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(Research Article)

Compressive strength of Ti-6Al-A4 after immersion test with artificial saliva pH 8.0 and dynamic testing

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Abstract

Dental implants are an alternative dental treatment that has been developed with one of the chosen materials, called Ti-6Al-4V. The pH environment in the oral cavity is expected not to affect the Ti-6Al-4V implant's durability.

The aim of this research was to analyze the change in compressive strength of the Ti-6Al-4V implant after dynamic and immersion tests with artificial saliva at pH 8.0.

The method that we used in this research is laboratory experimental and analytic research was conducted with 27 Ti-6Al-4V implant samples, which were classified into three groups as research subjects. Each group consists of 9 samples, including those with no treatment (UT), aquades solution (DW), and artificial saliva with a pH of 8.0 (AS). In the negative control group, the samples were treated dynamically in accordance with the ISO 14801 standard, while the samples in the positive control group were not treated. Samples from the treatment group were subjected to a dynamic test in accordance with ISO 14801 standards while being immersed in artificial saliva with a pH of 8.0. Thereafter, a compression test was conducted on the three sample groups. A one- way ANOVA test was used to analyze the comparison of treatment results.

The result for this research is the immersed Ti-6Al-4V implant in artificial saliva and dynamic testing with a stress of 50 N, 2 million load cycles, and a frequency of 12 Hz do not significantly impact the compressive strength of each Ti-6Al-4V sample.

In Conclusion, the dynamic treatment along with the immersion test on artificial saliva at pH of 8.0 seemed to have no effect on the compressive strength of each sample.

Keywords: TI-6Al-4V; Artificial Saliva; Dynamic Test; Compressive strength

1. Introduction

Tooth loss has an impact on both oral health and overall esthetic function. It is possible for patients who have missing teeth to develop a number of systemic and oral issues. A lifetime of rapid alveolar bone deterioration can be observed in the first three to six months following tooth loss. Then, particularly within the first year following tooth loss, the remaining teeth may migrate in the form of tipping, extrusion, or rotation. Usually, teeth that have no antagonists on the upper or lower regio teeth experience supra eruption. The extruding maxillary tooth will be accompanied by the formation of excessive fibrous binding tissue or excessively enlarged tuberosity in the event that the mandibular molar

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tooth is lost. These changes to the occlusal field and the lack of room for replicated tooth material may result. The teeth'svertical dimensions may also get smaller. Malnutrition may result from mastication abnormalities, which might disrupt the patient's ability to receive nutrition [24].

The treatment paradigms for patients with missing teeth have developed as an outcome of the predictability of dental implants. In the past, implants were utilized to increase the stability of full denture prosthesis in patients who were fully edentulous. The scope of implant rehabilitation programs for partially edentulous individuals has expanded with the introduction of different loading regimens due to more predictable treatment. Today, dental implants are a common kind of treatment and are frequently suggested for prosthetic rehabilitation. Despite implant therapy's relatively high predictability and substantial patient expenses, patient perceptions of success and patient reported outcome metrics have grown in importance in implant dentistry [9]. The quality of dental implant depends on the properties of the surface. Titanium (Ti) is the most common biomaterial used to fabricate dental implants because of its high biocompatibility and inherent nature of protective film formation. In order to have good interaction of the tissue and osseointegration, materials biocompatibility and roughness of the surface played an important role. Area of the implant improve cell migration and attachment to implant, and enhance osseointegration process. The cell bioactivity was improved and expected to have good osseointegration at early stage [13].

Material compatibility is crucial for successful dental implantation, with titanium alloys promoting osseointegration and being well-tolerated by living tissues. Surfaces should interact with surrounding tissue for bone-implant contact. Dental implants can be affected by changes in saliva pH due to infectious diseases, which can lower the pH level, affecting the durability of the metal implants. Factors like temperature, pH, humidity, stress, and microorganisms can also affect implant durability. The pH variation in the mouth cavity can affect the durability of the metal implants used. Implants can experience corrosion and porosity processes within the human body, resulting from unstable metal changes and increased degradation due to fluctuating ambient temperatures, changes in pH levels, high humidity, stress, and the role of other microorganisms [1, 2, 3, 6].

