Dentistry 3000

Vol 13, No 1 (2025)
ISSN 2167-8677 (online)
DOI 10.5195/d3000/2025.1088

Effect of Different Surface Treatment on Hardness of Dental Alloys

Evan Hussain Alwan[1], Sara Abdulbast Turki[2], Zaid Ezzat Abdul Majeed[2]

[1]Medical Technical Institute and [2]College of Health and Medical Technology, Middle Technical University, Iraq

Abstract

Objectives: Investigate different surface treatments on hardness of specimens produced by CAD-CAM milling techniques and selective laser melting technique. Materials and Methods: Thirty disc-shaped specimens were put into three main groups. Each group has ten examples of Co-Cr metal that were made of different materials. There were three kinds of milling: hard, selective laser melting (3D printer), and soft. Everything was cut up into 15 mm wide pieces that were 3 mm thick so that they could be used for more tests. The last step was to finish them off and make their surfaces smooth with a diamond grinder. A scanning electron microscope (SEM) was used to look at one example from each group and figure out how the surface of the metal frame was made. We tested how hard specimens were. We used the independent sample one-way ANOVA to determine differences. Results: Hardness tests for all test groups in the study showed that 3D printing usually gave the best hardness in the control and sandblast groups. Hard cutting gave the most hardness in the Laser group. We used One- and Two-way ANOVA and Levene's test to look at the data statistically. All the tests had p-values of 0.001, which means that the hardness values for each milling type are very different from one another. Conclusion: 3D printing generally resulted in the highest hardness values, and the control and sandblast groups hard milling showed superior hardness in the Laser group.

Open Access

Citation: Alwan EH et al. (2025) Effect of Different Surface Treatment on Hardness of Dental Alloys. Dentistry 3000. 1:a001 doi:10.5195/d3000.2025.1088
Received: October 21, 2025
Accepted: November 12, 2025
Published: December 12, 2025

Email: evan.hussain.alwan@gmail.com

Introduction

Pre-treatment of different CAD/CAM materials, such as ceramics, zirconia, resin-infiltrated ceramic, and resin-based composites, is required and will show differences in roughness, surface energy, and imperfections [1]. There is a need to establish best practices for obtaining a more favorable surface roughness and wear. It is known that depending on the material and the surface treatment, surface roughness, microhardness, volumetric loss, and height loss of enamel, are affected [2]. The chemical stability of CAD/CAM materials is also affected by surface treatment (glazed or polished) and unique signatures of ion elution can be detected [3]. The goal of our work was to determine what is the best approach to pretreat surface of CAD/CAM materials.

Material and Methods

Thirty metal specimens of 15 mm in dimensions and 3 mm thickness were used in this study. Metal specimens were fabricated by using CAD/CAM system and selective laser melting (3Dprinting) (Figure 1).

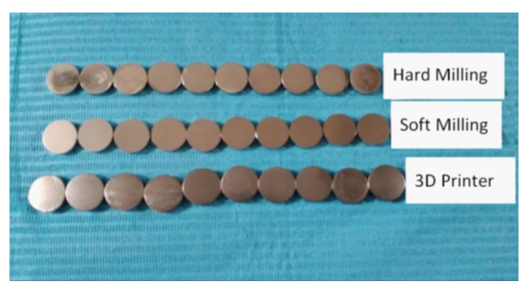

Figure 1. Specimens used in the study.

The specimens were put into three groups based on the three different ways:

Vol 13, No 1 (2025) DOI 10.5195/d3000/2025.1088

Hard milling: 10 specimens made from metal Kera-DISK hard milling (Eisenbacher DentalwarenED,GmbH).
Soft milling: 10 specimens metal made from Kera-DISK soft milling (Eisenbacher DentalwarenED,GmbH).
Selective laser melting: 10 specimens made of metal (Riton D150Dental 3D printer).

After printing, a carbide cutting bur was used to finish and a silicon diamond polisher bur was used to clean. Last, extra care was taken to clean each specimen with steam to get rid of any metal oxide dust that was still on them.

Scanning Electron Microscope (SEM) was used to study the metal surface topology and details of all groups (Figures 2 to 10).

