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ORTHODONTIC BRACKET FABRICATION USING THE INVESTMENT CASTING PROCESS

Sugeng Supriadi[1*], Tito Winnerson Sitanggang[1], Bambang Irawan S[2], Bambang Suharno[1], Gandjar Kiswanto[1], Tjokro Prasetyadi[3]

[1] *Department of Mechanical Engineering, Faculty of Engineering, Universitas Indonesia, Kampus Baru UI Depok, Depok 16424, Indonesia*
[2] *Department of Dental Material, Faculty of Dentistry, Universitas Indonesia, Jalan Salemba Raya No. 4, Central Jakarta, 10430, Indonesia*
[3] *Department of Metallurgy and Materials Engineering, Faculty of Engineering, Universitas Indonesia, Kampus Baru UI Depok, Depok 16424, Indonesia*

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ABSTRACT

Demand for dental health care is increasing, especially in the Orthodontic field. The main objective of orthodontic treatment is to restore malocclusion conditions. Malocclusion causes aesthetics issues for the patient's face and several discomforts like a difficulty in breathing or swallowing or speaking. If not repaired, a malocclusion could lead to other diseases, such as a greater risk of perforated teeth, gum irritation and temporomandibular disorder or pain in the lower jaw. Malocclusion can be remedied by Orthodontic Brackets. This research aim is to fabricate an orthodontic bracket that is suitable for the teeth structure of the Indonesian people. The fabrication method uses an Investment Casting process. The results show that orthodontic brackets have been successfully produced within an acceptable geometric tolerance, with the exception that surface finish quality has to be improved.

Keywords: Investment casting; Malocclusion; Orthodontic; Orthodontic bracket

1. INTRODUCTION

Malocclusion is the most common problem in the Orthodontic field (Wahl, 2008). Currently, the number cases of malocclusion in Indonesia occur in 90% of the total population or around 180 million cases (Ministry of Health, Republic of Indonesia, 2004). Malocclusion is a type of dental disease where a person's teeth are not aligned properly. Another definition of malocclusion is an irregular bite, crossbite, and overbite (Gallois, 2008).

Malocclusion may occur because of heredity. However, malocclusion can also occur due to habits, such as nail biting (Hamissi, 2011). The complications from malocclusion could cause discomfort, such as a difficulty in breathing, a difficulty in swallowing, difficulty in speaking, as well as aesthetics issues related to the patient's facial structure and appearance (Wisesa, 2010).

The most common method used to repair malocclusion is the treatment using an orthodontic bracket. Orthodontic brackets exert a certain degree of force to gradually change the position of the teeth into a better arrangement. Orthodontic brackets consist of three main parts: an orthodontic bracket itself, a wire bracket which serves to provide force and the rubber bracket

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* Corresponding author's email: sugeng@eng.ui.ac.id, Tel. +62-21-7270032, Fax. +62-21-7270033
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which serves to bind the wire in the orthodontic bracket slot (Alam, 2012).

There are several methods employed in orthodontic bracket production, such as Machining, Metal Injection Molding (MIM) and Investment Casting (Tamizharasi, 2010). Each process has its advantages and disadvantages. The advantages of machining are the use of Computer Numerical Control (CNC) machines, whose software is programmed to produce certain components in large quantities with exactly the same product quality and closer dimensional accuracy than when compared to casting, forming or shaping processes. However, the machining process has its disadvantages in that it generally takes longer and the cost is more expensive than other methods (Elhofy, 2011). Orthodontic bracket production in countries with advanced technology has evolved in the direction of 5-axis machining.

The advantages of Metal Injection Molding (MIM) are a high volume process with a minimum amount of finishing operations for parts made from a variety of metals. The more complex the shape, the better are the MIM economics. The disadvantage of MIM is the sintering step. Even though the sintering is consistent, it is hard to predict the results (Schieloer, 2006).

The Investment Casting process has its advantages in that it is suitable for producing parts with complex designs, whereas other processes are either too long and/or costly or there are no flash or parting lines. Otherwise, investment casting's simpler technology and dimensional accuracy is better than the other processes. However, investment casting has a disadvantage in that this process requires longer production cycle times than other processes (Diamond, 1965).

