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ЕЖЕМЕСЯЧНЫЙ НАУЧНЫЙ ЖУРНАЛ

Медицинские новости Грузии

საქართველოს სამედიცინო სიახლენი

GEORGIAN MEDICAL NEWS

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GMN: Georgian Medical News is peer-reviewed, published monthly journal committed to promoting the science and art of medicine and the betterment of public health, published by the GMN Editorial Board since 1994. GMN carries original scientific articles on medicine, biology and pharmacy, which are of experimental, theoretical and practical character; publishes original research, reviews, commentaries, editorials, essays, medical news, and correspondence in English and Russian.
GMN is indexed in MEDLINE, SCOPUS, PubMed and VINITI Russian Academy of Sciences. The full text content is available through EBSCO databases.

GMN: Медицинские новости Грузии - ежемесячный рецензируемый научный журнал, издаётся Редакционной коллегией с 1994 года на русском и английском языках в целях поддержки медицинской науки и улучшения здравоохранения. В журнале публикуются оригинальные научные статьи в области медицины, биологии и фармации, статьи обзорного характера, научные сообщения, новости медицины и здравоохранения. Журнал индексируется в MEDLINE, отражён в базе данных SCOPUS, PubMed и ВИНИТИ РАН. Полнотекстовые статьи журнала доступны через БД EBSCO.

GMN: Georgian Medical News – საქართველოს სამედიცინო სიახლენი – არის ყოველთვიური სამეცნიერო სამედიცინო რეცენზირებადი ჟურნალი, გამოიცემა 1994 წლიდან, წარმოადგენს სარედაქციო კოლეგიისა და აშშ-ის მეცნიერების, განათლების, ინდუსტრიის, ხელოვნებისა და ბუნებისმეტყველების საერთაშორისო აკადემიის ერთობლივ გამოცემას. GMN-ში რუსულ და ინგლისურ ენებზე ქვეყნდება ექსპერიმენტული, თეორიული და პრაქტიკული ხასიათის ორიგინალური სამეცნიერო სტატიები მედიცინის, ბიოლოგიისა და ფარმაციის სფეროში, მიმოხილვითი ხასიათის სტატიები.
ჟურნალი ინდექსირებულია MEDLINE-ის საერთაშორისო სისტემაში, ასახულია SCOPUS-ის, PubMed-ის და ВИНИТИ РАН-ის მონაცემთა ბაზებში. სტატიების სრული ტექსტი ხელმისაწვდომია EBSCO-ს მონაცემთა ბაზებიდან.

WEBSITE

www.geomednews.com

К СВЕДЕНИЮ АВТОРОВ!

При направлении статьи в редакцию необходимо соблюдать следующие правила:

1. Статья должна быть представлена в двух экземплярах, на русском или английском языках, напечатанная через **полтора интервала на одной стороне стандартного листа с шириной левого поля в три сантиметра**. Используемый компьютерный шрифт для текста на русском и английском языках - **Times New Roman** (**Кириллица**), для текста на грузинском языке следует использовать **AcadNusx.** Размер шрифта - **12**. К рукописи, напечатанной на компьютере, должен быть приложен CD со статьей.

2. Размер статьи должен быть не менее десяти и не более двадцати страниц машинописи, включая указатель литературы и резюме на английском, русском и грузинском языках.

3. В статье должны быть освещены актуальность данного материала, методы и результаты исследования и их обсуждение.

При представлении в печать научных экспериментальных работ авторы должны указывать вид и количество экспериментальных животных, применявшиеся методы обезболивания и усыпления (в ходе острых опытов).

4. К статье должны быть приложены краткое (на полстраницы) резюме на английском, русском и грузинском языках (включающее следующие разделы: цель исследования, материал и методы, результаты и заключение) и список ключевых слов (key words).

5. Таблицы необходимо представлять в печатной форме. Фотокопии не принимаются. **Все цифровые, итоговые и процентные данные в таблицах должны соответствовать таковым в тексте статьи**. Таблицы и графики должны быть озаглавлены.

6. Фотографии должны быть контрастными, фотокопии с рентгенограмм - в позитивном изображении. Рисунки, чертежи и диаграммы следует озаглавить, пронумеровать и вставить в соответствующее место текста **в tiff формате**.

В подписях к микрофотографиям следует указывать степень увеличения через окуляр или объектив и метод окраски или импрегнации срезов.

7. Фамилии отечественных авторов приводятся в оригинальной транскрипции.