Hardness test was done with an HV-1000Z Digital Micro Vickers Hardness Tester from HST in China. Before and after the surface treatment, a 9.8 N force for 20 seconds was used [4].

Surface was treated with a 1,064 nm Nd:YAG laser. When it was used to treat the surface, the laser was set to these settings: each spot has a 1.30 KV potential, 84.4 mJ of energy, 10 waves, and a 1Hz tone. The top of the sample was facing the laser beam in the opposite direction. This laser beam was bent by something with a focal length of 10 cm. The sample was put 10 cm from the lens with the help of a wheel with markings on it. A laser spot was put on the scale every five degrees to make a straight line around the edge of the item [5].

We used an aluminum oxide (Al_2O_3) sandblaster that was 110 mm long and 0.25 MPa for 30 seconds to make the surface of each specimen rough. A 10-minute ultrasonic bath with water was then used to clean the surface [2].

We used ANOVA, one-way, and two-way tests to compare hardness values for the groups.

Results/Discussion

The control group showed a mean hardness of 422.4 ± 1.32 Hv. The laser-treated group showed an increased mean hardness of 548.7 ± 1.59 Hv. The sandblast group exhibited the highest mean hardness of 554.2 ± 1.51 Hv (p=0.93).

By ANOVA, we found that the mean hardness (Hv) was significantly different between the groups (F=25,352.6, p=0.001). Post hoc analysis using Tukey's HSD test demonstrated that both the laser and sandblast groups had significantly higher mean hardness values compared to the control group with p-value of 0.001. Specifically, the laser group showed a mean increase of 126.37 Hv over the control group, while the sandblast group exhibited an even greater mean increase of 131.84 Hv over the control group. Furthermore, the sandblast group displayed a marginally higher hardness than the laser group, with a mean difference of 5.47 Hv, which was also statistically significant (p=0.001) as shown in Table 1.

For soft milling, the control group had a mean hardness of 447.3 ± 0.35 Hv. The laser group demonstrated a higher mean hardness of 452.1 ± 0.45 Hv. In contrast, lower mean hardness value was observed in the sandblast group with 443.6 ± 0.41 Hv (p=0.7).

The analysis of variance (ANOVA) for soft milling demonstrated a statistically significant difference in mean hardness (Hv) among the three groups (p=0.001). Post hoc analysis using Tukey's HSD test revealed that the laser group had a significantly higher mean hardness compared to the control group, with a mean difference of -4.76 Hv (p = 0.001). In contrast, the sandblast group exhibited a significantly lower mean hardness than the control group, with a mean difference of 3.75 Hv (p=0.001). Additionally, the laser group showed the highest mean hardness among all groups, significantly outperforming the sandblast group with a mean difference of 8.51 Hv (p=0.001) (Table 2).

The control group had a mean hardness of 596.3 ± 0.16 Hv. The laser group showed a lower mean hardness of 386.9 ± 0.39 Hv. Conversely, the sandblast group exhibited the highest mean hardness of 706.2 ± 0.42 Hv (p=0.7).

The analysis of variance (ANOVA) for 3D printing demonstrated a statistically significant difference in mean hardness (Hv) among the three groups (p=0.001). Post hoc analysis using Tukey's HSD test revealed that the control group had a significantly higher mean hardness compared to the laser group, with a mean difference of 209.43 Hv (p=0.001). However, the control group exhibited significantly lower mean hardness than the sandblast group, with a mean difference of -109.85 Hv (p=0.001). Among the groups, the laser group demonstrated the lowest mean hardness, in comparison to the sandblast group, with a mean difference of -319.29 Hv (p=0.001) (Table 3).

For the control (Hv) group, the mean hardness values for hard milling, soft milling, and 3D printing were 422.41 ± 1.32, 447.38 ± 0.35, and 596.35 ± 0.17, respectively. Among these, the 3D printing group exhibited the highest hardness value.

In the laser (Hv) group, the mean hardness values for hard milling, soft milling, and 3D printing were 548.79 ± 1.60, 452.15 ± 0.45, and 386.91 ± 0.39, respectively. Unlike the control group, hard milling had the highest hardness values, while the 3D printing group demonstrated the lowest values in this category.

