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Full Length Research Paper

Correlation of UV irradiation-induced wettability characteristics by factorial design of experiments on Ti_6Al_4V

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Biomimetic surface roughness and UV irradiation time will greatly affect their use of hydrophilic and hydrophobic surface of biological material, and then in turn affect cell adhesion, cell growth quality. Therefore, the main purpose of this study in different surface modification treatments on Ti_6Al_4V discs which around irradiation with UV light influence the wettability on the material surface. Then, Factorial design of experiments is used to understand the relationship between the pattern of Ti_6Al_4V. The results showed that the wettability on Ti_6Al_4V is negative correlation with surface roughness and UV irradiation time. There is the contact angle of the smallest and interaction situation on a smoother roughness surface (SG) and modified 60 min irradiation.

Key words: Ti_6Al_4V, wettability, ultraviolet, surface modification.

INTRODUCTION

In biological materials, Ti_6Al_4V has better bio-compatibility, corrosion resistance than the metal materials of stainless steel and Co-Cr-Mo alloys. In addition, titanium alloys and other high strength metallic materials compared to lower density and there with Bone close to the elastic coefficient. It has good mechanical properties, such as corrosion resistance, fatigue strength, formability, processability and low density. In biocompatibility, it is widely used in clinical dental and orthopedic materials on graft substitutes. The biocompatibility of titania contact with the nature of the surface, and it generated osseointegration between the implant and bone.

The most common used method of surface modification can include the following three ways: mechanical methods, chemical methods and physical methods (Liu et al., 2004). In recent years, Studies demonstrated that the surface characteristics of biomaterials and the growth of different cell types will have an impact (Flemming et al.,1999; Deligianni et al., 2001), including implant surface composition, surface energy, wettability, surface roughness, surface topography, etc (Advincula et al., 2006; MacDonald et al., 2004; Ponsonnet et al., 2003; Webster et al., 2004), they can affect cell adhesion, spreading, proliferation and differentiation (Zhou et al., 2006; Zhu et al., 2004; Anselme et al., 2000).

Osteoblast cells adhesion performance on Ti_6Al_4V is better than CoCrMo alloy than ploystyrene (Anselme, 2000). Cell adhesion when the material is not the rougher the better or more smoothly, such as the osteoblast like cells of the optimal cell adhesion between the surface roughness 0.05 - 1.2 μm (Huang et al., 2004). After various changes in surface roughness of pure titanium and titanium alloy, but also change the surface wettability and surface energy, but not completely positive (Lawrence et al., 2006).

Hence, in this study, we use the factorial design of experiments to observe changes in the situations and model surface wettability associated with the surface roughness after surface modification of Ti_6Al_4V alloy.

MATERIALS AND METHODS

Experimental materials

Two roughness kinds of surgical grade Ti-6A1-4V alloy (ASTM

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Table 1. Factorial design and observed values of process parameters.

Factors	Limits	Indicator variables	Roughness			
			SG		RG	
			-1		+1	
Time (min)	0	-1	94.794 94.704	95.494	73.368 74.626	74.414
	60	+1	33.778 29.538	31.574	34.602 28.966	30.426

Table 2. Analysis of variance for the process parameters.

Source	SS	d.f.	MS	F-radio	P-value
Main effects	8790.18	2	4395.09	1283.87	0.000
2-way interactions	317.12	1	317.12	92.63	0.000
Residual	27.39	8	3.42		
Total	9134.68	11			

F136-92) disc (12.7 mm$\varnothing \times$ 2.0 mm disk plates) were used in this study: (a) Smooth Group (SG) was mechanically polished using silicon carbide papers starting from grade 320, 400 ,600 ,800, 1000 to 1200 grits. (b) Rough Group (RG) was ground using silicon carbide papers in the sequence of 320, 400 and 600 grits. All discs were ultrasonically cleaned in 95% ethanol and rinsed three times in double-distilled water for 1 min and dried at room temperature. Then, they were placed in the incubator to maintain 40℃ for 24 h. Then, specimens were illuminated by 254 nm UV.

