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THE EFFECT OF REPETITIVE METAL CASTING ON THE TENSILE STRENGTH OF DENTURES

PENGARUH PENGGUNAAN BAHAN TUANG LOGAM BERULANG TERHADAP KEKUATAN TARIK BASIS KERANGKA LOGAM

Original Research Article
Penelitian

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A B S T R A C T

Background: *Dentures or prostheses function to replace chewing and dental arch structures. Denture plates used in dentistry are made with acrylic resin, metal, or a combination of acrylic and metal. Metals are shiny, opaque chemical substances and good conductors of heat and can be polished. Recycling or reusing used metal is an option in making prostheses because the price of new metal is increasing, and metal recycling is quite effective.* ***Purpose:*** *To determine the effect of repeated metal casting on the strength of the metal frame denture base.* ***Method:*** *The current research is a laboratory study with a tensile test in the form of dumbbells with iso 22674 with a length of 15 ± 1 mm and a diameter of 3 ± 1 mm. This research used 18 CoCr metal samples divided into three groups, namely 100% new metal group (control), 50% new + 50% repeated composition group, and 100% repeated group.* ***Result:*** *The mean strain of the new 100% CoCr metals group was 0.133%, strain mean of the new 50% CoCr + 50% repeated metals group was 0.1%, and the strain of the 100% repeated CoCr metals group was 0.066%. The average modulus of elasticity (MPa) for the new 100% CoCr metals group is 7866, or 711 MPa, the new 50% CoCr + 50% repeat metals group is 7538, or 833 MPa, the 100% CoCr metals group is 6659, or 336 MPa.* ***Conclusion:*** *The new 100% CoCr metal group has a higher average tensile strength value than the 50% new CoCr metal + 50% repeated group, and the lowest is the 100% repeated CoCr metal group.*

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A B S T R A K

Latar belakang: Gigi palsu atau protesa berfungsi menggantikan pengunyahan dan struktur lengkung gigi. Pelat gigi palsu yang digunakan dalam kedokteran gigi dibuat dengan resin akrilik, logam atau perpaduan antara akrilik dengan logam. Logam merupakan zat kimia mengkilap, buram dan merupakan konduktor panas yang baik dan dapat dipoles. Daur ulang atau penggunaan kembali logam bekas menjadi salah satu pilihan dalam pembuatan protesa karena harga logam baru semakin tinggi dan daur ulang logam cukup efektif. **Tujuan:** Mengetahui pengaruh pengecoran logam berulang terhadap kekuatan rangka logam basis gigi tiruan. **Metode:** Penelitian ini merupakan penelitian laboratorium dengan uji tarik berupa dumbbell dengan iso 22674 dengan panjang 15 ± 1 mm dan diameter 3 ± 1 mm. Penelitian ini menggunakan 18 sampel yang terbuat dari bahan logam yang dibagi menjadi 3 kelompok, yaitu kelompok logam 100% baru (kontrol), kelompok komposisi 50% baru + 50% berulang, dan kelompok berulang 100%. **Hasil:** Rerata regangan kelompok logam 100% CoCr baru adalah 0,133%, rerata regangan kelompok logam baru 50% CoCr + 50% berulang 0,1% dan rerata regangan 100% kelompok logam CoCr berulang 0,066%. Modulus elastisitas rata-rata (MPa) untuk kelompok logam 100% CoCr baru adalah 7866, atau 711 MPa, kelompok logam baru 50% CoCr + 50% berulang adalah 7538, atau 833 MPa, kelompok logam 100% CoCr adalah 6659, atau 336 MPa. **Kesimpulan:** Kelompok logam CoCr 100 % baru mempunyai memiliki nilai rata-rata *tensile strength* yang lebih tinggi dibandingkan kelompok logam CoCr 50% baru + 50 % berulang dan yang terendah kelompok logam CoCr 100 % berulang.

Kata kunci:
Gigi tiruan, Logam, Pengecoran Ulang, Kekuatan, Pengaruh

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INTRODUCTION

Advances in science generally affect the shift in people's needs for dental care, which initially only revolved around pain relief and the fulfillment of masticatory functions, to now being more likely to be aesthetic. Dentures are artificial teeth attached to a base or plate (Thambas A. and Dewi, 2012). Dentures can also be called prostheses, which replace the masticatory surfaces and the structure of the dental arch. These denture plates are mostly made with acrylic resin but can also be made with metal or metal alloys. Metal is one of the materials used in dentistry, one of them is a removable partial denture (GTSKL) (Rejeki, 2018; Wahjuni and Mandanie, 2017).