For the sandblast (Hv) group, the mean hardness values for hard milling, soft milling, and 3D printing were 554.26 ± 1.51, 443.64 ± 0.42, and 706.21 ± 0.42, respectively. Like the control group, 3D printing demonstrated the highest hardness values, while soft milling showed the lowest.

The analysis indicates a statistically significant differences in hardness values across the milling types with p-value is 0.001, suggesting a statistically significant difference in hardness among hard milling, soft milling, and 3D printing.

When you use the Bonferroni post hoc test, these gaps get even bigger. A big difference (p=0.001) was found between hard milling and soft milling. There was also a difference between hard milling and 3D printing and soft milling and 3D printing. There's no doubt that these two steps are different.

The p-value analysis for specific group differences confirms statistically significant differences in hardness across milling types within each group.

In the control (Hv) group, all comparisons yielded p-values of 0.001, indicating significant differences in hardness values. The difference between hard milling and soft milling was -24.97 (p=0.001), suggesting that soft milling resulted in slightly higher hardness.

The difference between hard milling and 3Dprinting was -173.93 (p=0.001), showing that 3D printing significantly increased hardness. Similarly, soft milling vs. 3D printing exhibited a difference of -148.95 (p=0.001), confirming that 3D printing had the highest hardness values.

In the laser (Hv) group, the hard milling vs. soft milling comparison showed a difference of 96.63 (p=0.001), indicating that hard milling resulted in significantly higher hardness than soft milling. The difference between hard milling and 3D printing was 161.87 (p=0.001), confirming that 3D printing had the lowest hardness values. Similarly, soft milling vs. 3D printing had a difference of 65.23 (p=0.001), further supporting the trend that 3D printing resulted in the lowest hardness in this group.

In the sandblast (Hv) group, significant differences were also observed, with hard milling vs. soft milling showing a difference of 110.61 (p = 0.001), confirming that hard milling resulted in significantly higher hardness. The difference between Hard milling and 3D printing was -151.95 (p = 0.001), indicating that 3D printing exhibited significantly higher hardness than hard milling. The largest difference was seen between soft milling and 3D printing, at -262.56 (p =

0.001), highlighting a substantial increase in hardness with 3D printing.

Overall, the p-values of 0.001 across all comparisons confirm highly significant differences in hardness values between milling types within each group. The findings reinforce that 3D printing generally resulted in the highest hardness in the control and sandblast groups, whereas Hard milling showed superior hardness in the laser group (Figure 11).

When orthodontic brackets had their surface treated with laser [6], they showed the highest shear bond strength when compared to sandblasting. On the other hand, bond strength of posts to dentin used in endodontic treatment was affected by the type of material but not by the surface treatment [7]. Laser surface treatment of composites used to repair bond strength of CAD/CAM resin nanoceramic showed improved micro-shear bond strength values, particularly short-pulse lasers [8].

Like our results, previous work has shown that surface treatment by sandblasting followed by acid etching was more effective that their individual applications and laser irradiation in terms of resin CAD/CAM ceramics retention [9]. However, combining laser and sandblasting for surface treatment of zirconia and metal resulted rougher surfaces than sandblasting alone, especially for metal [10].

3D printing can produce very strong dental alloys with high durability. Alloys like titanium and cobalt-chrome are commonly used for 3D printing and offer excellent strength for dental prosthetics. Certain 3D printed metals can be even stronger than their conventionally manufactured counterparts. The final hardness of the printed alloy is influenced by the base metal, the energy input of the printing process, and any subsequent heat treatments [11-13].

Conclusions

Hardness values varied. 3D printing generally resulted in the highest hardness values in the control and sandblast groups, whereas hard milling showed superior hardness in the laser group.

References

1. Roughness, surface energy, and superficial damages of CAD/CAM materials after surface treatment. Strasser T, Preis V, Behr M, Rosentritt M. Clin Oral Investig. 2018 Nov;22(8):2787-2797. doi: 10.1007/s00784-018-2365-6.

2. Effect of surface treatments on wear and surface properties of differentCAD-CAM materials and their enamel antagonists. Çakmak G, Subaşı MG, Sert M, Yilmaz B.J. Prosthet Dent. 2023 Mar;129(3):495-506. doi: 10.1016/j.prosdent.2021.06.023.

