Wettability x Roughness: A Study of Ti-CP Surfaces

Gilvan Bomfin e Sousa[1], Marina de Oliveira Cardoso Macêdo[2], Haroldo Reis Alves de Macêdo[2]

[1]Maringá State University, Maringá, Paraná, Brazil
[2]Biomaterials Research Laboratory – LaBioMat – IFPI – Campus Picos, Av. Pedro Marques de Medeiros, S/N – Picos, PI, Brazil,

Abstract**—** *Commercially pure titanium has characteristics that define it as an excellent biomaterial, and for presenting these properties, it is widely used for biomedical purposes. In view of this information, studies are being conducted on titanium in order to improve its biocompatibility and adaptation with human tissue. Several types of topographic, chemical and surface analysis are proposed in order to make Ti CP an increasingly biocompatible material. The present work aimed to analyze the surface roughness and wettability of Ti CP, as well as the correlation of these properties. Twelve titanium discs with different Ra roughness grades and different orientations of this roughness were used and then a wettability analysis was performed using the sessile drop technique using water. Relationships between wettability and roughness can be made from the results obtained.*

Keywords**— *Titanium, Roughness, Wettability.***

I. INTRODUCTION

Actually, with the increasing number of injuries associated with accidents and factors related to longevity, the use of implants is necessary, where they are made from biomaterials. Thus, the use of biomaterials is extremely important to provide a better quality of life for the population as a whole[1].

From this perspective, biomaterials comprise a significant fraction of the products used in both Health and Engineering, being estimated at 300,000 prostheses in about 10 years[2]. Thus, the problem of obtaining prostheses as close as possible to natural bone tissue is widely studied in the field of materials science.[3].

However, for a direct structural and functional connection between the living organized bone and the implant surface, Osseointegration [4],elements such as commercially pure titanium (Ti-CP), is widely used for the broad corrosion resistance, conformability, ductility and strength of a specific application[5], reducing rejection phenomena in the long run[6].

Ti-CP surface characteristics such as surface energy, roughness, wettability and topography are essential conditions for osseointegration [7].Considering the parameters, a material subjected to superficial modifications may present a reduction in the biological response time, in order to have a greater effectiveness in the adaptation of the implant with living organisms[8].

Thus, when there are changes in the roughness of Ti CP, consequently there will be a variation in the surface energy as well as its topography and wettability[9].

Roughness can be defined as a set of irregularities on the surface of a sample, including peaks and valleys relative to a reference plane or imaginary plane[10].There are fundamental parameters indicating roughness, which can be cited: Ra, Rq, Rz e Ap eAv.

The Ra parameter indicates the average variation between peaks and valleys of the imaginary surface mean line. Already Rq, the mean square value of the roughness profile deviations and Rz the mean value of the unit roughness obtained in five measurement lengths. Ap and Av are the areas of the peaks and valleys[11].

Surface wettability can be studied through the contact angle of the liquid with the solid surface. Thus, the higher the wettability, the greater the interaction of the surface with the biological environment[12]. In the study of wettability, wetness is the ease that gout has to spread and can be classified into two types: physical and chemical. The first can be classified as interfacial solids interactions as Van der Walls force[13], and the second type of wetting can be defined as the chemical reactions between a solid and a liquid, or surface tension decrease and greater wetting[14].

The contact angle calculated by Young's equation:

https://dx.doi.org/10.22161/ijaers.611.78 ISSN: 2349-6495(P) | 2456-1908(O)

$$\cos\theta_r = \frac{(\gamma_{sv} - \gamma_{sl})}{\gamma_{lv}} \qquad (1)$$

Were: γ_{sv}(solid-gas), γ_{sl}(solid-liquid),γ_{lv}(liquid-gas)[15]. The surface characterization of solids with respect to hydrophobic and hydrophilic surfaces can be determined from their respective contact angles[16]. Where, according to Young's equation, for θ_r <90 one has a hydrophilic surface and for θ_r> 90 a hydrophobic surface.

Wenzel's model studies the contact angle for a micro and nanoscale surface. Thus, on a smooth surface when we add a roughness to it, there is an increase in surface area, so that its initial contact angle values change, tending to increase. The phenomenon occurs because with the roughness, the material gains what Wenzel calls the roughness factorγ_w[15].

