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Studying Biomimetic Coated Niobium as an Alternative Dental Implant Material to Titanium (*in vitro* and *in vivo* study)

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Abstract:

Commercially pure titanium (cpTi) is widely used as dental implant material although it was found that titanium exhibited high modulus of elasticity and the lower corrosion tendency in oral environment. Niobium(Nb) was chosen for this study as an alternative to cpTi implant material due to its bioinert behavior and good elastic modulus and moderate cost in addition to corrosion resistance. This study was done to evaluate the effect of biomimetic coating on the surface properties of the commercially pure titanium and niobium implants by *in vitro* and *in vivo* experiments. The *in vitro* study was involved etching the samples of each material in HCl then soaking in 10M NaOH aqueous solution. These samples were then immersed in a 5 times concentrated simulated body fluid for 14 days. Scanning Electron Microscope, Energy Dispersive X-ray, and X-Ray Diffraction tests were done to analyze surface changes. The *in vivo* study was done by the implantation of screw-shaped implants (two from each material, uncoated and the other was biomimetically coated) in the tibias of New Zealand rabbits. After 2 and 4 weeks of healing period, 20 rabbits were sacrificed for each period. A removal torque was done for ten animals in each group, whereas the other ten were used for histological testing and histomorphometric analysis with optical microscope. The *in vitro* experiments showed that the use of 14 days immersion in a concentrated simulated body fluid produced a layer of calcium phosphate on metal surfaces. The removal torque values and new bone formation were increased significantly in Nb than Ti, in coated than uncoated screws, and in 4 weeks than 2 weeks healing periods. The Nb implants had better biomechanical and biological properties than the commercially pure titanium implants and can be used as an alternative dental implant.

Keywords: Biomimetic process, Histomorphometry, Niobium, Removal torque, Titanium.

Introduction:

Properties of titanium such as superior mechanical performance and brilliant biocompatibility make titanium the primary dental implant material of use (1). It was realized that titanium showed lower corrosion tendency in oral environment (2). At the same time leaching of ions such as Aluminum (Al) and Vanadium (V) that found in (Ti6Al4V) alloy were reported. This may cause serious danger, since Al act as a growth inhibition factor of bone and a possible cause of Alzheimer's disease, and V has powerful cytotoxicity. It is thought that a dangerous effect on the recipient organism may result when Ti6Al4V alloy implants were used (3).

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Niobium (Nb) has previously been explored in the 1980's and recent studies suggested the ability of Nb as an implant material. Niobium was used in this study as an alternative to cpTi implant material due to its bioinert behavior and lower elastic modulus and moderate cost in addition to corrosion resistance (3,4). Niobium and some niobium alloys are physiologically inert and thus hypoallergenic. For this reason, niobium is found in many medical devices such as pacemakers. When titanium implanted in bone, it is known that titanium will bond simply by morphological connection not by biological or chemical attachment(5), Calcium phosphate coating in particular hydroxyapatite bioceramics is widely used for both orthopedic and dental implants because of their unique advantage as they have chemical and mineral components similar to that of teeth and bone. The commercial coating technique is preferentially plasma spraying, because of their rapid and strong bonds to living bone tissues (6). Biomimetic method has been utilized to acquire layers of calcium phosphate, as a replacement to the

plasma spraying. The simplicity and cheap of this method in relation to the plasma spray method make it the process of choice(7). In this study, calcium phosphate coating was deposited on the surface of commercially pure titanium and niobium (Nb) metals by Biomimetic approach. *In vitro* and *in vivo* experiments were done to investigate the effect of this technique on the quality of the deposited layer and bone- implant interface.

Materials and Methods:

In vitro study

Samples preparation

20 titanium plates (cpTi) (grade 2, Straumann Company, Switzerland). and 20 niobium plates (Nb) (Straumann Company,Switzerland), of (10x10x1 mm) in length, width, and thickness respectively, were inserted in Ultrasonic bath of ethanol for 15 min to remove contamination and debris ,then put in a distilled water bath for 10 minutes at room temperature, after that the plates left to dehydrate at room temperature (8).

Biomimetic surface treatment

At first, etching of the samples in 36% HCl was done under inert atmosphere of Ar for two hours. The use of inert atmosphere was to make a controlled process and avoid extreme etching. Two hundred fifty (250) ml was used for etching the cpTi and Nb specimens. The etched samples were soaked in 10M NaOH aqueous solution. CpTi and Nb plates were soaked in a 450 ml of NaOH solution. After 24h of incubation at 60°C in oven, the plates were washed with deionized water and dried at 100°C (9). In the second step, the samples were soaked in a concentrated simulated body fluid (SBF). The concentration of the salts was 5 times more than that found in human blood plasma (10). The solution was prepared by dissolving reagent-grade NaCl, KCl, NaHCO₃, MgSO₄. 7H₂O, CaCl₂ and KH₂PO₄ into deionized water using hot plate stirrer with a magnetic stirring facilities. Table (1) shows the salt concentrations that were used in this study. The concentrations were multiplied by a factor of 5 from those in standard simulated body fluid .

