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Evaluation the Effect of Heat Treatment on Corrosion Resistance of Cobalt Chromium Alloys

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Abstract
The purpose of present study is to evaluate and comparison the effect of different milling technique surface of CAD/CAM for milled Co-Cr alloy specimens.
Material and Methods: The diagnostic divides 20 disc-shaped specimens into 2 main groups, each consisting of 10 specimens for Co/Cr alloys according to their construction, the material used in hard milling and soft milling. All samples for further examination were prepared as drilled discs (diameter 15 mm, height 3 mm) whose surfaces were then finished and polishing with a diamond polisher. Scanning electron microscopy (SEM) images with energy-dispersive beam spectroscopy (EDS) were acquired for one sample in each set to assess the surface topography of the metal framework. All samples were degreased, and steam cleaned samples and heat treated in accordance with the complete firing procedure. Then scanning electron microscopy (SEM) after heating. Samples prepared in the lab for electrochemical corrosion testing were polarized and corroded in accordance with their electrical potential. Results were recorded using Levenes test and anova, with appropriate data analyzed for differences between groups. Results: The results of this study presented that the Descriptive statistics for corrosion test (mmpy) for all experimental groups revealed that the hard milling group mean was the lowest among all groups of the study is recorded (0005), followed, Group soft milling (.0071). The data were statistically analyzed using Welch's ANOVA and Levene's test which revealed highly significant differences ($p<0.01$) among groups. Conclusion: Corrosion resistance decreases in the following order: soft metal milling > hard metal milling, according to the obtained corrosion parameter values.

Introduction:

Metal-ceramic restorations are considered the best option for dental implants regarding quality, long before they were considered the best option for aesthetic purposes[1,2]. Metal frame cracks remain a significant problem in dentistry; it's difficult to repair with ceramic veneers [3]. Clinical studies report that up to 5% to 10% of ceramic veneers can fracture over a period of 10 years. Efforts to improve the bond between metal and ceramic substrates have increased the likelihood of fracture, even under ideal circumstances [4,5]. Clinicians encounter many problems due to errors in metal processing and ceramic stacking. In addition to that, many causes for these errors are due to iatrogenic causes,requires a significant amount of time and money[3]. Certain laboratory processes can damage objects made from metal-ceramic due to metal contamination, insufficient metal oxides, thermal expansion compatibility issues and voids in the alloy. Additionally, the presence of voids in the ceramic [3]. Frame metals such as titanium need to be milling or casted into a specific shape before they can be mass-produced. Creating dentures with fixed prosthetics, or fixed dental prothesis (FPD), requires more difficulty and manipulation from the dental technician. This is due to the low manufacturing volume of this process [6]. Technological advancements in computers and machines have led to mass production of customized items via rapid prototyping or rapid manufacturing. This allows the dental industry to save time and money on every single product they produce. With this in mind, FDP can be mass produced with a single step instead of multiple steps [7,9]. Dental milling technology allows for large-scale production of personalized dental restorations with high quality at low cost. This allows for lower costs for manufacturing, decreased wait times for patients, and a decreased likelihood of error during the manufacturing process [7-10]. Additionally, milling manufacturing techniques enable the creation of custom dental products that match[11] or even exceed [12] the quality of traditionally manufactured products. Nonetheless, methods and processing routes for the various alloys used to manufacture dental implants, including FDP, vary between these technologies [13]. Metal-ceramic FDP are a type of patient-specific medical device made from ceramics and metals that are bonded together. The purpose of this research was to gather data on current CAD-CAM milling techniques used to create single crowns or FDPs. This was accomplished by examining the working process, metal alloy type, and effects of each component on the finished product's surface. Additionally, several interactions between framework and veneered ceramical layers were examined.

Materials and Procedures

Specimen preparation

An ideal prepared twenty metal specimens of (15 mm in dimensions and 3 mm thickness) were used in this study. metal specimens was fabricated by using CAD / CAM system. Shown in Fig. (1). Twenty metal specimens were introduced in this study, which is divided into two groups based on the two different techniques as follows: Fig. (2).