Materials characterization

Surface morphology and roughness

Surface morphology and roughness of the two types (SG, RG) were observed by the scanning probe microscope (SPM IIIa Dimension^{TM} 3000, Digital Instruments Inc., USA) which can measure very high magnification morphology of the substrate surface, the van der Waals force, friction coefficient.

Wettability

The wettability was evaluated using the sessile drop technique (Carlsson et al., 1986) which is a static contact angle assessment, mainly through the water like in the air phase, solid phase formed by the size of the contact angle to evaluate Hydrophilic and hydrophobic material itself. It was proceed by using 40℃ of de-ionized water dropped in each processed specimen where the water droplet was imprisoned within 10 sec of delivery and the images quality using a digital camera to take pictures. Subsequently, the contact angles were obtained by Image J which is a software of analysing image.

Design of the experiment

Design of experiments is a a powerful statistical analysis methods and modeling tools that can be used to estimate the main effects and interaction factors, and thus understand the variable impact on the results of the response, and then get a robust process. In general, the wettability of titanium surface parameters will mainly depend on surface modification of different ways, such as: surface roughness, UV irradiation time, so that a complete simulation of these parameters should be taken into account before the factors. However, it can prove the main parameters of surface roughness, UV irradiation time.

To carry out this study, a model consisting of a 2^2 design (Montgomery, 2006) was selected and 3 times of replicates for corner points. Forming a test matrix with two factors each taking two levels which are high (1) and low (-1) level, as can be observed in Table 1.

RESULTS AND DISCUSSION

Surface morphology of SG processing result is smoother than the RG. The result is shown in Figure 6a and 6b. Equation (1) shows the results when fitting a polynomial model to describe the CA parameter, taking into account that variables with a P-value greater or equal to 0.05 are not statistically significant at the 95% or higher confidence level, and Table 2 shows the variance analysis for the polynomial model:

$$\mathbf{CA} = 58.02 - 5.29\mathbf{x_1} - 26.54\mathbf{x_2} + 5.14\mathbf{x_1 x_2} \quad (1)$$

Where CA, x_1 ant x_2 are normalised variables representing: contact angle, roughness and time.

The R-squared and adjusted R-squared statistic indicates that the polynomial model explains 99.70% and 99.59% of the variability in CA. Since the P-value in the ANOVA table is less than 0.001, there is a statistically significant relationship between the variables at the 99.9% confidence level.

Figures 2 and 3 represent the normal probability distribution plot and the residuals versus fits plot. Although the high contact angle of Figure 3 is showed less variation, but these points of Figure 1 be showed

