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The Impact of Osteogenic Coatings on Implant Integration in Osteoporotic like Condition: A Systematic Review

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Abstract:

Around 3oo million individuals in the world suffer from osteoporosis, a condition where bones become weak and prone to fractures due to low bone density and poor bone structure. Fractures related to osteoporosis can lead to increased pain, disability, healthcare costs, and even mortality. Diagnosis typically involves measuring bone mineral density using a noninvasive technique called dual-energy X-ray absorptiometry. A systematic review was conducted to know the impact of osteogenic coatings on implant integration in osteoporotic condition.

Keywords: Osteoporosis, implant, prosthodontics, bone loss, Dentistry, Bisphosphonates, bone mineral density

I. INTRODUCTION

Defination:The definition is given by WHO in 1996 as "A systemic skeletal disease characterized by low bone mass and microarchitectural deterioration, with consequent increase in bone fragility with susceptibility to fracture."[1]

Osteoporosis is an incidious and progressive bone disease. The jawbone is likewise affected by this. The Greek terms "osteo," which means "bone," and "poros," which means "pore" or "hole," are the source of the phrase "osteoporosis," which means "porous bone."[2]

Osteoporosis is a frequent condition that primarily affects the elderly. The illness frequently progresses in a very slow manner. It is challenging to look at bone loss and make a firm diagnosis of the symptoms, especially in the early stages.[3]

Various treatments are available for osteoporosis, with the goal of decreasing the likelihood of fractures. These include estrogen therapy for post-menopausal women, selective estrogen receptor modulators like raloxifene, calcitonin, recombinant parathyroid hormone (teriparatide), strontium ranelate, and notably bisphosphonates, which are commonly prescribed in clinical settings.[4]

Since maintaining adequate bone volume (BV) and achieving high bone-to-implant contact (BIC) are crucial for ensuring implant stability in low bone mineral density (BMD) conditions, it is theorized that implant surfaces treated with osteogenic coatings stimulate osteoblastic activity. This, in turn, enhances both BV and BIC in osteoporotic-like (OP-like) environments compared to implants without such coatings.[5]

The goal is to evaluate how osteogenic surface coatings on implants will improve osseointegration in osteoporosis like conditions.

II. Material and methods: The study conducted a systemic review on osteoporosis and dental implant therapy, consulting databases such as PubMed, Cochrane, ISI, Dentistry Oral Science, SciELO, and Bireme for the past 24 years. The abstracts of the articles were retrieved, reviewed, and sorted based on the following inclusion and exclusion criteria. To be included in the study, the article had to be published in an English peer-reviewed journal and be an experimental study. The study excluded clinical or technical reports that simply described a incomplete publications like abstracts only, and review articles. Additionally, a manual search of specific journals was conducted to supplement the results from April 2000 to April 2023: The paragraph lists several dental journals, including The International Journal of Prosthodontics, Implant Dentistry, The International Journal of Periodontics and Restorative Dentistry, Journal of Prosthodontics, Clinical Oral Implants Research, and Clinical Implant Dentistry and Related Research. After conducting the search methods, 27 articles were chosen.

III. Results:

General Charactreristics of the Studies

Table 1. provides an overview of the main characteristics of the studies that were part of the current systematic evaluation. Every study was conducted in an experimental environment at a university from 6 to 19. Ten different research employed rats, three studies used rabbits, and one investigations used sheep. To induce conditions similar to osteoporosis, all research involved bilateral ovariectomies (OVX) on the animals (Table 1).[6-19] Following implant implantation, the follow-up time varied from two to tweenty weeks. Implants were positioned in the tibia or femoral condyle bone.

Table 1. Study Grouping and Implant Related Characteristics of Studies That Fulfilled Our Eligibility Criteria

Authors(year)	Specimen no.+ Age	Study Groups	Implant surface modification	Follow up + implant placement place	Study Outcome
A Sachse[6](2005)	25 sheep	Group 1- Control group Group 2-Coated with nonglycosylated recombinant human bone morphogenic protein 2	Coated with nonglycosylated recombinant human bone morphogenic protein 2.	20 weeks Placed laterallay Below both tibial plateaus.	This animal study was the first to show that using nonglycosylated BMP-2 coated on solid implants could promote bone healing and regeneration, even in older individuals with compromised health.
Alper yildiz DDS[7](2010)	36 Female rabbits(aged 6-12 months)	Group 1-Sham control group Group 2-Ovariectomy	Coated with zoledronic acid	8 weeks Placed in each tibia of the animal.	The findings of this research indicate that administering Zoledronic acid systemically may

