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Densitometric Evaluation of Osteon 3 as a Bone Graft Substitute in Zirconium Implants

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ABSTRACT

Aims: This experimental study was conducted to evaluate the effect of Osteon 3(Biphasic Calcium Phosphate) as a bone graft substitute on the bone response around Zirconium implants.

Materials and Methods: Twenty male New Zealand rabbits were used for this experimental study. Forty Zirconium implants were used on the twenty rabbits (i.e., two implants for each one). The implants were surgically placed into the right femoral bone, one implant was considered the control sample placed on the proximal femoral head and another implant placed at the distal femoral head with the addition of Osteon 3 material and considered the experimental sample. Each hole was kept 1 cm away from each femur head. The proximal preparation site was filled with Osteon 3 material and the Zirconium implant was inserted and screwed using the mini-implant screwdriver; this group was considered as (Zirconium implant + Osteon 3). The other Zirconium implant was inserted and screwed in the distal preparation site, which was considered the control group (Zirconium implant). The time intervals were three days, one week, two weeks, and four weeks, bone response was evaluated around the Zirconium implants after the euthanasia of the animals according to study time intervals. The Densitometric analysis was used for measuring the bone density around the Zirconium implant.

Results: The Densitometric readings for bone density showed a significant difference between the control group (Zirconium implant) and the experimental group (Zirconium implant + Osteon 3) regarding bone density at all the four periods.

Conclusions: The Zirconium implants osseointegrated with the surrounding bone. The use of Osteon 3 as a bone substitute around the Zirconium implant increases the rate of bone formation around the implant at the early stage of bone healing.

Keywords: Zirconiumimplant,Densitometric analysis, Biphasic Calcium Phosphate,Osteon 3, bone response.

I.INTRODUCTION

Zirconia implants were introduced into dental implantology as an alternative to titanium implants. Recent development and improvements in technology rendered ceramic implant materials with better mechanical properties, corrosion resistance, wear resistance, and high flexural strength. Such characteristics made them a potential alternative to conventional titanium implants [1].

Zirconia ceramics were first introduced to implant dentistry in the form of coatings onto metal-based implants to enhance osseointegration. In the last years dental implants made of Yttria-tetragonal zirconia polycrystals have appeared as an attractive metal-free alternative to titanium implants [2].

Zirconium is highly biocompatible with no local or systemic toxic effects. Zirconia seems to be a suitable implant material because of its toothlike color, mechanical properties, and low plaque affinity [3].

The selection of proper bone graft material is one of the important factors for successful hard tissue restoration in dental field. Alloplastic materials are recently used as bone substitute. They are biologically acceptable, allowing bone ingrowths and bone remodeling while maintaining volume [4].

Nowadays, Biphasic calcium phosphates (BCPs) are considered as the gold standard of bone substitutes in bone reconstructive surgery [5]. Biphasic calcium phosphates contain different concentrations of hydroxyapatite and tricalcium

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phosphate. They offer significant advantages over other calcium-phosphate ceramics due to controlled bioactivity and a balance between resorption and non-resorption, which favors the stability of the biomaterial while also promoting new bone formation [6].

II.MATERIALS AND METHODS

The study was approved by Research Ethics Committee board (College of Dentistry / University of Mosul / Department of Oral and Maxillofacial Surgery), under ethical approval number (UoM.Dent/ A.L.10/ 21).

Twenty male New Zealand rabbits weigh 1.5Kg ± 250grams were used for this experimental study. The animals were kept under standard conditions of feeding, housing, and ventilation. They were given a standard fresh greenery diet and tap water and were encaged separately in the same environment, their health was evaluated to exclude any medical conditions that would compromise the neutrality of the subjects.

Study design

The twenty rabbits were randomly assigned into four groups A, B, C, and D, based on the study time intervals (i.e., three days, one week, two weeks, and four weeks respectively). Forty Zirconium implants were used on the twenty rabbits (i.e., two implants for each one). The implants were surgically placed into the femoral bone, one implant was considered the control sample placed on the proximal femoral head and another implant placed at the distal femoral head with the addition of Osteon 3 material and considered the experimental sample.

Implants design and manufacturing

The implants were designed in a conical shape, with a coronal width of 2.5mm and a total length of 7mm. The threaded part of the implant was designed to be 5mm in length, leaving 2mm in head length. A slit was made in the implant's head to ease insertion using a mini-implant screwdriver with the aid of a pointed implant apical part.Figure (1).

