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Mechanical changes of sandblasted Ti-6al-4v using 100 µm Al_2O_3 after dynamic pressure treatment: *In vitro* study

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Abstract

Background: Implant materials have been developed in such a way to fulfill various requirements of mechanical properties, one of the methods to change mechanical properties of implant is the sandblasting method.

Purpose: This study aimed to determine the changes in mechanical properties of Titanium 6 Alloy 4 Vanadium (Ti-6Al-4V) sandblasted using 100µm Al_2O_3 after dynamic stress treatment.

Method: 32 Ti-6Al-4V implant samples divided into two groups, 16 samples of treatment group (PI) and 16 samples of control group (PII). The PI group is Ti-6Al-4V sandblasted by Al_2O_3 100 and the PII group is Ti-6Al-4V machined surface. Both groups of samples were given dynamic treatment as much as 2 million times and then performed a compression test.

Results: The results of data analysis showed PII> PI and there was a significant difference ($p<0.05$) between the PI and PII groups.

Conclusion: In conclusion, there's difference in mechanical properties of sandblasted Ti-6Al-4V using 100µm Al_2O_3 after dynamic pressure treatment.

Keywords: Ti-6Al-4V; Sandblasting; Mechanical properties; Al_2O_3

1. Introduction

Dental implants are an inseparable aspect in dentistry. Implant treatment helps dentists improve the patient's quality of life to a large extent. During the last few decade the development of dental implants has been very rapid. The age of the implant and the success rate of dental implant placement is quite high, around 90%. So dental implants are one of the preferred alternative treatments to restore function, anatomy, or aesthetics due to tooth loss [1].

Various materials have been used as dental implant materials such as metals and metal alloys, ceramics, carbon, carbon-silicon, polymers, and composites. One of the materials used is metal and metal alloy, these two materials are the most widely used materials in the manufacture of implants. Examples of metals and their alloys are titanium, tantalum, vanadium, cobalt, chromium, molybdenum and nickel [2].

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One of the commonly used materials for dental implants is Titanium 6 Alloy 4 Vanadium (Ti-6Al-4V). Ti-6Al-4V is a metal alloy consisting of titanium as the main material combined with 6% aluminum and 4% vanadium. Ti-6Al-4V has advantages including good corrosion resistance, high fatigue strength, and low elastic modulus [3].

Modifying the surface of the implant is necessary to improve osseointegration. There are various ways to modify the implant surface, which can be done by roughing the surface of the implant (surface roughness), one of which is the sandblasting method [4]. Sandblasting is a technique used to create a porous layer on the surface of dental implants by firing microscopic particles [3].

Aluminum Oxide (Al_2O_3) is a ceramic material that is commonly used in sandblasting techniques due to its affordable cost [5]. Al_2O_3 was chosen because it can produce a good rough surface texture on implants. In addition, sandblasting using Al_2O_3 can remove Si contamination from the titanium surface which can affect the success of implant installation [6]. A study conducted by Yurttutan & Keskin (2018) stated that Al_2O_3 can stimulate calcium flow in bones [7].

As long as the dental implant is implanted, the dental implant must be able to accept various load cycles. Most of these load cycles are derived from physiological or parafunctional masticatory activities such as bruxism. Given this load, the ability to withstand fatigue in dental implants is an important factor [8].

There are various kinds of problems in dental implant treatment. Dental implant problems are divided into two, namely biological and mechanical problems. Mechanical problems are problems that include general mechanical damage to implants, implant components, and also the external structure of the implant in clinical cases in the form of implant fractures. Mechanical problems begin to occur when implants are used for a long time [9]. One study reported that the incidence of fracture in implants was 0.2 to 1.1% and in the abutment or body of the fracture implant was 0.7 to 2.3% 10. Occlusal load is a key factor in the implant receiving load. Among these loads, parafunctional habits such as bruxism and clenching can increase the stress of the implant, leading to mechanical problems [9].

2. Material and methods

This type of research is an experimental laboratory with a post-test only control group design. The sample used was Ti-6Al-4V implant by PT Marthys Orthopedic Indonesia.

