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The Effects of Selenium Nanoparticles on the Osseointegration of a Titanium Implant in Rabbits: A Histomorphometric Investigation

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Abstract

Objective: One of the unique tooth or **tooth replacement prosthesis in the dental implant. To encourage bone formation where it is applied, our approach uses a biomaterial system that is easily obtainable, and able to induce osteoinductive growth factor. Selenium nanoparticles are**

Methods: Thirty-two implants consisting of commercially pure titanium rod were given to sixteen New Zealand rabbits. One implant was placed in each tibia of each rabbit. After implantation, eight rabbits were sacrificed every one to six weeks. For each animal, the left tibia implant was treated with selenium nanoparticles, whereas the right tibia implant was left uncoated. After staining each section with hematoxylin and eosin, the sections were examined histologically and assessed for histomorphometric analysis, which counted the number of bone particles that were formed.

Results: Selenium nanoparticle-coated titanium implants showed earlier bone growth, mineralization, and maturation than control comparisons. After all the bone parameters were examined histomorphometrically for the study, the healing durations of the two types of implants differed significantly.

Conclusion: Selenium nanoparticle-coated titanium implants had improved healing and osseointegration.

Keywords: Bone, Implant, Selenium Nanoparticles, Osseointegration.

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Introduction

The jawbone is attached to a surgical component called a dental implant or fixture to sustain a dental prosthesis [1]. The biological process of osseointegration—the intimate bonding of materials like titanium with bone is the foundation of contemporary implants [2]. An osseointegrated implant is an endosteal implant that has pores into which osteoblasts and supporting connective tissue can migrate. This term refers to bone that has grown up to the implant surface in oral implantology, devoid of any soft tissue layer in between [1,3].

A variety of surface treatment methods have enhanced the surface properties of titanium implants, promoting osseointegration by increasing implant stability and encouraging bone development [4]. Selenium nanoparticles (Se NPs) have potent antibacterial capabilities and have garnered significant interest. The trace element selenium is regulated by cellular redox homeostasis. It is also a constituent of selenoproteins, which govern vital biological functions like the elimination of reactive oxygen species and the regulation of specific enzymes. The method used to make Se NPs determines whether they can inhibit bacterial growth [5]. The goal of this work

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was to demonstrate the ability of Se NPs to promote osseointegration.

Material and Methods

A total of sixteen mature male New Zealand white rabbits, weighing between 1.5 and 2 kg, had thirty titanium rods with machined surfaces implanted. One implant was inserted into each rabbit's right and left tibia—one for experimentation and the other as a control. One- and six-weeks following implantation, animals were sacrificed.

The implants were divided into two groups: control (16 uncoated implants) and experimental (16 selenium-coated implants), each of which received a different treatment.

The rabbits' tibias were drilled holes of 3 mm in diameter, and they were used to insert the sterilizing implants. Prior to the right tibia receiving coated implants, the left tibia was treated with coated implants. following the rabbits' sacrifices at the prescribed times. Dissection was used to remove the soft tissue from the left and right tibias.

To construct implant-contained bone blocks, the right and left tibias were dissected, the soft tissue was removed to expose the complete bone, and slices were created at 5 mm from each implant's side to form implant-contained bone blocks. The right and left tibias were dissected, the soft tissue removed to reveal the whole bone. After the specimens were fixed with 10% formalin for 48 hours, the bone tissue was paraffin embedded and alcohol dehydrated. After that, the samples were decalcified using a solution of formic acid. Hematoxylin and eosin were used to stain 5-millimeter sections that had been prepared as normal. The histology was examined under a light microscope. Bone cells (osteoblast, osteocyte, and osteoclast), cortical bone thickness, trabecular breadth, thread width, and marrow space star volume were all assessed histomorphometrically.