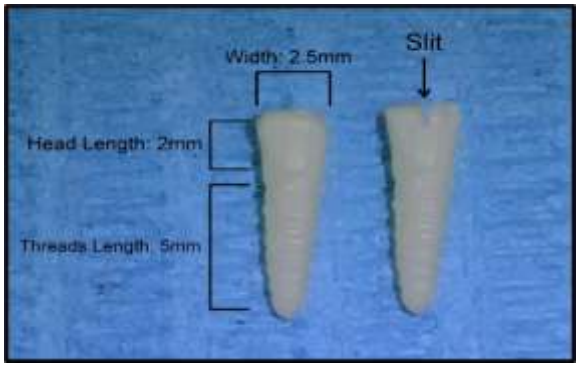

Figure (1): The Design of the Zirconium Implant.

Osteon 3 graft substitute

Osteon 3 biphasic calcium phosphate is a synthetic biocompatible osteoconductive bone graft material manufactured in porous homogenous particles composed of 60% H.A. (Hydroxyapatite) and 40% β-TCP (Beta-Tricalcium Phosphate), with calcium to phosphorous ratio of 1.59 and crystallinity of ≥ 70%. The particle size of this graft material is 0.2-0.5mm, while the void fraction (porosity) is 80% with interconnected micro and macro pores 200-400µm in size. It is easy to manipulate with excellent wettability.

The surgical procedure

All surgical procedures were performed under sterile conditions. The rabbits were put under general anesthesia using Ketamine Hydrochloride 10% at a 50mg/kg body weight dose mixed with the muscle relaxant Xylazine 2% at a dose of 5mg/kg body weight.

After shaving the skin fur along the right femur and disinfecting the surgical site; a 2 cm-long skin incision was made usingNo. 15 scalpel blade.Using a periosteal elevator, the dissected soft tissue was reflected, and femur bone was exposed.The implant holes created using a surgical handpiece and Dentium kit drill system(the pilot drill, then the guide drill Ø2.2)at a speed of 850 rpm and torque 50 N.cm under rigorous normal saline irrigation 50m/ sec Figure (2). Two holes were created, the proximal preparation site was filled with Osteon 3 material (0.2 gm) and the Zirconium implant was inserted and screwed using a mini-implant screwdriver. The other Zirconium implant was inserted and screwed in the distal preparation site, which was considered the control

International Journal Dental and Medical Sciences Research
Volume 4, Issue 2, Mar-Apr 2022 pp 64-69 www.ijdmsrjournal.com ISSN: 2582-6018

Figure (3).The flap was repositioned and sutured using 3/0 black silk nonabsorbable suture with a simple interrupted suturing technique.Antibiotic prophylaxis was given immediately after the surgical procedure by administering Oxytetracycline 20 mg/kg intramuscular injection, the same dose repeated once per day for five days.

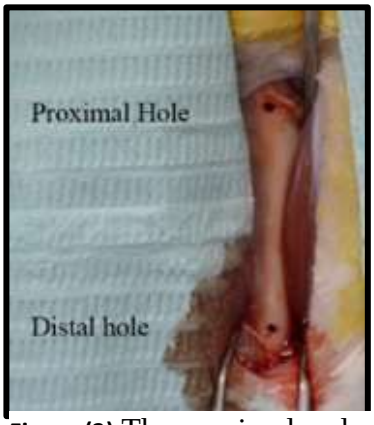

Figure (3): The proximal and Distal Hole after preparation in the Right Femoral bone of the Rabbit.

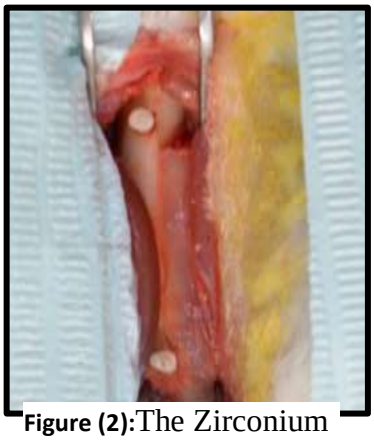

Figure (2): The Zirconium Implants after insertion in the Proximal and Distal hole.

The Densitometric Evaluation

The samples were subjected to a digital radiographic imaging using dental X-Ray tube machine (Dyson, DYS-M, ZHEJIANG GETIDY) and Dental X-Ray sensor (Carestream, RVG 5200)in Al-Rasheed Radiograph Center. For standardization,the distance between source and object was (10 cm), the Voltage (70 K.V.), Mille Ampere (7 mA), and time of exposure (0.3 seconds). The Densitometric analysis done using the X-Ray processing software (Carestream, C.S. Imaging Software version 7.0.3),five points (pixels) were selected along the implant threads at the trough of the serration, starting just below the cortical bone. The points chosen were: one at the apex of the implant in addition to superior (just below cortical bone) and middle (between the superior point and the apical point) on each side, Figure (4). The software calculated the bone density of each point and the average density of them. The average density was used in the statistical analysis.