8. При оформлении и направлении статей в журнал МНГ просим авторов соблюдать правила, изложенные в «Единых требованиях к рукописям, представляемым в биомедицинские журналы», принятых Международным комитетом редакторов медицинских журналов - http://www.spinesurgery.ru/files/publish.pdf и http://www.nlm.nih.gov/bsd/uniform_requirements.html
В конце каждой оригинальной статьи приводится библиографический список. В список литературы включаются все материалы, на которые имеются ссылки в тексте. Список составляется в алфавитном порядке и нумеруется. Литературный источник приводится на языке оригинала. В списке литературы сначала приводятся работы, написанные знаками грузинского алфавита, затем кириллицей и латиницей. Ссылки на цитируемые работы в тексте статьи даются в квадратных скобках в виде номера, соответствующего номеру данной работы в списке литературы. Большинство цитированных источников должны быть за последние 5-7 лет.

9. Для получения права на публикацию статья должна иметь от руководителя работы или учреждения визу и сопроводительное отношение, написанные или напечатанные на бланке и заверенные подписью и печатью.

10. В конце статьи должны быть подписи всех авторов, полностью приведены их фамилии, имена и отчества, указаны служебный и домашний номера телефонов и адреса или иные координаты. Количество авторов (соавторов) не должно превышать пяти человек.

11. Редакция оставляет за собой право сокращать и исправлять статьи. Корректура авторам не высылается, вся работа и сверка проводится по авторскому оригиналу.

12. Недопустимо направление в редакцию работ, представленных к печати в иных издательствах или опубликованных в других изданиях.

При нарушении указанных правил статьи не рассматриваются.

REQUIREMENTS

Please note, materials submitted to the Editorial Office Staff are supposed to meet the following requirements:

1. Articles must be provided with a double copy, in English or Russian languages and typed or compu-ter-printed on a single side of standard typing paper, with the left margin of **3** centimeters width, and **1.5** spacing between the lines, typeface - **Times New Roman** (**Cyrillic**), print size - **12** (referring to Georgian and Russian materials). With computer-printed texts please enclose a CD carrying the same file titled with Latin symbols.

2. Size of the article, including index and resume in English, Russian and Georgian languages must be at least 10 pages and not exceed the limit of 20 pages of typed or computer-printed text.

3. Submitted material must include a coverage of a topical subject, research methods, results, and review.

Authors of the scientific-research works must indicate the number of experimental biological species drawn in, list the employed methods of anesthetization and soporific means used during acute tests.

4. Articles must have a short (half page) abstract in English, Russian and Georgian (including the following sections: aim of study, material and methods, results and conclusions) and a list of key words.

5. Tables must be presented in an original typed or computer-printed form, instead of a photocopied version. **Numbers, totals, percentile data on the tables must coincide with those in the texts of the articles.** Tables and graphs must be headed.

6. Photographs are required to be contrasted and must be submitted with doubles. Please number each photograph with a pencil on its back, indicate author's name, title of the article (short version), and mark out its top and bottom parts. Drawings must be accurate, drafts and diagrams drawn in Indian ink (or black ink). Photocopies of the X-ray photographs must be presented in a positive image in **tiff format**.

Accurately numbered subtitles for each illustration must be listed on a separate sheet of paper. In the subtitles for the microphotographs please indicate the ocular and objective lens magnification power, method of coloring or impregnation of the microscopic sections (preparations).

7. Please indicate last names, first and middle initials of the native authors, present names and initials of the foreign authors in the transcription of the original language, enclose in parenthesis corresponding number under which the author is listed in the reference materials.

8. Please follow guidance offered to authors by The International Committee of Medical Journal Editors guidance in its Uniform Requirements for Manuscripts Submitted to Biomedical Journals publication available online at: http://www.nlm.nih.gov/bsd/uniform_requirements.html
http://www.icmje.org/urm_full.pdf
In GMN style for each work cited in the text, a bibliographic reference is given, and this is located at the end of the article under the title "References". All references cited in the text must be listed. The list of references should be arranged alphabetically and then numbered. References are numbered in the text [numbers in square brackets] and in the reference list and numbers are repeated throughout the text as needed. The bibliographic description is given in the language of publication (citations in Georgian script are followed by Cyrillic and Latin).

9. To obtain the rights of publication articles must be accompanied by a visa from the project instructor or the establishment, where the work has been performed, and a reference letter, both written or typed on a special signed form, certified by a stamp or a seal.