A major problem is that the entire supply of orthodontic brackets in Indonesia is still imported (Ministry of Health, Republic of Indonesia, 2005). This means the design of orthodontic brackets is not suitable or customized for the dental characteristics of the Indonesian people. This research aims to act as a tool for dentists to create a new design of orthodontic brackets that is specifically designed at an affordable price in Indonesia.

Generally, the production of orthodontic brackets uses a machining process, which is continued with the manual process of joining metal frameworks (Karra & Begum, 2014). This method gives better results, when compared to other methods. In this research, the method used in production of orthodontic brackets is an investment casting process. In Indonesia, investment casting is the most feasible method because of its simplicity and low cost production.

2. EXPERIMENTAL PROCESS

In this research, this innovative orthodontic bracket design is suitable for the teeth structure of the Indonesian people. This orthodontic bracket was designed and researched by T. Prasetyadi (Tjokro, 2014) as shown in Figure 1. The material is 316 Stainless Steel. This research and prototype development is carried out in several stages. The first process in investment casting is producing the wax pattern of an orthodontic bracket. This is done by using injection machines that inject the wax into the mold. Then, the wax pattern of the orthodontic bracket assembly is shaped into the tree form. The tree form is then dipped into ceramic slurry and allowed to harden.

After the ceramic slurry hardens, the ceramic slurry has a thickness in the region of 10 mm. The ceramic mold is then fired at a temperature over 1100°C to remove the remaining wax and to strengthen the ceramic mold. Afterwards, the molten metal is poured at a temperature of over 1600°C into the ceramic mold. The next step is the cooling process. The natural cooling process is carried out at temperature of 25°C, after which the ceramic mold is broken away. Then, the orthodontic bracket is cut from the tree form. Then a chemical cleaning process removes the remaining ceramic slurry, using a HF Chemical solution, followed by an ultrasonic cleaning process to achieve the final smooth casting result. The last stage is the geometric and surface roughness analysis, conducted by using a digital microscope and Surfcom 2900SD3.

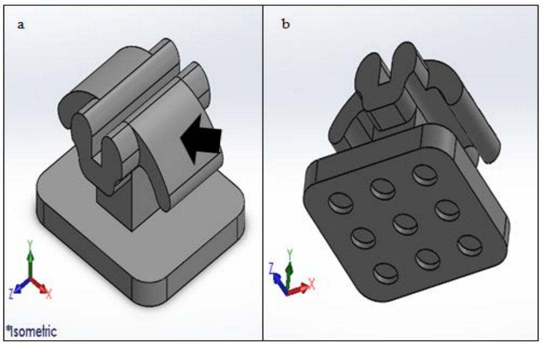

Figure 1 Design of Orthodontic Bracket. Black arrow indicates the new innovation for a wing Orthodontic Bracket design: (a) Isometric view; (b) Bottom view

3. RESULTS

3.1. Investment Casting Process

3.1.1. Pattern making

In the injection molding process, the mold design is dependent on the wax product. Previous research has successfully obtained the most optimal mold design using wax production of an orthodontic bracket (Tito, 2014), as shown in Figure 2.