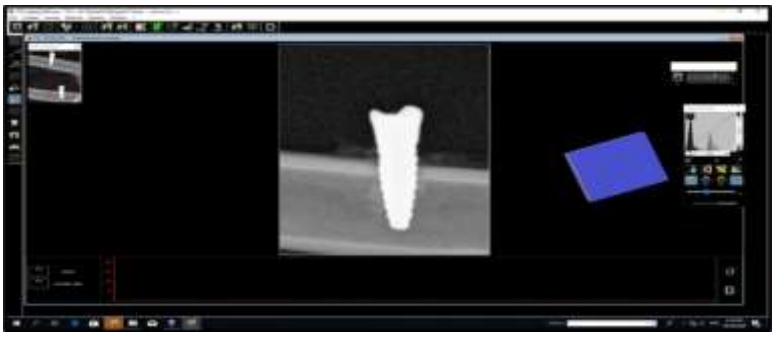

Figure (4): Screenshot Showing the Carestream, C.S. Imaging Software Version 7.0.3 Used for Densitometric Analysis.

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Statistical analysis

Microsoft Excel 365 and IBM SPSS 19 were used for descriptive and statistical analysis of the radiological data. Followed by performing a normality test, the Mann-Whitney test was employed to analyze the radiological data to demonstrate the differences between control and experimental groups. The difference considered statistically significant at $p \leq 0.05$.

III.RESULTS

The rabbits tolerated the surgical procedure well, and no rejection for the implants occurred. The results showed a statistically significant difference at $p \leq 0.05$ in bone density around the Zirconium implant between the group of (Zirconium) and the group of (Zirconium+Osteon3) at all time intervals.The results of the changes that occurred in bone density at each of the four periods of time and between the control (Titanium Implant) and experimental (Titanium Implant + Unigraft) groups are shown in Table (1) Figure (5).

Table(1): Comparison in the Changes of Bone Density Median Around Zirconium Implant During All the Four Periods Between Control and Experimental Groups.

Group	Three Days	Seven Days	Fourteen Days	Four Weeks
Zirconium Implant	102.8	123.8	108.0	113.2
Zirconium Implant+Osteon3	114.0	132.6	129.2	123.2

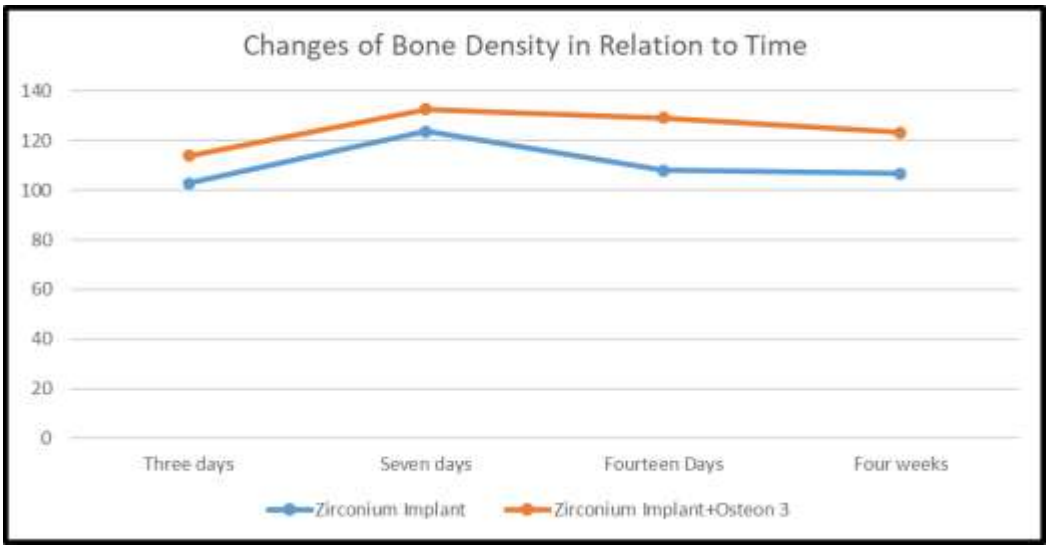

Figure (5): The Changes of Bone Density During the Four Periods of Time.