Results

In controls, histological examination showed that osteoid tissue had accumulated in several places **(Figure 1).**

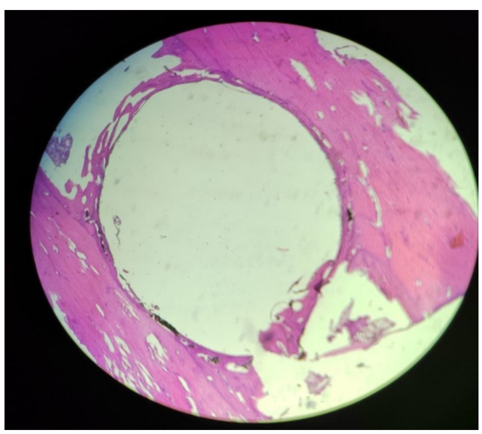

Figure 1. The histological examination of the control group after one week revealed that the thread region is filled with osseous tissue (H&E X10).

The implant's shape and thread region can be seen in the test specimens in Figure 2. Bone trabeculae were seen under higher magnification in the thread region. Osteocytes occupied the large lacunae in these trabeculae, and osteoblasts were clustered at their edges.

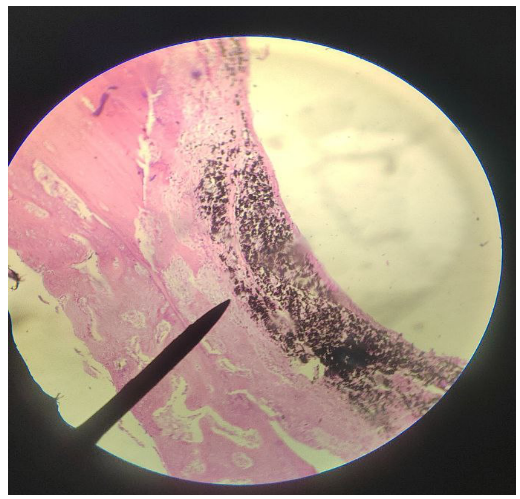

Figure 2. An examination of the six-week experimental group shows woven bone in the thread area, which was followed by the screw-shaped blood vessels and hyalinization (H&E X4).

The growth of thick bone trabeculae, surrounded by active osteoblasts and packed with large osteocytes, is visible in the histological image in controls at 6 weeks. Furthermore, continuing bone remodeling is demonstrated by the existence of osteoclasts and reversal lines at higher magnification (Figure 3).

The histology of test samples

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displayed mature, well-established bone that has osteocytes filled in the thread area and was encircled by osteoblasts. Under higher magnification, adult bone contained HA version lamellae (Figure 4).

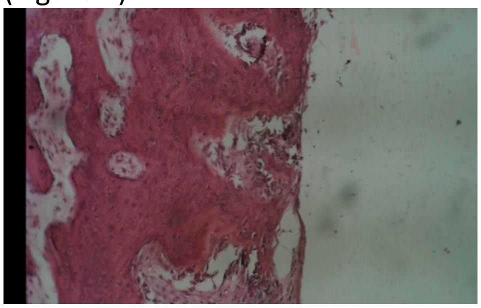

Figure 3. Osteocytes (OC), osteoclasts (OCL), and osteoblasts (arrows) may be seen in the thread region in the six-week control group's view (H&E X20).

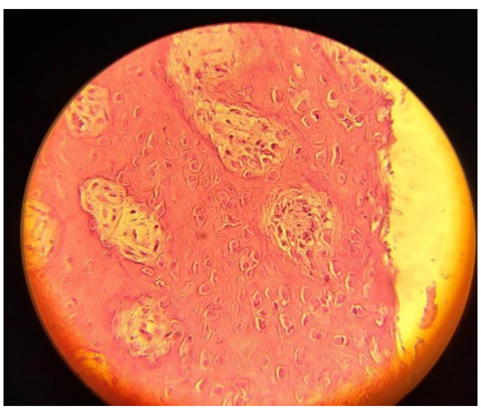

Figure 4. Osteocytes (OC) and a reversal line (RL) are seen in the magnified picture of the 6-week test group (H&E X100).

Bone architecture characteristics were determined by histomorphoetric analysis of the analyzed groups.

The experimental and control groups' descriptive statistics for the bone architecture parameters are shown in Table 1 for each healing interval.