The oral cavity's saliva is known to be the first liquid to interact with substances or materials from the outside. Saliva, which is composed primarily of water, also includes inorganic substances such as NaCl, KCl, NHCO3, HPO4, CaCO3, proteins, mucin, serum albumin, globulin, enzymes, epithelial cells, and lymphocytes [17]. Ti oxidation rapidly forms oxide and oxygen diffusion into titanium's bulk structure. Oxygen-enriched layers form due to high solubility and stabilizing effect. TiO2 is resistant to hostile environments, improves corrosion resistance, and promotes osseointegration and bone adhesion. It also serves as a barrier between the environment and the material. The human body's blood and extracellular fluids contain organic compounds, dissolved oxygen, inorganic anions, cations, amino acids, and proteins that can erode the TiO2 layer. Saliva, containing both organic and inorganic salts, is exposed to dental implants in the oral cavity and can be affected by factors like food and illnesses. Low salivary pH after acidic liquids or illnesses can encourage the corrosion of Ti dental implants. Fluoride exposure degrades Ti, causing the oxide coating to lose continuity and delaminate. Mechanical movement erodes the layer, exposing the implant to environmental deterioration and corrosion. According to the current study, adding Ti particles to artificial saliva boosted its corrosion resistance [11]. The type of style generated is related to the shape of the implant and the location of the placement. Compressive strength, which determines the maximum load a Ti-6Al-4V implant can withstand, is crucial as it affects the mechanical properties of the tooth material [21]. The load resistance involved is evaluated to determine the maximum load that can be borne before a fracture occurs. Dynamic loading is added to determine the degree of fatigue strength on the implant exposed to the mouth's burden in the oral cavity [18, 27].

The ISO 14801 standard is an international standard that establishes parameters for fatigue testing on dental implants, including transmucosal abutment and pre-production prosthetic components. It provides results that can be compared and describes the test method, including test instrument characteristics, geometry, sample holder, load application, test environment, load frequency, wave shape, and procedural characteristics [10]. The ISO 14801 standard uses the "*All on fou*r" technique, where two implants are placed vertically on the anterior region and two on the non-edentulous region, with an inclination angle of 30° to 45° degrees [25].

This example of a healing abutment, whose surface components often vary in various oral cavity conditions, serves as the basis for this study. As a result, it is anticipated that this study will pinpoint the specific types of oral environments that might affect the metal implant TI-6Al-4 V's surface components. Saliva in the mouth and teeth is typically wet, with a pH between 6.5 and 7.5 [19]. Dental implants can be affected by saliva pH variations, including infectious diseases, which can lower saliva pH to acid. This can lead to corrosion and porosity in implants due to unstable metals and environmental factors [1, 2, 3, 6]. The necessity for dynamic testing using the ISO 14801 standard puts the idea into practice by simulating the worst-case scenario of implant implantation [10]. Compressive strength must be studied because it relates to the mechanical properties of a tooth material, which can cause fractures or failures [4].

This study investigates the resistance of Ti-6Al-4V implant metal to pH changes in the oral cavity environment using an immersion test technique on artificial saliva at a pH base (8.0), assessing compressive strength and resistance.

2. Material and methods

In this study, the sample will be divided into several treatment groups, namely; (a.) Negative control group: A group of samples that were not tested by immersion and were not given dynamic treatment. (b.) Positive control group: Sample group that was tested by immersion in distilled water and given dynamic treatment. (c.) Treatment group: The sample group was subjected to an immersion test with artificial saliva pH 8.0 and given dynamic treatment.

2.1. Titanium Rod Ti-6Al-4V Specimen Assembly

In this study, screws made by PT. Marthys Orthopedic Indonesia were utilized with Ti-6Al-4V implants. an implant that is 26 mm in length and 3.25 mm in diameter. The implants were then separated into three groups of samples: non-treatment groups, groups with implant immersion in aquades with dynamic testing (ISO 14801), and groups with implant immersion in synthetic saliva at pH 8.0 with dynamic tests.

The study involved creating an implant using a 12 mm x 20 mm Brass Rod Holder, drilling a hole for the implant, and lining it with DEVCON® Plastic Steel Putty. A hemisphere-shaped specimen was created using VERABOND® Nickel Chromium. Artificial saliva was used for dynamic testing and compression tests, with a 30-degree inclination to simulate the worst conditions of implant installation in the oral cavity [26 , 15].

2.2. Immersion Test on Implants

The Immersion Test is a test by immersing a sample in environmental conditions that will be adjusted during the study. This immersion test aims to determine the resistance of the sample directly exposed to the pH degree of saliva (using artificial saliva pH 8.0) and the atmosphere of the oral cavity. Ti-6Al-4V implant specimens were immersed in a container containing artificial saliva 8.0. The same method was used for immersion using distilled water. The immersion test was conducted simultaneously with the dynamic test. In each device, the solution is filled according to ASTM G31-71 rules or as much as (0.2 to 0.4) x (sample surface area) [5 , 20].