Table 1. Chemical composition of simulated body fluid

Item	Description	Quantity gm./liter
1	NaCl	8.036
2	KCl	0.225
3	CaCl ₂	0.293
4	NaHCO ₃	0.352
5	K ₂ HPO ₄	0.230
6	MgCl ₂ .6H ₂ O	0.311
7	NaSO ₄	0.072

After completing dissolution, the solution was buffered at pH=7.3 with NH₄OH and HCl at 37°C. The instability of pH of the solution made by creation of carbonates next to absorption of carbon dioxide from the air makes buffering the solution close to physiologic levels is difficult to obtain. The samples were exposed to the solution under static conditions in a biological thermostat at 37°C for 14 days. The samples were immersed vertically in specific prepared slot in Teflon disc. After exposure, they were washed in deionized water and dried before the subsequent analysis.

Heat treatment

The coated samples were sintered for densification in a Carbolite furnace. The sintering was done at 400 °C under inert gas (argon) for one hour to prevent oxidation of the specimen.

Morphological, Elemental and Phase analysis

Scanning Electron Microscope (SEM) supported by EDX (Energy Dispersive X-ray analysis) was made on coated plates to verify the formation and concentration of the layer that was formed on the surface. X-ray analysis was made on the plate's pre and post coating. 3121 powders X-ray Diffractometer were used to analyze the plates using Cu K α radiation .The range of θ angles were swept one degree from 20- 60° . The peak indexing was made on the basis of Joint Committee on Powder Diffraction Standards (JCPDS).

In vivo experiment

Samples grouping

A total of 160 screws were fabricated and categorized according to the type of material used into two main categories. Cp (Ti) and pure (Nb) groups. In each group (80 screws) the screws were divided into:-

a. Control (non coated) group (40 screws): This group was subdivided according to healing interval into (2weeks and 4weeks groups) (Cont_2 and Cont_4). 20 screws for each group.

b. Experimental (coated) group (40 screws): This group was subdivided according to healing interval into (2weeks and 4weeks groups) (Coat_2 and Coat_4). 20 screws for each group coated by Calcium Phosphate compound (CaP).

Each of the above subdivisions (2 weeks and 4 weeks groups) further subdivided, according to the type of test performed, into: torque removal test group(10 screws) and histomorphometry group (10 screws)

Implant preparation

Implants were fabricated from each cpTi and pure Nb rods (Straumann Company,

Switzerland). Using lathe machine in the formation of screw type implant with 3mm in diameter and 8 mm in length in which smooth part is 3mm while threaded part is 5mm in length and pitch height is 0.6 mm. On the head of the screw there is a slot in which the head of screw driver fit for insertion and removal of screw. The screws were cleaned with ethanol in an ultrasonic cleaner for 15 minutes and dehydrated at 100°C. Forty screws from cpTi group and forty from Nb group were coated with CaP following the same procedure of biomimetic surface treatment done on the plate's samples. The selected soaking period in concentrated SBF was 14 days. 28% nitric acid was used for passivation of the uncoated implants for 1 hour and then deionized water with ultrasonic cleaner washed the screws for 5 minutes in each five separated washes. Implant, from each material (coated and uncoated), were kept in their airtight sheet then sterilized with gamma irradiation using gamma cells 220 with Co60 source. The radiation dose was 2.5-3.0 mega rad.

Surgical procedure

Forty adult New Zealand white rabbit males weighing ~2 kg were used. Animal house made of separate rooms was used during the study for animals storage and where animals had fed with standard pellets and drink water freely. The rabbits were left in the animal house for two weeks before surgical operation.

Animals' population (total of 40 animals) was divided into 2 groups, which were planned to be sacrificed at intervals of 2 and 4 weeks. Four implants/rabbit, two implants of cpTi in the right tibia and the other two from Nb in the left one. Micro dispenser engine was used for bone drilling at a rotary speed of 1000 rpm and 35 Ncm torque with copious amounts of distill water for cooling and washing. Finally, the screw was inserted and incision was sutured and sterilized.

Mechanical testing

The torque removal test was done by using digital torque meter device (Hitachi Maxwell LTD. /174, Japan) to unscrew the implant from the bone bed and to measure the peak torque (in newton. Centimeter) necessary to loosen that implant. The test was done after the animal was anesthetized and incision was made.

