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Title: Enhancing Surface roughness and Wettability of Commercial Pure Titanium Implants with Electrospun PCL/Chitosan/Cinnamon composite

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Abstract

To enhance the properties of titanium for implant applications,PCL/Chitosan/cinnamon watery extract composite were deposited on commercially pure titanium specimens using electro spinning technique . Water contact angle and surface roughness(Ra) tests were conducted, revealing significantly increased Wettability and(Ra) in the coated samples, a finding supported by statistical analysis. This increased surface roughness will potentially improve the Wettability properties of titanium which has demonstrated the significant impact of these surface characteristics on cellular responses to biomaterials.

Key wards: wettability, surface roughness,electrospinning ,cinnamon watery extract

1.Introduction:

Titanium has emerged as a highly favored biomedical material, particularly in the domain of dental implants. This because of exceptional biostability, high biocompatibility, minimal toxicity, impressive corrosion resistance, robust mechanical performance, and long-term durability (Abdullah ZS,et.al., 2023).

Numerous in vitro and in vivo investigations have underscored the pivotal role of titanium surface topography in enhancing implant performance (Al-Khafaji et al .,2020)The success of implant fixation is intricately linked to the properties of the implant's surface, which can be significantly improved through diverse surface coating technologies aimed at fostering osseointegration.(Jani GH. et al,2015).Surface characteristics such as topography, roughness, and wettability have consistently demonstrated their influence on cellular responses to biomaterials, as supported by a wealth of scientific studies (Tukmachi et al., 2021). Notably, micro-rough surfaces ranging from 1 to 100 µm increased surface area and facilities mechanical interlocking that course a direct impact on the torque and also have shown to stimulate osteoblast activity compared to their smooth counterparts, emphasizing the importance of surface roughness in promoting osseointegration (Ponsonnet L,et al, 2003).

Moreover, the utilization of polymer nanofiber (NF) coatings, particularly electrospun NFs, which mimic the natural extracellular matrix, has emerged as a promising strategy for enhancing implant performance. These coatings play a pivotal role in optimizing the surface characteristics of implant materials and fostering their biocompatibility and osseointegration potential. Also Polymer composites offer the advantage of facilitating the organized attachment of human cells to them. The morphological characteristics of these composites support cell growth, implantation, and migration.(Moghadasi et al.,2022).

The composite, comprising Chitosan, cinnamon, and PCL, exhibits promise in the context of wound healing ,the synergistic action of these components may stimulate tissue regeneration and support the healing process when applied to wounds (Stoica et al., 2015). Notably, the composite has demonstrated resistance to staphylococcal cell adhesion, which is pivotal for infection prevention. This characteristic suggests the composite's potential as a drug delivery carrier. PCL's capacity to regulate drug release, Chitosan's role in enhancing encapsulation, and the antimicrobial properties of cinnamon collectively make it a suitable candidate for drug delivery systems that mitigate infection risks (Sowmya et al., 2021).for tissue engineering ,thiscomposite, used as a scaffold, is biocompatible, non-cytotoxic, and biodegradable, making it an excellent choice for tissue engineering. It provides a supportive structure for cell growth and tissue regeneration(Osanloo et al.,2023).

Got this manuscript , to enhance the properties of titanium surfaces, we have employed a novel approach involving the incorporation of cinnamon particles loaded with a synthetic polymer, namely PCL. PCL is selected for its favorable mechanical properties, which contribute to the overall durability of the material. Furthermore, we have blended PCL with a natural polymer, Chitosan, known for its biodegradability and unique interactions with biological entities, such as proteins and cells. Chitosan offers a range of inherent advantages, including non-toxicity, antibacterial activity, and biodegradability. These polymer combinations facilitate the electrospinning of cinnamon particles onto the titanium surface, leading to an innovative and scientifically compelling approach to enhancing the material's characteristics.(Tamilarasi et al .,2023).

2.Materials and Methods:

2.1 Material:

Polycaprolactone (PCL polymer with a molecular weight of Mn = 80,000g/mol) purchased from Sigma Aldrich. Chitosan(CH) with a medium molecular weight (300 - 1000 cps)and a degree of deacetylation of ≥85%, purchased from Glentham Life Science. Acetic acid glacial with a molecular weight of 60.05, provided by Alpha chemika . Formic acid with a molecular weight of 46.03, also provided by Alpha chemika .