10. Articles must be signed by all of the authors at the end, and they must be provided with a list of full names, office and home phone numbers and addresses or other non-office locations where the authors could be reached. The number of the authors (co-authors) must not exceed the limit of 5 people.

11. Editorial Staff reserves the rights to cut down in size and correct the articles. Proof-sheets are not sent out to the authors. The entire editorial and collation work is performed according to the author's original text.

12. Sending in the works that have already been assigned to the press by other Editorial Staffs or have been printed by other publishers is not permissible.

Articles that Fail to Meet the Aforementioned Requirements are not Assigned to be Reviewed.

ავტორთა საყურადღებოდ!

რედაქციაში სტატიის წარმოდგენისას საჭიროა დავიცვათ შემდეგი წესები:

1. სტატია უნდა წარმოადგინოთ 2 ცალად, რუსულ ან ინგლისურ ენებზე,დაბეჭდილი სტანდარტული ფურცლის 1 გვერდზე, 3 სმ სიგანის მარცხენა ველისა და სტრიქონებს შორის 1,5 ინტერვალის დაცვით. გამოყენებული კომპიუტერული შრიფტი რუსულ და ინგლისურენოვან ტექსტებში - **Times New Roman (Кириллица)**, ხოლო ქართულენოვან ტექსტში საჭიროა გამოვიყენოთ **AcadNusx.** შრიფტის ზომა – 12. სტატიას თან უნდა ახლდეს CD სტატიით.

2. სტატიის მოცულობა არ უნდა შეადგენდეს 10 გვერდზე ნაკლებს და 20 გვერდზე მეტს ლიტერატურის სიის და რეზიუმეების (ინგლისურ,რუსულ და ქართულ ენებზე) ჩათვლით.

3. სტატიაში საჭიროა გაშუქდეს: საკითხის აქტუალობა; კვლევის მიზანი; საკვლევი მასალა და გამოყენებული მეთოდები; მიღებული შედეგები და მათი განსჯა. ექსპერიმენტული ხასიათის სტატიების წარმოდგენისას ავტორებმა უნდა მიუთითონ საექსპერიმენტო ცხოველების სახეობა და რაოდენობა; გაუტკივარებისა და დაძინების მეთოდები (მწვავე ცდების პირობებში).

4. სტატიას თან უნდა ახლდეს რეზიუმე ინგლისურ, რუსულ და ქართულ ენებზე არანაკლებ ნახევარი გვერდის მოცულობისა (სათაურის, ავტორების, დაწესებულების მითითებით და უნდა შეიცავდეს შემდეგ განყოფილებებს: მიზანი, მასალა და მეთოდები, შედეგები და დასკვნები; ტექსტუალური ნაწილი არ უნდა იყოს 15 სტრიქონზე ნაკლები) და საკვანძო სიტყვების ჩამონათვალი (key words).

5. ცხრილები საჭიროა წარმოადგინოთ ნაბეჭდი სახით. ყველა ციფრული, შემაჯამებელი და პროცენტული მონაცემები უნდა შეესაბამებოდეს ტექსტში მოყვანილს.

6. ფოტოსურათები უნდა იყოს კონტრასტული; სურათები, ნახაზები, დიაგრამები - დასათაურებული, დანომრილი და სათანადო ადგილას ჩასმული. რენტგენოგრამების ფოტოასლები წარმოადგინეთ პოზიტიური გამოსახულებით **tiff** ფორმატში. მიკროფოტოსურათების წარწერებში საჭიროა მიუთითოთ ოკულარის ან ობიექტივის საშუალებით გადიდების ხარისხი, ანათალების შეღებვის ან იმპრეგნაციის მეთოდი და აღნიშნოთ სურათის ზედა და ქვედა ნაწილები.

7. სამამულო ავტორების გვარები სტატიაში აღინიშნება ინიციალების თანდართვით, უცხოურისა – უცხოური ტრანსკრიპციით.

8. სტატიას თან უნდა ახლდეს ავტორის მიერ გამოყენებული სამამულო და უცხოური შრომების ბიბლიოგრაფიული სია (ბოლო 5-8 წლის სიღრმით). ანბანური წყობით წარმოდგენილ ბიბლიოგრაფიულ სიაში მიუთითეთ ჯერ სამამულო, შემდეგ უცხოელი ავტორები (გვარი, ინიციალები, სტატიის სათაური, ჟურნალის დასახელება, გამოცემის ადგილი, წელი, ჟურნალის №, პირველი და ბოლო გვერდები). მონოგრაფიის შემთხვევაში მიუთითეთ გამოცემის წელი, ადგილი და გვერდების საერთო რაოდენობა. ტექსტში კვადრატულ ფჩხილებში უნდა მიუთითოთ ავტორის შესაბამისი N ლიტერატურის სიის მიხედვით. მიზანშეწონილია, რომ ციტირებული წყაროების უმეტესი ნაწილი იყოს 5-6 წლის სიღრმის.

