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Effect of Osseodensification Technique in Implant Placement in Osteoporotic Bone (An Experimental Study)

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Abstract

This study aimed to evaluate histologically the effect of the osseodensifcation technique in implant placement in an osteoporotic bone of an animal model compared to the conventional one. This experimental study was conducted on twenty-one adult female New Zealand white rabbits. Osteoporosis has been induced to rabbits by intramuscular injections of dexamethasone (3 mg/kg) four weeks prior to implant placement. After osteoporosis induction, every rabbit received two implants, one implant using the conventional technique on the right tibia (control group), and the other implant using osseodensification technique on left tibia (study group). Subsequently, seven rabbits were sacrificed at three different intervals of time: this was done for the first group of rabbits 24 hours after implantation (baseline), the second group 30 days after implantation, and the third group 60 days after implantation. Then, (H&E) stained sections and Alizarin red stained sections were prepared for histological evaluation for the bone around dental implants for both groups. Analysis of (H&E) stained sections showed no obvious difference between the two groups after 24 hours however the study group showed more bone density in comparison to the control group after 30 days and after 60 days, in which the surrounding bone exhibited thick and more connected trabecula. Statistical results of histological analysis of area % Alizarin red staining sections showed that there was a statistically significant difference between (Conventional) and (Osseo-densification) groups ($p<0.001$) which indicating increasing in the bone density and bone condensation in the study group in comparison to the control group. Osseodensification technique may be considered as an effective method for increasing bone density and bone condensation around dental implants placed in the osteoporotic bone which increases the chance for success of osseointegration.

Keywords: Dental Implant, Osseodensification, osteoporosis, Densah Bur.

Full length article **Corresponding Author*, e-mail: elbashier@yahoo.com

1. Introduction

Success of dental implant placement depends on achieving the principle of osseointegration which is clinically identified by the asymptomatic implant fixation to the bone surrounding and histologically by direct contact between the bone and implant without soft tissue obstruction(1). The mechanical contact of the external implant surface to the walls of the recipient osteotomy site achieves primary implant stability, which is one of the most critical criteria for osseointegration of dental implants. Improving primary implant stability requires evaluating bone density, surgical method, and implant design(2).

Osteoporosis is a systemic skeletal disease characterized by reduced bone strength that predisposes to an increased risk of fractures(3). According to studies published by Donos et al., in 2015 and Giro et al., in 2015 , systemic diseases such as osteoporosis might impair bone repair and thus the predictability of dental implants(4,5). Osteoporotic bone cells show lower levels of proliferation, lower levels of transforming growth factor β1 production, and higher levels of interleukin-6 production as compared to osteoblasts taken from healthy patients(6). Furthermore, the quantity of mesenchymal osteogenic stem cells has been reduced in osteoporotic situations(7) and the investigation of osteoporotic patient tissues indicated changes in collagen stability, alignment, and composition(8,9).Considering all of these facts, it is plausible to assume that osteoporosis has a negative impact on the osseointegration and bone formation processes of dental implants. However, advancements in

surgical procedures appear to offer significant hopes for better clinical results(10).

Improving primary stability in low bone density locations is desirable but difficult, and has typically been performed by underpreparing the implant site(11)**.** In an in vitro research, a 10% underpreparation of the implant site was found to be sufficient to enhance primary stability in individuals with poor bone quality (12) . Another method for improving primary implant stability in poor bone quality is to use osteotomes to condense and compress bone apically and laterally to form a layer of compact bone at the implant interface (13)**.** However, these approaches have limits during surgery. The surgeon must continuously strike the summers osteotome with a mallet to advance it, which is a tough method that can be difficult for the surgeon to control and might result in inadvertent displacement, fracture, or patient side effects such as vertigo(14)**.**

Traditional implant site preparation techniques are subtractive in nature, involving digging bone and preparing the implant bed using gradually larger drills moving in a clockwise direction while being irrigated copiously(15)**,** While osseodensification (OD), a newly developed non-subtractive drilling technique, was recently introduced, allowing for more intimate engagement of the implant with the osteotomy site and increasing primary stability by compacting bone at the osteotomy walls with specially designed drills rotating in a counterclockwise direction(16,17)**.**

The osseodensification bur geometry permits compacting the bone along the inner surface of the implant osteotomy site without cutting, rotating in reverse mode (anti-clockwise direction) at a rotating speed of 800 to 1500 rpm with generous saline solution irrigation to prevent bone overheating. Additionally, compacting the remaining bone fragments around the implant serves as an autograft that promotes osseointegration by serving as nucleating surfaces for osteoblasts(16,18)**.**When compared to conventional drilling, OD was reported to produce higher insertion and removal torque, increased primary and secondary stability, higher bone-to-implant contact (BIC), and larger bone volume (BV) around implants(13), however its effect on implant placement in osteoporotic bone is still unclear.

2. Material and Methods

Twenty-one adult female New Zealand white rabbits, 4-5 months of age, weighting between 3-3.5 kg were used in this study. They were kept separately in stainless steel cages in an everyday animal facility, which maintained a room temperature of 21–24°C with a relative humidity of 40–60% and a 12-hour light–dark cycle. There were daylight hours during the light cycle. There was access to the standard food (containing 0.8% calcium and 0.5% phosphorus) and tap water.

2.1 Ethical approval

All experiments have been conducted in the animal house of the Faculty of Pharmacy, Nahda University, Egypt according to the recommendations and approval of the Ethics Committee of the Faculty of Dentistry, Minia University. Committee number (75) at 30/11/2020.