For both the experimental and control groups, the mean values of thread width, trabecular breadth, and cortical bone thickness rose with time. The mean values for the Selenium-coated (Se coated) group are greater than those for the control group at every stage of recovery. The mean marrow space during the healing process, with the Se coated group showing a more pronounced fall than the control group. The mean values for the number of osteoblasts and osteocytes in the experimental and control groups grew over time, although the Se coated group's mean values increased more quickly in 1- and 6-week intervals than the control group. The osteoclast number was smaller in the Se-treated group than in the control group at the same time in week 6 for both groups, based on the mean values.

There was a statistically significant difference between the control and experimental groups in each healing phase.

Discussion

Assessing the effect of Se NPs on the bone-implant interaction was the aim of the present study. Se NPs seem suitable for use in medicine, either on their own or in conjunction with antibiotics that are currently available. The antibacterial properties of Se NPs stop the growth of pathogens, including bacteria, fungi, and viruses. Selenium nanoparticles are thought to be a safer and less hazardous biomaterial for surface coatings than many other nanoparticles, such as copper oxide, zinc oxide, and silver nanoparticles, which are utilized to alter the surfaces of medical devices [6].

The histology observations for the experimental and control groups showed that all sections had a favorable healing course; however, the rates of bone remodeling and deposition varied with each healing interval. After one week of implantation in control animals, the sections clearly indicated the replacement of the blood clot by granulation tissue with a substantial number of collagen fibers, fibroblasts, and osteoblasts, as well as the onset of osteoid tissue formation. In implants that had been treated with Se, osteoblast differentiation had already begun to replace the granulation tissue with new bone.

Implant-associated infections can be prevented or reduced using two primary strategies. Anti-adhesive surfaces were developed to stop or reduce germs' initial adherence to the implant surface. The second technique is mixing antimicrobial drugs with the polymeric implant components. Surfaces treated with oxygen plasma are among the

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surfaces that exhibit adhesion resistance.

Following a one-week break, the histology sections of the control group revealed delicate bone trabeculae with newly produced woven bone. Compared to the control group, the Se-treated group had more and thicker bone trabeculae. Due to its chemopreventive and chemotherapeutic properties, selenium seems to be a promising anticancer biocompatible orthopedic implant material. Se NPs can also effectively prevent and treat S. aureus and S. epidermidis infections, which are among the most frequent causes of implant failure. Staph. aureus and Staph. epidermidis adhesions were greatly decreased when a 0.5 percent sodium selenite solution was applied to the titanium discs [7].

The findings also demonstrated a notable change in bone architecture parameters over time. The length of time spent on bone deposition and maturation may be responsible for increases in trabecular width, cortical width, thread width, and trabecular number over six weeks as opposed to one. Conversely, a decrease in bone marrow star volume over time may result from faster bone matrix building, which will cause wider bone trabeculae. These results corroborate research by Depprich et al. [8,9], which discovered that enhanced bone-to-implant contact was observed at every stage of recovery by histomorphometric examination. The findings also demonstrated a notable change in bone architecture parameters over time. When bone formation settles and reaches its final measurement, no more osteoblasts are needed beyond those needed to sustain biological activity. This is because the production of more osteoblasts is necessary for any new tissue formation, which explains why the number of osteoblasts and osteocytes increased over time. These findings are consistent with those of Al-Molla et al. [10-13], who discovered that whereas osteoblast counts decreased with time, osteocyte counts rose.

Table 1. Descriptive data for each group's bone architecture characteristics.

Descriptives									
Bone Formation	Groups	N	Mean	Std. Deviation		95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
	control (1w)	8	1.13	0. 06		1.01	1.4	1.13	1.45
	control coated (1w)	8	1.48	0.08		1.5	1.6	1.43	1.87
Bone Formation	Groups	N	Mean	Std. Deviation		95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
	control (6w)	8	1.67	0.05		1.15	1. 05	1. 6	1. 8
	control coated (6w)	8	2.54	0.1		2 02	2. 8	1.9	2.5

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Conclusion

The study showed that by promoting osteogenic mesenchymal tissue, osteoblast formation, and early osteoid tissue apposition, selenium nanoparticles (SeNPs) enhanced and sped up the osseointegration of titanium implants.

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