

# Effect of Pitch Thread Combination of Dental Implant on Fatigue Safety and Life Performance

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**Abstract**— During the implant procedure, one factor determining the surgery's success is the dental implant's stability. The stability index includes fatigue safety and life performance. A dental implant's thread pitch has been regarded as the essential factor for fatigue safety in many studies. However, the effect of the mixed thread pitch on fatigue safety and life performance are rarely investigated. Therefore, this study examines the impact of thread pitch on implants on the fatigue safety factor and dental implants' life. Four types of implants were studied: (0.5mm Pitch, 0.8mm Pitch, Combination Pitch (0.8mm with upper 0.5mm and 0.8mm with lower 0.5 mm). The material of a dental implant used in this study is Ti6Al4v. According to ISO standard 14801, the fatigue safety factor is presented and compared using ANSYS/Workbench software. The results show that the combination pitch (0.8mm with upper Pitch 0.5 mm) has the highest life and safety factors.

**Keywords**—dental implant, thread pitch, fatigue safety factor, life performance, ANSYS/Workbench

## I. INTRODUCTION

Implant stability is one of the things that must be considered in the installation of dental implants. Implant stability also affects dental implant anchorage [1], which will affect dental implant placement success. The definition of implant stability is the amount of micromotion relative to the surrounding bone [2]. From the description, it can be seen that Macro-design determines the implant stability value. Implant stability is influenced by several factors, namely bone quality and quantity, implant design, biocompatibility, osseointegration, and clinical manageability [3]–[6].

Fatigue design shows the behavior and performance of dental implants in the face of repetitive loads. [6]. Dental implant fatigue has been shown to cause abutment fracture and mechanism failure [7]. Fatigue in dental implants is similar to fatigue in mechanical engineering, which accepts repeated loads below the load capacity that the material can take. The difference is, the fatigue dental implant load received is up to  $5 \times 10^6$  cycles [7]–[9]. However, this method only approximates in vivo conditions and does not represent the truth. The ISO 14801 standard is only for comparing dental implant design to fatigue [10].

Studies aimed at improving implant stability, implant insertion efficiency, and fatigue have been carried out recently. Improvements in design, medical studies, and engineering are among them. Besides increasing the implants in the engineering field's surface structure, improvements in the micro and macro properties were also carried out [11]. Macro-design is anything related to the dimensions, size, and shape of the implant. It includes thread angle, thread depth,

thread shape, and thread angle [12]–[14]. And so, the micro-design is anything other than the dimensions, size, and shape of the implant. Micro-design includes implant material, roughness, surface morphology, and coating [14].

There have been many studies concerning the effect of Pitch and shape on dental implants on fatigue. However, studies that specialize in mixed Pitch for square threads in dental implants are rare. This study aimed to compare the pitch change in the dental implant square thread to fatigue using the FEA method.

## II. METHOD AND MATERIALS

This study uses FEA to determine the effect of mixed Pitch and its location on fatigue in dental implants.

### A. Implant Modeling

Implant modeling of the study using Solidwork 2016 x64. This study also using Hyper Works 13.0.110 for the meshing model. Fatigue analysis using ANSYS Workbench 16.2 software. The dental implant used as a model is a tapered 3-piece dental implant. The 3-piece dental implant parts are shown in Fig. 1.

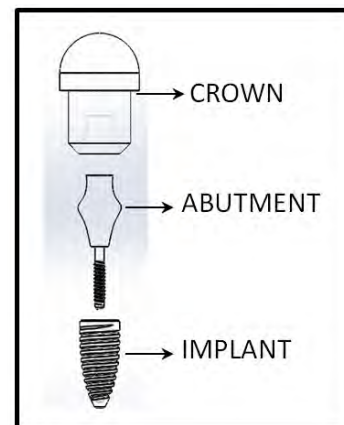


Fig. 1. Three-Piece Dental Implant Parts

### B. Model

All sections have the exact dimensions in height and diameter because the study's focus is the size and position of the thread pitch. The neck of the implant is 2 mm and 4.5 mm in diameter. The implant is 12mm high from the bottom. Other parts of the body have the same specific shape for evaluating the thread design against fatigue and stress distribution.