2.2 Experimental protocol

Induction of osteoporosis All animals received daily intramuscular injections of dexamethasone (3 mg/kg) [AMRIYA PHARM. IND. ALEX. EGYPT] four weeks prior to implant placement in order to create osteoporosis-like (OP-like) conditions. To confirm that the bone was in an OP-like condition, direct radiographs of the legs were taken.

2.2.1 Grouping

Twenty-one rabbits have been involved in the study. Every rabbit received two implants, one implant using conventional technique on right tibia (control group), and the other implant using osseodensification technique on left tibia (study group). Then following three-time intervals, seven rabbits were sacrificed: the first group was sacrificed immediately following implantation (baseline), the second group was sacrificed 30 days after implantation, and the third group was sacrificed 60 days after implantation.

2.2.2 Anaesthetic protocol

Prior to surgery, the animals fasted for 12 hours. Ketamine (KETAMAX 50MG INJ (Troikaa Pharmaceuticals Ltd)) and Xylazine (20 mg, M.H. Reg. No. 1373/99 Vet; ADWIA, Egypt) were given intramuscularly. Additionally, 2% (w/v) Lidocaine (Mepecaine, Alexandria Co. for Pharmaceuticals, Egypt) was administered locally at the surgery sites.

2.2.3 Surgical protocol

2.2.3.1 surgical site preparation and incision

Following the establishment of general anesthesia, each animal's tibia region was shaved, cleaned with iodine, and a 3-cm-long incision was made through the skin and fasciae to expose the tibiae shafts using blunt dissection **Fig. (1**).

2.2.3.2 Implant bed preparation using osseodensifcation technique

Following left tibiae exposure, under continuous irrigation with sterile saline, using a physio-dispenser, osteotomy was carried out using osseodensification drilling (OCD) using multi fluted tapered burs. Pilot drill of Densah® Burs (1.7 mm) was inserted to the desired depth (6 mm) (Clockwise drill speed 800 rpm with copious irrigation), **Fig. (2)**. Preparation proceeded in densification mode through the sequential stepped drilling with the Densah® Burs (counter-clockwise drill speed 800 rpm) with copious irrigation using drill size 2.3 (VT1828) followed by drill size 3.3 (VT2838) according to the protocol suggested by the Versah® for placement of 4.2 mm diameter, 6 mm length ROOTT implant in soft bone **Fig. (3).**

2.2.3.3 Implant bed preparation using conventional technique

After exposure of the right tibiae, osteotomy was done using conventional drilling technique according to instructions of the manufacturer (clockwise drill speed 800 rpm with copious irrigation) to place 4.2 mm diameter, 6 mm length ROOTT implant **Fig. (4)**.

2.2.3.4 implant insertion

Implants (4.2 mm diameter, 6 mm length ROOTT implants) were inserted into osteotomy sites using torque ratchet at 40 N/cm **Fig. (5).**

2.2.3.5 Surgical flap repositioning and suturing

Following cleansing of the surgical site, a 3/0 black silk interrupted suture was used to reposition and stabilize the flap, as shown in **Fig. (6**). The area was then washed with a mixture of iodine and 70% (v/v) ethanol**.**

2.3 postoperative care

Following surgery, PAN-Terramycin antibiotic was administered intramuscularly to each animal at a dose of 1.0 cm3 per kilogram (Oxytetracycline HCl; Pfizer, Egypt) for 3 days in a row, along with an analgesic at 0.05 mg/kg. Following surgery, the animals were instantly free to bear full weight without any constraints on their mobility.

2.4 preparation of specimens

According to the time intervals of the study, an intravenous overdose of Nembutal (NYSE:LLY, Indianapolis, IN) was given which resulted in the sacrifice of rabbits, both tibiae were removed from each rabbit as shown in **Fig.(7).** Bone samples were kept in neutral buffered formalin 10% for fixation followed by decalcification in 10% formic acid and routine processing protocol by passage of tissue sections in different grades of alcohols and changes of xylene ended by embedding in melted paraffin.

2.5 Assessment method

Five µm sections were cut and stained with hematoxylin and eosin for light microscopy. For evaluation of bone density at the site of the implant, Alizarin red stain was used. Olympus CX-43 light microscope (Olympus, Japan) equipped with ToupCam XCAM digital camera (Toup Tek, China) were used to examine the slides and capture images.

2.6 Statistical methodology

Statistical analysis of area % Alizarin red staining**.** The mean and standard deviation values were calculated for each group in each test. Data were explored for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests, data showed parametric (normal) distribution. One-way ANOVA was used to compare between more than two groups in non-related samples (Time periods). Paired sample t-test was used to compare between two groups in related samples (Groups). The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

3. Results

3.1 Light Microscopic examination of HE-stained sections

3.1.1 After 24 hours

At this early point of time, no signs of bone healing were observed in both control and study groups. The peri-implant bone area was filled with inflammatory cells fragments of necrotic bone without new bone formation in control group **Fig. (8)** meanwhile study group showed minimal inflammatory reaction and bone necrosis **Fig. (9).**

3.1.2 After 30 days

Control group **Fig. (10)** exhibited the presence of newly formed small bone fragments at the bone to implant contact edges with thin and less connecting trabeculae in the surrounding bone meanwhile study group **Fig. (11)** showed larger newly formed bone fragments at the bone to implant contact edges and other filling the trabecular space. The surrounding bone in the study group showed distinct calcification lines.

3.1.3 After 60 days

Despite the peri- implant bone areas in both groups were covered by newly formed bone fragments the surrounding bone density was lower in control group **Fig. (12)** meanwhile study group **Fig. (13**) showed larger new bone fragments filling the peri-implant bone area and extending into the trabecular space. The surrounding bone exhibited thick and more connected trabeculae.

