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Evaluation the Castability of Titanium Casting Alloy

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الخلاصة

الاهداف: تهدف الدراسة الى تقييم قيمة الصب لسبيكة التيتانيوم و مقارنتها مع قيمة الصب لسبائك النيكل-كروم و كوبالت-كروم بواسطة قياس قيمة الصب و نسبة الثقوب. **المواد و طرائق العمل** : ثلاثون عينة حضرت لاجراء فحص قيمة الصب و نسبة الثقوب. قيمة الصب قيست حسب طريقة (هينمان) باحتساب عدد القطع الناتجة للعينة . ونسبة الثقوب قيست حسب نظرية (ارخميدس). استخدم اختبار تحليل التباين و اختبار دنكن للتحليل الاحصائي. **النتائج:** اظهرت النتائج ان سبيكة التيتانيوم تمتلك اقل قيمة للصب و اعلى نسبة ثقوب. سبيكة الكوبالت-كروم لديها القيمة المتوسطة بين التيتانيوم و نيكل-كروم. سبيكة النيكل-كروم تمتلك اعلى قيمة صب و اقل نسبة ثقوب. **الاستنتاجات:** هناك فرق معنوي بين قيم الصب و نسب الثقوب للسبائك المختلفة وان الاختلاف بين قيم الصب له علاقة باختلاف درجات الانصهار للسبائك المختلفة.

ABSTRACT

Aims: is to evaluate the castability of titanium alloy and compare it with that of nickel-chromium and cobalt-chromium alloys by measuring castability and porosity values. **Materials and methods**: A total of 30 samples were prepared for castability and porosity tests. Castability was measured by castability test according to Hinman method by measuring the numerical number of the reproduced segments of casting samples . Porosity value was measured by determined the porosity percentage according to (Archimedes) method . ANOVA and Duncun's multiple range test were carried out to determine the significant difference at $p \leq 0.05\%$. **Results:** the results showed that titanium alloy has a lowest value of castability and the highest value of porosity percentage, While cobalt-chromium alloys has intermediate values. Nickel-chromium alloy has highest value of castability and the lowest value of porosity. **Conclusion:** there is a significant differences between the castabilty and porosity values among different casting alloys used. The differences between the catability values are related to variance between the melting temperature of the different casting alloys, the higher the melting temperature the less castability value.

Key words: Castability, Titanium, porosity

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INTRODUCTION

Cobalt Chromium (Co-Cr) based alloys was introduced in 1930 and is well known for its high Young's modulus, fatigue strength, wear resistance and corrosion resistance. The castable cobalt alloy, (CoCrMo) has been used in the casting of dental prostheses and artificial joint product. [1,2,3] Co–Cr alloys are hard, rigid and mostly corrosion resistant; however, the retainer arms have often lacked adequate flexibility. To a lesser extent, both nickel (Ni)-based and Co–Cr–Ni alloys have also been used but problems relating to Ni allergy have limited their popularity.[4-6] Pure titanium has proved to be less frequently allergenic. Improved casting technology and the development of techniques like laser welding have facilitated the widespread use of titanium for denture bases. The advantages of titanium bases with respect to the resin bases include smaller volume, lightness, resistance, better dimensional stability, better fit and better biocompatibility. Moreover, as used in dentistry, 99.6% of commercially pure titanium is nontoxic, hypoallergenic, one half the weight of cobalt-chromium, radiograph translucent, inexpensive, and price stable. Along with these significant benefits, it is important to note that titanium can be used for partial denture frameworks, complete denture bases, metal-ceramic restorations, and implant suprastructures. [7-10] Despite the low density of titanium (4.50 g/cm2), a titanium framework supplies excellent strength and favorable hardness. High elongation and a low fatigue value allow titanium clasps to accommodate deep undercuts. [11]

Unfortunately titanium is inherently difficult to cast because of its high melting temperature, strong affinity with gases such as oxygen, hydrogen and nitrogen, as well as its high reactivity with most investment materials. [12-14]

The aims of this study is to evaluate the castability of titanium (Ti) casting alloy and comparing it with that of nickel-chromium (Ni-Cr) alloy and cobalt- chromium (Co-Cr) alloy. Castability determined by measuring castability value and porosity percentage of the cast specimens.