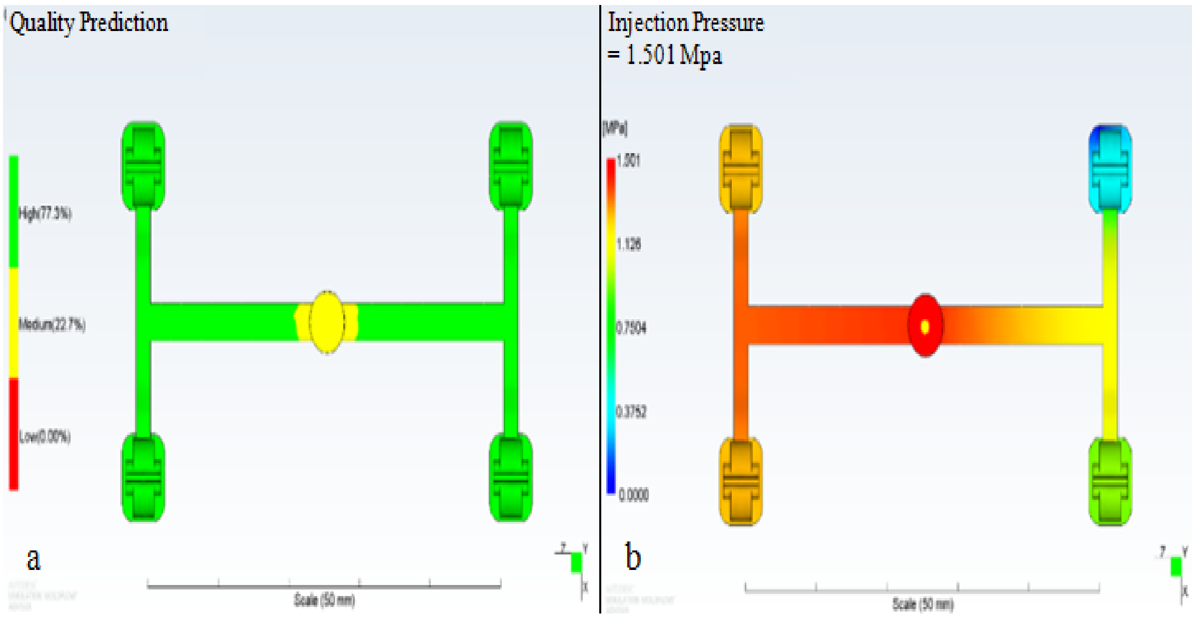

Figure 2 Result of injection molding simulation. The orthodontic bracket is shown in the Green Zone in terms of quality prediction. This means in the wax-produced model there are no apparent defects during the solidification process. This mold design needed a pressure around 1.50 Mpa: (a) Quality prediction; (b) Injection pressure

This simulation result is used as a reference to design a mold prototype. The mold is then divided into two segments, namely a micro mold and a base mold. A micro mold is used to form the orthodontic bracket prototype. Whereas, the base mold, as the foundation of the entire micro mold, also contained a sprue, a runner and an ingate. The micro mold is divided into three parts, as shown in Figure 3. The base mold is also divided into a top side and a bottom side, respectively. This separation aims to simplify the process of removing the wax pattern from the mold system. The mold is fabricated by using an Electrical Discharge Machine (EDM).

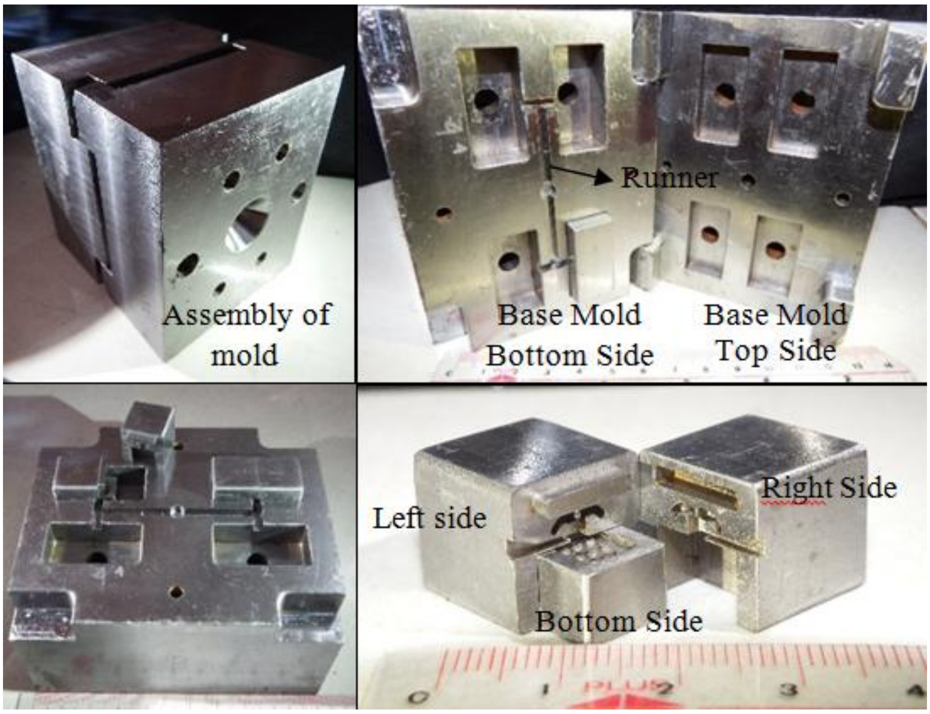

Figure 3 Components of the mold system

Using the optimal parameters with the wax melting point at 68^{o}C with a pressure around 1.50 Mpa, the injection molding process wass carried out and it successfully produced the wax mold for the orthodontic bracket. Figure 4 shows the results of the wax mold for the orthodontic bracket prototype.