3.2 Examination of Alizarin red staining sections

For evaluation of bone density at the edges of the implant, Alizarin red stained sections were used **Fig. (14-19)**. control group showed normal bone density meanwhile study group exhibited increased staining affinity indicating increased bone density.

3.2.1 Statistical results of histological analysis of area % Alizarin red staining

The mean and standard deviation values were calculated for each group in each test. Data were explored for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests, data showed parametric (normal) distribution. One-way ANOVA was used to compare between more than two groups in non-related samples (Time periods). Paired sample t-test was used to compare between two groups in related samples (Groups). The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

3.3 Effect of time

3.3.1 Conventional group (control group)

There was a statistically significant difference between (Baseline), (After 30 days) and (After 60 days) groups where ($p<0.001$). A statistically significant difference was found between (Baseline) and each of (After 30 days) and (After 60 days) groups where ($p=0.011$) and ($p<0.001$). No statistically significant difference was found between (After 30 days) and (After 60 days) groups where ($p=0.066$).

3.3.2 Osseo-densification group (study group)

There was a statistically significant difference between (Baseline), (After 30 days) and (After 60 days) groups where ($p<0.001$). A statistically significant difference was found between (Baseline) and each of (After 30 days) and (After 60 days) groups where ($p<0.001$). Also, a statistically significant difference was found between (After 30 days) and (After 60 days) groups where ($p=0.010$).

3.4 Relation between groups

3.4.1 Baseline

There was a statistically significant difference between (Conventional) and (Osseo-densification) groups where ($p<0.001$).

3.4.2 After 30 days

There was a statistically significant difference between (Conventional) and (Osseo-densification) groups where (p<0.001).

3.4.3 After 60 days

There was a statistically significant difference between (Conventional) and (Osseo-densification) groups where (p<0.001). Bar chart representing Alizarin red for different groups is shown in **Fig. (20)**.

4. Discussion

This study was designed as an experimental comparative study in which every rabbit receives two implants (one from each group) to allow for comparison of the different drilling bur types within each sample, which offers a similar healing potential with a similar immunological and microbiological condition(19). The study group's drills were made to be used counterclockwise, which increased the contact surface area between the fixture and the bony walls by allowing bone to condense and autograft alongside the walls and at the apical end of the osteotomy site**.** The control group's drills, on the other hand, were made to remove bone from the osteotomy walls in order to make enough room for the implant, which in turn will cause a decline in the quantity and quality of bone anchored to the fixture (20,21)**.**

New Zealand rabbits were chosen as the experimental animals for this study because they are relatively simple to handle and maintain; healthy animals of this type are easily available from local laboratories. Furthermore, this species is known to retain genetic consistency, which results in very minimal variation in morphological, histological, and physiologic properties among animals(22,23)**.** Because the bone healing response in such animals begins during the first week, peaks around 3-4 weeks, and reaches a relative stable state with relatively little bone remodeling 8 weeks after implant insertion, animal sacrifice was performed at three-time intervals after implant insertion**.** The general histological picture of bone and vascular architecture has actually shown to remain relatively unchanged in previous cases where follow-up lasting longer than a year has been conducted(24,25).

Osteoporosis is a prevalent condition that causes a reduction in bone mass and strength, particularly in postmenopausal women. Osteoporosis affects the jawbone as well, and it was thought to be a potential contraindication to the placement of dental implants(26,27)**.** The percentage of contact between the implant's surface and the bone can be influenced not only by implant parameters and surgical process, but also by patient-dependent variables such as bone quantity and quality. It is vital to ensure appropriate primary stability of implants in order to accomplish osseointegration. Thus, osteoporosis, which is characterized by bone loss, microstructure changes, and a decrease in bone regenerating ability, has been identified as a risk factor for dental implant placement(28)**.**

In the present study, examination of (H&E) stained sections of the study and control groups after 24 hours showed that there was no obvious difference between the two groups, however Alizarin red staining sections showed statistically significant difference in bone density and bone condensation between the two groups. After 30 days, examination of (H&E) stained sections showed that there was difference in bone formed around dental implant which was thin and less connecting trabeculae in the control group while the study group showed larger newly formed bone fragments at the bone to implant contact edges and other filling the trabecular space. The surrounding bone in study group showed distinct calcification lines.

Alizarin red stained sections examination showed increasing in bone density and condensation in study group in comparison to the control group which showed that there was statistically significant difference between the two groups in bone density and condensation after 30 days. After 60 days, the study group showed more bone density in comparison to the control group in (H&E) examination, in which the surrounding bone exhibited thick and more connected trabeculae. On the other hand, Alizarin red staining sections showed increased bone density at the peri-implant bone area in the study group in comparison to the control group which indicated that there was statistically significant difference in bone density and condensation after 60 days between the two groups.

Two methods exist for preserving bone: auto-grafting of bone particles along the length and at the apex of the osteotomy, and compaction of cancellous bone resulting from viscoelastic and plastic deformation. Through plastic deformation caused by the sliding of flutes across the surface of the bone with a compressive force less than the ultimate strength of the bone, the OD technique redistributes bone material on the osteotomy surface. Fresh, hydrated bone trabecular material is ductile and has a good plastic deformation capacity. In order to lessen friction and more uniformly distribute the compressive stresses, the irrigation fluid and the fluid content of the bone can aid in this process by forming a lubricating layer between the two surfaces(29). JImbo et al., in 2014 justified The use of the osseodensification technique by the fact that densifying the bone that will be in direct contact with the endosteal device will produce higher levels of primary stability because of physical interlocking (higher degree of contact) between the bone and the device as well as faster new bone growth formation because osteoblasts will nucleate on the instrumented bone that will be in direct contact with the endosteal device(30). Therefore, using the osseodensification technique resulted in increasing the bone density in the study group in comparison to the control group in which conventional technique has been used.

