Mechanical and microstructural evaluation of CoCr alloys manufactured via selective laser melting (SLM)

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Abstract

Dental prosthesis components are widely produced with CoCr alloys. New near net shape techniques has been used nowadays as an alternative route. The aim of this study was evaluated the mechanical properties and the microstructural characterization of CoCr dental alloys manufactured by SLM and to investigated the correlation of chemical composition between mechanical properties of standard specimens. Yet there is an important knowledge of performance properties, dimensional, mechanical and microstructural of this process as reported recently works (MERGULHÃO et al., 2015a, 2015b; PODESTÁ et al., 2015).

Materials and Methods

The Co-Cr alloys gas atomized was provided in accordance with SLM process granulometric range (20-50 μm). The confirmation of the chemical composition by fluorescence spectrometer X-ray energy dispersive (Shimadzu EDX-720 equipment) of powders is presented in Table 1. Figure 1 shows the flow chart of the process, images of tests and specimens.

Table 1 – Chemical compositions (weight %) of the Co-Cr alloys powder gas atomized.

ELEMENTS	ALLOYS		
	ASTM F75	**EOS**	**Remanium Star**
Co	63,86 ± 0,07	62,00 ± 1,00	64,60 ± 0,20
Cr	28,96 ± 0,04	25,00 ± 1,00	26,70 ± 0,20
Mo	7,02 ± 0,01	7,00 ± 1,00	-
W	-	6,00 ± 1,00	8,00 ± 0,05
Nb	-	< 0,20	0,27 ± 0,01
V	-	< 0,20	0,19 ± 0,01
Fe	0,16 ± 0,01	0,20 ± 0,10	0,10 ± 0,01
S	-	-	0,19 ± 0,01
Si	-	-	0,18 ± 0,01