MATERIALS AND METHODS

To evaluate the castability of the alloys two methods were performed : *First method: Castabilty test:* The method used for evaluation of castability was described by Hinman *et al*. [11] , which determines the potential of dental alloys to reproduce the mesh of a nylon net used as the standard. For preparation of each castability pattern, a 10 × 10 mm square-shaped nylon net containing 100 open squares which served as a template for construction of a wax pattern. Wax strands 2 mm in diameter (Gego, Germany) were placed along the crossing segments of the nylon net, which formed a 90 degree angle at their junctions as in Figure (1).

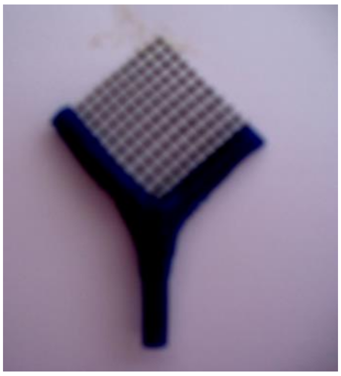


Figure (1): Wax pattern.

The pattern isolated with liquid vaseline and placed in a crucible former. The castability patterns were invested using conventional investing technique with a phosphate-based investment (Degussa, Germany). Investments were proportioned and handled according to the manufacturers' instructions. Samples for (Ni-Cr , Co-Cr and Ti alloy Grade II) were prepared and casted at Halab Center for prosthodontic (Halab, Syria). Samples for Ni-Cr alloy (BEGO, Germany) and samples for Co-Cr alloy (Biosil- Degussa, Germany) were melted and injected into the mold by centrifugation. Samples of Ti alloy Grade II (OROTIG, Italy) melted and casted in an argon arc centrifugal machine [9] (Neutrodyn manfredi, Italy) . Melting temperature of Ni-Cr alloy is about 850°C [15,16] , for Co-Cr alloy about 1300 ^{O}C [17] and for Ti alloy about 1700 ^{O}C [18-20] .The cast specimens were sandblasted with aluminum oxide to remove investment residues.

The procedure for assigning a numerical value for castability to the cast specimens was done :a square-shaped nylon net with modified dimension (15 X15 X 1 mm) provides a grid with 100 open squares and 220 segments. The number of completely reproduced cast segments was counted, divided by 220 and multiplied by 100 to obtain a percentage designated as "castability value".

This indicated the accuracy of the alloy to reproduce the wax pattern details [21]. The determined complete and incomplete segments are shown in Figure (2).

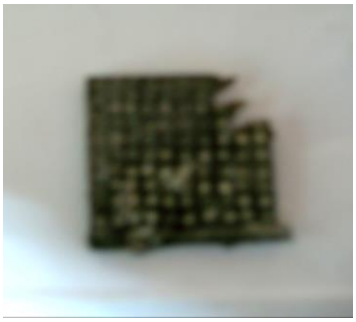


Figure (2) : Casting alloy sample.

Second method: Determination of porosity test: Samples for determination of porosity were prepared in a uniform size (10 ±1mm) × (10 ± 1mm) × (1± 0.1mm) (length, width and thickness respectively) as shown in Figure (3).

Figure (3): Sample for porosity test.

Casting procedure of different alloys was performed as in first method. Water displacement (Archimedes) method was used for the determination of porosity. Electronic balance (AND, Japan) was used to measure the weight of the sample. The porosity percentage of the cast samples were determined based on the Archimedes' theory. The percentage of porosity are defined in following equation [1,22,23]:

$$\%porosity = \frac{wc - wa}{wc - wb} \times 100\,\%$$

Where :
Wa = Weight of sample in air
Wb = Weight of sample in water
Wc = Weight of sample in air after submerged from water

A total of 30 samples were prepared (5 samples per alloy for each method) . Castability data were submitted to statistical analysis using one-way ANOVA and Duncun's multiple range test to determine the significant difference among different alloys at $p \leq 0.05\%$.