In 1932, Wenzel proposed his relatively simple model for rough surfaces[17]. With it, one can observe how roughness affects wettability due to the increase of contact angle. The contact angle of the Wenzel equation is described as follows:

$$\cos\theta_w = r_w \frac{(\gamma_{sv} - \gamma_{sl})}{\gamma_{lv}} = r_w \cos\theta_r \qquad (2)$$

$\theta_w$is called Wenzel's apparent contact angle, as opposed to the actual contact angleθ_r*to* Young's equation for a smooth surface[15].

II. MATERIALS AND METHODS

Initially we worked with 12 samples of Ti CP, where they were submitted to the metallographic preparation of sanding with silicon carbide sandpaper with granulometry ranging from 220# a 2000# and polishing using alumina of1 μm, 0,5 μm e de 0,03 μm respectively, making them all the same.

After the discs were homogenized, they were divided into three groups according to the direction of the grooves that were made with the sandpaper, was used a sandpaper of 80#, 220#, 600# e 1200 #. To measure the final roughness a standard roughness meter was usedTime Group Inc., model TA 630 and Ra parameter.

After roughness analysis, the samples were subjected to the determination of the contact angle, which was made by the sessile drop method using water as wetting liquid. The contact angle value was measured using the Surftens DEMO software.

III. RESULTS

Figure 1 shows the roughness results for different working groups. A decrease in Ra roughness was observed as the sanding grain size was increased, as expected since 1200 # sandpaper is thinner than 80 # sandpaper for example.

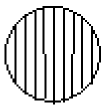
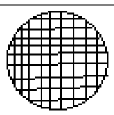
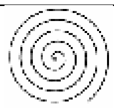
	Orientation	**Sandpaper 80 #**	**Sandpaper 220 #**	**Sandpaper 600 #**	**Sandpaper 1200 #**
Group 1	 1	1- 1,656 µm	4- 0,698 µm	7- 0,289 µm	10- 0,186 µm
Group 2	 2	2- 1,734 µm	5- 0,713 µm	8- 0,232 µm	11- 0,209 µm
Group 3	 3	3- 1,201 µm	6- 0,404 µm	9- 0,289 µm	12- 0,159 µm

Fig.1 – Roughness orientation for different groups

Comparing the three groups, it can be observed that group 2 had higher Ra roughness than the others, except for condition 7. This difference can be attributed to the pressure variation used during mechanical and manual sanding.

https://dx.doi.org/10.22161/ijaers.611.78 *ISSN: 2349-6495(P) | 2456-1908(O)*

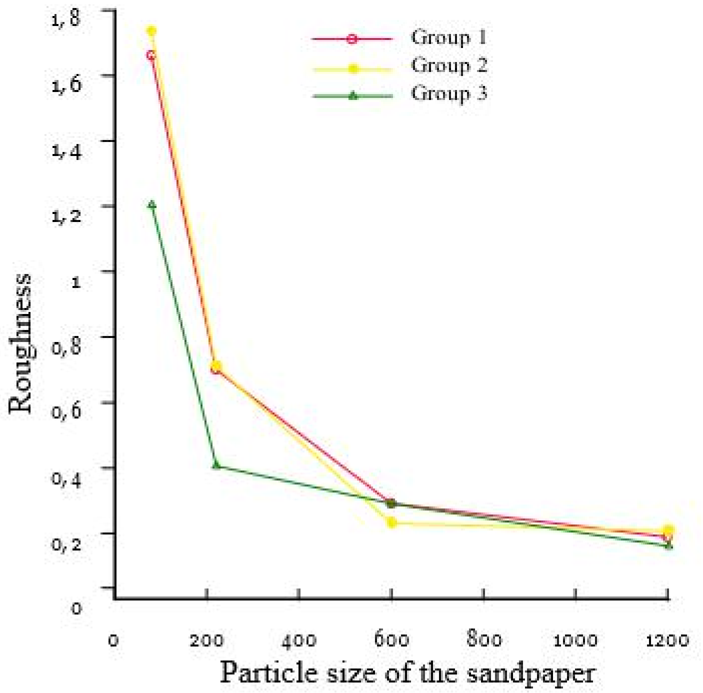


Fig.2 –Roughness x different particle size of the sandpaper.