Histological testing

Histological testing for a total of 80 screws (all Ti and Nb groups) was evaluated under optical microscope. At first the animal anesthetized with overdose of medication then Bone cutting was done. After histological treatment steps, the paraffin block

- that hold the cut specimens in the center- placed in microtome to be sectioned into multiple horizontal sectioning with (4-5µm in thickness /section) then sectioned specimens placed on a slide. This process was performed for both materials in each healing interval. Staining of the tissue was done by placing the slide into haematoxylin and eosin stains for 10 minutes.

Shapiro described the new bone to look like coarse meshwork (trabecular bone) of pink tissue surrounding patches of much lighter or unstained tissue or matrix. In this study the area of new bone was labeled as in Shapiro's description (11). The computer software (Maryland, USA) was used to calculate New Bone Formation Area (NBFA). The micrographs were examined in PC and areas of new bone were outlined with the help of specialized pathologist and by the aid of (image j) program that facilitate accurate measurements of these areas.

Results and Discussion:

SEM,EDX and XRD analysis

Images of SEM for cpTi surface after SBF immersion is shown in (Fig.1). Scanning Electron Microscopy of the coating obtained as in (Figs 1a&b) revealed that the surfaces of the cpTi specimen were wholly and homogeneously coated with a fine-structured layer. The presence of few cracks in the coating may be attributed to the drying process. The coating was found to consist of globules in the range of 1-2 µm (Fig 1c). The assessment of an individual globule at higher magnification displayed Nano metric nuclei (Fig. 1d).

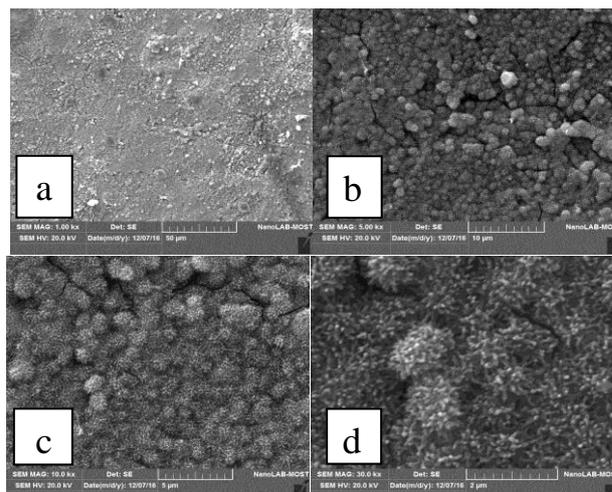


Figure 1. SEM micrographs for cpTi specimen at (a&b) lower magnification, (c&d) higher magnification after immersion in 5XSBF.

While the SEM ,After soaking the Nb plate in SBF for two weeks, showed a layer of coating with different shapes and grains in lower magnification (**Fig. 2 a&b**) then the higher magnification (**Fig. 2b&d**) revealed a large and small crystals in different aggregations forming a tree like or spindle like arrangements

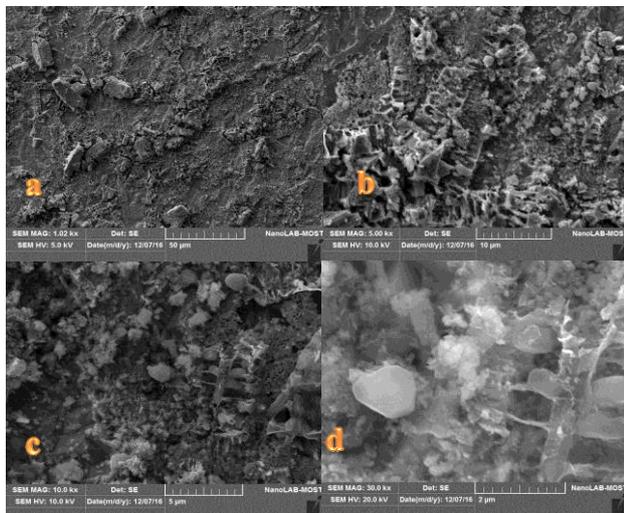


Figure 2. SEM micrographs for Nb specimen at (a&b) lower magnification, (c&d) higher magnification after immersion in 5XSFBF.

The corresponding EDX patterns of Ti substrate immersed in SBF for two weeks are shown in (**Fig.3**), which indicates the appearance of transition energies of the calcium element Ca K α and Ca K β at 3.68 and 4.03 KeV respectively. The phosphorus transition energies PK α and PK β 2.02 and 2.13 KeV and the energies of matrix element Ti K α and Ti K β 4.51 KeV and 4.92 KeV are shown in the pattern.