9. სტატიას თან უნდა ახლდეს: ა) დაწესებულების ან სამეცნიერო ხელმძღვანელის წარდგინება, დამოწმებული ხელმოწერითა და ბეჭდით; ბ) დარგის სპეციალისტის დამოწმებული რეცენზია, რომელშიც მითითებული იქნება საკითხის აქტუალობა, მასალის საკმაობა, მეთოდის სანდოობა, შედეგების სამეცნიერო-პრაქტიკული მნიშვნელობა.

10. სტატიის ბოლოს საჭიროა ყველა ავტორის ხელმოწერა, რომელთა რაოდენობა არ უნდა აღემატებოდეს 5-ს.

11. რედაქცია იტოვებს უფლებას შეასწოროს სტატია. ტექსტზე მუშაობა და შეჯერება ხდება საავტორო ორიგინალის მიხედვით.

12. დაუშვებელია რედაქციაში ისეთი სტატიის წარდგენა, რომელიც დასაბეჭდად წარდგენილი იყო სხვა რედაქციაში ან გამოქვეყნებული იყო სხვა გამოცემებში.

აღნიშნული წესების დარღვევის შემთხვევაში სტატიები არ განიხილება.

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Содержание:

EFFECT OF HEAT TREATMENT DURATION AND COOLING CONDITIONS ON TENSILE PROPERTIES AND HARDNESS OF SELECTIVE-LASER-MELTED COBALT-CHROMIUM ALLOY

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Abstract.

Background: The mechanical properties of cobalt-chromium (Co-Cr) alloys produced through selective laser melting (SLM) can be enhanced by the application of the post-heat treatment, but it is still unclear how long the heat treatment should last and how the cooling rate affects the tensile properties and hardness of the alloy.

Aim of this study: Investigate the effects of heat treatment for one hour and six hours, respectively, at 1150 C, and three cooling conditions (AC, FC, and WC), on the tensile strength, elongation, and hardness of SLM Co-Cr alloy specimens. **Materials and methods:** Thirty-five Dumbbell shaped specimens (50×12×2 mm) (ISO 6892-1:2016), and thirty-five rectangular-shaped specimens (34×13×1.5 mm) ISO (22674:2016) were manufactured and divided into seven groups, based on the use of heat or cold and the duration of both. Tensile strength and Vickers hardness tests were performed on the specimens.

Results: When it comes to tensile strength, the (FC1) group took the bottom spot with a score of (991.21 MPa) while the control group came out on top, boasting an impressive (1362.41 MPa). When it came to elongation, the control group had the lowest score (4%), while the best-treated group scored (17%). The lowest and highest value of tensile strength was similarly affected.

Conclusion: Water-quenched groups showed better tensile properties and hardness than other groups. As a result, increasing the cooling rate is an effective way to improve the ductility and hardness of the SLM Co-Cr alloy.

Key words. Selective laser melting (SLM), heat treatment, cooling conditions, tensile strength, elongation.

Introduction.

Removable partial dentures (RPD) are an essential component of prosthodontic sciences, which restore and maintain a patient's oral function, comfort, appearance, and health by replacing missing teeth and craniofacial tissues [1]. Cobalt chromium (Co-Cr) alloys are commonly utilized in the production of biomedical equipment, such as dental devices because they have superior mechanical properties, good biocompatibility, low wear rate, and high corrosion resistance [2].

Selective laser melting (SLM) is a revolutionary approach to additive manufacturing that is uplifting the dental industry. This cutting-edge technology is rapidly replacing the traditional lost-wax method for producing Co-Cr dental devices. With SLM, this innovative process uses laser technology to create intricate designs and structures, resulting in dental devices that are not only more accurate but also more durable than ever before. In terms of mechanical properties and metal release, research has demonstrated that Cr-Co parts made using SLM technology are superior to those made using conventional casting methods [3,4]. This SLM process leads to microstructures with smaller grains than those formed through traditional casting methods. In other words, the SLM technique produces incredibly fine-grained structures that result in some pretty impressive properties [5].