Metal is a shiny, opaque chemical substance that is a good conductor of heat or electricity and can be polished. Pure metals are rarely used in dentistry (Lenggogeny and Masulili, 2015) pure metal because it is too soft, too tough like iron, and easily corrupted. Types of dental metals include metals and alloys. Metals consist of precious metals, namely gold (Au), platinum (Pt), palladium (Pd), iridium (Ir), rhodium (Rh), osmium (Os), and ruthenium (Ru), and base metals (Base Metal). Base metals are basic metals used in dental alloys, including silver (silver), copper (copper), zinc (zinc), and indium. Per kilogram, so many dental technicians in the laboratory use scrap metal for metal casting (Anusavice, 2003; Callister, 2007; Manaranche and Hornberger, 2007; Noort, 2007).

Repeated and the most frequently performed was metal casting of 50% new + 50% repeated, namely 21 technicians or 46.66%, and those who did 100% repeated casting of metal or alloy were 19 people or 42.22%. So far, dental technicians have yet to know, and no one has researched how to compare the strength between 100% new metal castings, 50% new + 50% repeatable metal castings, and 100% repeatable metals or alloys. Based on the survey data above, the researcher wants to know whether repetitive metal casting affects denture strength (Eka *et al*., 2022). The design of this research is experimental laboratory research. This research aimed to determine the effect of repeated metal casting on the strength of the denture.

MATERIAL AND METHOD

The material used in this research is a cobalt-chromium metal alloy with an experimental laboratory-based research method. This research was conducted at the Dental Engineering Laboratory of the Health Polytechnic of the Ministry of Health Jakarta II Indonesia from March to July 2022 for the manufacture of specimens for tensile strength tests carried out at the *Static Laboratory of the Structural Strength Technology Center* (B2TKS) BRIN Puspitek Area Gd. 20, Tangerang Selatan Indonesia. The shape and size of the tensile test specimen are in the form of a dumbbell by ISO 22674 with a length of 15 ±1 mm and a diameter of 3 ± 1 mm. This research used 18 CoCr metal samples divided into three groups: the 100% new metal group (control), the 50% new + 50% repeated composition group, and the 100% repeated group. The three groups were then tested for tensile strength. The repeated metal used is the metal resulting from one casting.

Determination of specimen size was determined according to ISO 22674: 2016 (E) standards (Figure 1) consisting of 3 groups with 6 specimens in each group and according to the Frederer (Formula 1). Information, t: number of treatments is 3, r: number of repetitions; in which $r \geq 6 \rightarrow r = 5$ (Ariyani and Tiffany, 2016). Total number of specimens: number of treatments x specimens x 1 type of acrylic resin: 3 x 6 x 1 = 18 specimens.

$$(t-1)\,(r-1) \geq 15 \quad \text{.....} \quad (1)$$

A total of 18 specimens in each group were obtained: six specimens with the metal composition of group 1, namely 100% new metal (control), group 2 with a composition of 50% new metal + 50% repeated metal, and group 3 with a composition of 100% repeated metal. After the casting results are obtained, the specimen is tidied up and turned, a connector is made to lock with the connector, and a tensile test can be carried out.

The specimen was made from wax, and then cast with cobalt chromium according to the sample (Surdia, 1980). After the casting results are obtained, the specimen is tidied up and placed in a place prepared for testing (Figure 2). Each group of six specimens was then subjected to a tensile test according to ISO standard 22674:2016 (E) with the UPM 1000 10 KN tool with SNI tool 8389-2017 carried out at the Static Laboratory. The loading was carried out at a speed of 6.0 mm/min at the most prominent point of the middle palate between the premolar and molar areas with a UPM round plunger. The load on the fracture of the denture base (in kg) and the amount of deflection before fracturing in mm (fracture deflection) were recorded. Flexural strength is calculated using the standard formula (Shotwell, 2008). The collected data were analyzed using the statistical package for the social sciences (SPSS, version 23.0, Chicago, IL, USA). The mean and standard deviation were calculated. An *Independent Sample T* test was used to analyze the data, and $p\text{-value} < 0.05$ was considered significant. The results after tensile test to break can be seen in Figure 3.