The results of our study are in agreement with the study by Trisi et al. ,in 2016 reported significant increase of ridge width ,bone volume percentage (%BV) and bone density with OD technique than the regular method in sheep iliac crests(21). In addition, Lopez et al., in 2017 observed a final substantial increase in bone area fraction (BAF) and bone density in the OD group compared to the standard drilling technique group in sheep cervical vertebral bodies(18). Witek et al., in 2019 validated the same findings, reporting a considerably greater BAF and bone density in the OD group in the iliac crests of female sheep(15)**.**

Fig 1: Tibiae of the rabbit is shaved **(A)** and 3 cm incision is made **(B)** to expose the tibiae shaft **(C)**.

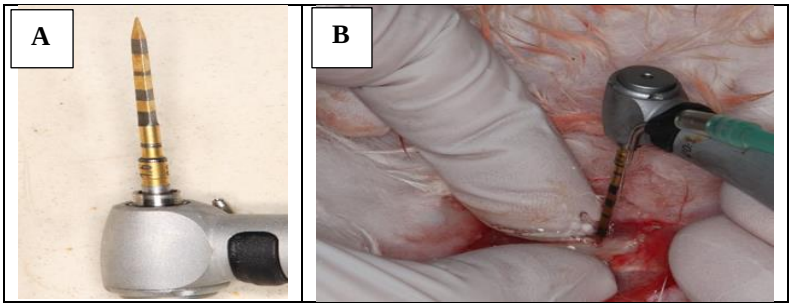

Fig 2: Pilot drill of Densah® Burs (1.7 mm) **(A)** was inserted to 6 mm depth (clockwise direction, speed 800 rpm) **(B)**.

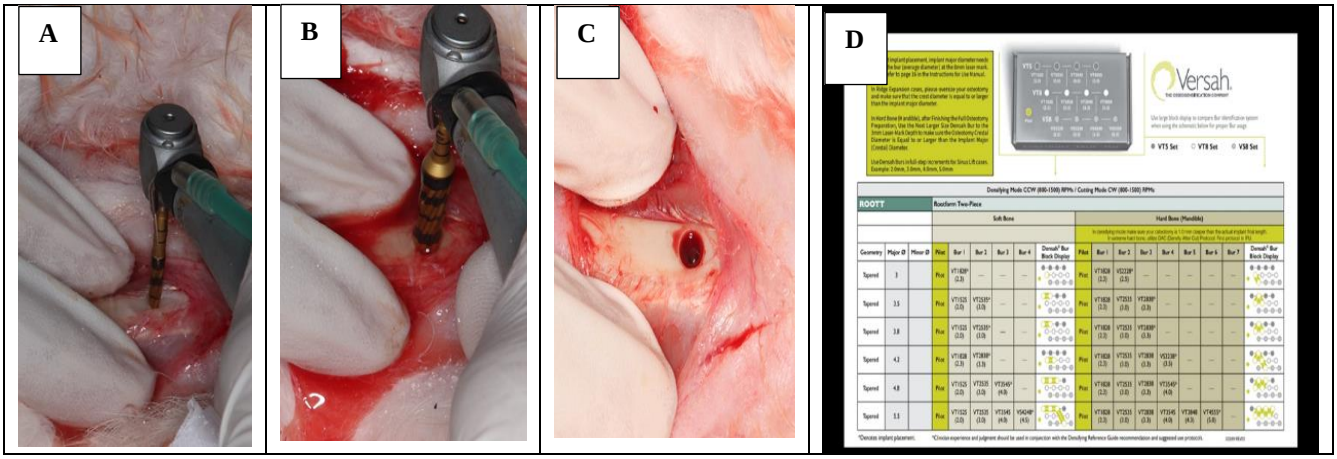

Fig 3: Densah® Burs drill size 2.3 **(A)** followed by drill size 3.3 **(B)** (counter-clockwise drill speed 800 rpm) to prepare the implant site **(C)** according to Versah® protocol **(D).**

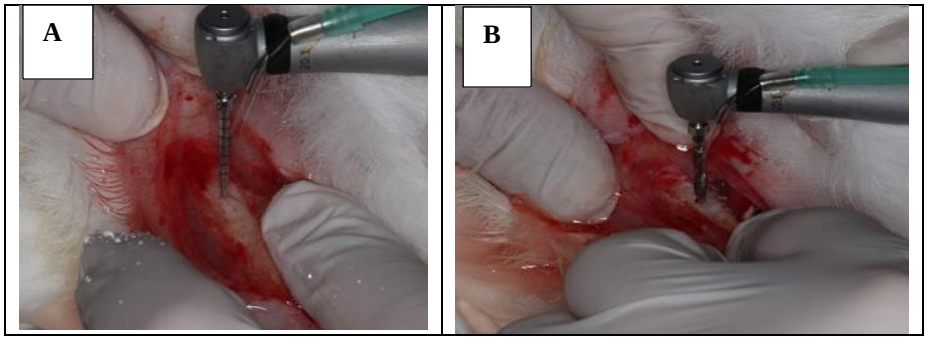

Fig 4: Drills of ROOTT implant placement surgical kit inserted to 6 mm depth (Clockwise drill speed 800 rpm)