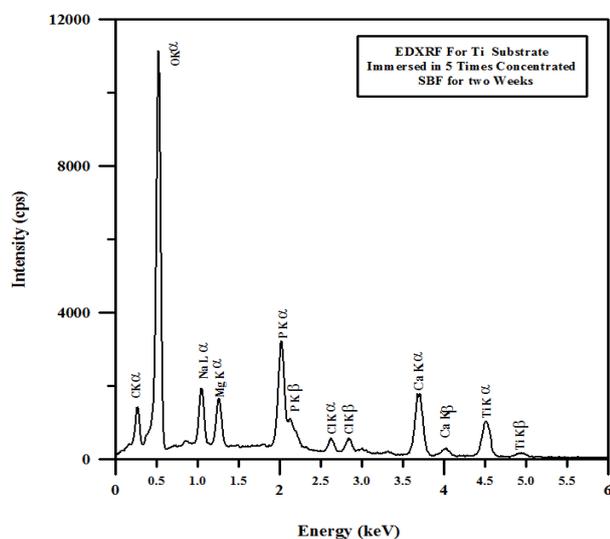


Figure 3. Energy-dispersive x-ray (EDX) pattern of cpTi after immersion in 5XSFBF.

The pattern clearly shows that the Ca/P layer covered well the Ti surface as the transition energies intensity of Ca and p are much higher than that of Ti. The Ca/P ratio varied between 1.83 and 2.14.

EDX patterns of Nb substrate immersed in SBF for two weeks are shown in (**Fig. 4**), which show the transition energies of the calcium element Ca K α and Ca K β at 3.70 and 4.01 KeV respectively. The phosphorus transition energy PK α are 2.02 KeV and the energy of matrix element Nb K α 2.17 KeV are shown in the pattern. This means that the layer formed on the surface is comprised of calcium and phosphorus elements.

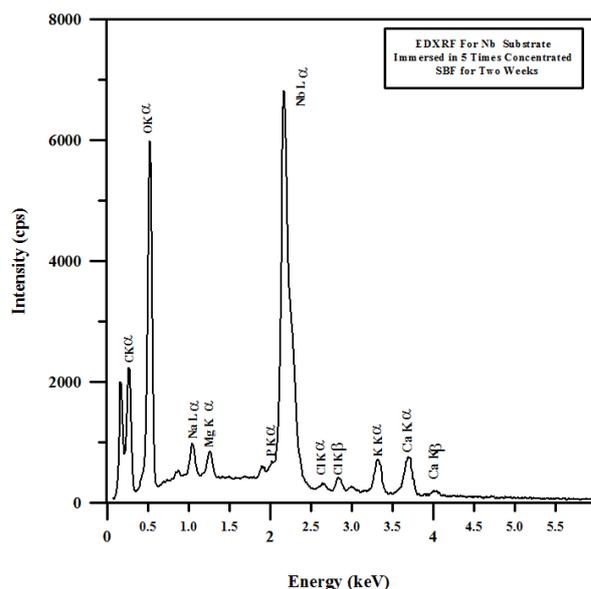


Figure 4. Energy-dispersive x-ray (EDX) pattern of Nb after immersion in 5XSFBF.

The pattern clearly shows that the Ca/P layer covered well the Nb surface as the transition energies intensity of Ca and p are much higher than that of Nb. The Ca/P ratio varied between 1.77 and 1.67.

XRD patterns of cpTi specimens before and after immersion for two weeks in simulated body fluid SBF (biomimetic treatment) are shown in (**Fig.5**). The XRD results were indexed according to the data reported by the International Center for Diffraction Data (ICDD) for the hexagonal Ti (JCPDS-ICDD file # 44-1294) and the hexagonal Ca₅(PO₄)₃(OH) (JCPDS-ICDD file # 09-0432).

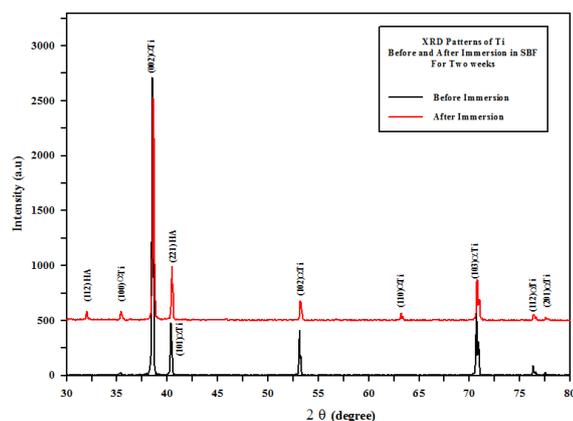


Figure 5. X-ray diffraction pattern of Ti substrates before and after immersion in SBF for two weeks.