SLM exhibits a drawback in that the manufacturing process induces residual stress within the parts due to the distinctive thermal cycle of rapid melting and cooling [6,7].

Post-heat treatment is an essential phase to decrease any remaining stresses and enhance the mechanical properties of the produced parts [8].

Materials and methods.

The specimens were fabricated using Co-Cr powder that is commercially available (Riton Model: C01, Foshan Rxton Technology Co., China). The composition of Co-Cr powder is displayed in (Table 1). The 3D models were designed using 3ds Max ® software (AutoDesk, USA). SLM machine (Riton D-150, Foshan Rxton Technology Co., China) (Figure 1) was used for the manufacturing process of the specimens by using standard deposition settings for the Riton Model: C01 powder at a laser power of 165 W, laser wavelength of 1.064 µm, laser speed of 1050 (mm/sec), as well as a layer thickness of 20 to 50 µm. The specimens underwent a rigorous SLM process and were now ready for the next step - heat treatment. To initiate this process, we carefully placed them into the furnace (triton rt 1300 Foshan Rxton Technology Co., China). The furnace was set up in an environment filled with Nitrogen gas, creating the perfect conditions for the heat treatment process to begin. We made sure to follow the building direction of 0o angle to the plate to ensure the best possible outcome for our specimens. After the SLM process, the specimens were brought to the furnace (triton rt 1300 Foshan Rxton Technology Co., China) to begin the heat treatment process. The machine was operating in an atmosphere with Nitrogen gas. The building direction of 0o angle to the plate was used.

Table 1. *Composition of the Co-Cr powder.*

Co	Cr	Mo	W	Si	Fe	C	Ni
60 %	28%	5 %	5 %	< 1 %	< 0.75 %	< 0.16 %	< 0.1 %

First, the furnace was cranked up from room temperature to a scorching 760°C. After reaching this temperature, it was maintained for a tense 10 minutes. Next, the furnace was pushed even further to a blistering 1150°C. This temperature was then held steady for a whole hour or even six hours, depending on the desired outcome. Finally, the furnace was shut down, leaving us with a product that had undergone a truly impressive heat treatment, the whole process was completed at a ramp rate of 10°C per minute.

Figure 1. *SLM Machine.*

Here's how we conducted the heat: First, we cranked up the temperature of the furnace from room temperature to a whopping 760 C. Then, we kept it steady for 10 minutes to let the heat penetrate deep into the material. After that, we turned up the heat even more to 1150 C and held it there for one hour or six hours (depending on the material). And finally, we switched off the furnace, bringing an end to this exciting heat treatment process. We didn't just randomly increase the temperature. We used a ramp rate of 10 C/min, which allowed for a controlled and gradual increase in temperature. This ensured that the material was properly heated and treated, resulting in the best possible outcome [5].

The first groups of specimens were removed from the furnace and cooled to room temperature in the open air after heat treatment. These groups were named AC1 and AC6. The second group was kept in the furnace until they reached room temperature. The names for these groups were FC1 and FC6, respectively.

The final groups were taken from the furnace after the 1 h / 6 h timer expired and cooled via water quenching using tap water. These groups are named WC1 and WC6, correspondingly. The control group was not subjected to any heat treatment or cooling and was designated as control.

After separation from the plate, supporting structures were completely removed using a metal engine and tapered carbide burs. To ensure that the specimens' dimensions remain intact, we utilized stone burs (NHT02, Denmart, China) to remove the green oxide layer. We followed the manufacturer's instructions meticulously to ensure that the process was carried out with utmost precision. This step was crucial in preserving the overall quality of the specimens.

1. Tensile Strength Test

Thirty-five sleek and stylish dumbbell-shaped specimens. Each specimen measures 50x12x2mm and was expertly manufactured in accordance with the rigorous standards of the International Organization for Standardization (ISO) 6892-1:2016. These specimens are designed for tensile testing of metallic materials at room temperature, and we've provided five for each group (Figure 2) [9,10].

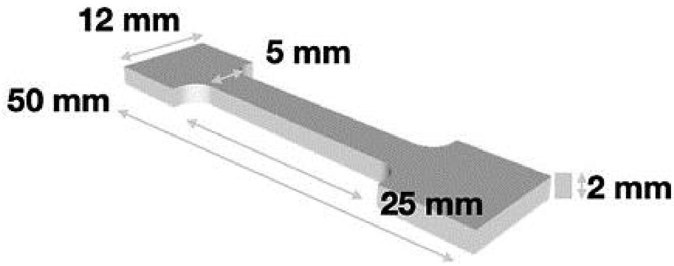

Figure 2. *Tensile Specimen.*

We conducted some exciting experiments on the dumbbell-shaped specimens using a top-of-the-line universal testing machine (STM 1000, Santam Engineering Design Co., Iran) to measure their tensile strength. By subjecting the specimens to uniaxial forces, we were able to determine their 0.2% yield strength (0.2% YS) and elongation, which were then calculated using the stress-strain curve.