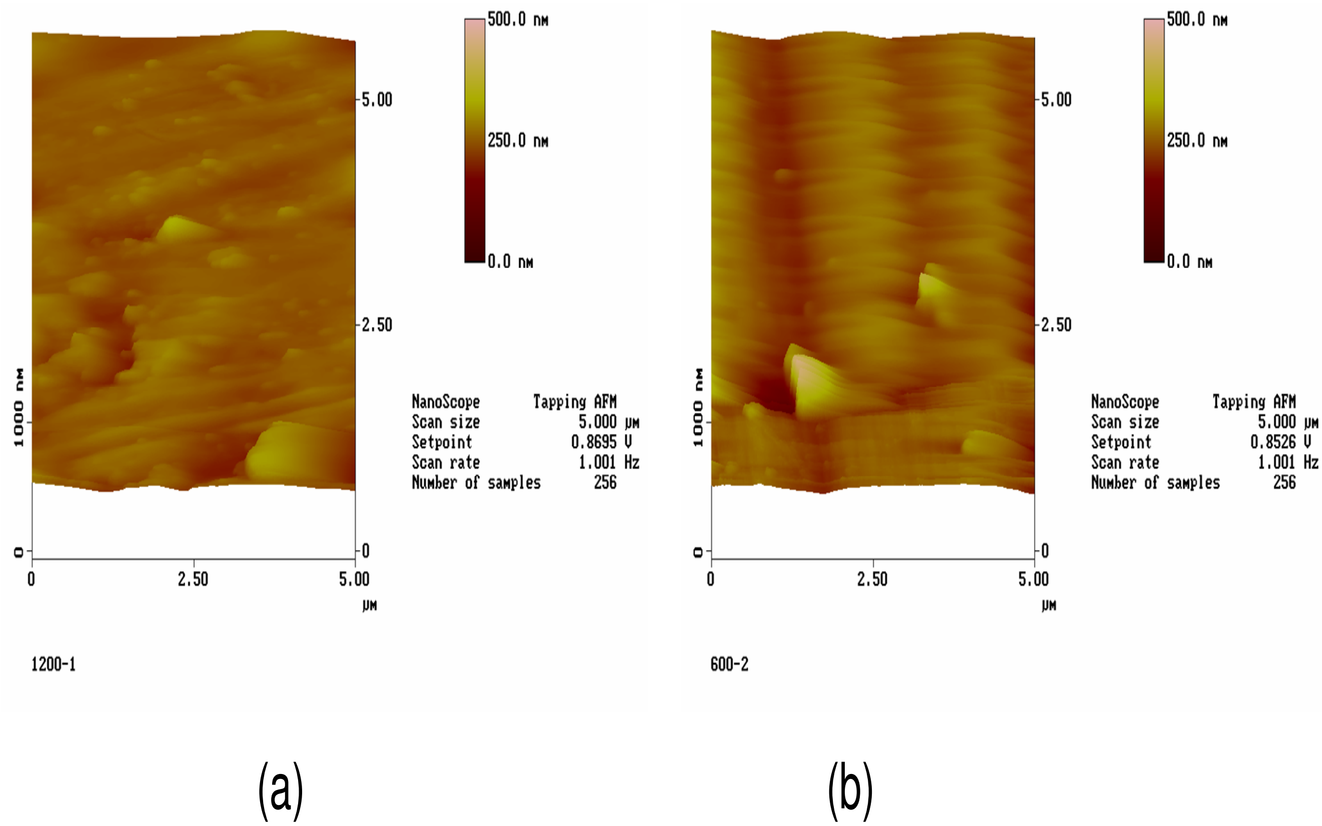

Figure 1. SPM images of different treatment. (a) SG (b) RG.