The lattice of α -Ti phase is expanded in the treated region and the peak positions are shifted to higher Bragg angles. The pattern shows a systematic shifting of most peaks of α -Ti toward upper 2θ . Such a shift in the Ti peak position indicating the formation of new compound on the surface and it can be seen clearly from Fig.5 the formation of (112) HA at 2θ position 32.192 and the shift of (101) α Ti from its position at 2θ 40.370 to for (221) HA at 2θ 40.452. The (112) and (221) peaks are corresponding to the crystalline hydroxyapatite ($P6_3/m$) belonging to the hexagonal symmetry.

Figure 6 illustrates the structural changes in the surface of Nb substrate biomimetically treated in SBF. The XRD patterns show a dramatic shift of the α -Nb peaks toward upper 2θ side. The HA formation after the immersion of Nb substrate for two weeks in SBF can be seen from strong peaks of (322) HA at 2θ 55.879 and (512) at 2θ 69.699.

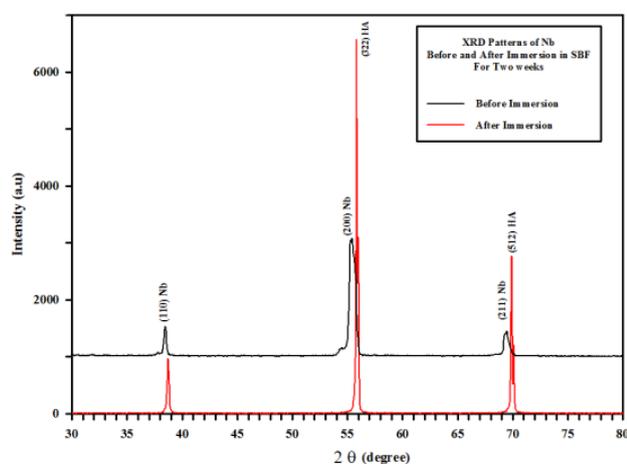


Figure 6. X-ray diffraction pattern of Nb substrates before and after immersion in 5XSBF for two weeks.

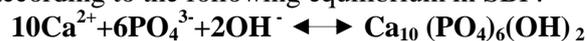
Various researches suggest the application of various biomimetic coatings that can be

beneficial for implant therapy success (12, 13). This study employed an HA surface coating on the samples because of its proven osteoconductive properties. When titanium immersed in SBF an HA layer formed on its surfaces and this layer is able to achieve crystallinity and morphology as in those of a bone-like apatite (14). A favorable aspect of this study coincides with the proposition that increased crystallinity of HA coatings appears to slow resorption of HA (15). In this study the results, obtained from using a 5 times concentrated SBF, are in consistency with the investigation of Chen et al in 2005 that the use of more than one time concentration will accelerate the formation of CaP with resultant similar properties. (10) Generally, biomimetic coating processes are performed for about seven to fourteen days (16).

The results gained supposed that when Ti and Nb plates immersed in NaOH liquid, sodium titanate and sodium niobate hydrogel layers formed on its surface respectively. This is similar to a previous study results in which porous sodium titanate and sodium niobate titanate hydrogel layers formed when Ti-Nb alloy plates treated with NaOH solution. After that plates soaked in a simulated body fluid (SBF) for 14 days then calcium phosphate compounds attached to the surface such behaviour is called bioactivation of niobium and titanium and it's like the bioactivation reported previously of alkali treated Ti and Ti-Nb alloy (17). The CaP compounds precipitation on the alkali treated metal plates may be attributed to the morphology of the surface layer of the plates since immersion of treated plates into an electrolyte solution (like SBF) making its surface as cathodic reaction of oxygen reduction:



This reaction leads to a local increase in pH at the surface which is more pronounced at the porous surface of the plates that may decrease the solubility of the HA by increasing its ionic activity product according to the following equilibrium in SBF:



So HA start to precipitate on the surface of the metal forming nuclei of apatite which then grow by absorbing more Ca^{2+} and PO_4^{3-} from SBF that is supersaturated with respect to the apatite (18).

The SEM micrographs for Ti and Nb supported the formation of coating layer on the plates after SBF immersion and the shapes of the particles were different between Ti and Nb, and this may be attributed to the difference in surface layer composition as this is supported by EDX result due to difference in surface roughness and hardness between the two metals. The EDX analysis indicated a continuous calcium and phosphorus deposition on the surface. The prominent peaks

corresponding to the deposited layer accompanied with a gradual decrease of titanium and niobium peaks intensity, which revealed the gradual thickening of the coated layer. The XRD data showed peaks indicating the presence of crystalline HA phases as well.