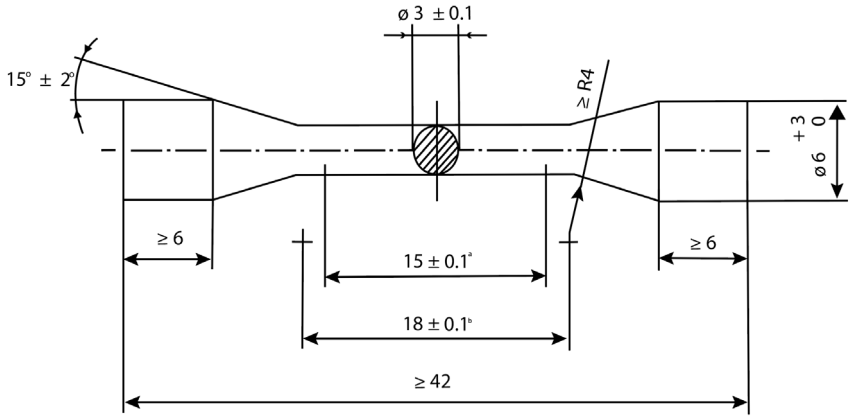

Figure 1. Test specimen by ISO 22674 (dimensions in millimeters)

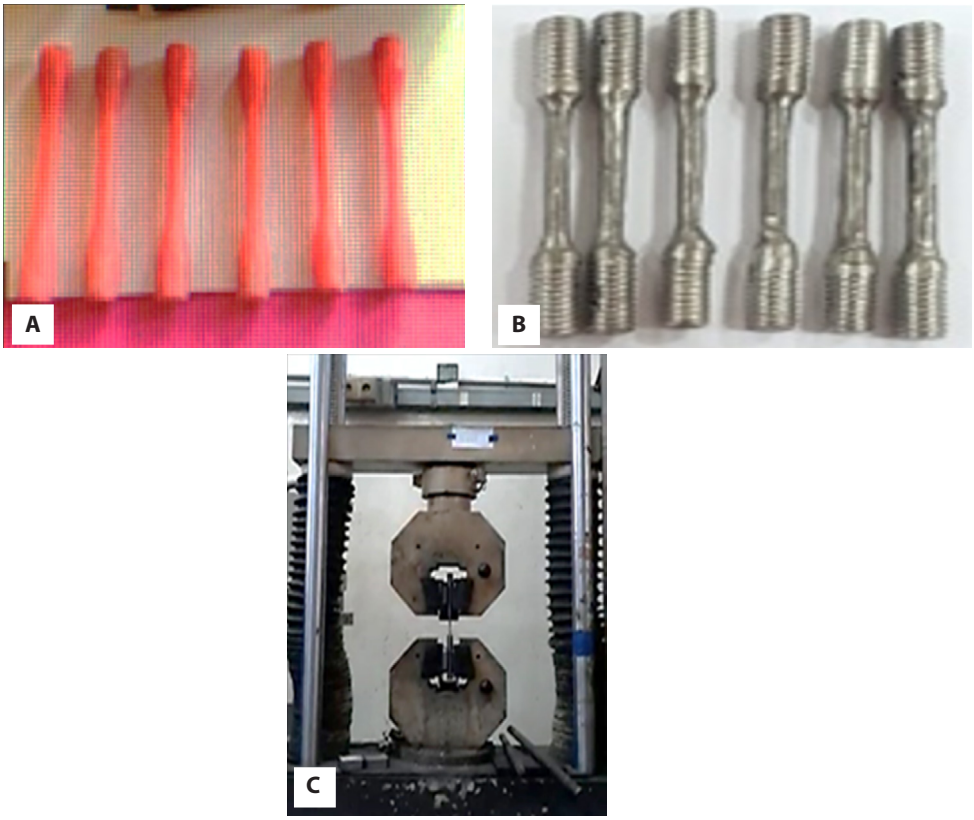

Figure 2. (A) Wax test specimen, (B) Cobalt cromium test specimen, (C) Tensile strength test using the *Universal Testing Machine* (UTM) by clamping both ends of the sample and then pulling it until it break

Figure 3. Results after tensile test to break. (A) New 100% CoCr metal, (B) New 50% CoCr metal + 50% repeated, (C) 100% repeated CoCr Metal

RESULT

The tensile strength value was measured using a *Universal Testing Machine* (UTM) by clamping both ends of the sample and then pulling it until it broke. The tensile strength value is calculated using the Formula 2.

$$\sigma = \frac{F}{A} \quad (2)$$

Information: σ = tensile strength (MPa); F = pulling force (N); A = minimum cross-sectional area (mm^2). The data obtained will be entered into tables and data processing is carried out using the Windows SPSS program version 23 computer. In the first stage, the normality test was carried out with the following results shown in Table 1.