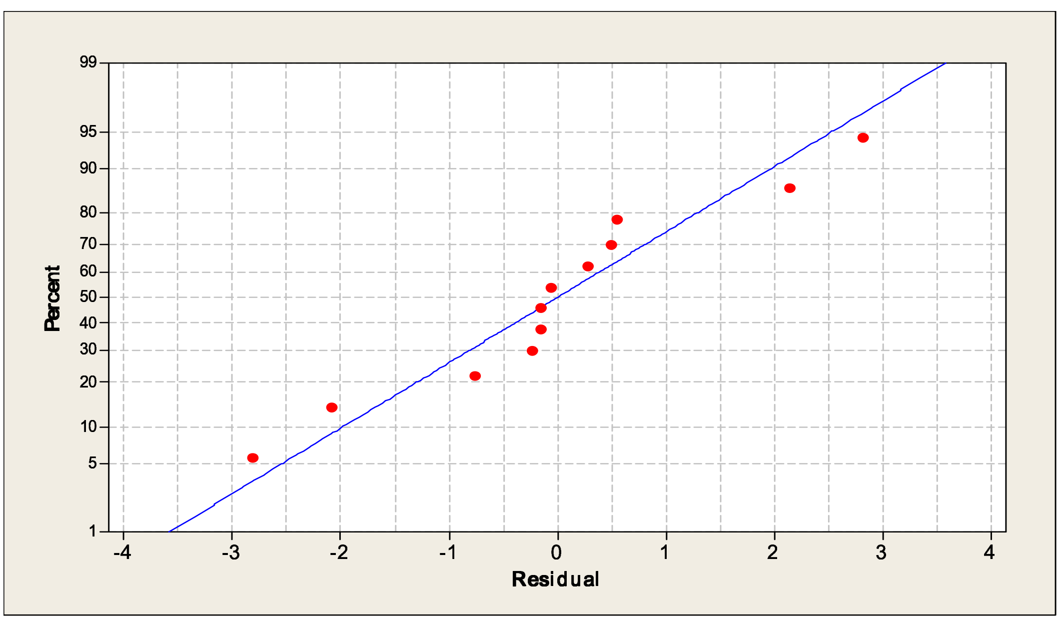

Figure 2. Normal probability plot for wettability.

normal probability distributions. Because of the time factor and roughness factor are displayed a positive and a small effect, the result will increase the level with reduced hydrophobicity. However, there is a interaction

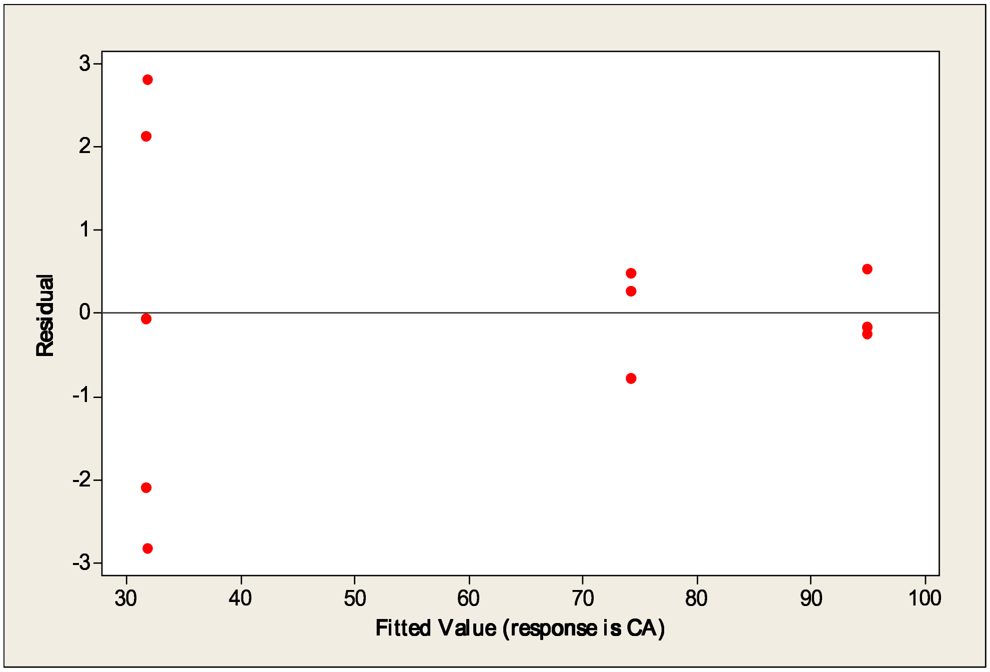

Figure 3. Residual versus fits plot for wettability.