Mechanical test

For the 2 weeks period, coated Nb screws (Coat_Nb_2 group) showed the highest resistances to removal torque with mean value of 21.10 N.cm compared to the torque needed for the coated cpTi implant screws (Coat_Ti_2 group with mean value 17.9 N.cm). Regarding the uncoated implants the mean torque values needed to remove the cpTi and Nb screws without coating were 8.90 N.cm, 14.10 N.cm respectively.

The highest removal torque mean value was for coated niobium screws after 4 weeks period which was 44.30 N.cm while for coated Ti screws; the mean was 36.90 N.cm after the same period. The uncoated cpTi (Cont_Ti_2) and Nb (Cont_Nb_2) removal torque mean values were (27.10), (32.60) N.cm respectively after 4 weeks interval.

Independent t – tests for equality of means of torque values were calculated between different implant materials (cpTi vs Nb), different surface types (coated vs uncoated) for the two weeks healing period and also for the 4 weeks healing period (Table 2) and the tests showed highly significant differences between all the types of comparisons.

Table 2. independent t –test for equality of means of torque values between (cpTi and Nb) screws of all groups' type at 2 and 4 weeks interval.

types of comparism	Mean Differences	T	Df	p-value Sig. (2-tailed)
Cont_Ti_2 x Cont_Nb_2	-5.200	-13.377	18	.000
Coat_Ti_2xCoat_Nb_2	-3.200	-6.000	18	.000
Cont_Ti_2 x Coat_Ti_2	-9.000	-17.428	18	.000
Cont_Nb_2 xCoat_Nb_2	-7.000	-9.391	18	.000
Cont_Ti_4 x Cont_Nb_4	-5.500	-14.758	18	.000
Coat_Ti_4 x Coat_Nb_4	-7.400	-9.348	18	.000
Cont_Ti_4 x Coat_Ti_4	-9.800	-18.375	18	.000
Cont_Nb_4 xCoat_Nb_4	-11.700	-20.939	18	.000

P<0.05 = significant

At the same time paired t – tests for equality of means of torque values were used for different healing periods (2w vs 4w) as in **Table (3)** - for the

screws of the same surface type and the same implant material- and showed highly significant differences between different periods of time.

Table 3. paired t-test for equality of means of torque values of cpTi and Nb groups between 2 and 4 weeks intervals.

types of comparism	Mean Differences	T	Df	Sig. (2-tailed)
Cont_Ti_2 x cont_Ti_4	-18.200	-62.630	9	.000
Coat_Ti_2 x Coat_Ti_4	-19.000	-45.062	9	.000
Cont_Nb_2 x Cont_Nb_4	-18.500	-32.875	9	.000
Coat_Nb_2 x Coat_Nb_4	-23.200	-40.454	9	.000

Effect of type of material on torque removal values

The results showed that all niobium implants have more torque values than titanium implants and there is a significant differences between the two types of materials within the same time period and same surface condition (coated or uncoated) this may be attributed to the differences in surface morphology and surface roughness since niobium showed more roughness and irregularities at the surface than titanium also niobium had similar biocompatibility to titanium (19, 20).

Effect of healing period on torque removal values

It was shown in this study that a significant difference between different time periods was present for the same metal and same type of surface (coated or control). This agreed with the study of **Johanson and Albrektson in 1987** that demonstrated an increase in the removal torque values with time. They supposed that increase in healing time associated with the increase in bone formation and remodeling that lead to increase in bone-implant contact and subsequent increase in mechanical resistance of the implant to removal (21).

Effect of coating on torque removal values

The results revealed that the biomimetic treated screws (coated Ti or coated Nb) significantly differ from control screws (non treated) for the same period of time and for the same material, that may be due to the formation of HA layer upon implantation of treated TI and Nb samples into the human body, thus promote the bonding of the implant to the surrounding bone was due to similarity of coating layer to bone structure. This bone bonding capability could make Nb metal an attractive material for hard tissue replacements.