Table 1. Normality test

Specimen groups	*Shapiro-wilk*		
	Statistic	df	Sig.
New 100% CoCr metal	0.933	6	0.605
New 50% CoCr metal + 50% repeated	0.977	6	0.938
100% repeated CoCr metal	0.800	6	0.800

Based on Table 1, it can be seen that the tensile strength value of CoCr metal is 100% new metal (control), the composition group is 50% new + 50% repeated, and the 100% repeated group that in this research, after the data normality test was carried out on the tensile strength group CoCr metal, the 100% new metal group (control) to the 100% repeat group through the *Shapiro-wilk* test with a significance level (*p-value* <0.05), the results obtained were normal data distribution because all research groups had a *p-value* > 0.05. Then, proceed with a homogeneity test; the results obtained are *p-value* > 0.05, so the data in the three research groups are considered homogeneous. Find the average tensile strength value of CoCr metal in the 100% new metal group (control), the 50% new + 50% repeated composition group, and the 100% repeated group.

Table 2 presents the findings for the CoCr metal groups, including the 100% new metal, the 50% new + 50% repeated composition group, and the 100% repeated group (N=18). The average tensile strength value in each group varies, with the new 100% CoCr group demonstrating the highest average value of 1042.283 MPa. This significant result piques interest, especially when compared to the average value for the new 50% CoCr + 50% repeated group of 735.893 MPa and the smallest average tensile strength found in the 100% repetitive CoCr metals group of 439.497 MPa. Table 3 further illustrates the statistical analysis conducted to determine the significance of these findings.

Table 2. Average tensile strength values for CoCr metal: 100% new metal group, 50% new + 50% repeated composition group, and 100% repeated group (N = 18)

Group	N	Tensile strength minimum (MPa)	Tensile strength maximum (MPa)	Average tensile strength (MPa)
New 100% CoCr metal	6	983.0	1125.2	1042.283 ± 53.3292
New 50% CoCr metal + 50% repeated	6	671.6	855.9	735.893 ± 66.4792
100% repeated CoCr metal	6	338.3	563.1	439.497 ± 85.2194

Table 3. *Least Significance Different* (LSD) test – *One way* ANOVA

	Sum of squares	df	Mean square	F	Sig
Between groups	1090731.634	2	545365.822	112.634	.000
Within groups	72629.175	15	4842.945		
Total	**1163360.818**	**17**			

Table 4. *Post Hoc* test

	Group	Mean difference	Sig.
New 100% CoCr metal	New 50% CoCr metal + 50 % repeated	288.3900	0,000*
	100% repeated CoCr metal	602.7867	
New 50% CoCr metal + 50% repeated	New 100% CoCr metal	-288.3900	
	100% repeated CoCr metal	-314.3900	
100% repeated CoCr metal	New 100% CoCr metal	-602.7867	
	New 50% CoCr metal + 50% repeated	-314.3967	

* Significant

The average strain of the new 100% CoCr metals group was 0.133%, the average strain of the new 50% CoCr + 50% repeated metals group was 0.1%, and the 100% repeated CoCr metals group was 0.066%. The average of the *Elastic Modulus* (MPa) of the new 100% CoCr metals group is 7866, 711 MPa, the average of the elasticity moduli of the new 50% CoCr + 50% repeated metals group is 7538, 833 MPa, and the average of the elasticity moduli of the CoCr metals group is 100 % repeat of 6659.336 MPa. The average maximum force of the new 100% CoCr metal group is 7500 N, the average of the new 50% CoCr + 50% repeated metal group maximum force is 5583.33 N, and the average of the maximum repeated 100% CoCr metal group is 2750 N.

Table 3 shows the significance between the CoCr metal group, the 100% new metal group, the 50% new + 50% repeated composition group, and the 100% repeated group on the tensile strength test (N = 18). To find out the significance of the difference in the average value of the *Tensile Strength* (MPa) test in the metal CoCr group, the 100% new metal group (control), the 50% new + 50% repeated composition group and the 100% repeated group, a *One-way* ANOVA test was performed with a value the significance of *p-value* < 0.05 and because the *p-value* obtained was 0.000 (Ho was rejected), a follow-up test was carried out, namely the *Post Hoc LSD* test to determine the difference in significance between the groups.

It can be seen from the *Post Hoc* test Table 4 that the significance (p) of the New 100% metal CoCr group and the new 50% metal CoCr + 50% repeated and 100% repeated metal CoCr group in the tensile strength test found that there was a significant difference (*p-value* < 0. 05), namely p = 0.000. In the group of new 50% metal CoCr + 50% repeated with new 100% metal CoCr and 100% repeated metal CoCr in the tensile strength test, there was a significant difference (*p-value* < 0.05), i.e. p = 0.000. In the group of 100% metal CoCr repeated with new 100% metal CoCr and 50% new metal CoCr + 50% repeated in the tensile strength test, there was a significant difference (*p-value* < 0.05), i.e. p = 0.000.