There are four types of threads used in this study. Implant model 1 has a square-shaped thread with a pitch of 0.8 mm on the lower part of the body and 0.5 mm at the top of the body.

Implant model 2 has a square shape with a pitch of 0.8 mm throughout the body. Implant model 3 has a square-shaped thread with a pitch of 0.5 mm on the lower part of the body and 0.8 mm at the top of the body. Meanwhile, the model 4 implant has a square-shaped thread with a pitch of 0.5 mm in all parts of its body. Fig. 2 shows the thread model used in this study.

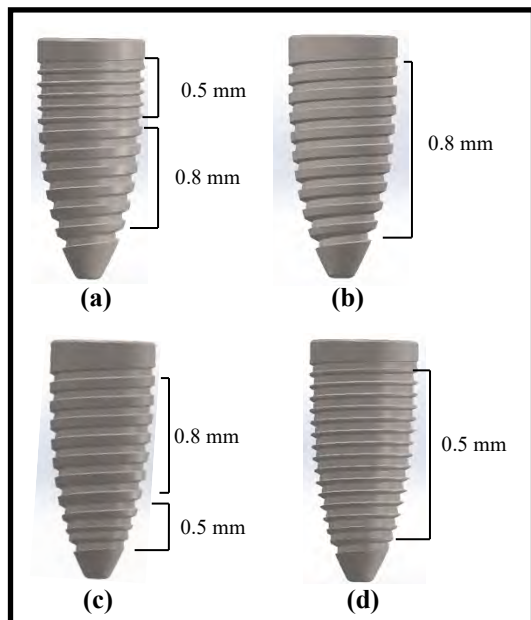


Fig. 2. Thread Model Used in This Study (a) Model 1 Pitch 0.5 mm upper, 0.8 mm lower, (b) Model 2 Pitch 0.8 mm, (c) Model 3 Pitch 0.8 mm upper, 0.5 mm lower, (d) Model 4 Pitch 0.5 mm.

C. Fatigue

Fatigue for dental implants testing protocols developed in 2003 by the Organization for International Standardization. In 2007 a revision was made. ISO standards can be carried up to 5 million cycles in a dry state [9], [15]. Finite Element Analysis (FEA) is prepared under ISO 14801. The axis loading angle according to the standard of fatigue experiment is 30°. Fig 3 is a picture of the FEA dental implant arrangement. According to ISO 14801, fatigue tests are carried out on rigid and fixed clamping devices.

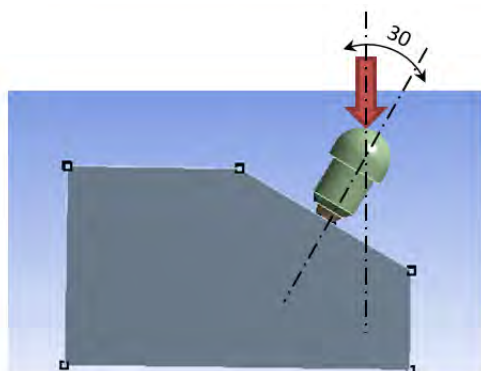


Fig. 3. The arrangement of the FEA under ISO 14801

D. Materials

In this study, all parts of the dental implants used Titanium Alloy (Ti6Al4V). Titanium alloy is widely used as a material for dental implants, and there have been many studies using this material [10], [15], [16]. For holders, this study uses cortical bones of material. The mechanical properties of the material used for the dental implant are shown in Table 1. All materials used in this study are considered homogeneous, linearly elastic, and isotropic.