2.2 Plant extracts preparation:

Cinnamon bark was finely ground and sieved to create a powder.This powder was mixed with sterile water, heated at 60°C for an hour, filtered, and concentrated under reduced

pressure to form a semi-solid substance. After drying, it became a solid brown extract with spherical particles around 3.29 micrometers, stored at 4°C(Al-Dhaher .,2013).

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2.3.Substrate preparation for vitro study :

In this study, commercially pure titanium grade II discs with 20 mm diameter and 2 mm height from Smart DEM-Germany were employed. The discs were prepared by polishing with a sequence of SiC paper (320, 400, 600, 800, 1000 grit) and then subjected to two rounds of 5-minute sonication with acetone, ethanol, and distilled water. Following the polishing and cleaning, the discs were allowed to air dry for 15 minutes at room temperature .(Al-Khafaj et al.,2021 ; Safi IN et al.,2022).

2.4 Preparation of electrospinning solutions :

Following a previous study (Van der Schueren, L et al,2012), a polymer blend was created using 8% PCL and 10% chitosan(was reported as the ratio of chitosan mass to PCL mass in the solution). PCL was dissolved in a mixture of acetic and formic acid (3:7 v/v) with magnetic stirring for 3 hours. Chitosan was added, and the mixture was stirred overnight to form a clear and homogeneous Chitosan/PCL blend. A 12mg/ml cinnamon extract was then added and stirred for an hour, followed by 10 minutes of homogenization with an ultrasonic homogenizer (Model 300VT Ultrasonic Homogenizer, USA). These prepared PCL/Chitosan/cinnamon solutions were ready for the electrospinning coating process.

The optimization of electrospinning parameters is summarized in the following table(1).

Table 1 The optimization of electrospinning parameters

Flow Rate (ml/h)	Voltage (kV)	Distance (cm)	Needle Gauge (mm)	Humidity (%)	Temperature (°C)
0.6	25	15	0.7	35-55	Room Temperature

2.5 Wettability assay:

Wettability was assessed using deionized distilled water and the sessile drop technique (Optical contact angle SL200KS, China). This involved placing 1 ml of distilled water on both coated and control disks and measuring the contact angle of the water for 10 seconds. The test was repeated three times, and contact angles were measured using a camera-based contact angle meter.

2.6 The atomic force microscope assay (AFM):

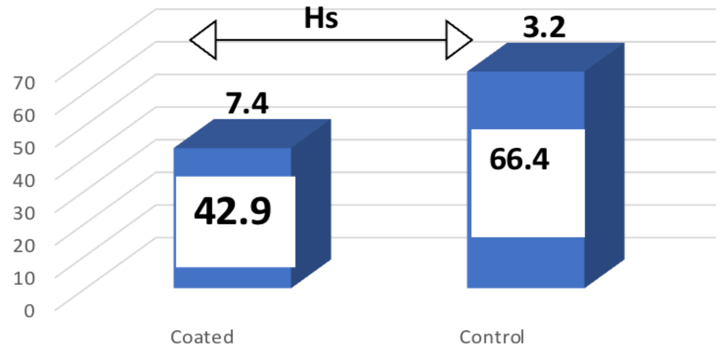
The study employed AFM to measure surface roughness and create high-resolution 3D images of coated and uncoated material surfaces. TT-2 AFM model was utilized in non-contact mode due to the rough nature of the metal surfaces, enabling detailed surface topography and morphology analysis.we measuring the arithmetical mean roughness (Ra) which is the arithmetical mean height that indicates the average of the absolute value along the sampling length.(Nicolas et al .,2020)

3.results:

3.1 Water Contact Angle

Coated samples exhibited reduced contact angles compared to uncoated ones, indicating the significant impact of the coating on substrate wettability. Data are summarized in Figure 1, showing a mean contact angle for coating were 42.68°, a standard deviation of 13.22°, while control 66.39 +-3.17

Figure 1 level of Contact angle wettability



3.2 Atomic Force Microscopy (AFM) Surface Analysis:

For the examination of surface morphology and surface roughness, AFM was mployed to analyze two groups: uncoated titanium samples and nano-fiber coated titanium samples. The 3D images with respective profile curve of both groups are visually depicted in Figure 2. Comparison of the mean values of surface roughness(Ra) for these two groups is summarized in figure 3, which highlights that the coating group exhibited the highest mean surface roughness values.