Figure 2 shows a new representation of the data in Figure 1, where it can be seen that group 3, group in which the surface treatment done by an automatic sander had an initial disparity in relation to groups 1 and 2, which had their roughness orientations done manually, but for the sandpaper 1200 all had similar roughness.

Figure 3 shows the contact angle values for all conditions analyzed. A relationship between the contact angle values and those of the Ra roughness was observed, this relationship is justified based on Wenzel's theory which shows that when a sample has different roughness its surface area increases, and from Young's equation for energy. This new area tends to receive a roughness factor, making the larger this factor, the wetter the material becomes.

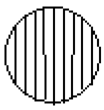
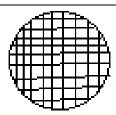
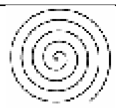
	Orientation	Sandpaper 80 #	Sandpaper 220 #	Sandpaper 600 #	Sandpaper 1200 #
Group 1	 1	1- 23,18°	4- 28,12°	7- 24,7°	10- 32,38°
Group 2	 2	2- 21,44°	5- 25,18°	8- 32,12°	11- 34,16°
Group 3	 3	3- 23,96°	6- 19,16°	9- 26,96°	12- 26,24°

Fig.3 - Contact angles for different groups

From the roughness and contact angle data, the graph of figure 4 was constructed, where the contact angle with the roughness was related for the three different topographies analyzed.

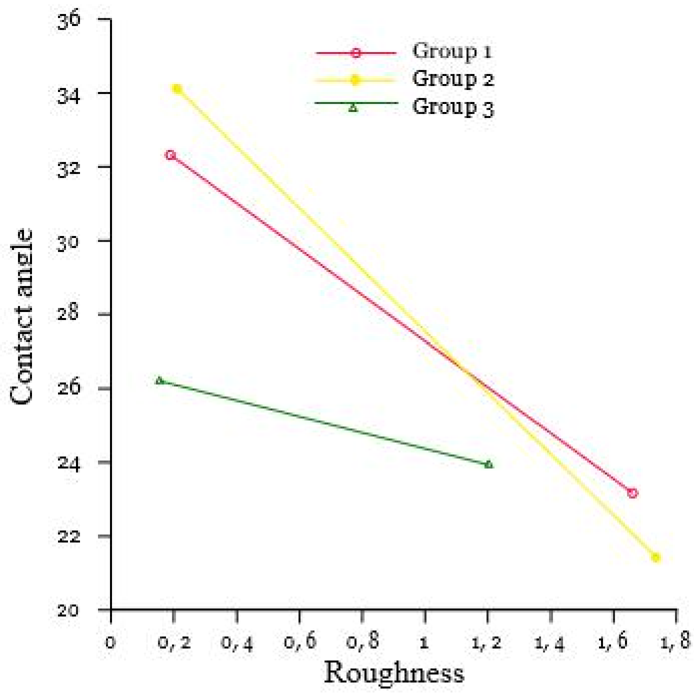


Fig.4 - Analysis of the contact angle relationship as a function of roughness for the different groups analyzed.

In figure 4, it was observed that the group 2 presented the best results of roughness as well as wettability, because for higher degree of roughness had greater wettability and for lower roughness values, consequently the samples wet less. Among the analyzed groups, group 3 was again quite different from the others, thus it was observed how the mechanical surface treatment affected the analyzed samples from group 3.

IV. CONCLUSIONS

It was observed that we can relate the roughness and wettability of a material through the Young and Wenzel equations, and thus, it can be observed that samples with different degrees of roughness tended to have larger and smaller contact angles, directly correlating to roughness with wettability.

REFERENCES

[1] GUASTALDI, A. C.; APARECIDA, A. H. Fosfatos de Cálcio de Interesse Bioló- gico: Importânciacomo Biomateriais, Propriedadese Métodosde Obtençãode Recobrimentos, Química Nova, v.33, n.6, p. 1352-1358,2010.

[2] PIRES, A. L R.; BIERHALZ, A. C. K.; MORAES, A. M. Biomateriais: Tipos, Aplicações e Mercado, Química Nova, v.38, n.7, p. 957-971,2015.