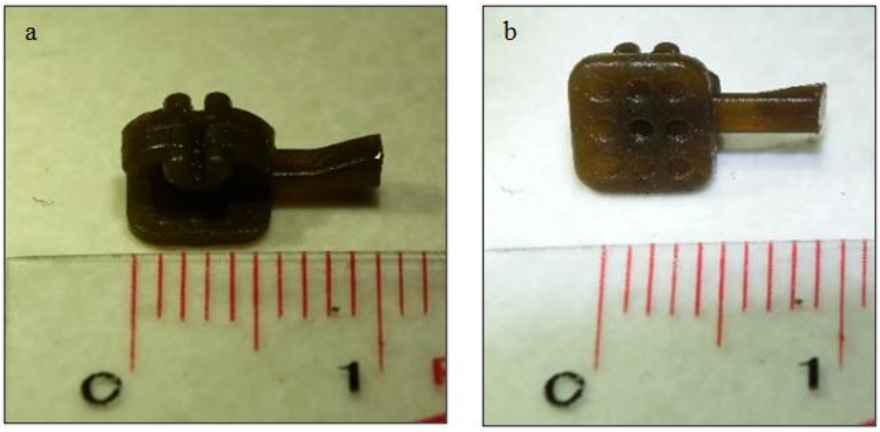

Figure 4 Result of injection molding process. There is no defect on the wax product: (a) Top view; (b) Bottom view

3.1.2. Investment casting

A simulation has been carried out on the investment casting process with Magma5 Simulation Casting Software. This simulation uses the factory default sprue. The purpose of this simulation is to predict when the porosity phenomenon appears in the orthodontic bracket casting. The results indicate that casting of the product is suboptimal because the predicted porosity phenomenon in the wing of the orthodontic bracket occurred. The result is shown in Figure 5.

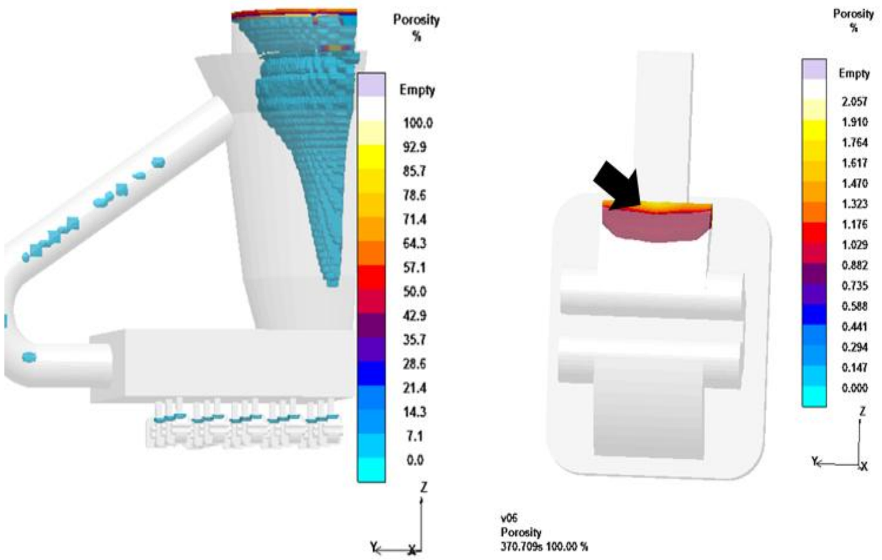

Figure 5 The black arrow indicates the phenomenon of porosity in the Wing-Bracket with ± 1.17% possibility

Porosity can happen because there is no venting or exhaust air channel, thus causing air molecules to be trapped inside the mold. The air trap bursts and forms air droplets, which then freeze and become pockets of porosity. Figure 6 shows the phenomenon of air being trapped at a 30% fill stage during the casting process.