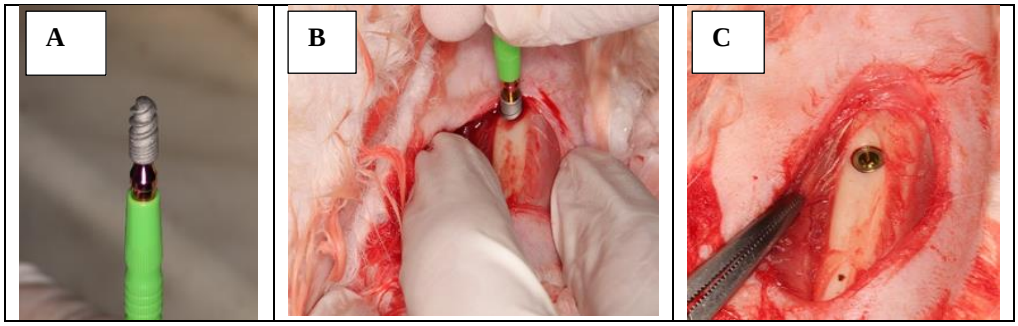

Fig 5: 4.2 mm diameter, 6 mm length ROOTT implant **(A)** inserted into osteotomy sites using torque ratchet at 40 N/cm **(B, C)**

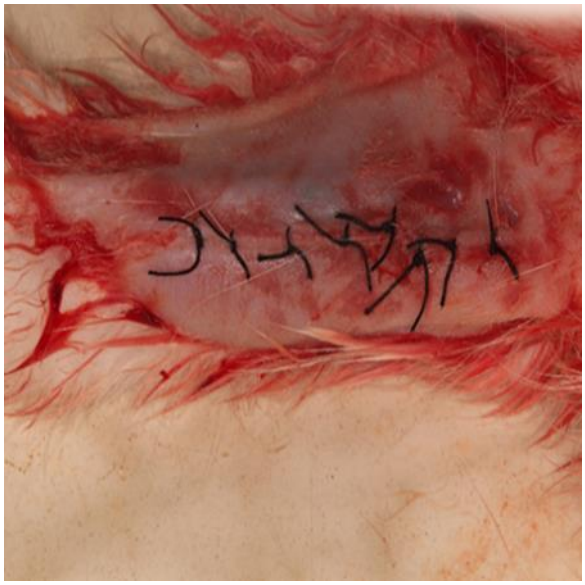

Fig 6: 3/0 black silk interrupted suture used to reposition and stabilize the flap

Fig 7: Tibia removed after sacrifice of rabbit

After 24 hours

Control group

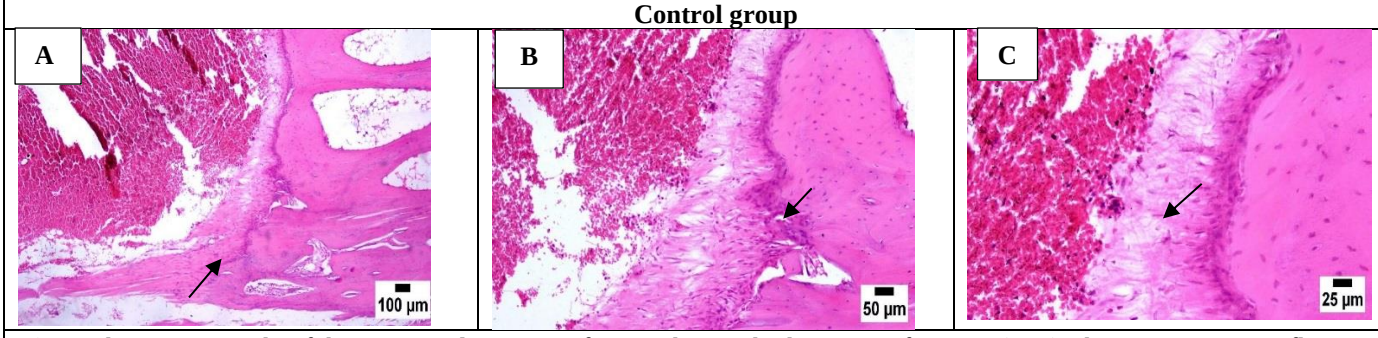

Fig 8: Photomicrograph of bone,Control Group, after 24 hours, higher magnification **(B,C)** showing intense inflammatory reaction,fibroplasia and bone fragments at the peri-implant bone area (arrow) (H&E).

Study group

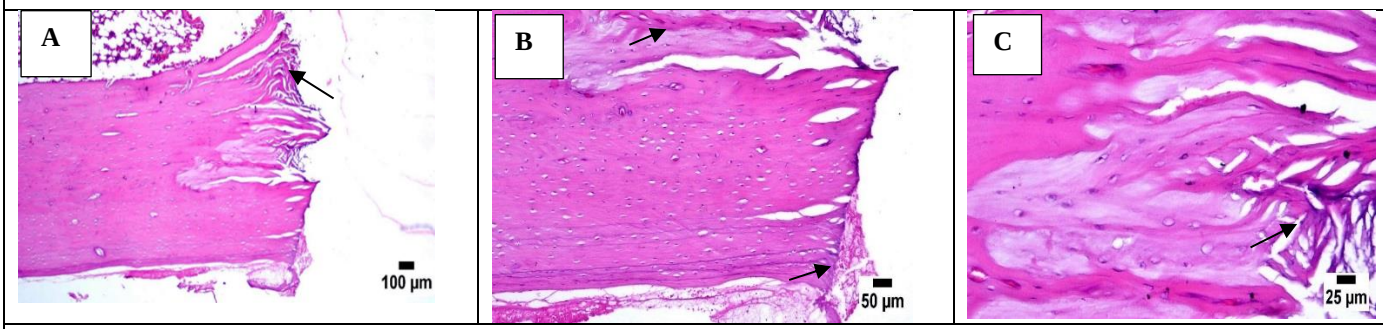

Fig 9: Photomicrograph of bone, Study Group, after 24 hours ,higher magnification**(B,C)** showing mild bone necrosis at the peri-implant bone area (arrow) (H&E).