Hard milling: 10 specimens metal Kera-DISK hard milling were constructed from (Eisenbacher DentalwarenED,GmbH).
Soft milling: 10 specimens metal. Kera-DISK Soft milling were constructed from (Eisenbacher DentalwarenED,GmbH).

Specimen fabrication

All milling and sintering protocols were followed in accordance with the manufacturer's instructions for the metal, and the CAD-CAM system was Exocad software (GmbH, Germany) was used to create the specimens; the same design is programmed for all types of metal CAD/CAM specimens. Then used carbide cutters bur for finishing and silicon diamond polisher bur for polishing and then, all the specimens were cleaned carefully with a steam cleaned to remove any metal oxide dust, traces left on the specimen.

Scanning Electron Microscope (SEM) with energy dispersive-ray spectroscopy (EDS)
With the aid of SEM many images captured with different magnification powers. The SEM images have provided the project with excellent visual images for the metal surface topology and details of all groups. Fig. (3) Shows the SEM for the hard and soft milling in the Fig. (4) before heat treatment.

Porcelain Firing Processes Simulated by Heat Treatment
All samples underwent a complete firing program (Vita, VACUMAT 6000M), which included two opaque materials, two dentin and one final glaze. HT corresponds to Vita, and the specific process of vacuumat 6000 M ceramics is shown in Table (1). In addition, scanning electron microscopy (SEM) observation after heating. Figure (5) hard milling, Figure (6) SEM after heat treatment of soft milling.

Electrochemical corrosion test
Electrolytes Solution preparation
Electrolytes used in artificial saliva conditions were prepared using laboratory-grade chemicals. The pH of the solution was maintained at exactly 7.4. The composition of the artificial saliva is given in Table (2).

Tafel Extrapolation
The electrochemical corrosion test system consists of a potentiostat, glass cells and electrodes. Use a one-liter cylindrical glass vessel with three electrodes: WE (working electrode), CE (counter electrode), and RE (reference electrode). According to the manufacturer's instructions, the samples were attached to a 1 cm diameter hole in the side of a cylindrical cell and exposed to the solution through the hole for one hour. With the circuit de-energized, the potential difference between the working and reference electrodes is recorded. This means the current is zero and the circuit is open. Open circuit potential is the name of this potential. Corrosion current density was measured by analyzing data values (current-voltage) using potentiostat software and a potentiostat-type corrosion meter CHI 604e (China)and measured the polarization curve for Co-Cr samples show in the Fig.(7). The setup shows a gradual change in the corrosion potential Ecorr and the corrosion current density Icorr, showing the corrosion behavior of the studied material. The usual corrosion rate depends on the balance between opposing electrochemical processes. The first is an anodic reaction that occurs when a metal is oxidized and gains electrons. On the other hand, cathodic reactions involve the removal of electrons from metals through reduction reactions. These two processes need to maintain a state of equilibrium in order to prevent net electron flow. Both reactions can take place on the same metal or on two separate metals connected by an electrical current.

Results:

Statistical analysis
The data was studied using the mean and standard deviation (SD) values, which were calculated using SPSS (Version 24.0). The corrosion resistances of different groups were compared using the Student's levence-test and Welch's ANOVA. There were many significant differences between the groups tested. Both p-values less than 0.001 were considered statistically significant; results were more significant when p-values were moderate. According to the descriptive analysis in Table (3), the greatest mean value of corrosion test was (.0071) recorded in soft milling group , while the lowest was (.0005), recorded in hard milling group as shown in the bar chart Fig.(8). In table (4). Post Hoc Tests The source of statistical difference was further investigated by analysis of data using Games-Howell test as in Table (4). The table shows a difference that is statistically significant between each two of the studied groups (hard milling and soft milling). Table (5): test of homogeneity of variances Levene's test. For the homogeneity of variance, there is heterogeneity of variance, and the variance between groups has a statistically significant difference, as shown in Table (5). Table(6):Welch's ANOVA, Welch's ANOVA test revealed a high statistically

significant difference with F(2,12.28)=85.57 and P-value= 6.16E-8 among the studied group as shown in Table (6).