3. Effect of different surface treatments and thermomechanical aging on the ion elution of CAD-CAM materials. Sert M, Çakmak G, Subaşı MG, Donmez MB, Yilmaz B. J Prosthet Dent. 2022 Jun;127(6):926.e1-926.e10. doi: 10.1016/j.prosdent.2022.03.021.

4. Al Jabbari YS, Barmpagadaki X, Psarris I, et al. Microstructural, mechanical, ionic release and tarnish resistance characterization of porcelain fused to metal Co–Cr alloys manufactured via casting and three different CAD/CAM techniques. J Prosthodont Res 2019; 63:150-156.

5. Yilmaz A, Akyil MÅ, Hologlu B. The effect of metal primer application and Nd: YAG laser irradiation on the shear-bond strength between polymethyl methacrylate and cobalt-chromium alloy. Photomedicine and Laser Surgery. 2011;29:39-45.

6. Shear bond strength of orthodontic brackets to specimens fabricated from temporary restorative materials by 3D-printing, CAD/CAM technology, and the conventional technique after surface treatment by sandblasting and laser. Alijani S, Fotovat F, Rezaei Soufi L, Alafchi B, Mohammadkhani MH. Int Orthod. 2023 Dec;21(4):100790. doi: 10.1016/j.ortho.2023.100790.

7. Surface treatment effects on bond strength of CAD/CAM fabricated posts to root canal dentin. Oguz Ahmet BS, Egilmez F, Ergun G, Cekic Nagas I. Am J Dent. 2019 Jun;32(3):113-117.

8. Effects of Er,Cr:YSGG Laser Surface Treatments and Composites with Different Viscosities on the Repair Bond Strength of CAD/CAM Resin Nanoceramic. Degirmenci A, Unalan Degirmenci B. Polymers (Basel). 2024 Aug 2;16(15):2212. doi: 10.3390/polym16152212.

9. The impact of various surface treatments and Er-YAG laser irradiation on the bond strength of resin matrix CAD/CAM ceramics to resin cement. Usta Kutlu İ, Yerliyurt K. Lasers Med Sci. 2025 Apr 21;40(1):201. doi: 10.1007/s10103-025-04460-5.

10. Effect of Combined Surface Treatments on Surface Roughness and Resin Bond Strength to Y-TZP Ceramic and Nickel-Chromium Metal Alloy. Sayin Ozel G, Okutan Y, Oguz Ahmet BS, Ozdere E. Photobiomodul Photomed Laser Surg. 2019 Jul;37(7):442-450. doi: 10.1089/photob.2018.4590.

11. 3D printed zirconia used as dental materials: a critical review. Su G, Zhang Y, Jin C, Zhang Q, Lu J, Liu Z, Wang Q, Zhang X, Ma J.J Biol Eng. 2023 Dec 21;17(1):78. doi: 10.1186/s13036-023-00396-y.

12. Three-Dimensional Printing and CAD/CAM Milling in Prosthodontics: A Scoping Review of Key Metrics Towards Future Perspectives. Cioloca Holban C, Tatarciuc M, Vitalariu AM, Vasluianu RI, Antohe M, Diaconu DA, Stamatin O, Dima AM.J Clin Med. 2025 Jul 8;14(14):4837. doi: 10.3390/jcm14144837.

13. Effect of Surface Treatments on the Bond Strength of Computer-aided Design and Computer-aided Manufacturing Lithium Disilicate to Restorative Materials: A Systematic Review. Shoorgashti R, Ehsani SS, Ducret M, Rokhshad R.Eur J Prosthodont Restor Dent. 2024 Nov 29;32(4):423-433. doi: 10.1922/EJPRD_2777Shoorgashi11.

Vol 13, No 1 (2025) DOI 10.5195/d3000/2025.1088

Table 1. Summary of comparisons for hard milling specimens.

		Mean	SD	Std. Error	"95% Confidence Interval for Mean"		F-test	P-value
					Lower Bound	Upper Bound		
Hard milling	Control (Hv)	422.4	1.32	0.41	421.46	423.36	25352	0.001
	Laser (Hv)	548.7	1.59	0.50	547.64	549.92		
	Sand blast (Hv)	554.2	1.51	0.47	553.17	555.33		
	Total	508.4	61.9	11.31	485.34	531.62		
Post hoc analysis (Tukey HSD)								
		Mean Difference					P-value	
Control (Hv)	Laser (Hv)	-126.37364					0.001	
	Sand blast (Hv)	-131.84160					0.001	
Laser (Hv)	Sand blast (Hv)	-5.46797					0.001	

Table 2. Summary of comparisons for soft milling specimens.