2. Vickers Hardness Test

To measure the hardness of our rectangular specimens (34×13×1.5 mm), we used a cutting-edge micro hardness tester straight from Otto Wolpert in Germany. This tool is equipped with a 136° diamond pyramid indenter and a 4.9 N load, it was programmed to perform Vickers hardness (HV) tests with pinpoint precision. We didn't just rely on the manufacturer's instructions though - we made sure to follow them to a T, ensuring accurate results. And to make sure our data was as reliable as possible; we took three data points for each sample [11].

Results.

The statistical analysis was done using the SPSS program (version 29) (IBM Corp., NY, USA), employing descriptive statistics, normality tests, analysis of variance test (One-way ANOVA), coupled with Duncan's multiple range test to demonstrate the difference between groups at $P \leq 0.05$ significance level.

1. Tensile Strength Test

Descriptive statistics including mean value measured in megapascal (MPa) and standard deviation of tensile strength, 0.2 yields (MPa) and elongation percentage are presented in (Table 2). After analyzing the results of our tensile strength tests, the (FC1) group, unfortunately, came in last place with a value of (991.21MPa). However, the clear winner in this category was the control group, with an impressively high value of (1362.41 MPa). As for elongation, the control group struggled a bit, coming in dead last with a measly (4%) value. But fear not, as the (AC6) group swooped in to steal the show with the best elongation value of the bunch.

The lowest value of tensile strength between tested groups was presented by the (FC1) group with (991.21MPa). The highest value was presented by the control group with (1362.41 MPa). For elongation, the worst value was found in the control group with (4%) and the best value was found in the (AC6) group.

***Table 2.** Descriptive statistics for tensile strength, 0.2 YS and elongation.*

group	Tensile strength means (MPa)	Std. Deviation	0.2 YS (MPa)	Elongation (%)
control	1362.41	170.57	912	4
AC1	1097.82	100.60	616	11
FC1	991.21	91.17	596	8
WC1	1191.05	144.39	658	13
AC6	1135.27	127.36	771	14
FC6	1149.42	141.71	736	10
WC6	1262.61	173.03	810	17
ISO 22647:2016			500	2

***Table 3.** Normality Test for tensile strength.*

Group	Shapiro-Wilk		
	Statistic	df	Sig.
CONTROL	.932	5	.608
AC1	.924	5	.553
FC1	.920	5	.532
WC1	.997	5	.997
AC6	.942	5	.678
FC6	.988	5	.973
WC6	.969	5	.870

***Table 4.** Tensile strength of studied samples.*

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	424255.9	6	70709.3	3.677	0.008
Within Groups	538502	28	19232.2		
Total	962757.9	34			

***Table 5.** Descriptive statistics for Vickers Hardness test.*

	N	Mean	Std. Deviation	Minimum	Maximum
CONTROL	5	452.2	34.85972	419.00	510.00
AC1	5	417.8	21.42895	390.00	448.00
FC1	5	376.8	41.40894	324.00	423.00
WC1	5	572	40.18084	523.00	624.00
AC6	5	405	54.05553	339.00	487.00
FC6	5	374.6	24.99600	351.00	411.00
WC6	5	498.2	45.52692	432.00	552.00
Total	35				

A normality test was performed on the obtained values (Table 3). Shapiro- Wilk test revealed that the values were distributed normally ($P > 0.05$).

Tensile strength values for all groups were tested using a one-way ANOVA (Table 4). The analysis revealed a statistically significant difference ($P = 0.008$) between the groups subjected to varying cooling and the control group.

In accordance with the Duncan's multiple range test, it was observed that the control group exhibited the maximum tensile strength value, while the groups (WC6 and WC1) followed. The test also revealed that the tensile strength of the furnace cooled (FC1) group had decreased significantly (Figure 3).