Figure 1 Ti-6Al-4V implant by PT Marthys Orthopedic Indonesia

The implant used is an implant made from T1-6Al-4V produced by PT. Marthys Orthopedic Indonesia screw type. The implants were then divided into 2 groups consisting of the (PI) group, namely Ti-6Al-4V sandblasted Al_2O_3 100 m and the (PII) group, namely Ti-6Al-4V machined surface. The location for sandblasting was at the neck of the Ti-6Al-4V implant. Then all implants were made of implant holders made of ARALDITE® Standard Setting Epoxy Glue in the form of a cube with a side length of 10 mm. After setting the seat, grinding is carried out to ensure the specimen can stand upright. The next step is to make a specimen head made of VERABOND® Nickel Chromium in the form of a ball with a diameter of 8 mm.

Figure 2 Ti-6Al-4V implant with implant holder made of ARALDITE® Standard Setting Epoxy Glue and specimen head made of VERABOND® Nickel Chromium

The Dynamic Fatigue Testing Machine used in this research is the Hung Ta Load Cell Type HT-9711T5. Dynamic Fatigue Testing Machine is regulated according to ISO 14801 with some adjustments to suit this research. The amount of pressure applied to the research specimen is 100 N. The frequency set on the Dynamic Fatigue Testing Machine during the test is 15 Hz according to the ISO 14801 standard. The number of loading cycles given is 2 million assuming the use of dental implants for 2 years. The assembled specimen is then mounted on a jig from the Dynamic Fatigue Testing Machine and then subjected to dynamic pressure treatment. The process of applying dynamic pressure to the specimen takes 2 days so that the total time required to apply dynamic pressure is about 32 days. Specimens that have been treated with dynamic pressure are then subjected to a compressive test using the universal testing machine Hung Ta Type HT-9501 to determine the value of the mechanical properties of the Ti-6Al-4V implant specimen.

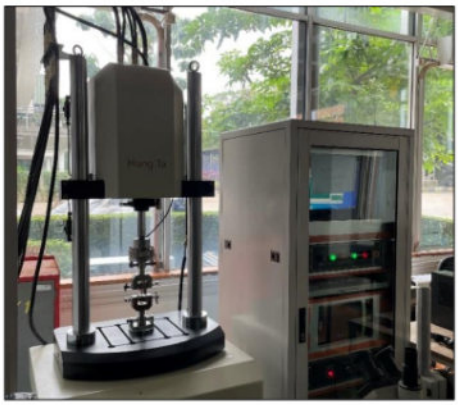

Figure 3 The Hung Ta Load Cell Type HT-9711T5. Dynamic Fatigue Testing Machine

3. Results

This study used an implant made from T1-6Al-4V produced by PT. Marthys Orthopedic Indonesia. The Implant implanted in the Laboratory of the Faculty of Mechanical Engineering, University of Indonesia, Depok. The Dynamic Fatigue Testing Machine used within the process of applying dynamic pressure to the specimen takeswith total time required to apply dynamic pressure is about 32 days. Specimens that have been treated with dynamic pressure are then subjected to a compressive test using the universal testing machine Hung Ta Type HT-9501 to determine the value of the mechanical properties of the Ti-6Al-4V implant specimen.

Figure 4 The compressive test of T1-6Al-4V using the universal testing machine Hung Ta Type HT-9501

The Ti-6Al-4V implant was then subjected to a compression test to obtain the mechanical properties of the specimen. The results of the average and standard deviation of the sample group are shown in the following image:

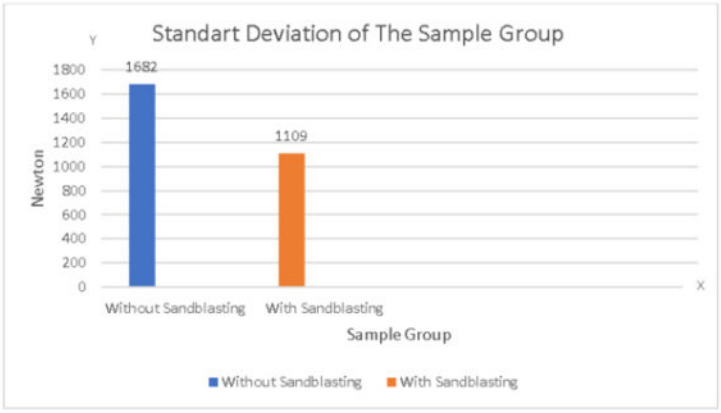

Figure 5 The average and standard deviation of the sample group with left image without sandblasting and right image with sandblasting

4. Discussion

This study aims to determine the effect of the sandblasting technique to increase surface roughness but at the same time change the mechanical properties of Ti-6Al-4V. Sandblasting is a technique used to create a porous layer on the surface of dental implants by firing microscopic particles so that the surface of the implant becomes rough. Sandblasting changes the surface topography and surface energy of the implant surface, thereby increasing wettability, cell proliferation, cell growth, and the osseointegration process [11].

The main consideration in selecting the material used for sandblasting is that when applied to the implant surface it produces a clinically suitable rough surface. Al_2O_3 was chosen because it can produce a good rough surface texture on implants. In addition, sandblasting using Al_2O_3 can remove Si contamination from the titanium surface which can affect the success of implant installation [6]. A study conducted by Yurttutan & Keskin (2018) stated that Al_2O_3 can stimulate

calcium flow in bones. The particle size used varies from 25 to 250 m [7]. A study reported that the use of small particles did not give the expected surface results but the use of particles with a size that was too large resulted in a surface that was too rough [6]. Therefore, in this study, a particle size of 100 m was used.

Based on the results of research that has been done. The results of the compression test (compressive test) of machined surface Ti-6Al-4V (PII) are greater than sandblasted Ti-6Al-4V (PI) and are significant. When a chewing load is applied to the implant, fracture was defined as the plastic deformation of the implant surface. So that the accumulation of cycles results in deformation. The average masticatory cycle of a person in general can affect the life of the implant although it does not cause significant damage when the chewing load is applied to the implant. The frequency of mastication in normal people is generally around 2700 times a day or equal to 10 million times per year. However, under general conditions, the chewing cycle does not occur continuously [12].

The results of this study are in line with several studies that reported that sandblasting has the effect of reducing the maximum endurance strength of Ti-6Al-4V by up to 40%. The decrease in maximum resistance is caused by the surface treatment, namely sandblasting which makes small defects on the surface that play a role as stress raisers. These defects are thought to act as crack initiators so that the rough surface accelerates crack nucleation. [11,13]. The sandblasting technique makes the implant surface deform in the form of sharp ridges and defects in the form of cracks. The deformity created by sandblasting is thought to initiate fatigue cracks of Ti-6Al-4V implants when subjected to large amounts of stress so that they can trigger fracture faster than Ti-6Al-4V implants without sandblasting.

Thus, sandblasting was initially carried out to obtain a rough surface so as to increase osseointegration but also had a negative effect in the form of defects on the implant surface that could trigger fatigue cracks [9]. This phenomenon can be controlled by controlling the surface roughness of dental implants with appropriate sandblasting techniques [11]. However, until now there is no optimal standard both sandblasting pressure, particle size, and velocity in the sandblasting technique to obtain osseointegrity while not triggering fatigue too quickly [9].

In this study, there are limitations where the dynamic pressure treatment that should follow the ISO 14801 standard needs to be adjusted. The dynamic pressure treatment was carried out without stopping which was incompatible with chewing movements in humans. The results of the data obtained are in the form of compressive test values which are still in the form of raw data that can still be further processed into more valid data. The limitations of this study are due to the time limitation of the study, the availability of a large enough cost, and the ability of the tool.

5. Conclusion

There is a change in the mechanical properties of sandblasted Ti-6Al-4V using 100µm Al_2O_3 after dynamic pressure treatment.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors have no conflict of interest to declare.

Statement of ethical approval

The present research work does not contain any studies performed on animals/humans subjects by any of the authors.

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