		Mean	SD	Std. Error	"95% Confidence Interval for Mean"		F-test	P-value
					Lower Bound	Upper Bound		
Soft milling	Control (Hv)	447.3	0.35	0.11	447.1	447.6	1086	0.001
	Laser (Hv)	452.1	0.45	0.14	451.8	452.4		
	Sand blast (Hv)	443.6	0.41	0.13	443.3	443.9		
	Total	447.7	3.56	0.65	446.3	449.0		
Post hoc analysis (Tukey HSD)								
		Mean Difference					P-value	
Control (Hv)	Laser (Hv)	-4.76252					0.001	
	Sand blast (Hv)	3.74538					0.001	
Laser (Hv)	Sand blast (Hv)	8.50789					0.001	

Table 3. Summary of comparisons for Laser treatment.

		Mean	SD	Std. Error	"95% Confidence Interval for Mean"		F-test	P-value
					Lower Bound	Upper Bound		
3D printer	Control (Hv)	596.3	0.16	0.05	596.2	596.4	21958	0.001
	Laser (Hv)	386.9	0.39	0.12	386.6	387.1		
	Sand blast (Hv)	706.2	0.42	0.13	705.9	706.5		
	Total	563.1	134.7	24.5	512.8	613.4		
Post hoc analysis (Tukey HSD)								
		Mean Difference					P-value	
Control (Hv)	Laser (Hv)	209.43					0.001	
	Sand blast (Hv)	-109.85					0.001	
Laser (Hv)	Sand blast (Hv)	-319.29					0.001	

Vol 13, No 1 (2025) DOI 10.5195/d3000/2025.1088

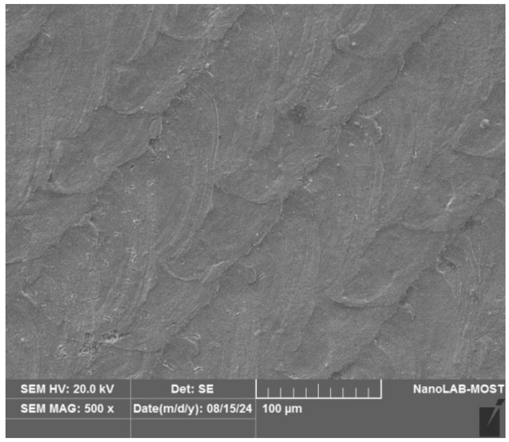

Figure 2. The scanning electron microscope (SEM) of 3D printer before surface treatment.

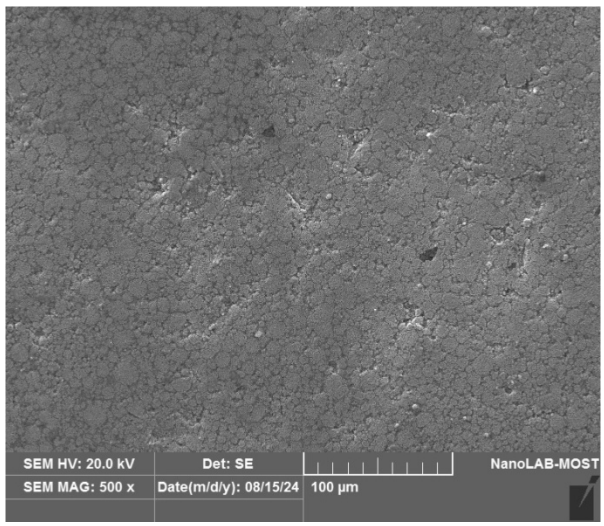

Figure 3. The scanning electron microscope (SEM) of soft metal before surface treatment.