General histological description of implant in different intervals

In of 2 weeks interval for Nb screws (Fig 7 left), section showed implant site (arrow) with marrow elements and early osteoid formation at the margin of the native bone. H and E X40 while (Fig 7 right) higher magnification showed a cellular marrow with delicate osteoid bone trabeculae (arrow). (H and E X400)

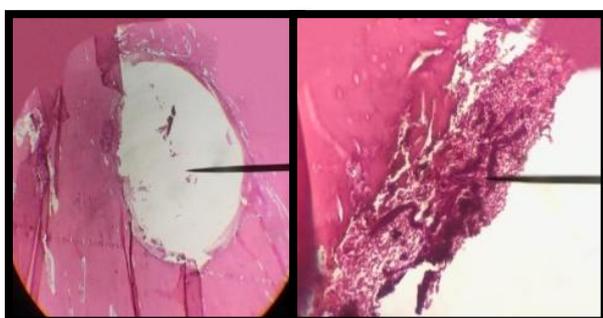


Figure 7. Light micrograph for portion of rabbit tibia after 2 weeks of coated Nb screw implantation. On the left lower magnification (x40) showed the implant site (arrow), while on the right higher magnification (x400) showed delicate osteoid bone trabeculae (arrow).

While for 4 w interval, Low power (Fig. 8 left) revealed abundant osteoid formation surrounding the site of implant (H and E X40) and High power (Fig. 8 right) showed osteoid bone

trabeculae with prominent osteoblastic activity (arrow) (H and E X400).

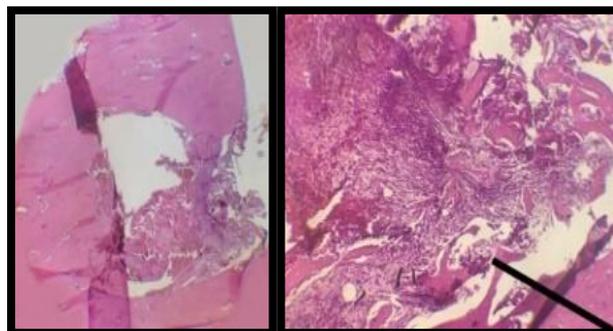


Figure 8. Light micrograph for portion of rabbit tibia after 4 weeks of coated Nb screw implantation. On left lower magnification (x40) showed the implant site (arrow), while on the left higher magnification (x400) showed prominent osteoblastic activity (arrow).

Histomorphometric analysis of implant in different intervals

For the 2 weeks period, coated Nb screws showed the highest NBFA value (1.57 mm²) in relation to NBFA of coated cpTi screws with mean value of (1.22 mm²). Concerning the uncoated implants, the mean NBFA values around the cpTi and Nb screws without coating were (0.22 and 0.83mm²) respectively.

After 4 weeks of healing period, the highest NBFA mean value was also for coated niobium screw which was 5.41 mm² while for coated Ti screws, the mean was 3.50 mm² after the same period. The uncoated cpTi and Nb NBFA mean values were (2.08) and (2.78) mm² respectively after 4 weeks interval. T – test for equality of means of NBFA values between cpTi and Nb (coated or uncoated) screws at 2 weeks and at 4 weeks healing periods showed highly significant differences between different surface types of screws (coated vs uncoated) of the same material and at the same period of time, and between different materials (cpTi vs Nb) of screws for the same surface type and the same period of healing as described in (Table 4).

Table 4. Independent t –test for equality of means of NBFA values between (cpTi and Nb) screws of all groups' type at 2 and 4 weeks interval.

types of comparism	Paired Differences	T	Df	Sig. (2-tailed)
Cont_Ti_2 - cont_Nb_2	-.61260	-28.694	18	.000
Coat_Ti_2 - Coat_Nb_2	-.35050	-4.553	18	.001
Cont_Ti_2 -Coat_Ti_2	-1.00680	-37.988	18	.000
Cont_Nb_2 - Coat_Nb_2	-.74470	-9.702	18	.000
Cont_Ti_4 - Cont_Nb_4	-.70480	-7.886	18	.000
Coat_Ti_4 - Coat_Nb_4	-1.91680	-7.638	18	.000
Cont_Ti_4 - Coat_Ti_4	-1.42090	-16.805	18	.000
Cont_Nb_4 - Coat_Nb_4	-2.63290	-12.197	18	.000

Also t-test was used for testing the equality of means of NBFA between implant screws at different periods of healing time (2weeks vs. 4

weeks) and presented a highly significant difference as demonstrated in **table (5)**.

Table 5. paired t-test comparison of NBFA mean of cpTi and Nb groups between 2 and 4 weeks intervals.

types of comparism	Paired Differences	T	df	Sig. (2-tailed)
Cont_Ti_2 - Cont_Ti_4	-1.86120	-48.769	9	.000
Coat_Ti_2 - Coat_Ti_4	-2.27530	-22.441	9	.000
Cont_Nb_2-Cont_Nb_4	-1.95340	-24.559	9	.000
Coat_Nb_2-Coat_Nb_4	-3.84160	-17.713	9	.000

Effect of implant material

The results showed significantly higher New Bone Formation Area (NBFA) with Nb implant in comparison with cpTi samples. More NBFA values were obtained for Nb groups. This is supported by previous studies that showed the superior performance in biocompatibility of Nb than titanium, utilizing cell lines and testing proliferation, metabolic activity and maintenance of cell morphology (22), and more surface roughness of the Nb samples when compared to titanium. (19).

