Comparison of antibacterial activity of strontium and zinc-doped hydroxyapatite (Zn-Sr-HAP) coating on stainless steel miniplates with control.

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Abstract:

Aims: This study aims to analyse and compare the antibacterial properties of strontium and zinc-doped hydroxyapatite stainless steel miniplates and screws with controls. **Materials and methods:** The control group had an uncoated SS plate; the SS plate in the G1 group had strontium-doped hydroxyapatite coating (Sr-HAP); the G2 group had zinc-doped hydroxyapatite coating (Zn-HAP); and the G3 group had strontium and zinc-doped hydroxyapatite coating (Zn-Sr-HAP). Agar diffusion experiments were used to evaluate the antibacterial effectiveness of the groups against standard type-culture microorganisms, namely Streptococcus mutans. The wells are filled with the sample being tested for antimicrobial properties. **Results:** The study found significant differences in the ZOI among the three coated implants for the S-mutans microorganism tested. The G3 group showed the highest amount of ZOI (17), followed by G2 (15) and G1 (12) (Table 1). The S3 group showed the highest ZOI (16), followed by S2 (13) and S1 (10) (Table 2). In both plates and screws, the control group showed no ZOI. **Conclusion:** Strontium and zinc-doped hydroxyapatite coatings on stainless steel miniplates have antibacterial properties. It has shown to be better than the respective coatings when done individually.

Keywords:

Introduction:

The predominant materials utilised in the production of miniplates in maxillofacial surgery are stainless steel and titanium. Both materials are frequently employed in internal fixation because of their notable mechanical robustness and compatibility with biological systems [1]. Nevertheless, their inclination to host infections can differ. Stainless steel has been shown to cause a higher incidence of postoperative infection than titanium [2]. This leads to loosening of fixation material or plate exposure in the oral cavity. Titanium has been preferred to stainless steel nowadays for its increased biocompatibility and antibacterial properties [3, 4]. This study aims to analyse and compare the antibacterial properties of strontium and zinc-doped hydroxyapatite stainless steel miniplates and screws with controls.

Materials and methods:

In a previous study done and published by us, we have described the methodology of synthesis of Zn-Sr-HAP powder done by electrochemical deposition on stainless steel miniplates. The coating presence in the plates and screws has been verified by Fourier transform infrared (FTIR) spectroscopy [5]. This study aims to assess the antibacterial property of the coated plates by using an agar diffusion assay.The control group had an uncoated SS plate; the SS plate in the G1 group had strontium-doped hydroxyapatite coating (Sr-HAP); the G2 group had zinc-doped hydroxyapatite coating (Zn-HAP); and the G3 group had strontium and zinc-doped hydroxyapatite coating (Zn-Sr-HAP).