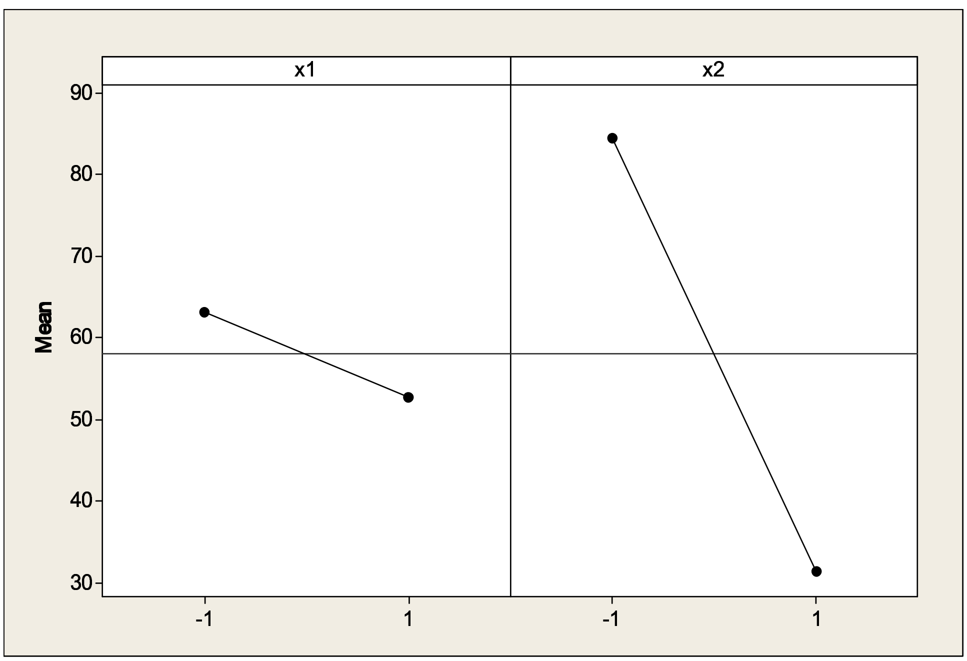

Figure 4. Main effects plot for wettability.

effect where the two factors are at high levels.

Figure 4 shows the estimated CA as a function of each experimental factor and Figure 5 shows the interaction plot for roughness and time. In each plot, the factor of concern is varied at its high level, while all other factors remain unchanged at their central values. It can be observed that roughness and time negatively affect the CA parameter.

Figure 6 shows the estimated CA parameter as a function of each of the normalised independent variables. Low of surface represents the value of the CA parameter. The other factors are held constant, where CA represents

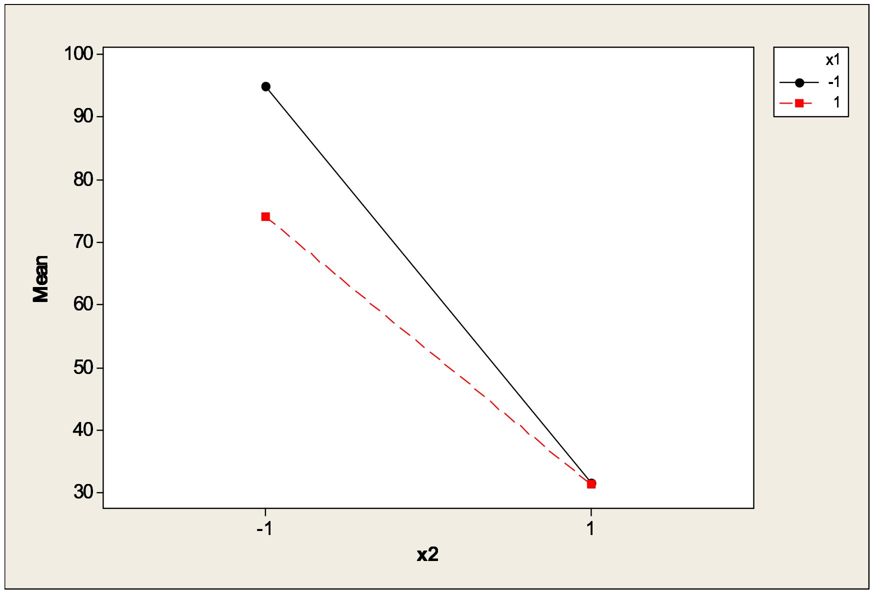

Figure 5. Interaction plots for wettability.