The statistical analysis done using (Mann-Whitney Test)and the results are shown in Table (2)

International Journal Dental and Medical Sciences Research
Volume 4, Issue 2, Mar-Apr 2022 pp 64-69 www.ijdmsrjournal.com ISSN: 2582-6018

Table (2): Statistical Analysis using Mann-Whitney Test Comparing the Bone Density Results around Zirconium Implant During All Four Periods.

Zirconium Implant / **Zirconium Implant +Osteon3**	**Sig.**
Day 3	.047*
Day 7	.016*
Day 14	.047*
Day 28	.116

* Significantly different at p≤0.05

The Radiographical images of the Zirconium implants in the femur bonein each time interval for both groups are displayed in Figure (6).

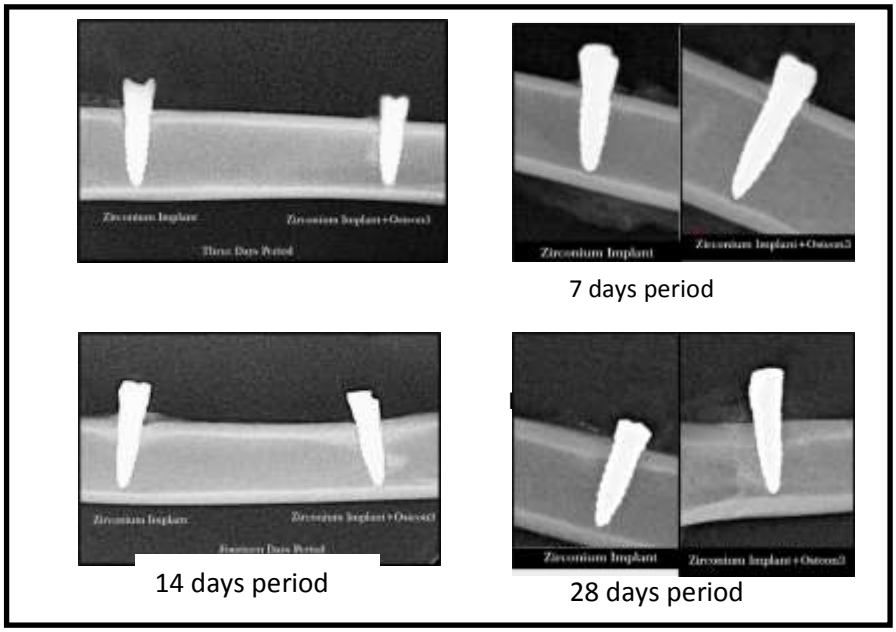

Figure (6): The Radiographical Images of the Zirconium Implants in the Femur Bone for Both Groups during the Four Periods.

IV.DISCUSSION

The present comparative study aimed to evaluate the effect of Osteon 3 material on the bone behavior around Zirconium implant.The Zirconium implant embedded in the femur bone without Osteon 3 was considered control and compared with the experimental site which was filled with Osteon 3 material previous to Zirconium implant insertion.The behavior of the bone around Zirconium implant was analyzed during four different healing time periods: 3, 7, 14, and 28 daysusing Densitometric analysis.

After 3 days from implantation,

The bone density in the group of Zirconium implant with Osteon 3 is higher than the bone density around group of Zirconium implant. The granules of the Osteon 3 material (β-TCP) do not dissolve spontaneously, this results in an increase in the opacity of the x-ray image of the

bone. The β-TCP resorb by a cell-mediated process involving multinucleated giant cells and macrophages [7].

After 7 days from implantation,
The bone density increased around Zirconium implant at seven days, and it was higher in the group of Zirconium implant with Osteon 3.

After 14 days from implantation,
The bone density decreased in both groups; it was much less in the group of Zirconium implant than the group of Osteon 3. Since the H.A. is a biodegradable material and replaced by the newly formed bone [8].

After 28 days from implantation,
The densitometric readings revealed a decrease in bone density in both groups.This indicates that the presence of Hydroxyapatite particles stimulates mineralization of bone matrix by positively modulating the expression of bone-specific markers and enhancing calcified matrix deposition during osteogenic differentiation [9]

V.CONCLUSIONS

Within the limitation of the present study, it can be concluded that the CAD/CAM designed Zirconium implants showed a successful osseointegration with the surrounding bone and the Biphasic Calcium Phosphate stimulates more bone formation around the implant. The Zirconium implant enhanced by Biphasic Calcium Phosphate seems to be a promising implant material.

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