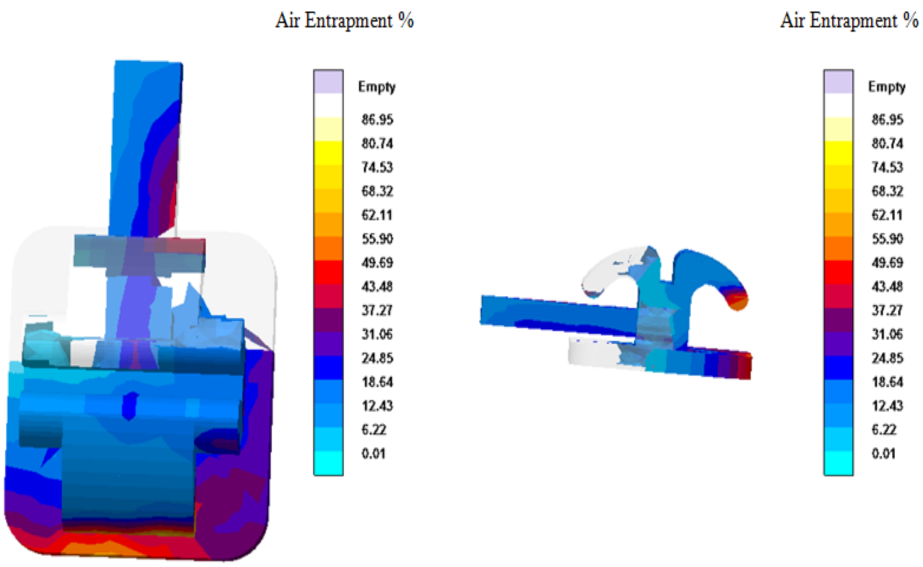

Figure 6 The black arrow indicates the air entrapment phenomenon at a 30% fill

By using this configuration, the investment casting process is then carried out. This configuration can produce 27 orthodontic bracket pieces. The casting of the tree configuration of wax is shown in Figure 7. The result shows that production orthodontic bracket using the investment casting process has been successfully accomplished. Figure 8 shows the results of the orthodontic bracket casting prototype.