		group(OVX) Group 3- OVX + Zoledronic acid group			enhance the integration of titanium implants in bone affected by osteoporosis.
Nikos Mardas[8](2011)	36 Rabbits	Group A-12 Rabbits with weekly doses of alendronate Group B- 12 received no treatment Group C-12 rabbits were sham operated and used as healthy controls.	Modified etched hydrophilic titanium	4-16 weeks Placed in parietal bones	The employment of modSLA surface appears to enhance bone healing and osseointegration in osteoporotic rabbits. However, the use of bisphosphonates may hinder the osseointegration process of newly formed bone during the initial healing phase.
Hamdan S Alghamdi[9](2013)	30 Rats	Group 1- 15 wistar rats by OVX Group 2- Control Group (Sham operated)	Coated with calcium phosphate or collagen type -I	12 weeks Placed in femoral condyles	Utilizing calcium phosphate (CaP) and collagen type-I surface coatings for bone implant surface modification has a positive impact on the bone implant interface in the osteoporotic rat model.
Jian- Ping Li[10](2014)	46 Rabbits	Group 1-12 sham operated Group 2- 12 With OVX Group 3- 12 With OVX+ ZA	Coated with Hydroxyapetite	2-8 weeks Placed bilaterally in tibia	Systemic administration of Zoledronic acid (ZA) effectively enhances the initial bone healing of implants in autogenous grafted bone of osteoporotic rabbits. This is achieved by improving early osseointegration and implant fixation
Amarjit S Virdi[11] (2015)	Rats	Group 1- Sham – ovx Group 2- Ovx group	Sclerostin antibody treatment	4,8& 12 weeks. Placed in the medullary cavity of distal aspect of the femur	Treatment with Scl-Ab improved the fixation of implants by promoting bone formation and reducing bone resorption. This resulted in

					increased contact between the bone and the implant, as well as enhancements in trabecular bone volume and structure.
Zhou –Shan Tao[12] (2016)	50 female rats (Aged 3 months)	Group 1- Hydroxyapatite Coated (0% & 10%) Group 2-Zinc Coated (0% & 10%) Group 3- Magnesium Coated (0% & 10%) Group 4 – Strontium Coated (0% & 10%)	Zinc, Magnesium, Strontium-incorporated hydroxyapatite coated titanium implants.	12 weeks Placed in femur bone.	This study revealed that coatings made of hydroxyapatite, which included 10% of zinc, magnesium, and strontium ions, promoted implant osseointegration. They also enhanced the trabecular microstructure and improved implant fixation, with varying effects depending on the type of metal ions used.
Behnosh O Malekzadeh[13] (2018)	44 Rats	Group 1-4 healthy rats Group 2- 40 OVX rats	Insulin coated titanium implants	1-3 weeks Placed in tibia.	The local application of insulin shows promise in stimulating bone formation and may have anti-inflammatory effects in osteoporotic rats.
P Korn[14](2019)	64 rats	Group 1-OVX Group 2- OVX+ZOL	Combination of an anti-resorptive zoledronic acid (ZOL) implant-coating and a systemically applied sclerostin antibody.	3 months Placed in proximal tibia.	Study proves that, the combined use of ZOL and the osteoanabolic sclerostin antibody proved to be more effective than either treatment alone.
Ethan M Lotz[15] (2019)	40 Rats (8 Months Old)	Group 1-SHOVX +PBS Group 2- SHOVX +BIS Group 3- OVX +PBS Group 4- OVX + BIS	Ibandronate treatment.	5 Weeks, 25 Days, 1 week Placed in distal metaphysis of each femur.	The findings indicate a decrease in osseointegration in osteoporotic animals. Ibandronate at clinically relevant doses was effective in stopping the progression of osteoporosis.