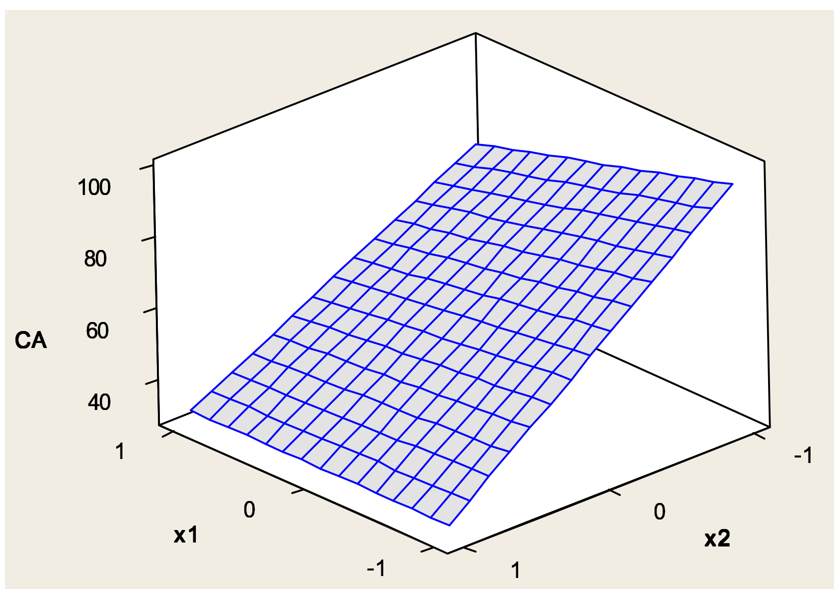

Figure 6. Estimated response for wettability.

contact angle, x_1 represents roughness and x_2 represents time.

Figure 7 shows contours for each of the response surfaces. From this figure, it may be easily deduced that the CA parameter improves with the decrease of roughness and time of UV irradiation.

Conclusions

In this work, it has been shown to be due to a combination of design and experimental techniques can be applied to the modeling of the behavior depends on two variables. This has been an effective way, not by the need for a large number of experiments.

In this work, it is observed that surface roughness and UV irradiation time have a negative influence on the contact angle average as increasing any of the two previous variables means increasing the wettability parameter. In addition, there is an optimum value of UV irradiation time that provides a minimum value of contact angle.

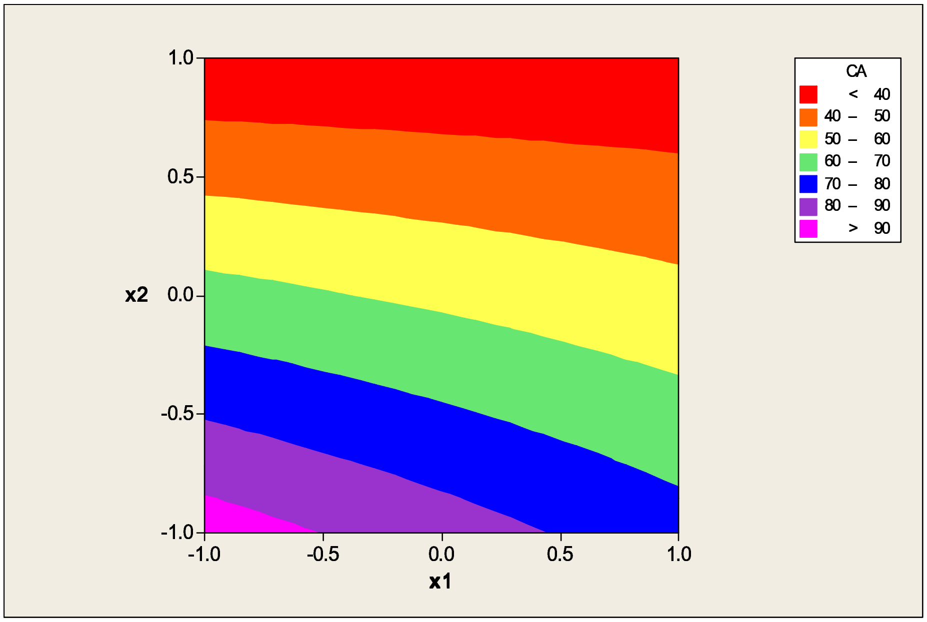

Figure 7. Contours of estimated response surface for x1 vs. x2.