TABLE III. MECHANICAL PROPERTIES

Implant Part	Materials	Young Modulus (MPa)	Density (kg/mm <sup>3</sup> )	Poisson's Ratio
Crown, Abutment and Implant	Ti6Al4V	1.1e+05	4.5e-06	0.35
Holder	Cortical Bone	1.3e+04	2.4e-06	0.3

III. RESULT AND DISCUSSION

In this study, FEA is used to analyze the best thread model in its effect on fatigue. 3D Finite Element (FE) Model was meshed using HyperWorks v13.0.101. A tetra mesh with a solid enclosed volume is used with 1262679 total elements. Static stress analysis was performed using ANSYS Workbench 16.2.

Implant stability can be analyzed based on the stress transfer at the bone-implant interface. [17]. Von Mises is used to determining the weak point of implants [18]. Von Mises affects fatigue. The existence of stress- transfer from the implant to the surrounding bone significantly affects the dental implant design [6]. A comparison of von-mises values can be seen in Fig 4. The highest von-mises stresses are shown in red and the lowest in blue. From Fig 4, it appears that model 1 has the lowest von mises value (456.44 MPa), and model 2 has the highest von mises value (220.15 MPa).

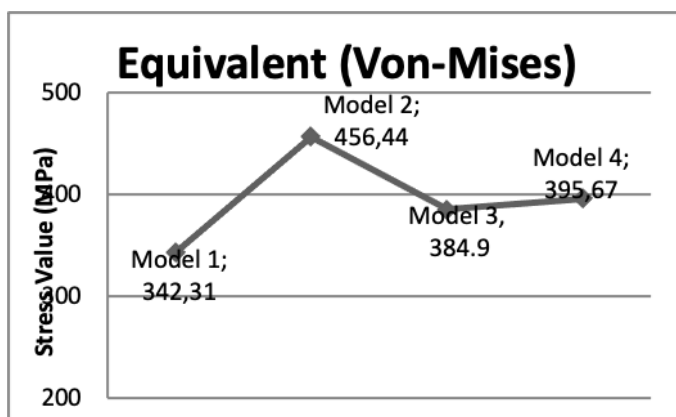


Fig. 4. Equivalent Von-Mises Stress Value

It can be seen from Fig 5 that the highest von-mises is located around the neck region. This is following a study conducted by [19]. The same result is also shown by [20], that von-mises concentration occurs around the neck.

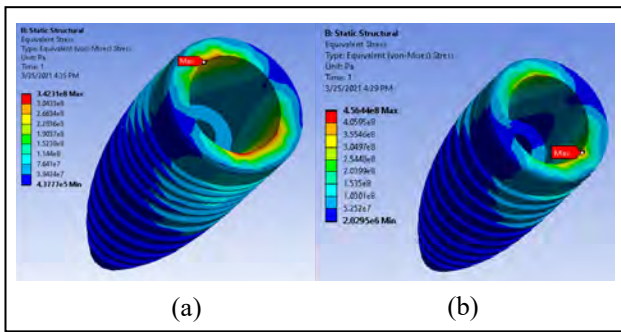


Fig. 5. Equivalent Von-Mises Stress Location (a) Model 1 Von-Mises stress, (b) Model 2 Von-Mises Stress Location

Fatigue can be a problem that affects the life of dental implants [21]. The stress concentration, which occurs between the implant and the structure or bone surrounding and the material's degradation, can determine fatigue behavior and dental implants' life [3].

The safety factor is the ability of a structure to withstand the loads placed on it. Therefore, the safety factor can be used as a benchmark in predicting dental implants' failure [6]. Fig 6 shows that Model 1 has the highest safety factor value, followed by model 3, and model 2 has the lowest safety factor. With the highest safety factor, it can be said that model 1 had the highest performance index of fatigue.