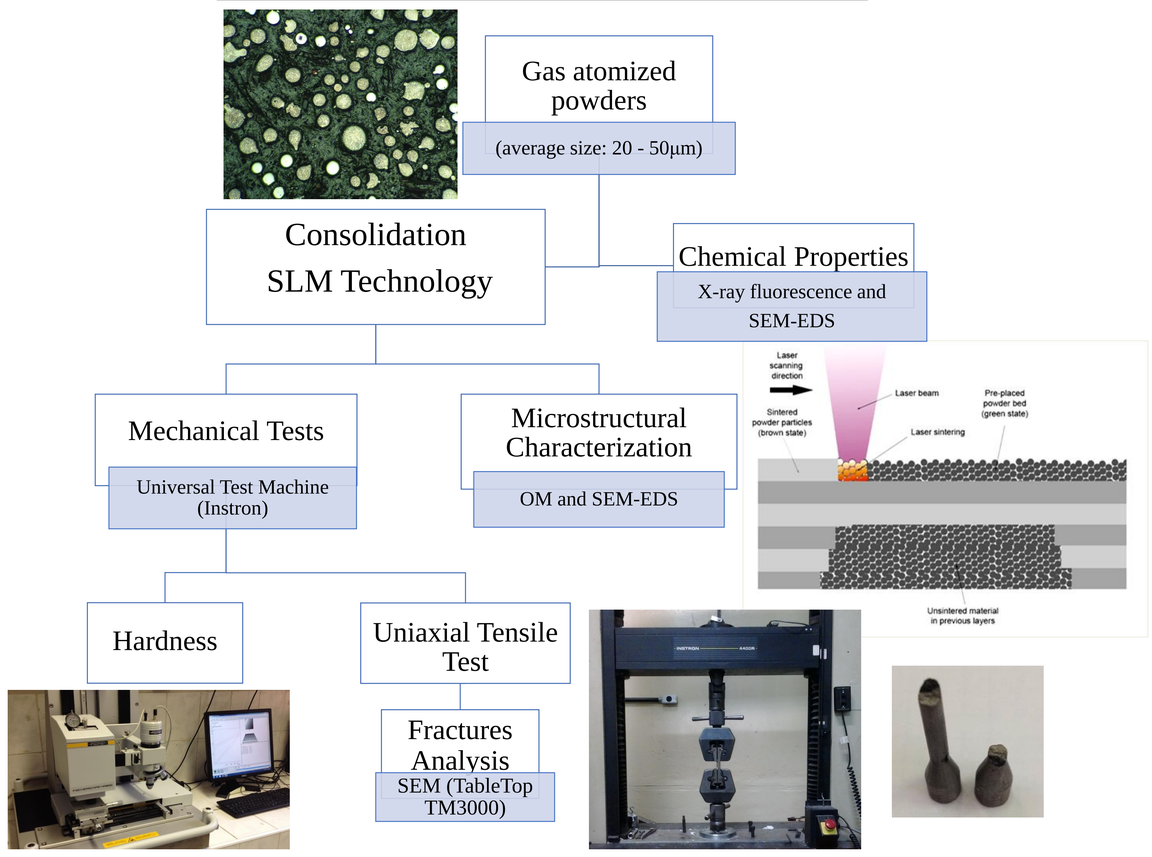

Figure 1 – Flow chart of the process of this study and images of tests and specimens.

Results

The mechanical data results and the verification with minimum mechanical properties required by the standards are presented in Table 2 and stress curves Figure 1. The mechanical properties obtained for the consolidation of the alloy CoCr alloys by SLM technique fits the type 5 as manufactured.

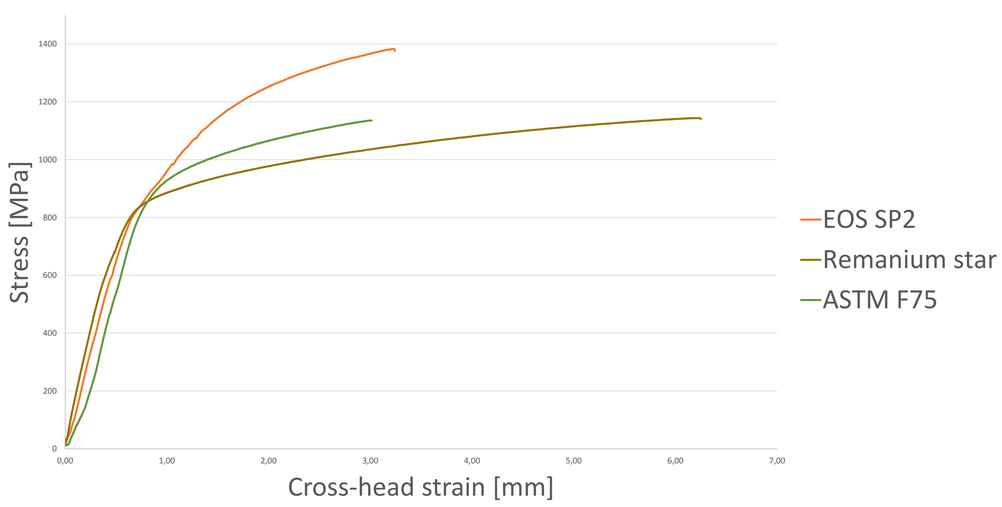

Figure 2 – Tensile curves of stress-strain SLM CoCr alloys.

Table 2 – Comparison of the results (mean and standard deviation) of mechanical properties in the SLM samples of CoCr alloys compared with the mechanical properties required according to the standards ISO 22674.

Reference	Type	0,2% YS [MPa]	Elongation [%]	E [GPa]	UTS [MPa]	Hardness [HV0.3N/10s]
ASTM F75	SLM	731,50 ± 40,31	13,73 ± 5,32	276,70 ± 12,63	1136,95 ± 0,92	420,62 ± 21,16
EOS SP2	SLM	788,40 ± 158,12	7,68 ± 0,80	265,58 ±7,24	1327,39 ± 63,40	509,91 ± 20,54
Remanium Star	SLM	578,00 ± 74,03	24,00 ± 4,46	283,36 ± 6,09	1125,37 ± 21,58	502,46 ± 8,90
ISO 22674:15	1	80	18	-	-	-
	2	180	10			
	3	270	5			
	4	360	2			
	5	500	2	150		