Effect of healing time

The effect of healing period on the values of NBFA showed a significant difference between 2 weeks and 4 weeks interval groups for both Nb and cpTi screws since new bone formation values increase significantly with time. This may be due to continuous activation of osteoblast cell for new bone formation with time

Effect of coating

Regarding the effect of CaP coating on bone formation, it was noticed in this study that the values of bone formation (NBFA) varied with the type of implant surface and how long the material had been implanted. In this case, dynamic interactions between the cells and the coating material are inevitable, which explains the higher level of cell functionality associated with coated implant in this study. Moreover, the ion concentrations around the cells increased as the coating layers dissolved which seems to induce the precipitation of HA with subsequent adsorption and bone cell attachment (23).

Conclusions:

Within the limitation of this study we conclude that Nb metal can be bioactivated as in Ti metal. The Nb screws showed significant larger removal torque values when compared to Ti screws at 2 weeks and 4 weeks healing interval at the same time histomorphometric analysis revealed that Nb screws showed significant higher NBFA values than Ti screws in 2w and 4w healing period.

Niobium metal with or without a CaP coating has relevant physical and biological properties as an implant material and may be used as an alternative to Ti metal.

Conflicts of Interest: None.

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دراسة النيبيوم المطلي بالمحاكاة البايولوجية كمادة زراعة اسنان بديلة للتيتانيوم (دراسة مختبرية و حيوية)

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الخلاصة:

يستخدم التيتانيوم الخالص تجارياً (cpTi) على نطاق واسع كمادة لزراعة الأسنان على الرغم من أنه وجد أن التيتانيوم أظهر معامل مرونة عالية وقابلية تأكل أقل في البيئة الفموية. تم اختيار النيبيوم (Nb) لهذه الدراسة كبديل لمادة cpTi بسبب سلوكها الحيوي الخامل وتكلفتها المعقولة ومعامل المرونة المعتدلة بالإضافة إلى مقاومة التآكل. أجريت هذه الدراسة لتقييم تأثير الطلاء المحاكي للبيولوجيا على خصائص السطح لغرسات التيتانيوم والنيوبيوم النقية تجارياً في التجارب المختبرية والحيوية. اشتملت الدراسة المختبرية على حفر عينات من كل مادة في حمض الهيدروكلوريك ثم نقعها في عشرة مولارية محلول مائي لهيدروكسيد الصوديوم NaOH 10M. ثم تم غمر هذه العينات في مائع مشابه للجسم مركز بمقدار 5 مرات أكثر من ما هو في جسم الإنسان لمدة 14 يوماً. لتحليل تغييرات السطح، تم إجراء كل من مسح المجهر الإلكتروني، والأشعة السينية المشتتة للطاقة، واختبار حيود الأشعة السينية (SEM و EDX و XRD). أجريت الدراسة في الجسم الحي عن طريق زرع غرسات على شكل برغي (اثنان من كل مادة، واحدة غير مطلية والأخرى مطلية بيومترياً) في عظم الرجل للأرانب النيوزيلندية. بعد 2 و 4 أسابيع من فترة الشفاء، تم التضحية بعشرين أرنب لكل فترة. تم إجراء عزم الدوران للإزالة لعشرة حيوانات في كل مجموعة، في حين تم استخدام العشرة الأخرى للاختبار النسيجي والتحليل النسبي مع المجهر الضوئي. وأظهرت التجارب في المختبر أن استخدام الغمر خلال 14 يوماً في المائع المشابه للجسم المركز ينتج طبقة من كالمسيوم الفوسفات على السطوح المعدنية. تزيد قيم عزم الإزالة والتكوين العظمي الجديد بشكل ملحوظ في Nb من Ti، في الغرسات المطلية من غير المطلية، وفي 4 أسابيع من فترات الشفاء أكثر من 2 أسابيع. تميزت غرسات Nb بخصائص بيولوجية وميكانيكية أفضل من غرسات التيتانيوم الخالص تجارياً ويمكن استخدامها كمادة بديلة لزراعة الأسنان.

الكلمات المفتاحية: طريقة المحاكاة البايولوجية، المساحة النسيجية، نيبيوم، عزم الدوران، تيتانيوم