[3] GUTIERRES, M.; LOPES, M. A.; HUSSAIN; N. S.; CABRAL, A. T.; ALMEIDA, L.;SANTOS,J.D.SubstitutosÓsseos:ConceitosGeraiseEstadoActual,ArquivosdeMedicina, v.19, n.4,p.153-162,2006.

[4] HAYASAKI, C. L.; SOUSA, E. A. C. Modelagem de estruturas ósseas e próteses através do método dos elementos finitos, XIII SIMPEP-Bauru, SP,2006.

[5] OPINI, V. C. Preparação,Processamento e Caracterização de Ligas de Titânio com Alta Resistência Mecânica Baseadas na Liga Ti-5553. Dissertação (Mestrado em Engenha- reia Mecânica)–Faculdade de Engenharia Mecânica da Universidade Estadual de Campinas, UNICAMP, Campinas,2012.

[6] SARTORI, R. Análise de Corrosão e Fratura de Implantes/ Componentes Protéticos de Titânio Comercialmente Puro, após serem Submetidos a Ciclos de Fadiga em um Meio Fluoretadocom Diferentesp H. Dissertação (Mestradoem Odontologia)-Universidade Estadual Paulista, Faculdade de Odontologia, Unesp, Araraquara,2006.

[7] ELIAS, C. N.; BUSQUIM, T.; LIMA, J. H. C.; MULLER, C. A. Caracterização e Torquede Remoçãode Implantes Dentárioscom Superfície Bioativa, Revista Brasileirade Odontologia, v.65, n.2, p. 273-279, 2008.

[8] CATÃO,C.D.S.;RABELLO,I.P.;MOREIRA,A.M.A.;FOOK, M.V.L.;ARAÚJO, C.J.;SOARES,R.S.C. Bioactivity evaluation of laser treated NiTi alloysfordental application, RFO, v.19, n.1, p.48-56,2014.

[9] SOUZA,G.B.CaracterizaçõesFísicas,Químicas,edeBioatividadedeSuperfíciesde TitânioModificadasparaAplicaçãoBiomédica.Tese(DoutoradoemEngenhariaeCiênciados Materiais) – Universidade Federal do Paraná, Setor de Tecnologia e Setor de CiênciasExatas,
UFPR, Curitiba, 2010

[10] BUSQUIM,T.P.E estudo invitroeinvivo da osseointegração de implantes de titânio com superfícies biomimetizadas.

2012. 151 f. Tese (Doutorado em Ciências e Engenharia de Materiais)- Universidade Federal de São Carlos- UFScar, São Carlos,2012.

[11] COUTINHO, M. P. Rugosidade e Molhabilidade do Titânio Usado em Implantes Dentários com Superfícies Tratadas. Rev. bras. odontol. Rio de Janeiro, v. 66, n. 2, p.234-238, jul./dez.2009.

[12] MARQUES, C. Tratamento de Superfície de Implantes de Titânio. 2007. 108 f. Dissertação (Mestrado em Ciências dos Materiais) - Programa de Pós- Graduação em Ciências dos Materiais, Instituto Militar de Engenharia. Rio de Janeiro,2007.

[13] ANEZIRIS, C. G.; HOMOLA, F. High temperature wetatability of refractories in contactwithmetlts,Handbook,GermanCeram.Soc.,Technical CeramicMaterials,Kriegesmann, Cap.5.4.2.1, p, 1-32,2005.

[14] NASCIMENTO, R. M.; MARTINELLI, A. E.; BUSCHINELLI, A. J. A., Review article: recent advances in metal- ceramic brazing, ceramic 49, 178-198,2003.

[15] WAINBERG, R. Molhabilidade e rugosidade de superfícies: Caracterização inter- ferométrica e sua correlação com a rugosidade. Trabalho de Conclusão de Curso apresentado aoInstitutodeFísicadaUniversidadeFederaldoRioGrandedoSulcomorequisitoparcialpara obtenção do título de Bacharel em Física-Pesquisa Básica. Porto alegre,2014.

[16] LUZ,A. P.; RIBEIRO,S.;PONDOLFELLI,V.C.Artigorevisão:usodamolhabili- dade na investigação do comportamento de corrosão de materiais refretários. Cerâmica 57. p. 174-183,2008.

[17] WENZEL,R.N.Resistanceofsolidsurfacestowettingbywater, Ind.Eng.Chem,v.28,n.8, p.988-994,1936