The microstructure of the specimens was evaluated by OM and SEM as showed in Figure 3. It is possible to observe the homogeneous microstructure and absence of second phases. The SLM technique provides formation of ultrafine grains within ellipsoid geometry formed by the fusion laser beam action

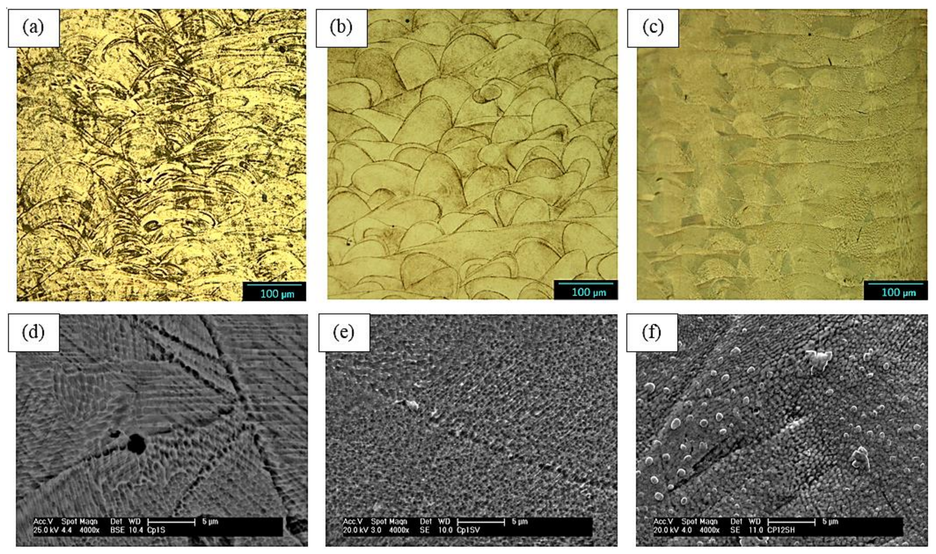

Figure 3 – Images of microstructural analysis after etch CoCr alloys. OM micrographs of: (a) ASTM F75 sample, (b) EOS SP2 sample and (c) Remanium star sample. SEM micrographs of: (d) ASTM F75 sample, (e) EOS SP2 sample and (f) Remanium star sample.

The fractures of the specimens are showed in the Figure 4. The formation of "dimples" is homogeneously distributed in the microstructure of the samples, representing a ductless and toughness fracture.

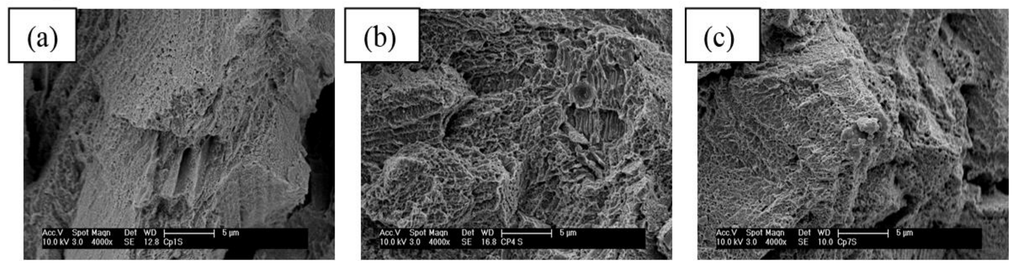

Figure 4 - SEM images of tensile fractures. SLM samples: (a) ASTM F75; (b) EOS SP2; (c) Remanium star.

Conclusions

The SLM technique allowed obtaining samples with great mechanical properties satisfying the standard ISO22674. Fracture analysis indicate a ductile regions by the presence of dimples.
The microstructural characterization of selective laser melting allowed to obtain samples with improved chemical homogeneity over the molten sample and a refined grains, originated by the rapid and localized solidification.
The laser melting technology proved an unique microstructure in differents Co-Cr alloys without segregation of seconds phases, ensuring a promising manufacture process to fabrication prosthetics and dental implants.

Acknowledgments

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