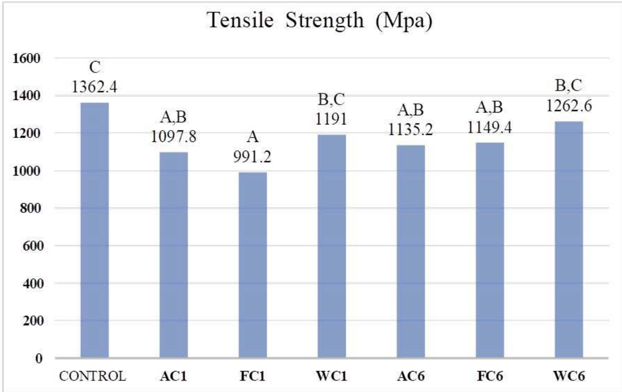

***Figure 3**. Duncan's multiple range test for Tensile strength.*

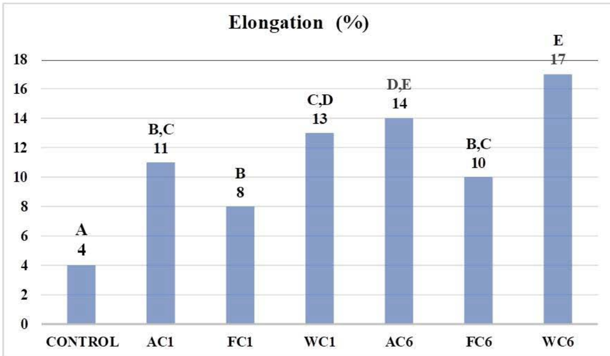

***Figure 4**. Duncan's multiple range test for Elongation.*

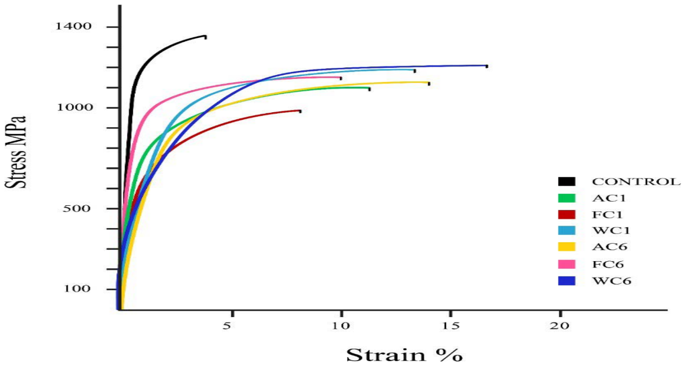

***Figure 5**. Stress-Strain Curve, adapted from (Kajima et al., 2018).*

Significant differences in elongation were found between the groups ($P = 0.001$) according to the analysis of variance test ANOVA results and Duncan's multiple range test (Figure 4). The stress-strain curves for the groups are shown in (Figure 5).

2. Vickers Hardness Test

Descriptive statistics (Table 5) for the Vickers Hardness test reveals that the (WC1) and (WC6) groups had the highest values of Vickers hardness in comparison to the other test groups.

A normality test was performed on the values (Table 6). The results of the Shapiro-Wilk tests indicated that the data adhering to a normal distribution, with a p-value greater than 0.05.

Vickers Hardness values for all groups were subjected to a one-way ANOVA test (Table 7). The results of the statistical analysis revealed a statistically significant difference (P 0.001) between water-quenched groups and groups that were under other cooling conditions. The results of Duncan's multiple range test indicated a decrease in Vickers hardness values for the (FC1) and (FC6) groups. (Figure 6).

Table 6. *Normality test for Vickers Hardness.*

	Shapiro-Wilk		
	Statistic	df	Sig.
CONTROL	0.865	5	.245
AC1	0.968	5	.863
FC1	0.951	5	.744
WC1	0.942	5	.679
AC6	0.946	5	.705
FC6	0.888	5	.349
WC6	0.954	5	.765

Table 7. *Vickers Hardness for the studied samples.*

ANOVA					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	154549.771	6	25758.295	16.973	<.001
Within Groups	42492.400	28	1517.586		
Total	197042.171	34			

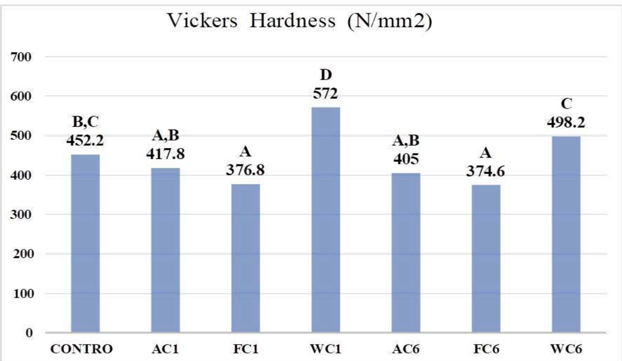

Figure 6. *Duncan's multiple range test for Vickers Hardness.*

Discussion.