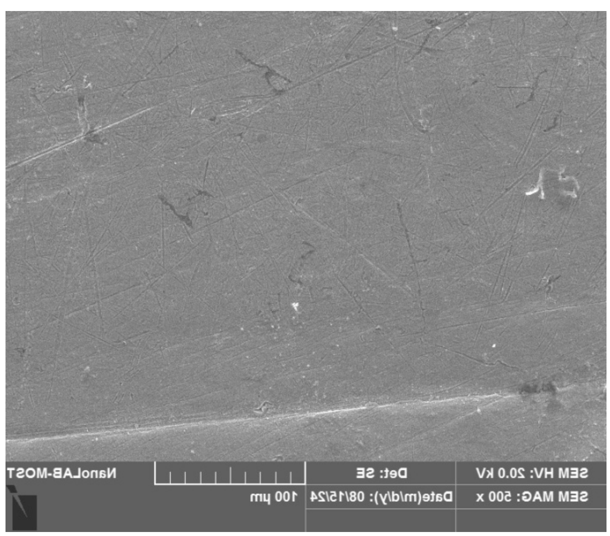

Figure 4. The scanning electron microscope (SEM) of hard metal before surface treatment.

Vol 13, No 1 (2025) DOI 10.5195/d3000/2025.1088

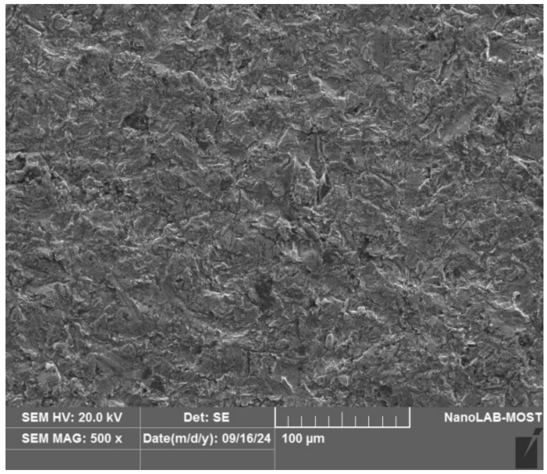

Figure 5. The scanning electron microscope (SEM) of soft metal after surface treatment sandblast.

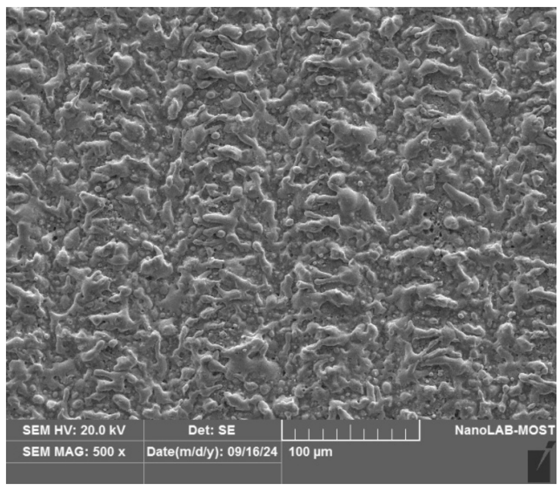

Figure 6. The scanning electron microscope (SEM) of soft metal after surface treatment laser.

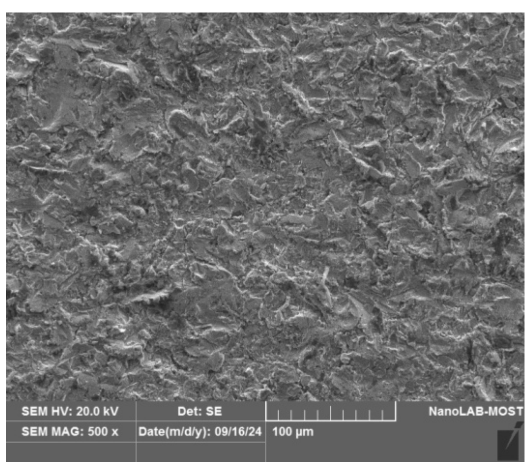

Figure 7. The scanning electron microscope (SEM) of (3Dprinter metal) after surface treatment sandblast.