2.3. Dynamic Stress Treatment

This study utilized the Hung Ta Load Cell Type HT-9711T5 Dynamic Fatigue Testing Machine, with a 50N specimen pressure and 12 Hz frequency adjustment, and 2 million loading cycles for dental implants. The dynamic test duration was calculated after 46 hours, with each sample taking 2 days for treatment. After dynamic pressure treatment, the specimens were subjected to a compressive test to determine their mechanical properties ISO 14801, 2016).

In this study, each 1 sample takes 2 days for dynamic pressure test treatment thus the total time required is 54 days for all samples. Dynamic treatment was done by the application of dynamic pressure in accordance with ISO 14801 standards is carried out when the assembled specimen is then mounted on a jig from the dynamic fatigue testing machine Hung Ta Load Cell Type HT-9711T5.

After being subjected to dynamic pressure treatment, the specimens were then subjected to a compressive test using a universal testing machine Hung Ta Type HT-9501 to determine the mechanical properties of the Ti-6Al-4V implant specimens.

2.4. SEM (Scanning Electron Microscope) Test

Scanning Electron Microscope (SEM) in this study used the latest machine produced by HITACHI (HITACHI FLEXSEM 100). The operation of SEM begins with an electron beam emitted from an electron gun equipped with a tungsten filament cathode. The beam is focused by condenser lenses and passes through scanning coils or deflector plates in the electron column. The energy exchange between the electron beam and a specimen is detected through high-energy reflections, secondary electron emissions, and electromagnetic radiation emissions. The current of the beam absorbed by the specimen is also detected and used to create images. Electronic amplifiers amplify signals, which are displayed as brightness variations on the cathode light tube. The resulting image is derived from signal intensity distribution maps emitted from the scanned specimen area [12].

2.5. Data Analysis

The data analysis of the results of this study will be performed in a normality test with the Saphiro-Wilk Test, a homogeneity test with a levene test, and an ANOVA one-way test to see the difference between an untreated Ti-6Al-4V Implan group, immersed in aquades and treated dynamically, and a sample group immersed into artificial saliva pH 8.0 and given dynamic treatment. At the end of the study, further analysis was conducted using Tukey-HSD to compare the average results of treatment after the analysis trial.

3. Result

This research began with the manufacture of Ti-6Al-4V implant specimens according to the design. Next, a compressive test was carried out using the universal testing machine Hung Ta Type HT-9501 and a dynamic test according to ISO 14801 standards. During the dynamic test, the specimens were immersed in artificial saliva pH 8.0.

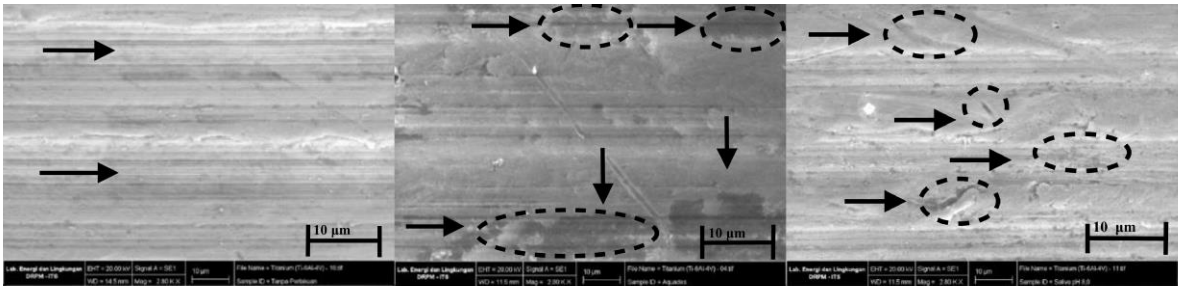

Figure 1 SEM Result of untreated (A). SEM Result of aquades (B). SEM Result of artificial saliva pH 8.0 (C).

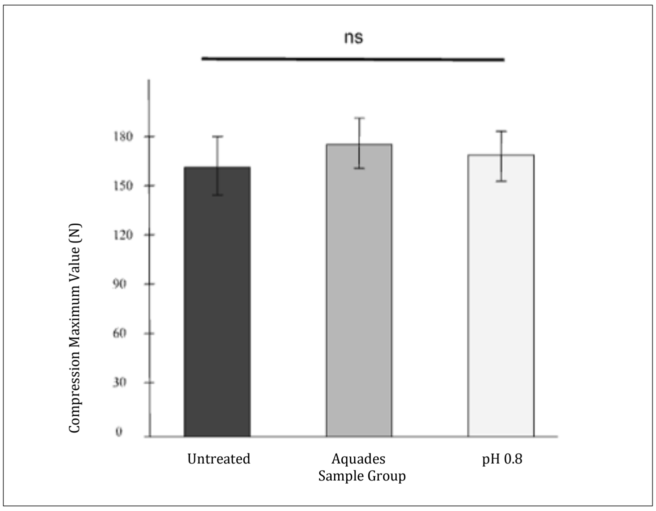

Figure 2 The result diagram shows the average maximum compression value (N) along with the error bars as the standard deviation value for each sample group.