After 30 days

Control group

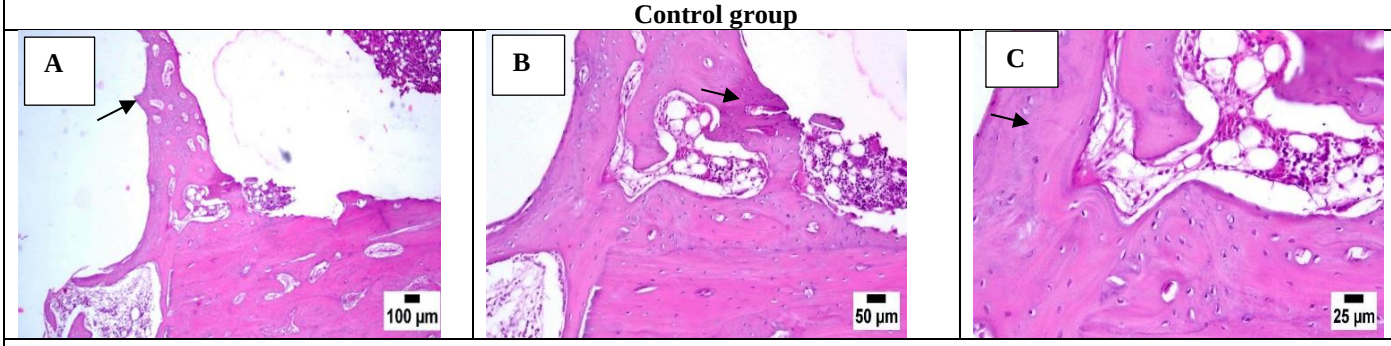

Fig 10: Photomicrograph of bone, Control Group, after 30 days, higher magnification**(B,C)** showing small newly formed bone fragment (arrow) in the trabecular space (H&E).

Study group

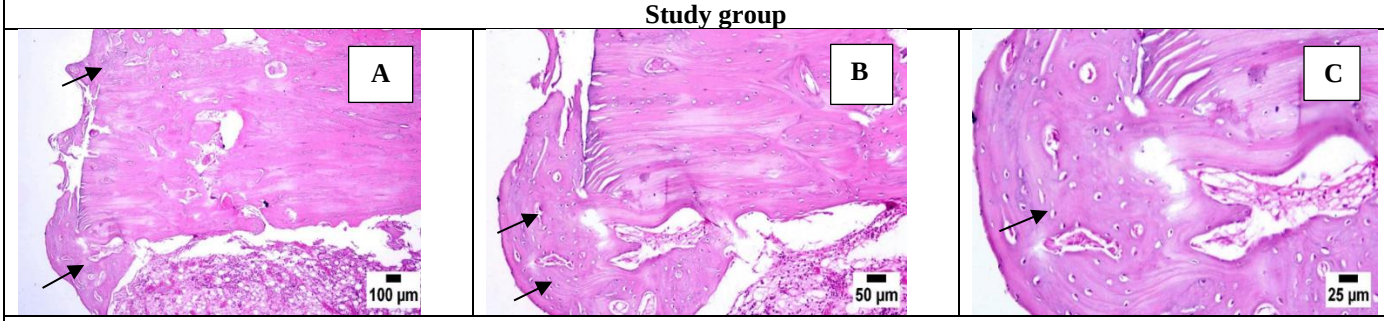

Fig 11: Photomicrograph of bone, Study Group, after 30 days, higher magnification **(B, C)** showing newly formed bone at the area of bone to implant contact and in trabecular space (arrows) (H&E).

After 60 days

Control group

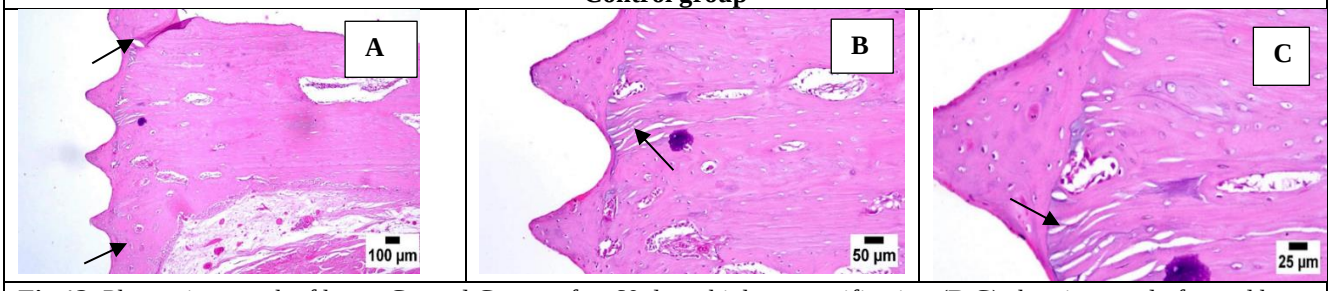

Fig 12: Photomicrograph of bone, Control Group, after 60 days, higher magnification **(B,C)** showing newly formed bone fragment with decreased bone density at the peri- implant bone area (arrow) (H&E).