Figure 1: Control, G1, G2, and G3 plates in agar plate

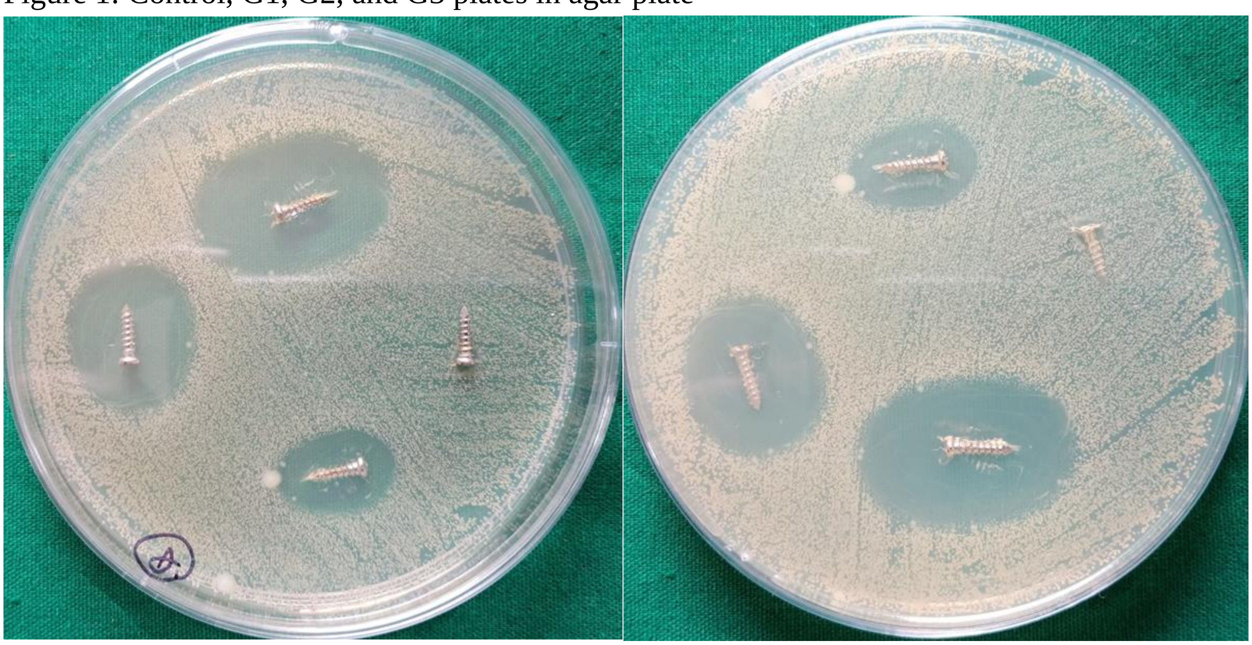

Figure 2: Control, S1, S2, and S3 screws in agar plate

The antibacterial method is a widely used technique to evaluate the antimicrobial activity of coated material. This study had In this method, the coated discs were placed on an agar plate that had been inoculated with a test microorganism. Agar diffusion experiments were used to evaluate the antibacterial effectiveness of the groups against standard type-culture microorganisms, namely Streptococcus mutans. The wells are filled with the sample being tested for antimicrobial properties.The isolates for all tests were cultivated overnight in mitis-salivarius (MS) agar at 37 ◦C in an oxygen-rich chamber. After incubation, the results are interpreted based on the formation of inhibition zones around the wells, and the G3-coated disc showed better inhibition compared to Control, G1, and G2 with 17 mm of measurement (Figure 1 & 2). The zones of inhibition (ZOI) were established by accurately measuring the diameter of the clear zone using a metric ruler placed against the rear surface of the Petri dish.

Results:

The study found significant differences in the ZOI among the three coated implants for the S-mutans microorganism tested. The G3 group showed the highest amount of ZOI (17), followed by G2 (15) and G1 (12) (Table 1). The S3 group showed the highest ZOI (16), followed by S2 (13) and S1 (10) (Table 2). In both plates and screws, the control group showed no ZOI.

Control	G1	G2	G3
0 mm	12 mm	15 mm	17 mm

Table 1: Zones of inhibition in each group of plates

Control	S1	S2	S3
0 mm	10 mm	13 mm	16 mm

Table 2: Zones of inhibition in each group of screws

Discussion:

Although the human body typically tolerates these metals well, their surface might gradually accumulate roughness or tarnish, creating an opportunity for bacterial colonisation. Infections in stainless steel miniplates are frequently associated with a multitude of causes [6]. Stainless steel surfaces are prone to microabrasions and roughness, particularly when not adequately polished. This coarse texture can serve as a breeding ground for bacteria, resulting in illnesses [7]. The corrosion byproducts of stainless steel can facilitate the development of biofilms, in which bacteria attach to the surface and create a defensive layer. The presence of alloying metals such as nickel and chromium in stainless steel can provoke allergic reactions or inflammatory responses in certain individuals, therefore potentially heightening the susceptibility to infection [8].

Titanium is often favoured in modern surgical practices due to its superior biocompatibility and corrosion resistance. It is less reactive and more stable in the biological environment compared to stainless steel. Titanium's exceptional corrosion resistance minimises the risk of material degradation [9]. Its surface forms a natural oxide layer that resists further corrosion and biofilm formation. This characteristic helps reduce the potential for bacterial colonisation and subsequent infections [10, 11]. Titanium is less likely to induce allergic reactions or inflammatory responses compared to stainless steel. Biocompatibility of titanium reduces the risk of complications that could lead to infections [12]. Titanium surfaces can be treated or coated to enhance their integration with bone tissue and reduce bacterial adhesion. Techniques such as anodisation or the application of antimicrobial coatings can further decrease infection risks.

Metals coated on the surface of the implants slowly leech from the implant [13]. These leeched metal ions are responsible for the enhanced properties. In this study, hydroxyapatite is used as a porous coating medium in which Zn and Sr are doped. Zn attaches to the bacterial cell wall, causing increased permeability, and it also affects the metabolism of aminoacids [14, 15]. Zn ions have a highly oxidative character and cause the release of reactive oxygen species. This causes bactericidal action. Sr causes inhibition of cell wall synthesis, protein synthesis, and DNA replication, causing bactericidal action [16].

In our study, the combination of strontium and zinc has been shown to cause synergistic effects in antibacterial properties and has been better than them being coated individually. Also, no ZOI in the control group signifies that the uncoated SS plate and screw show that stainless steel does not have any significant role in antimicrobial effect.

Conclusion: Strontium and zinc-doped hydroxyapatite coatings on stainless steel miniplates have antibacterial properties. It has shown to be better than the respective coatings when done individually.

Limitations of the study:

It is crucial to conduct additional research on zinc and strontium coating in order to evaluate its antimicrobial qualities, cell adhesion, and osseointegration in animals.

Conflict of interest: This study did not receive any funding.

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Library Progress International, 44(3), 1846-1852

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