Discussion:

Several academic studies have examined the effects of porcelain enameling on various metals used for dental prostheses. During the process, metal oxides develop on the alloy that diminish its ability to resist corrosion. The formation of a chromium oxide layer on Co-Cr dental alloys reduces the performance of their corrosion resistance. This is because different manufacturing processes produce alloy morphologies with different oxidation patterns [14-16]. Dentists need to understand how the alloy structure changes after the fabrication process. This is especially important for metals to ceramic transitions. Several researchers studied corrosion and the structure of dental alloys before and after oxidation. One researcher even studied the microstructure of alloys composed of CoCr and other elements. None of these studies found any changes in CoCr-based alloys when cycling temperatures [17]. After high-temperature testing, all samples passed with flying colors. The researchers of Jabari et al. [18] found that conventional metal-casting, milling and soft-metal milling all yielded the same results in their Co-Cr alloy creation. Furthermore, they discovered that porcelain firing had no impact on the structural integrity of the metal produced by these methods.

Conclusion:

The microstructure of the oxide covering the surface of the alloy after high-temperature imitation firing affects its corrosion resistance. After high temperature hardening, the MHM alloy has the most corrosion resistance because of its homogenous oxides.

Acknowledgement

I would like to thank Dr. Sabiha and my beloved family for helping get this work done.

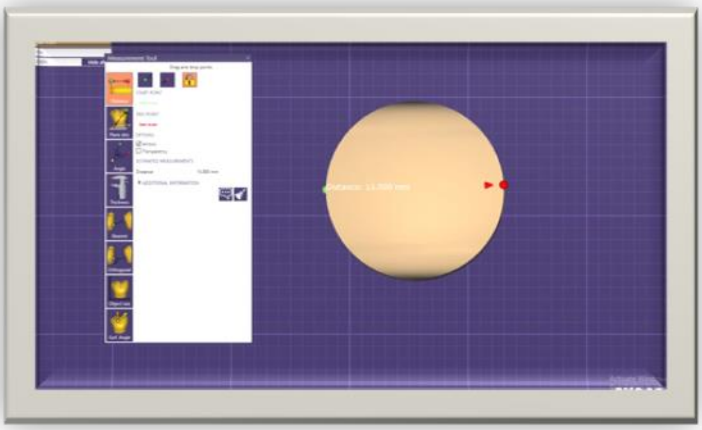

Fig. (1) Design of the sample by CAD CAM system

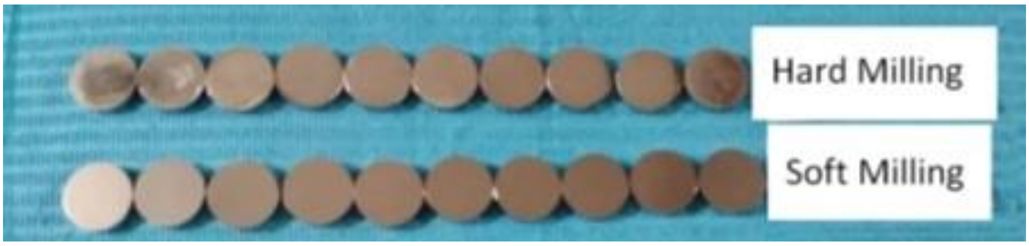

Fig. (2) Types of the samples

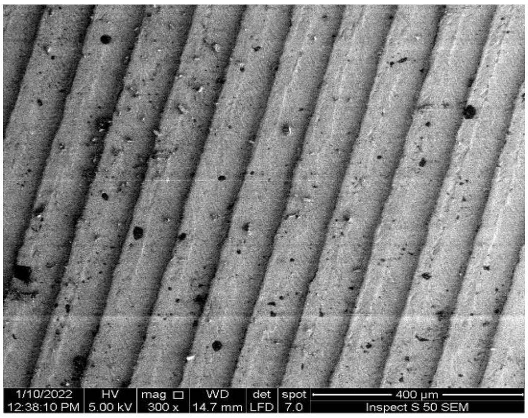

Fig. (3) SEM results for a hard milling sample before heat treatment.