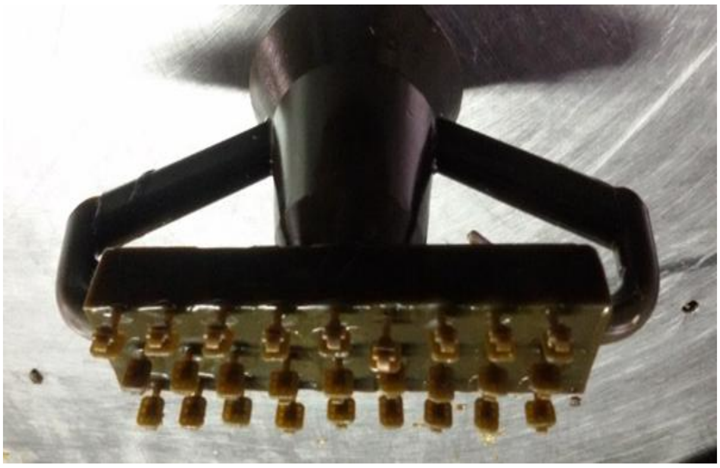

Figure 7 Tree configuration of wax in investment casting

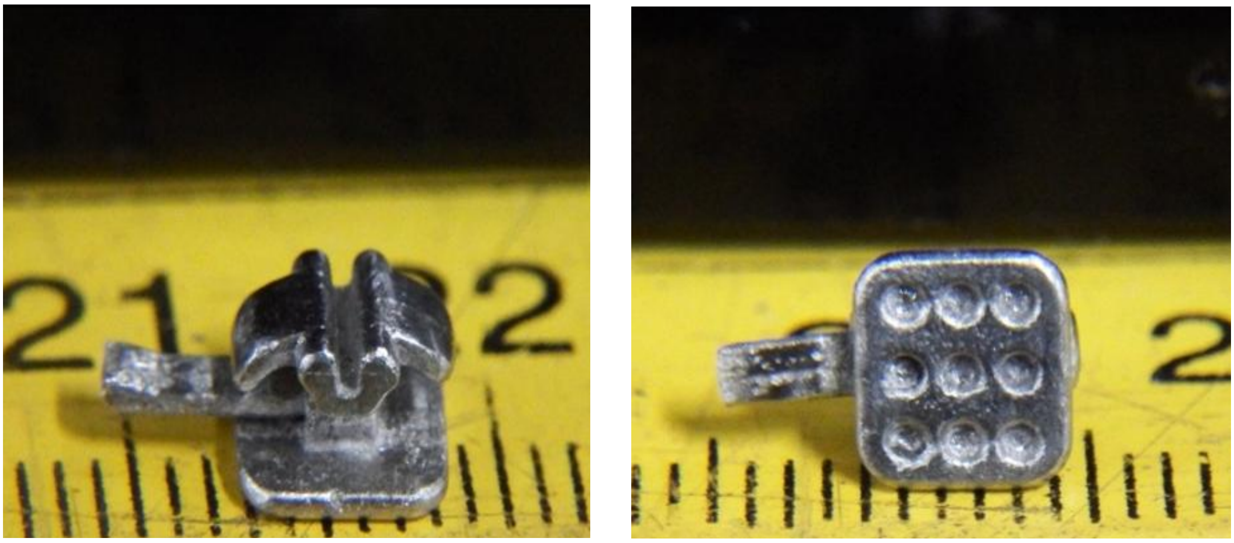

Figure 8 The result of production orthodontic bracket by using investment casting

4. DISCUSSION

Surface roughness, geometry and the phenomenon of porosity in the investment casting process for the prototype orthodontic bracket were analyzed.

4.1. Surface Roughness Analysis

Surface roughness was analyzed in two sections. Surface roughness analysis was carried out at each step in the production of the prototype orthodontic bracket, namely: Mold, Wax Pattern, Ceramic Slurry, Casting Product, Chemical Cleaning and Ultrasonic Finishing. The results are shown in Figure 9.

Figure 10 shows the average surface roughness value during the production of the prototype orthodontic bracket is 0.91 µm, while the average surface roughness value for an existing orthodontic bracket is 0.53 µm. The differences in value are highly significant. The surface roughness of the prototype product casting is high, because the surface roughness of the ceramic slurry is still poor (4.48 µm). Furthermore, an additional polishing process is necessary.

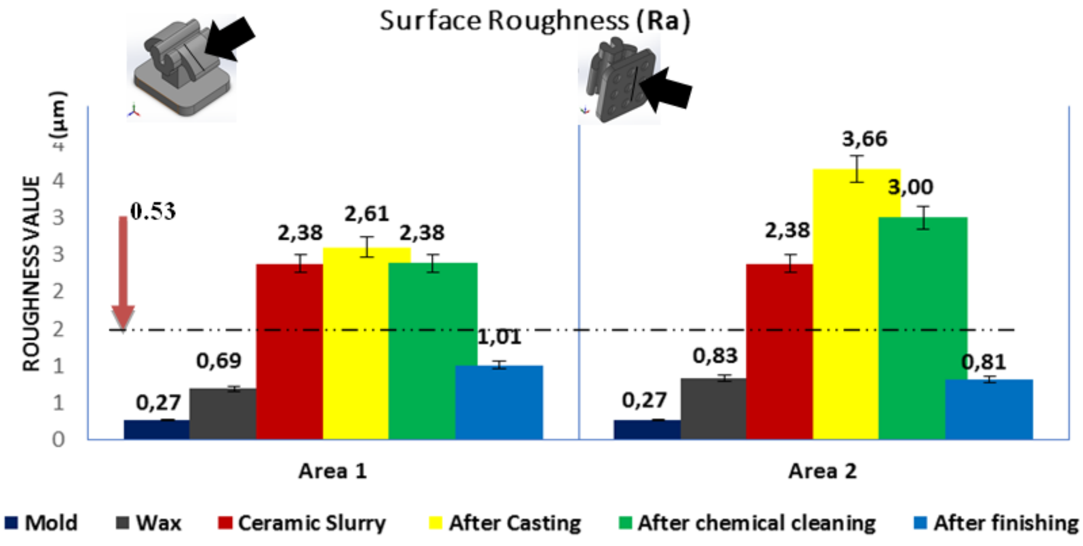

Figure 9 The comparison of surface roughness value. The black arrow indicates the measured area. The red arrow indicates the surface roughness value of the standard orthodontic bracket. Error bars indicate the spread