RESULTS

Casting aims to provide a copy of the wax pattern as much accurate as possible and thus, castability, defined as the capacity of an alloy to reproduce mold details, is of paramount importance for a successful casting procedure. [21] Among the various properties that are indispensable for a good clinical performance of dental alloys, castability plays a fundamental role because the long-term success of a restoration depends on the correct reproduction of details.[16] The means and standard deviation of the castability values of the dental alloys are shown in Table (1).

Table (1): Mean and standard deviation of the castability value for dental alloys

Alloys	No	Mean %	SD±
Titanium	5	67.45	1.388
Cobalt-chromium	5	78.086	1.085
Nickel-chromium	5	84.36	1.66

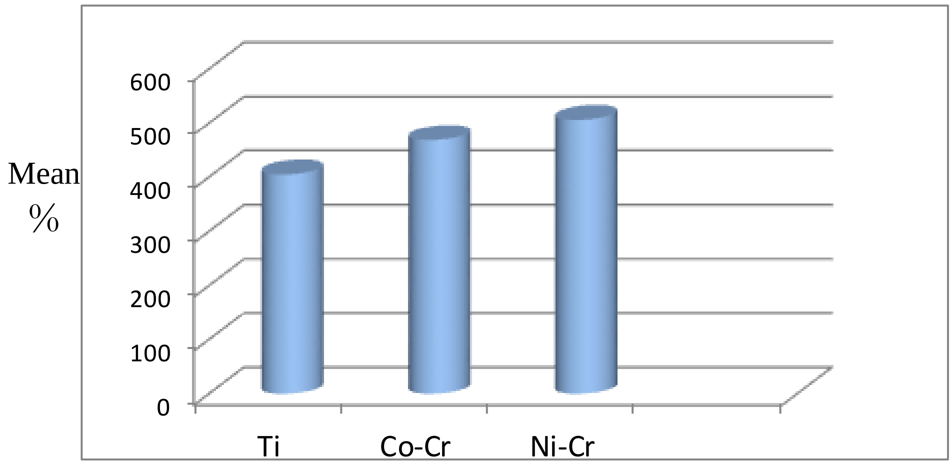
No: number of samples

The result showed that the mean value of castability of nickel-chromium alloy (Ni-Cr) was (84.36 %), which is higher than for cobalt-chromium alloy (Co-Cr) alloy (78.086 %), For Titanium alloy (Ti) the castability value was the least (67.45 %) . This result agreed with the result of Adriana *et al.* [21] Who concluded that two different (Co-Cr) alloys casted with Hinman *et al.* [11] castability methods had a castability value (61.5 % - 67.2% respectively), both values were lower than that of (Ni-Cr) alloy (85%). The result of ANOVA and Duncun's multiple range test in Table (2), Figure (4)

Table (2): ANOVA of the castability value for dental alloys.

Source of variance	DF	Mean square	F-value	P*
Between groups	2	365.36	187.08	0.000
Within groups	12	1.95		
Total	14			

DF : degree of freedom; P*: Means are highly statistically significant different at $p \leq 0.05\%$



Means with different letters are statistically significant different at $p \leq 0.05\%$
Figure (4): Duncun's multiple range test of castability value for dental alloy

Showed that there was a significant difference between the mean of castability value among different dental alloys at $p \leq 0.05\%$ .This result can be explained in that Ni-Cr–based alloys present a lower melting point during the heating process which reduce the fusion temperature and increase the alloy fluidity that is needed for good castability. [15,16] Table (3)