		(BIS-Biphosphonates PBS-Phosphate buffered saline)			However, these doses did not improve the osseointegration of microrough titanium implants.
Liu J[16](2021)	90 female Rats	Group 1-5 rats sham operated Group 2- 5 rats OVX 80 rats then further divided into two groups: Group 1-DFO(deferoxamine) 40 rats Group 2- 40 rats in control group	Hypoxia stimulators on titanium prosthesis.	12 Weeks Placed in tibia	The localized administration of DFO, which activates the HIF-1α signaling pathway, can enhance osteogenesis and the integration of a prosthesis in osteoporotic bone.
Yan R[17] (2022)	20 Rats	Group 1- sham operated Group 2- OVX	Sr, Zinc augmented titanium implants.	8 weeks Placed in femur bones.	Considering all the results, study infer that co-doping with Zn and Sr could be a promising modification method to enhance the properties of titanium implants in an osteoporotic bone microenvironment by promoting osteogenesis and angiogenesis.
Geng Tengyu[18] (2022)	40 Rats (12 week old)	Group 1- 10 Sham Operated Group 2- 30 OVX	Strontium Doping	2-4 weeks. Placed in femur as well as in tibia	Surfaces incorporating strontium (Sr) that have been treated through hydrothermal reactions have shown improved osteogenic differentiation and early bone osseointegration in osteoporotic models.
Yang X[19](2024)	24 feamle rats	3 groups	A dual – functional strontium coated titanium implants.	4- 8 weeks Placed in femur	In osteoporotic rats with femoral defects, Ti-PDA-Sr implants showed enhanced osteo-immunomodulatory capabilities and

					facilitated osseointegration with the surrounding tissues after eight weeks of implantation.

Table 2. Implant Related Characteristics of the studies included:

Authors (year)	No. of Implants Placed	Implant Shape	Implant Length (mm)	Implant Diameter (mm)	Implant Surface Characteristics
A Sachse[6](2005)	50 Implants	Cylindrical	12 mm		BMP coating
Alper yildiz DDS[7](2010)	36 Implants	Cylindrical			Zoledronic and titanium coated implants
Hamdan S Alghamdi[9](2013)	30 Implants	Cylindrical		2.85 mm	Grit blasted and then cleaned in nitric acid 10%, acetone & ethanol.
Zhou –Shan Tao[12] (2016)	50 Implants	Cylindrical	20 mm	1 mm	Grit blasted and then cleaned in acetone for 10 min.
Liu J[16](2021)		Oval	5 mm	1.5 mm	
Yan R[17] (2022)	40 Implants	Cylindrical	7 mm	2mm	Field emission scanning electron microscopy with energy – dispersive x-ray spectrometer
Geng Tengyu[18] (2022)	20 Implant	Cylindrical	2 mm	1.8 mm	Ti plates was examined using field emission scanning electron microscopy. Contact angle measurement for wetting properties. Samples was placed in 10 ml of phosphate buffered saline solution at 37 degree celcius.
Yang X[19](2024)	24 implants	Cylindrical	10 mm	1.2 mm	Ti implants was cleaned in an ultrasonic bath using dimethyl ketone, ethyl alcohol, and deionized (DI) water

There is no details given about the implant characteristics in studies by Nikos Mardas[8](2011), Jian- Ping Li[10](2014), Amarjit S Virdi[11] (2015), Behnosh Malekzadeh[13] (2018), P Korn[14](2019) & Ethan M Lotz[15](2019). P Korn[14](2019) placed 128 implants while Amarjit S Virdi[11] (2015) placed cylindrical implants only this much of information is given about these studies.

Discussion

Almost 80% of the evaluated literature indicated that, in OPlike circumstances, osteogenic coatings surrounding implant surfaces improve bone growth, BIC, and BV. These findings lead one to believe that in both systemically healthy individuals and patients with osteoporosis, implants with a rough surface encourage the growth of bone around the implant. It is important to note, nonetheless, that every conclusion presented in this study came from research using animal models. Within two weeks to twenty weeks following OVX, OP-like circumstances were created in these trials.Particularly, different coating materials were chosen for each of the included investigations.ZOLcoated implants also show better osseointegration in OPlike settings than noncoated implants, accordingto three

studies.7,10,14 According to one theory, ZOL coatings enhance HAcoated implant osseointegration in OPlike settings by changing the trabeculae's rodlike form to a platelike structure (after an oestrogen deficit), like structure (after an oestrogen deficit), which increases the amount of bone around the implant and enhances implant attachment. Nevertheless, studies have also shown that covering implant surface with osteoanabolic sclerostin antibody in addition toZOL results in the largest BIC compared to ZOL usage alone. Results from a recent experimental study indicated that the secondary stability of implants is linked to the bone-implantcontact(BIC). According to the reviewed literature, the diameters of the implants employed in the various investigations differed; nonetheless, the histologic results of the majority of the research showed that, in animals with and without OPlike condition, coated implants had considerably moreBIC surrounding them than noncoated surfaces.

Conclusion: According to experimental evidence, osseogenic surface coatings on implants improved osseointegration in osteoporosis like condition; nevertheless, more extended prospective clinical trials are necessary to evaluate the contribution of oseogenic coatings for osseointegration enhancement in people with osteoporosis.

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