Coating

Control

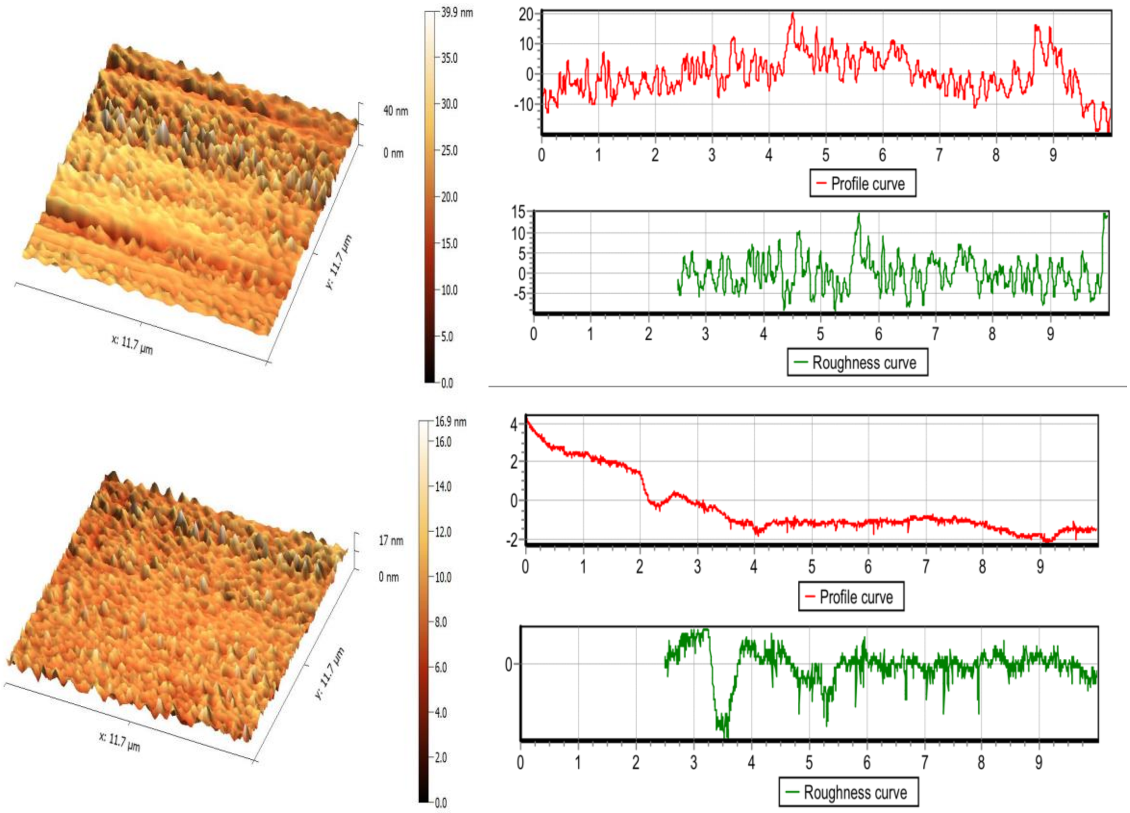


Figure 2 Atomic force microscopy (AFM) 3D topographical images with respective profile figure of control and coated samples.

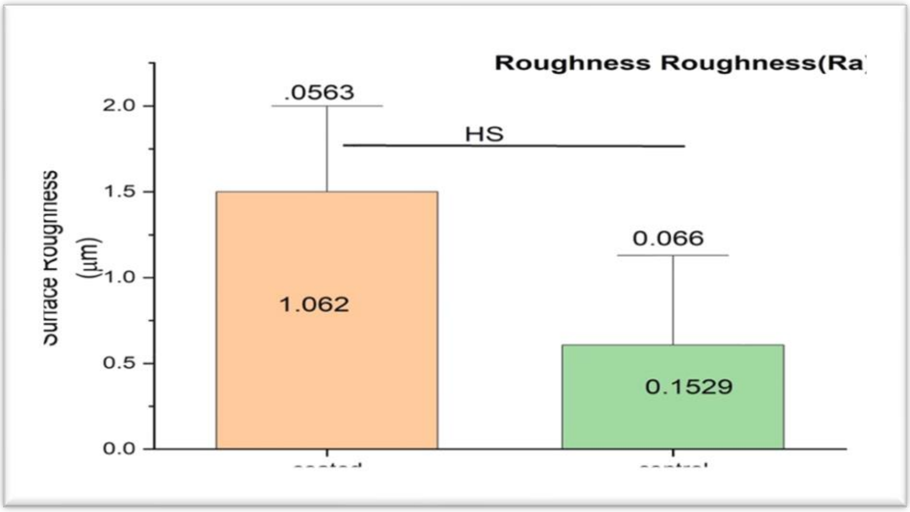


Figure 3:Surface Roughness (Ra) mean Comparison with t test (significant difference)