Table (3): Mean and standard deviation of the porosity value for dental alloy

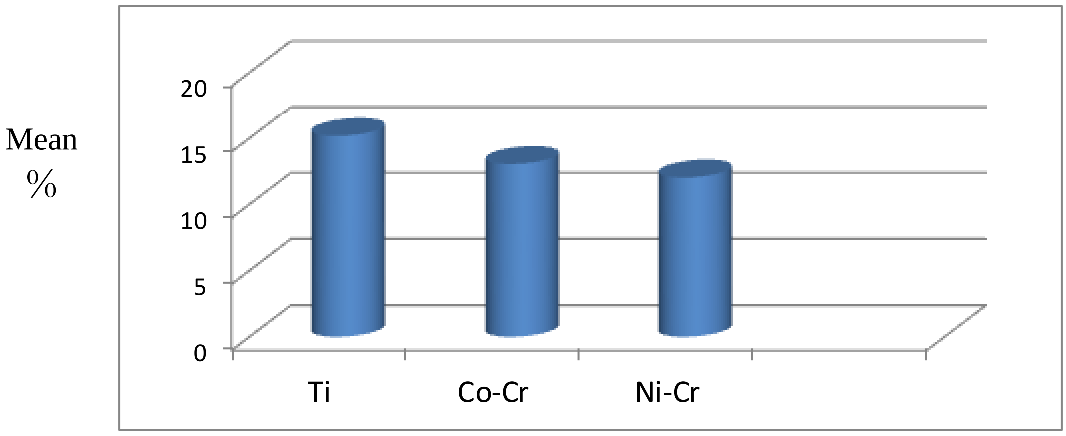
Source of variance	DF	Mean square	F-value	P*
Between groups	2	12.92672	1.3E+04	0.000
Within groups	12	0.00096		
Total	14			

Showed the means and standard deviation of the porosity values of the dental alloys. The result showed that the mean value of porosity of (Ni-Cr) alloy was (12.024 %), which is the least value. The porosity value for (Co-Cr) alloy was (13.048 %) . For (Ti) alloy the porosity value was the highest (15.176 %). Porosity is a valuable indicator of casting quality but even small pores can expose clasp arms and occlusal rests to a high risk of fracture. [24] Inert gas entrapment within the molten metal is the primary reason for porosity in castings.[18]In relation to strength, there are 2 types of porosities: internal porosity and surface notches. Internal porosities have little effect on the strength of the framework if the size and number of them are negligible. However, notches located on the framework surface may negatively affect the longevity of the structure because a narrow and long notch is susceptible to corrosion and metallic fatigue. [11] In titanium casting, pores are developed by gas entrapment and gases produced from reactions between titanium and investment materials. [2,7] and metal shrinkage upon solidification. [18,24] The main disadvantage is the relatively high incidence of failures during manufacture, which significantly increases cost.[7,25] The result of ANOVA and Duncun's multiple range test in Table (4), Figure (5)

Table (4): ANOVA of the porosity value for dental alloys

Alloys	No	Mean %	SD±
Titanium	5	15.176	0.047
Cobalt-chromium	5	13.048	0.015
Nickel-chromium	5	12.024	0.021

DF : degree of freedom; P*: Means are highly statistically significant different at p ≤ 0.05%



Means with different letters are statistically significant different at p ≤ 0.05%
Figure (5): Duncun's multiple range test of porosity value for dental alloy

Showed that there was a significant difference between the mean of porosity value among different dental alloys at $p \leq 0.05\%$. The result of Duncun's test in Figure (5) showed that (Ti) alloy has the highest porosity value, this result can be explained in that titanium is an inherently difficult metal to cast because it has a high melting point and great reactivity at high temperatures with elements such as oxygen, hydrogen, nitrogen, and silicon. Reactivity results in chemical reactions between molten metal and atmospheric air, as well as with investment material, resulting in a surface contamination zone consisting of compounds of titanium, mainly with silicon (Si), phosphorous(P), and oxygen(O). The high level of hardness of these phases makes removal difficult, mechanical polishing complicated, and increases the risk of corrosion intraorally.[18] , in that contaminated zone that result from the reaction of titanium at high temperature with hydrogen, silicon (Si) and nitrogen from investment material other than atmospheric air oxygen which prevent the oxidation of titanium , so increase risk of corrosion intraorally. [18]

CONCLUSION

There is a significant difference between the castability and porosity value of the different dental casting alloys(Ti, Ni-Cr and Co-Cr). Ni-Cr alloy has the highest value of castability and the least value of porosity, Co-Cr alloy has intermediate values,while Ti alloy has the lowest value of castability and highest value of porosity. The differences between the catability values are related to variance between the melting temperature of the different casting alloys, the higher the melting temperature the less castability value.

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