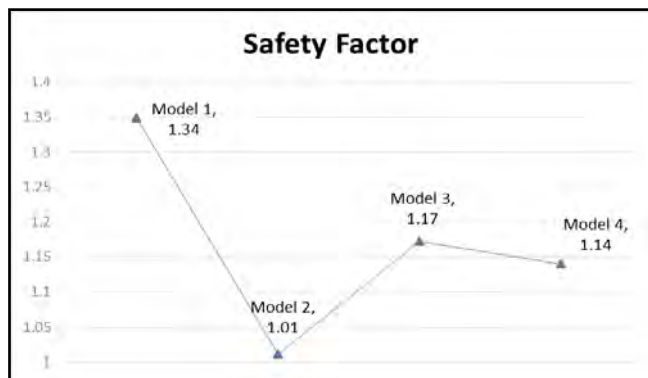


Fig. 6. Safety Factor

Dental implants always experience a load, especially when masticating. This masticating load affects fatigue and ultimately determines the life of dental implants [21]. Simulations can estimate the life of a dental implant without losing a lot of time and money. By using simulation also can be determined the life of dental implants using specific materials. The S-N material curve data of Ti6Al4V is needed. To simulate the life of the dental implant, Fig 7 shows the S-N Curve of Ti6Al4V.

FEA is used to determine the performance design thread. Then, analysis of the life fatigue of dental implants using ANSYS Workbench 16.2. Also, the fatigue theory used is Goodman Fatigue Theory. This study uses a cycle value of  $5 \times 10^6$  cycles [21].

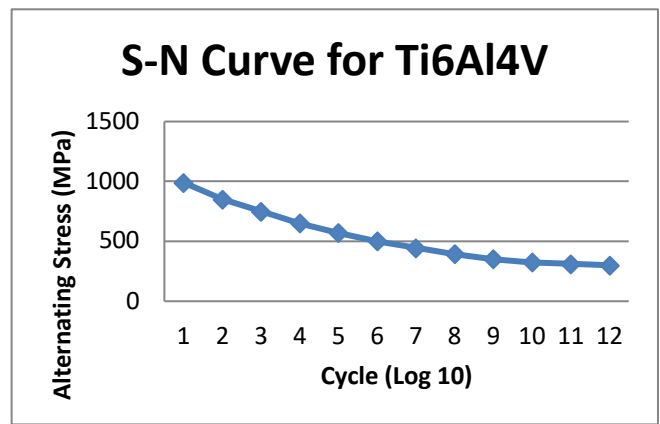


Fig. 7. S-N Curve for Ti6Al4V [22]

The life values of Models 1,2,3, and 4 are presented in Fig 8. There is a significant difference in the value of the life of these dental implants. Dental implants with a large value pitch have less life and vice versa. However, for mixed Pitch (Model 1 and Model 3), the difference lies in the pitch position, and it appears that the minor pitch position at the top has a better lifetime value.

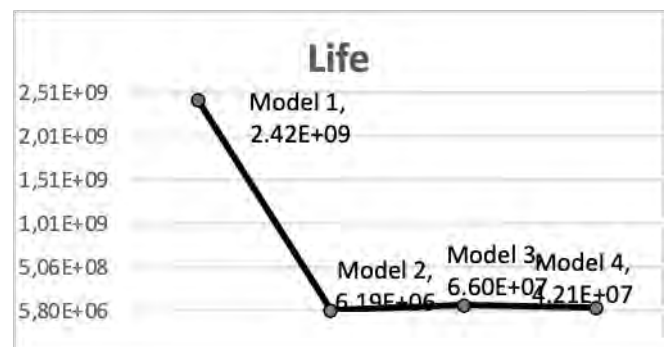


Fig. 8. Life

#### IV. CONCLUSION

Dental implant fatigue determines the success of its placement. From the study's discussion, several conclusions can be drawn, especially concerning the design thread. Several models of implants with different pitches have been compared, with findings to be drawn.

1. There is a correlation between the value of the pitch and pitch location with von mises stress. Where a higher pitch value will have a higher von mises stress as well, the location of the Pitch with the smaller value is at the top will result in a lower von mises value.
2. For the safety factor and life factor values, they are inversely related to von mises. A bigger pitch value will actually make the safety factor and life smaller, likewise with the location of the Pitch. For a lower pitch value, with the above position, it will make the safety factor, and life values higher as well.

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