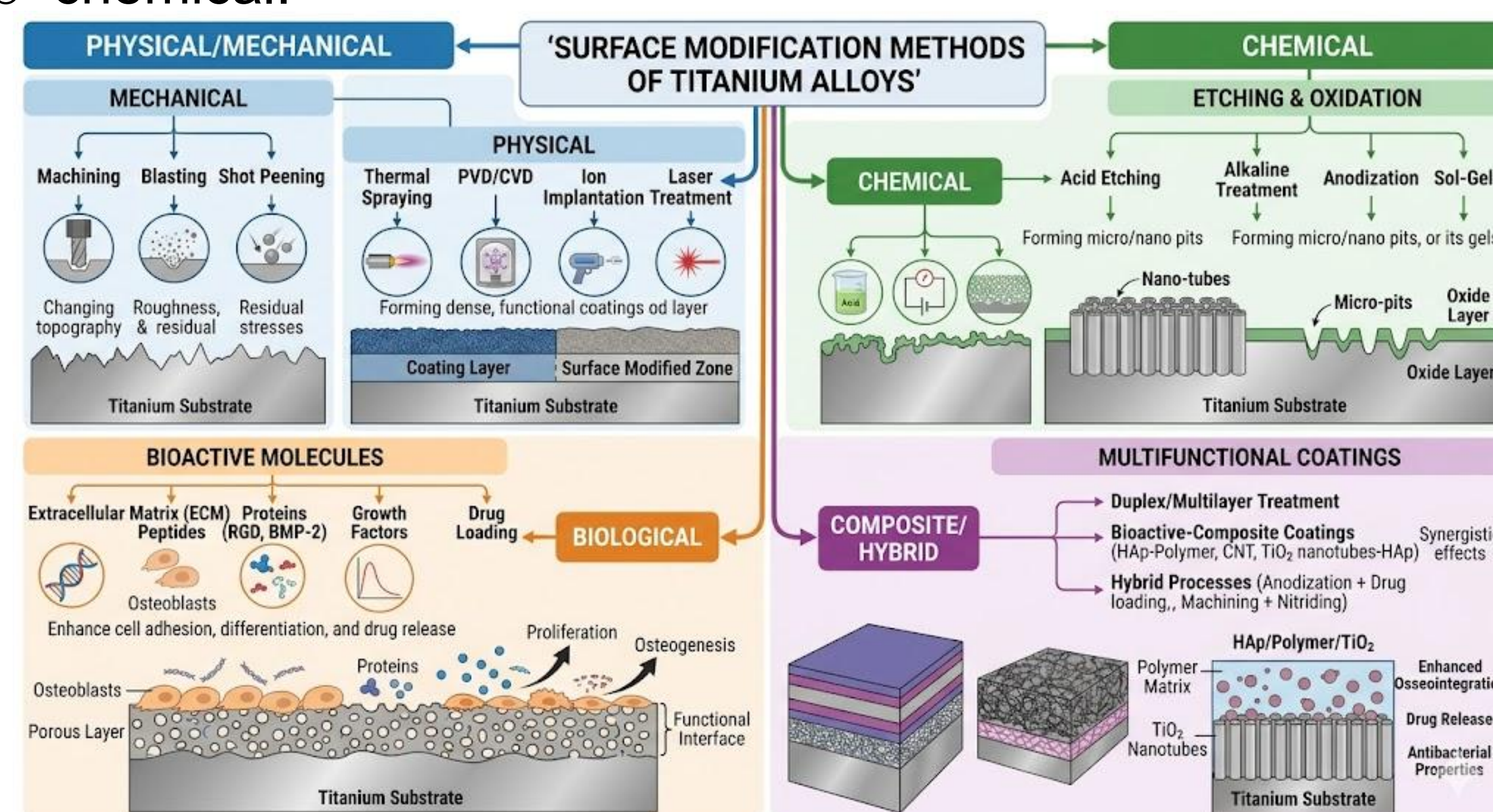


Figure 3 Surface modification methods

FUTURE WORK/ REFERENCES/ACKNOWLEDGMENT

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