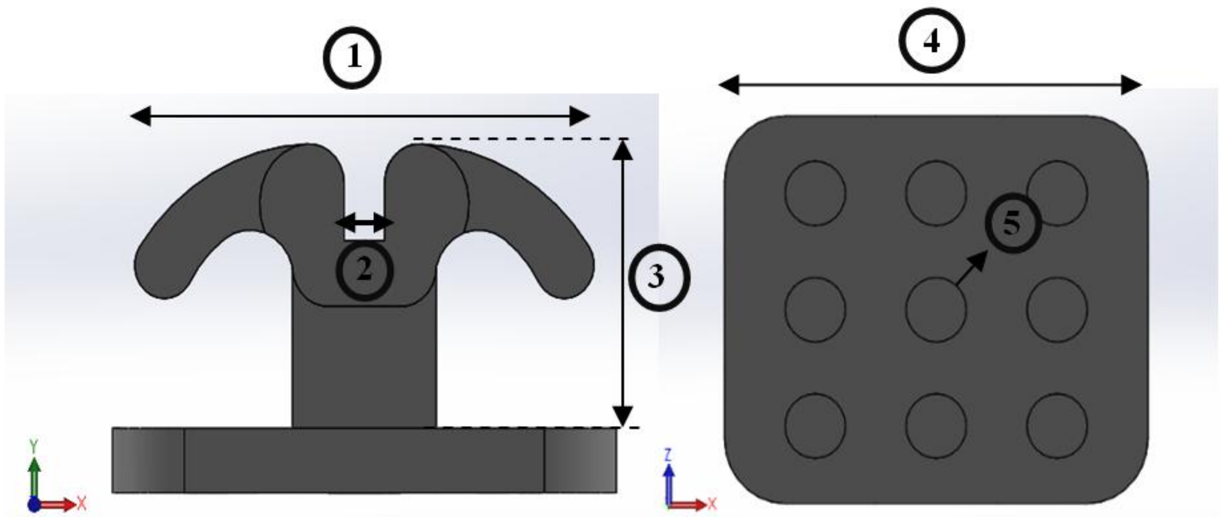

Figure 10 Section area which was analyzed for geometric analysis

4.2. Geometric Analysis

Surface roughness, geometry and the phenomenon of porosity in the investment casting process for the prototype orthodontic bracket were analyzed. Geometric analysis occurred at each step of the investment casting process for the orthodontic bracket prototype design, wax and casting. The results are shown in Figure 11.

The results show there is a difference in dimension at each stage of the investment casting. From the five-sections, Section Three has the highest dimensional difference (14.02%). This is due to the shrinkage phenomenon which is greater on the vertical axis.