Study group

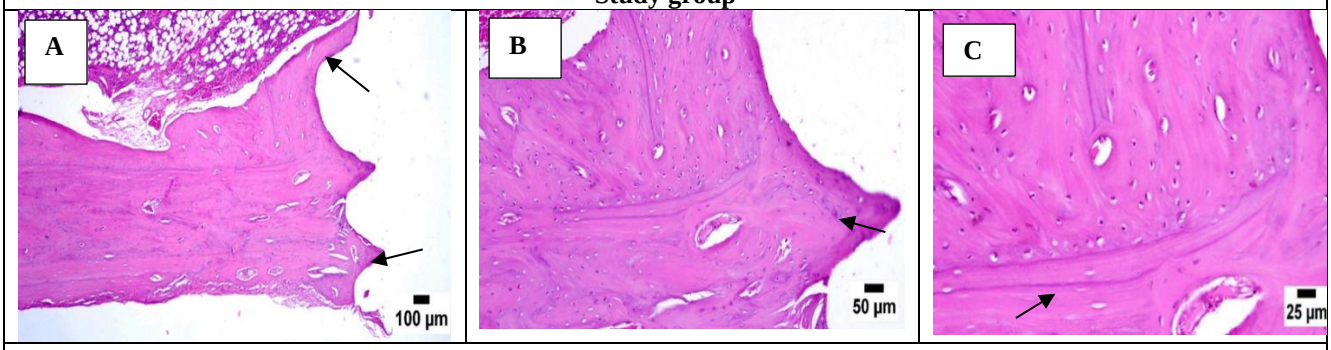

Fig 13: Photomicrograph of bone, Study. Group, after 60 days higher magnification **(B,C)** showing bone formation in both bone to implant contact area and in trabecular space (arrows) (H&E).

Control group	Study group
After 24 hours	
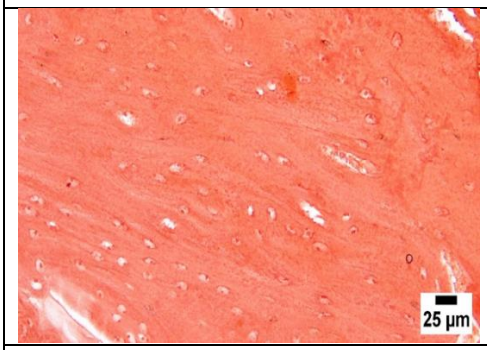	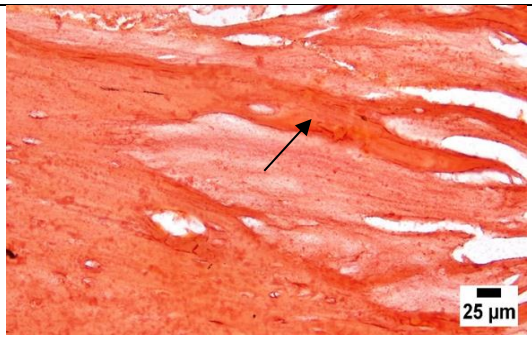
Fig 14: Photomicrograph of bone, Control group after 24 hours showing normal bone density at the peri-implant bone area (Alizarin red).	**Fig 15:** Photomicrograph of bone, Study group after 24 hours showing increased bone density at the peri- implant bone area (Alizarin red).
After 30 days	
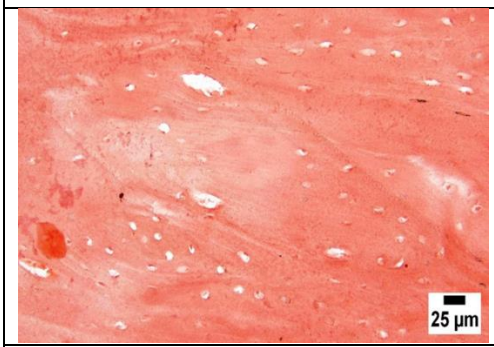	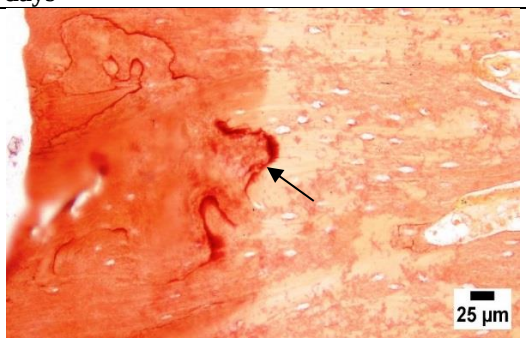
Fig 16: Photomicrograph of bone, Control group after 30 days showing normal bone density at the peri- implant bone area (Alizarin red).	**Fig 17:** Photomicrograph of bone, Study group after 35 days showing increased bone density (arrow) at the peri-implant bone area (Alizarin red).

After 60 days	
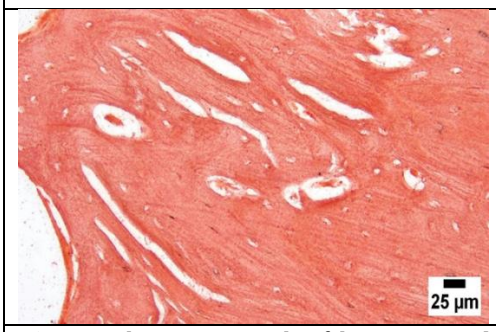	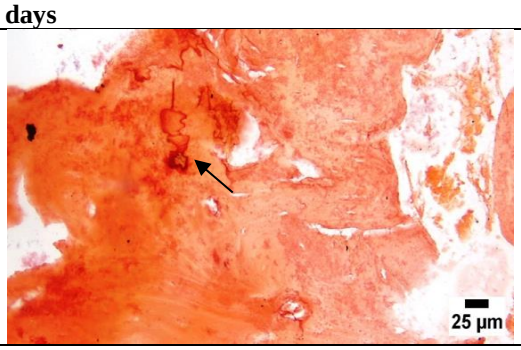
Fig 18: Photomicrograph of bone, Control group after 60 days showing normal bone density at the peri- implant bone area (Alizarin red).	**Fig 19:** Photomicrograph of bone, Study group after 60 days showing increased bone density at the peri- implant bone area (Alizarin red).