In this study, the polynomial model has been used. However, there are some other models, such as fuzzy theory that can simulate this behavior makes it an effective way.

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REFERENCES

Advincula MC, Rahemtulla FG, Advinculac RC, Adae ET, Lemonsa JE, Bellisa SL (2006). Osteoblast adhesion and matrix mineralization on sol–gel-derived titanium oxide. Biomaterials, 27(10): 2201-2212.

Anselme K (2000). Osteoblast adhesion on biomaterials. Biomaterials, 21(7): 667-681.

Carlsson SL, Rouslund TR, Albrektsson B, Albrektsson T, Branemark PI (1986). Osseointergration of titanium implant. Acta Orthop. Scand., 57(4): 285-289.

Deligianni DD, Katsala N, Ladas S, Sotiropoulou D, Amedee J, Missirlis YF (2001). Effect of surface roughness of the titanium alloy Ti-6Al-4V on human bone marrow cell response and on protein adsorption. Biomaterials, 22(11): 1241-1251.

Deligianni DD, Katsala ND, Koutsoukos PG, Missirlis YF (2001). Effect of surface roughness of hydroxyapatite on human bone marrow cell adhesion, proliferation, differentiation, and detachment strength. Biomaterials, 22(1): 87-96.

Flemming RG, Murphy CJ, Abrams GA, Goodman SL, Nealey PF (1999). Effects of synthetic micro- and nano-structured surfaces on cell behavior. Biomaterials, 20: 573-588.

Huang HH, Ho CT, Lee TH, Lee TL, Liao KK, Chen FL (2004). Effect of surface roughness of ground titanium on initial cell adhesion. Biomol. Eng., 21: 93-97.

Lawrence L, Hao L, Chew HR (2006). On the correlation between Nd YAG laser-induced wettability characteristics modification and osteoblast cell bioactivity on a titanium alloy. Surf. Coat. Technol., 200: 5581-5589.

Liu X, Chub PK, Dinga C (2004). Surface modification of titanium, titanium alloys, and related materials for biomedical applications. Mater. Sci. Eng., 47: 49-121.

MacDonald DE, Rapuano BE, Deo N, Stranickc M, Somasundaran P, Boskeyd AL (2004). Thermal and chemical modification of titanium-aluminum-vanadium implant materials effects on surface properties, glycoprotein adsorption, and MG63 cell attachment. Biomaterials, 25: 3135-3146.

Montgomery DC (2006). Design and analysis of experiment 6/E. Sixth Edition. New York: John Wiley and Sons.

Ponsonnet L, Reybier K, Jaffrezic N, Comte V, Lagneau C, Lissac M, Martelet C (2003). Relationship between surface properties (roughness, wettability) of titanium and titanium alloys and cell behaviour. Mater. Sci. Eng., 23(4): 551-560.

Webster TJ, Ejiofor JU (2004). Increased osteoblast adhesion on nanophase metals: Ti, Ti_6Al_4V, and CoCrMo. Biomaterials, 25(19): 4731-4739.

Zhou W, Zhong X, Wu X , Yuan L, Zhao Z, Wang H, Xia Y, Feng Y, He J, Chen W (2006). The effect of surface roughness and wettability of nanostructured TiO_2 film on TCA-8113 epithelial-like cells. Surf. Coat. Technol., 200: 6155-6160.

Zhu X, Chen J, Scheideler L, Reichl R, Geis-Gerstorfer J (2004). Effects of topography and composition of titanium surface oxides on osteoblast responses. Biomaterials, 25: 4087-4103.