The present study's results (Table 2) revealed that the control group exhibited the highest tensile strength, without any application of heat parameters or cooling to the specimens. Despite exhibiting the highest levels of strength, such as Tensile Strength and 0.2% Yield Strength, the control group's elongation was not ideal for medical applications. The large amount of γ phase with dense stacking faults should be credited for the high strength of the As-SLM alloy. The mechanical properties of As-SLM Co-Cr alloy must thus be improved by heat treatment in order to dissolve the network structure that contains a diamond-like pattern and re-crystallize a more uniform one [8,10]. The 0.2% yield strength and ultimate tensile strength exhibited a reduction subsequent to a 6-hour heat treatment compared to the SLM group without heat treatment [9,11].

Co-Cr-based alloys undergo a phase transformation from the γ phase to the martensite ε phase during the cooling process. But water quenching at temperatures above 1100 C can produce a significant amount of martensite. This discovery has been reported by several studies and sheds new light on the properties of these alloys [12-14].

Rapid cooling rates played a role in ε martensite formation. This implies that the heating and cooling methods have a huge impact on the fractions and phases of Co-Cr [10]. After heat treatment, quenching Co-based alloys with water or ice promotes the formation of ε martensite. When less drastic cooling rates, such as air or furnace cooling are applied to the alloys, this effect appears to be eliminated [12].

It is widely known that the cooling rate affects the grain size, which in turn affects the mechanical properties of the Cobalt chromium alloy. According to Wai Cho et al. [5] in their microstructure analysis, samples that were cooled by air had finer grains than those that were cooled by a furnace because of the higher cooling rate. The microstructure recrystallized after one and six hours of heat treatment at 1150 C.

After undergoing thermal treatment, the Co-Cr alloy showcased a remarkable transformation with a more uniform microstructure and texture, resulting in a visually pleasing finish [15]. Interestingly, as the duration and temperature of the heat treatment increased, the alloy's ductility saw a slight uptick, while the tensile strength showed a marginal decrease [11]. In a separate study, Wai Cho et al. [5] found that rapid cooling rates played a pivotal role in enhancing the alloy's elongation, further demonstrating the alloy's impressive malleability.

The results of our tests using the one-way ANOVA (Table 7) and Duncan's multiple range test (Figure 6), it turns out that groups (WC1) and (WC6) are significantly different from all the other groups when it comes to their Vickers Hardness values.

According to the findings of this study, rapid cooling rate i.e., water quenching is the most effective method for improving Vickers hardness in Co-Cr alloys. This result could be explained by the selective laser melting (SLM) procedure involving a rapid thermal cycle of heating and cooling, leading to the development of fine grains within the solidified layer [16-19].

Surfaces of specimens produced using the SLM technique had a uniform microstructure, and as the microstructure became more uniform, the specimens grew harder" [19]. Igual-Muoz & Mischler [20]. concluded that slower cooling processes, such as furnace cooling, cause grain size to increase and, as a result, mechanical properties, such as hardness, to decrease. Presotto et al. [21]. concluded that the slightly higher ε- phase peak of the SLM group is associated with enhanced hardness. No significant differences in Vickers hardness measurements were observed between the Furnace Cooled and Air-Cooled specimens [5].

Conclusion.

This study delved into the remarkable outcome of Co-Cr alloy specimens produced via selective laser melting (SLM), and the effects of heat treatment on their tensile strength and hardness. To be precise, the specimens were subjected to heat treatment at a staggering 1150 C for one and six hours and then cooled under three distinct conditions - air cooling, furnace cooling, and water quenching. The study revealed that the cooling rate plays a significant role in determining the mechanical properties of SLM Co-Cr alloys. Surprisingly, the heat treatment duration didn't have much of an impact. An increase in the cooling rate considerably enhanced the alloy's elongation, as compared to the slow cooling rate inside the furnace. But a rise in the cooling rate also improved the hardness of the alloy, making it stronger and more durable. After rigorous testing, it was concluded that heat treatment for one hour, followed by water quenching, produced the most convenient mechanical properties among all other groups. In conclusion, this study sheds light on the outcome of Co-Cr alloy specimens and how different cooling rates affect their mechanical properties. The findings could pave the way for further research and development of more efficient and robust alloys.

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