Vol 13, No 1 (2025) DOI 10.5195/d3000/2025.1088

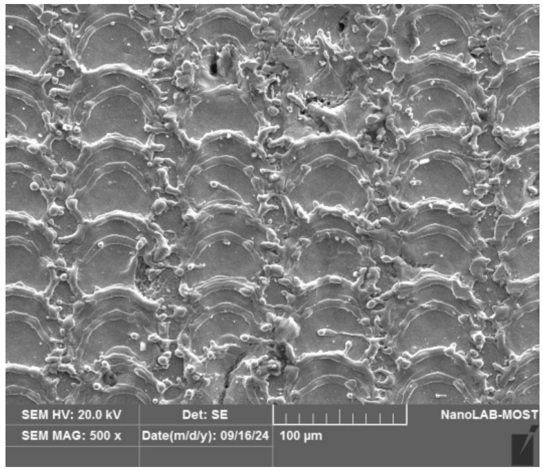

Figure 8. The scanning electron microscope (SEM) of (3Dprinter metal) after laser surface treatment.

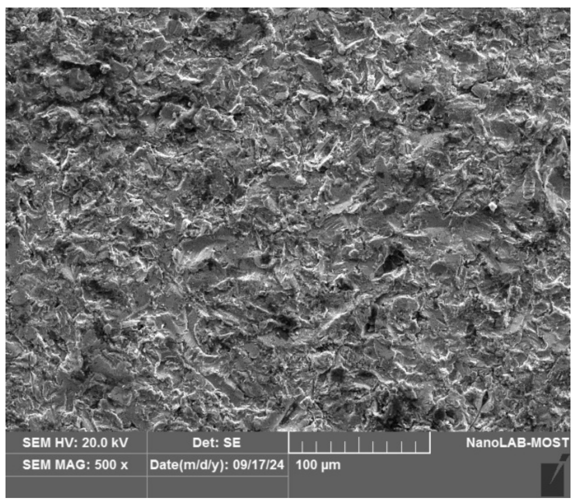

Figure 9. The scanning electron microscope (SEM) of (hard metal) after sandblast surface treatment.

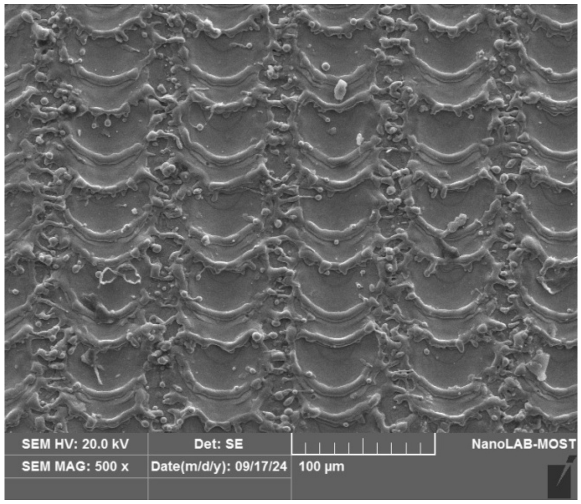

Figure 10. The scanning electron microscope (SEM) of (hard metal) after laser surface treatment.

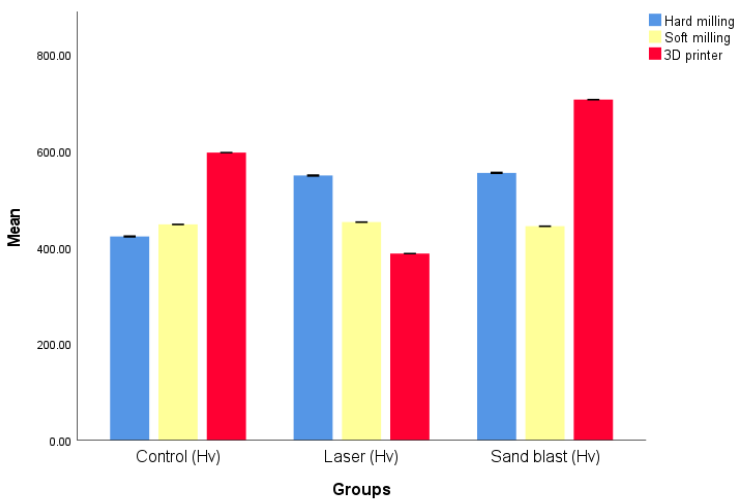

Figure 11. Hardness comparisons for the study.