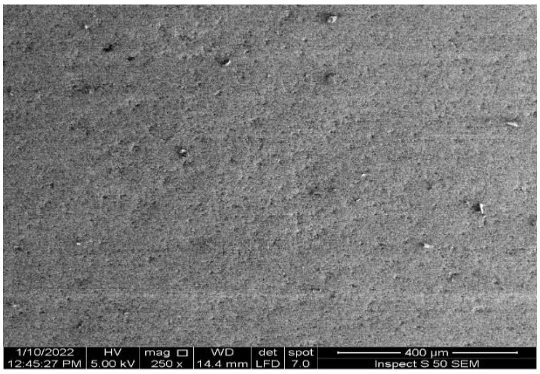

Fig. (4) SEM results for a soft milling sample before heat treatment.

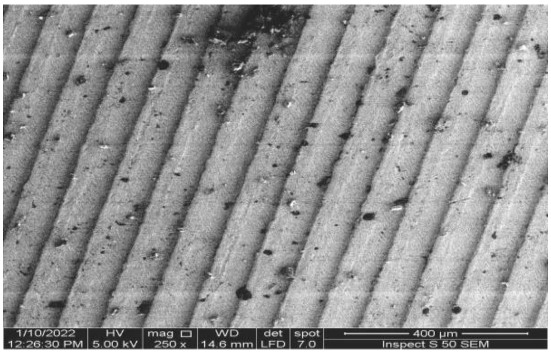

Fig. (5) SEM image of the sample surface during hard milling after heat treatment.