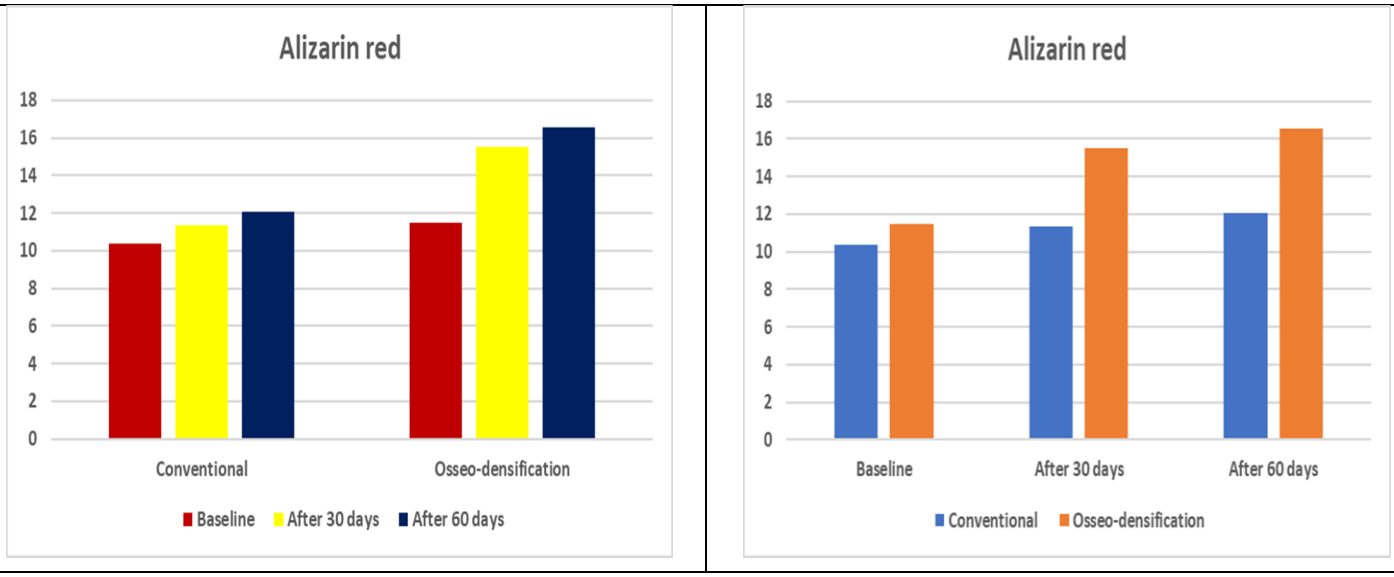

Fig 20: Bar chart representing Alizarin red for different groups.

Table 1: The mean, standard deviation (SD) values of Alizarin red of different groups.

Variables	Alizarin red								
	Conventional				Osseo-densification				p-value
	Mean	SD	Min	Max	Mean	SD	Min	Max	
Baseline	10.37 ^{bB}	0.54	9.48	11.33	11.49 ^{cA}	0.58	10.36	12.02	**<0.001***
After 30 days	11.34 ^{aB}	0.58	10.65	12.52	15.52 ^{bA}	0.46	14.85	16.33	**<0.001***
After 60 days	12.05 ^{aB}	0.54	11.00	12.69	16.54 ^{aA}	0.67	15.62	17.82	**<0.001***
p-value	**<0.001***				**<0.001***				

- Means with different small letters in the same column indicates significant difference, means with different capital letters in the same row indicates significant difference *; significant ($p<0.05$) ns; non-significant ($p>0.05$).

Pai et al.'s 2018 systematic assessment of literature on the OD drilling technique indicated that this method resulted in smaller osteotomies when compared to conventional drills. It also resulted in increased bone density, percentage bone volume, and bone-to-implant contact, all of which improved implant stability. It was proposed that OD caused the formation of bone fragments that acted as nucleating surfaces, stimulating fresh osteogenesis around the implants and resulting in increased bone density and stability(31)**.** Our results in the ossoendisifcation group were compatible with results achieved by padhyea et al.2020 systematic review of literature published about OD by Densah bur. He found by using an animal model, that osseodensification is a successful method of improving the primary stability of implants in low density bone(32). On the other hand, a study Mello-Machado et al., in **2021** reported that there was no difference histologically between osseodensification and conventional drilling in implant placement in low dense bone(33)**.**

5. Conclusion

Within limits of the study, osseodensification technique may be considered as effective method for increasing bone density and bone condensation around dental implants placed in osteoporotic bone which increases the chance for success of osseointegration.

Recommendation

It is important to emphasize that the data generated by this study is derived from an animal study so further clinical research to understand the effect of osseodensifcation in implant placement in osteoporotic bone is required**.**

Ethics

All experiments have been conducted in the animal house of the Faculty of Pharmacy, Nahda University, Egypt according to the recommendations and approval of the Ethics Committee of the Faculty of Dentistry, Minia University. Committee number (75) at 30/11/2020.

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Conflict of interest

None of the authors have any disclosed conflicts of interest.

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