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4.Discussion

This study was performed to evaluate the effects of PCL /chitosan /cinnamon extract as coating on surface modification of titanium implant .Surface topography, roughness, and wettability has been shown to significantly affect cellular responses to biomaterials in several studies. The behavior of cells on biomaterial surfaces is determined by the interaction between implant and cells, which is related to surface roughness. To improve bone cell adhesion and proliferation, it is thoughtful to mimic the cellular environment by creating materials with nano topography. While nano topographic features are important for the recruitment and migration of bone cells to the implant surface, micro topographically complex surfaces are equally vital in increasing the degree of bone-to-implant contact. (Tukmachi et al.,2021)

Surface roughness has an important effect on the wettability and surface energy of surface of implant .(Zhang J,et al, 2023).the difference in wettability between the two surfaces reveals that the exposed atoms of chitosan and cinnamon had a stronger wetting affinity than its counterpart uncoated substrate surface, indicating that the addition became increasingly hydrophilic because of the presence of active groups in chitosan, these active groups formed hydrogen bonds with water. (Hamad et al.,2023)

The coated samples showed a markedly different surface topography, attributed to the electrospinning process, resulting in irregularly distributed fibers, giving rise to a structured and textured topography. Thicker accumulations of fibers in the coating led to variations in height and a more pronounced topography. In contrast, the uncoated titanium samples exhibited a smooth and uniform surface with minimal roughness.(Al-Khateeb et al.,2023).

The results suggest that the coating process significantly alters the surface topography, and this can have implications in fields where surface characteristics are important, such as biocompatibility, adhesion, and material performance. The increased roughness observed in coated samples could potentially enhance certain interactions with biological materials or affect mechanical properties.

Correlation between roughness and wettability

In the results section, as demonstrated with figure 4, it was observed that increasing surface roughness is linked to an increase in surface wettability, reflecting positive correlation between these two characteristics. Surface roughness plays a crucial role in influencing wettability. Roughening the surface leads to an expansion in surface area, providing more opportunities for liquid molecules to interact with the surface. This expanded surface area results in more robust capillary forces, enhancing surface wetting. This phenomenon is commonly observed in materials science, where rougher surfaces tend to exhibit greater wettability due to their increased surface energy (Wang et al., 2020

Ongoing intensive research is focused on the fundamental theories of how roughness affects wetting, a topic of significant relevance in both technical and biomedical fields. A key insight from Wenzel's theory is that hydrophilic surfaces with contact angles below 90° become even more hydrophilic when roughened, while hydrophobic surfaces become more hydrophobic with surface roughening(Hay KM et al .,2008)

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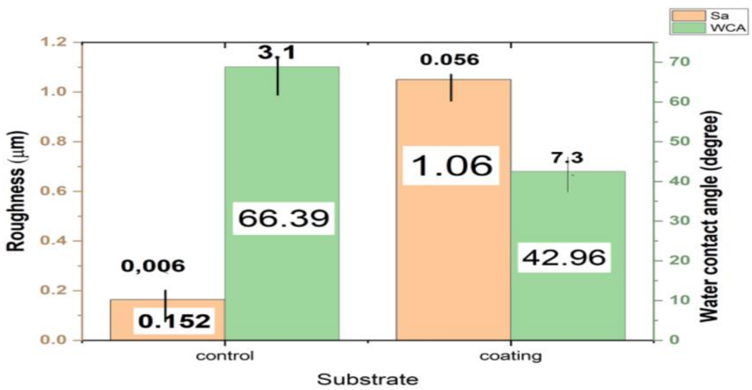

Figure 4. The relationship between roughness and wettability values is displayed in (Figure 4.3).

5.Conclusion

The research findings suggest that the electrospinning technique for applying the PCL/Chitosan/cinnamon extract composite onto titanium surfaces holds promise for enhancing implant materials. The increased wettability and surface roughness are indicative of improved biomaterial responses, which can positively impact implant performance and osseointegration. This study provides valuable insights into innovative approaches to enhancing the properties of titanium for biomedical applications, particularly in the field of dental implants.

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