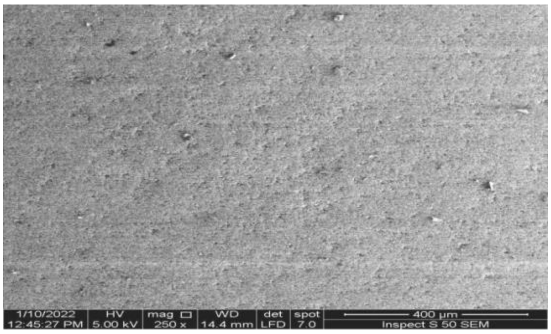

Fig. (6) SEM image of the surface of the soft milled sample after heat treatment

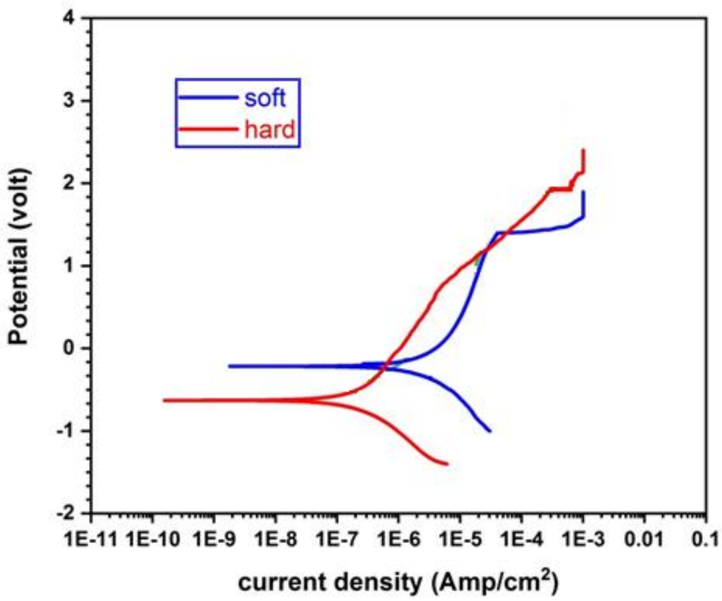

Fig. (7) Polarization curve for Co- Cr samples

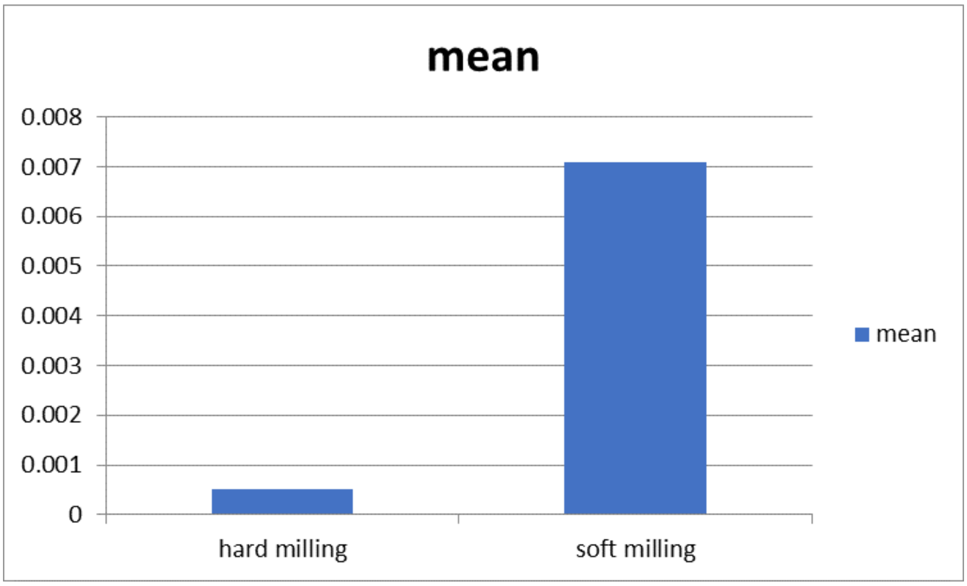

Fig. (8) Bar chart of the corrosion test (mmpy) for two hard milling and soft milling groups.

Table (1): processes of the applied heat treatment (HT).

Firing prosses	Preheating temp.°C	Drying time (min)	Rais of temp.(°C /min)	Final temp.	Holding time (min)	Total time
Oxidation	500	0	100	980	5	9.48
Opaque 1	500	2	79	950	1	8.38
Opaque 2	500	2	79	950	1	8.38
Dentine 1	500	6	55	930	1	15.54
Dentine 2	500	6	55	920	1	15.38
Final Glaze	500		80	920	1	6.15

Table (2): the chemical composition of Artificial saliva.

ITEM	DESICRIPTION	QUANTITY gm/1
1	NACL	0.70
2	KCL	1.30
3	KSCN	0.33
4	NaHCO3	1.50
5	KH2PO4	0.20
6	Na2HPO4	0.26

Table (3): Descriptive statistics for corrosion tests (mmpy) for all test groups

	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
				Lower Bound	Upper Bound		
Hard milling	.0005	.0002	6.507E-5	.0004	.0007	.0001	.0008
Soft milling	.0071	.0016	.0005	.0060	.0083	.0034	.0088
Total	.0037	.0031	.0005	.0026	.0049	.0001	.0088

Table (4): multiple comparisons using Games-Howell between each two of the studied groups
.

(I) Groups	(J) Groups	Mean Difference (I-J)	Sig.	95% Confidence Interval	
				Lower Bound	Upper Bound
Hard milling	Soft milling	-0.006*	0.001	-0.00802	-0.00517

*. The mean difference is significant at the 0.05 level.

Table (5): Homogeneity of variance test for corrosion test groups

Levene Statistic	df1	df2	Sig.
11.558	2	27	.001

Table (6): Welch's ANOVA test for corrosion test among all groups

	Statistic	df1	df2	Sig.
Welch	85.574	2	12.280	6.164E-8

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