There is a statistical test criterion used in this test; a significance value (sig.) or p-value, if the significance or p value is greater than 0.05 then H_0 is accepted. In other words, the research data is distributed normally. Each treatment generally has a significance value greater than 0.05. Thus, H_0 is accepted and the research data for each group of samples are normally distributed or it can be said that the normality assumption has been met.

Based on the variance homogeneity test data, a measurement result with a significance value greater than 0.05 is obtained. In this case, H_0 is accepted so that the data results can be concluded that there is a homogeneous variance and the assumption that the variation is homogenic has been met.

Based on the one-way ANOVA test, there was no significant influence between independent variables on dependent variables. It's proved by test results of an insignificant nature. Besides, the same thing can be reviewed through further testing with the Tukey-HSD test. The study analyzed the maximum compression value of artificial saliva with artificial saliva pH 8.0 compared to the non-treated group. The results showed no significant difference, with a significance value of 0.511 and a significant value of 0.452. The mean difference value of 1,90794 indicated that themaximum compression value in the pH group of 8.0 was greater than the non-treatment group. Conversely, a negative value indicated that the maximum compression in the first group was lower than the second group.

The analysis of multiple comparisons can be simplified by showing homogeneous subsets. Treatment in the same subset indicates no significant difference, and statistically, it can be concluded that there is one effect of the same influence, meaning that the intertreatments in this study only give the same or significantly different influence. This approach simplifies the analysis of results on multiple comparisons and helps in understanding the impact of different treatments.

4. Discussion

In this study, the durability of Ti-6Al-4V alloy dental implants in an alkaline environment was tested using artificial saliva with a pH of 8.0. The results showed that there was no significant influence between the sample groups without treatment, distilled water, and artificial saliva with a pH of 8.0 on the durability of the implants. However, the duration of implant usage correlated with the amount of load received, and excessive chewing cycles could cause deformation of the implants. Therefore, it is recommended that the duration of implant usage should not exceed 6-10 years, depending on the type of implant [8 , 14].

The testing setup involved attaching the implant specimens to a tilted bench vise at a 30-degree off-axis angle, according to the ISO 14801 standard for fatigue testing of implants and abutments. The degree of tilt and the applied load cycles were implemented until the specimens experienced fatigue and fracture. Most mechanical failures in implant restorations are caused by fatigue. The failures can occur in the abutment area, implant body, or implant screw, depending on the implant diameter, load case, and position. The accumulation of chewing cycles can lead to fatigue-related failures [26 , 15].

Factors that affect the mechanical strength of implants include the load conditions during chewing and physiological conditions such as osseointegration and alveolar bone resorption. The alveolar bone plays a crucial role in providing support to the teeth and achieving ideal prosthetic reconstruction in terms of aesthetics and function [7, 23]. The duration of usage for one-piece implants is directly correlated with the amount of load received by the implant. The intensity of load during chewing ranges from 20N to 120N, depending on the type of food consumed. However, chewing cycles do not occur continuously at the same load level. During the testing process, a load cycle of 50N was applied, which corresponds to an average of 2 million load cycles [8].

Implants made of the Ti-6Al-4V alloy, which consists of titanium (90%), aluminum (6%), and vanadium (4%), are currently preferred due to their biocompatibility, biomechanical properties, good physical and mechanical characteristics, and high corrosion resistance [16, 22, 27]. The low Young's modulus of the Ti-6Al-4V alloy contributes to the high success rate and long-term survival of dental implants. However, the pH level of saliva in the oral cavity can vary due to factors such as saliva flow.

5. Conclusion

Based on testing of the Ti-6Al-4V implant alloy, it can be concluded that immersion conditions in artificial saliva at pH 8.0, 50 N loading, 2 million treatments, and 12 Hz frequency did not significantly affect the compressive strength of the implants. The maximum compression strength did not change significantly between the pH 8,0 treatment group, aquades group, and pH group 8,0 compared to the group without treatment.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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