DISCUSSION

Recycling or foundry reuse of scrap metal is an option in today's life because the price of new metal is increasing, and more effective and intelligent recycling or casting it will help reduce and minimize the dangers of the mining process. The current research aims to determine the effect of repeated metal casting on the strength of the metal frame denture base. The results of this research show that the average value in the tensile strength test in the new 100% CoCr metal group has a higher tensile strength value of 1042.283 MPa, followed by the new 50% CoCr + 50% repeated metals group, which was 735.893 MPa. The lowest was the 100% repeated CoCr metals group, 439.497 MPa. Compared to the value of the new 100% CoCr metals group, the tensile strength is the highest based on the amount of concentration. The reason is because the latest 100% CoCr metal has not been contaminated with other materials such as investment and others compared to CoCr metal, which has undergone repeated casting. This research is in accordance with Thopegowda *et al*. (2013) study, that there was a decrease in the hardness of repeated metals in the tensile strength test because there was a biocompatible failure due to alloy contamination and low loss of fusing components during the subsequent recasting procedure.

Pimenta *et al*. stated that the tensile strength and hardness increased after the first casting and decreased after the subsequent recasting procedure (Pimenta *et al*., 2012; Wise, 2001). This is different and contrary to the results of James *et al*. (2018), that there is no significant difference in the hardness of the metal that has been recast several times, which affects the dimensions of casting accuracy depending on the method used and also on the various materials involved in its manufacture.

According to Agrawal *et al*. (2015), there is no static difference in the value of the tensile strength of the metal cast repeatedly with the new one. Bandela and Kanaparthi (2021) said there was no drastic change in the hardness and microstructure even after seven consecutive melting and reforming of the base metal alloy (Bandela and Kanaparthi, 2021). According to Slokar Benić *et al*. (2004), the hardness remained unchanged after repeated reforming, and the hardness could be increased by adding titanium to the base metal alloy (Slokar Benić *et al*., 2004). Another study by Budi (2011) stated using or reinforcing steel resulted in lower strength than using new reinforcement. This is due to repeated heating at high temperatures (Budi, 2011; Wylie *et al*., 2007).

According to Ayad and Ayad (2010), the variation in the tensile strength value in each sample can also be caused by the metal casting mixing process, which is carried out at different speeds. The strain of the new 100% CoCr Metals group was higher than that of the new 50% CoCr + 50% repeated metals group and the 100% repeated CoCr metals group. This was because, during the tensile test, the new 100% CoCr group was longer and more robust than the new 50% CoCr + 50% repeated group and the 100% repeated 100% CoCr metal group. The *Modulus of Elasticity* (MPa) of the new 100% CoCr Metals group is 7866, 711 MPa higher than the elastic

modulus of the New 50% CoCr + 50% repeated metals group and the 100% repeated CoCr metals group. This occurs due to the difference in strain values between the metal groups new 100% CoCr with new 50% CoCr metal + 50% repeating and 100% repeating CoCr metal group.

Syaja'iy (2010) mentioned that there are differences in value and there is a decrease in the modulus of elasticity between the parent concrete or new concrete and the repair or repetition of materials. The same thing was also expressed by Souisa (2011), the modulus of elasticity of Cr Steel was higher than that of alloyed iron (brass) after the tensile test (Bauer *et al*., 2006; Souisa, 2011). This is different from what was revealed by James *et al*. (2018). There is no significant difference in the elastic modulus of the metal that has been re-cast several times, affecting the accuracy dimensions.

The maximum force of the new 100% CoCr metal group is 7500 N, higher than the new 50% CoCr + 50% repetitive metal group and the 100% repetitive CoCr metal group. This is primarily due to the fact that the new 100% CoCr metal group remains uncontaminated, unlike the metals in the new 50% CoCr + 50% repeated metals and the 100% repeated CoCr metals group, which have been contaminated with other materials such as carbon, oxygen, and investment materials, leading to a decrease in their modulus of elasticity.

CONCLUSION

Within the limitations of this research, the repetition of metal casting significantly affects tensile strength, strain, modulus of elasticity, and force. The new 100% CoCr group had higher tensile strength, strain, elastic modulus, and force than the new 50% CoCr + 50% repeated metals group and the 100% repeated 100% CoCr metals group. It is recommended for the manufacture of denture bases that the best is a metal casting 100% new metal compared to metal 50% new CoCr + 50% repeated metal and 100% repeated CoCr metal group.

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