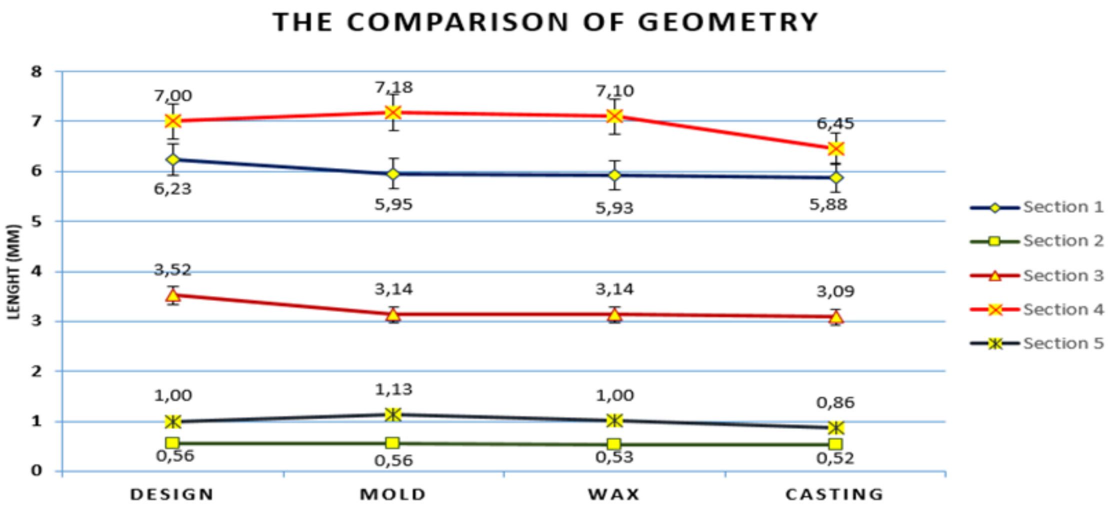

Figure 11 Section areas for geometry analysis. Error bars indicate the spread

4.3. Porosity Analysis

Surface roughness, geometry and the phenomenon of porosity in the investment casting process for the prototype orthodontic bracket were analyzed.

The digital microscope Anyview is used for the porosity analysis. The result is shown in Figure 12. It can be seen that at the wing bracket there is the porosity phenomenon. The porosity size is around 25 µm. The porosity can occur because of the existence of trapped air. This phenomenon can be resolved by using a riser.

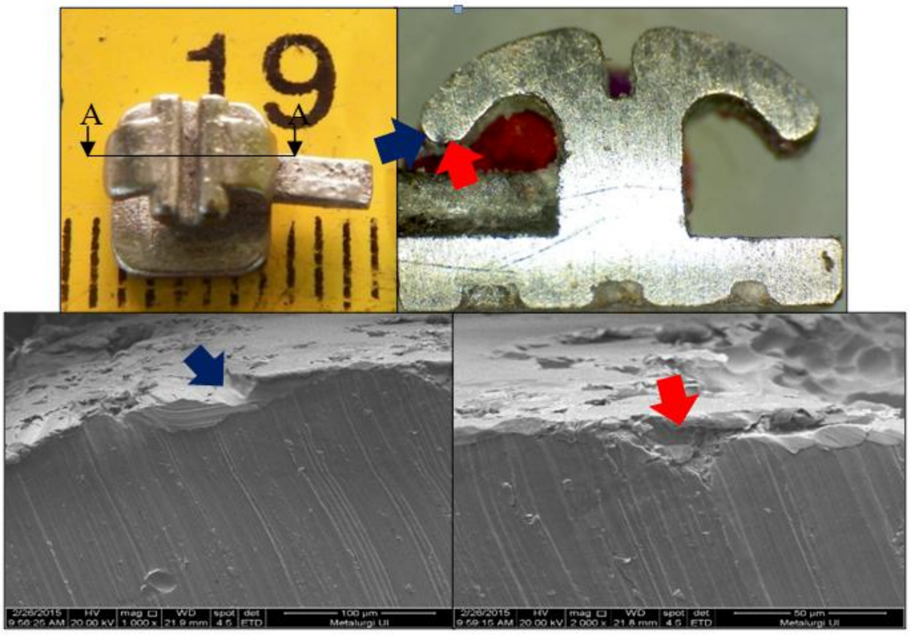

Figure 12 The orthodontic bracket is split into two sections. The blue and the red arrow indicate the position of the porosity phenomenon

5. CONCLUSION

This research was conducted on the production of orthodontic brackets by using the investment casting process. The results show that that an orthodontic bracket has been successfully produced with acceptable tolerances in geometrical and surface characteristics. The surface roughness value is 0.91 µm. However, there is still a considerable difference in the values of surface roughness between the existing orthodontic bracket and the new prototype. The existing orthodontic bracket in the market is approximately 0.53 µm. Also, there is the porosity phenomenon at the wing of orthodontic bracket prototype. Further research is needed to obtain the optimal configuration of the investment casting process to overcome the phenomenon of shrinkage that occurs as well as the need for an improvement in surface finish quality with additional polishing.

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