



Analytical Services Division

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a division of Sheffield Assay Office

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Outcome

Precious Metal Reclamation at SAO

Chemical Composition of Dental Scrap

Melting , Sampling and Assaying

Case Study

Conclusions



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Reclamation of Precious Metal Scrap



Analytical Service Business Scope

Melts and assays 25-50kg of scrap per week (20-40 melts)

Composition varies widely from one melt to another

Segregation within each melt likely to occur

Customer requirements

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Chemical Composition: Dental Alloy Classification

Precious Metal Alloys

Gold-based

- Au, Pd, Pt \geq 75%
- Au 80%-45%; Pd 1-40%
- Ag 25%-5%; Pt, In, Ir, Cu, Zn, Sn

Palladium-based

- Au, Pd, Pt \geq 75% (most Pd with Ag)

Semi-Precious Metal Alloys

Low Gold

- Au, Pd, Pt (25%-75%)
- Au $<$ 20% ; Pd \sim 20%
- Ag $<$ 40%; In, Ir, Cu, Zn, Sn, Ru, Co

Silver-based

- Ag-Pd (with/out Cu)

Base Metal Alloys

Co 50%-70% and Cr 25%-35%

- Co-Cr-Mo-Si-Mn
- Co-Cr-Mo-w-Si
- Co-Cr-Mo-Ti

Ni 60%-80% and Cr 10%-30%

- Ni-Cr-Mo-Si
- Ni-Cr-Mo

Au $<$ 45% is replaced by Pd

Pd $>$ 10% gives to alloy white colour

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Dental Waste Composition Tested

Other element contents:

Porcelain (SiO₂, Na₂O, Al₂O₃, K₂O) 60%

Ni 15%

Sn 2%

Cr 8%

Co 4%

Cu 5%

Mo 5%

In 1%

Class 1

Au ~45%; Pd ~5%

- Ag ~30%; Pt < 0.5%

Class 2

Au ~30%; Pd ~5%

- Ag ~15%; Pt < 0.5

Class 3

• Au < 15%; Pd ~35%

- Ag ~20%; Pt < 0.5

Class 4

• Au < 7%; Pd ~20%

- Ag ~7%; Pt < 0.5



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Melting Dental Scrap

Furnace and Crucibles

- Induction furnace
- Clay graphite crucible / Zirconium crucible
- At least 2 steps melting process

Fluxes and Additives

- Borax ($\text{Na}_2\text{B}_4\text{O}_7$)-scrap (1:1)
- CaF_2 -Borax (1:5)
- Cu metal/ CuO :10-200%

Casting and Cleaning

Drying and Weighing



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Sampling Dental Bars

Methods:

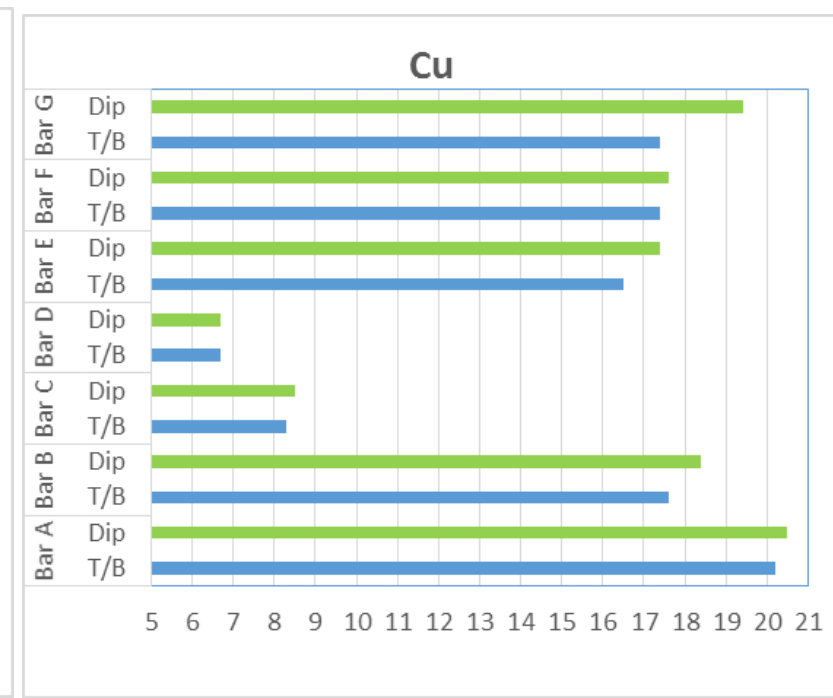
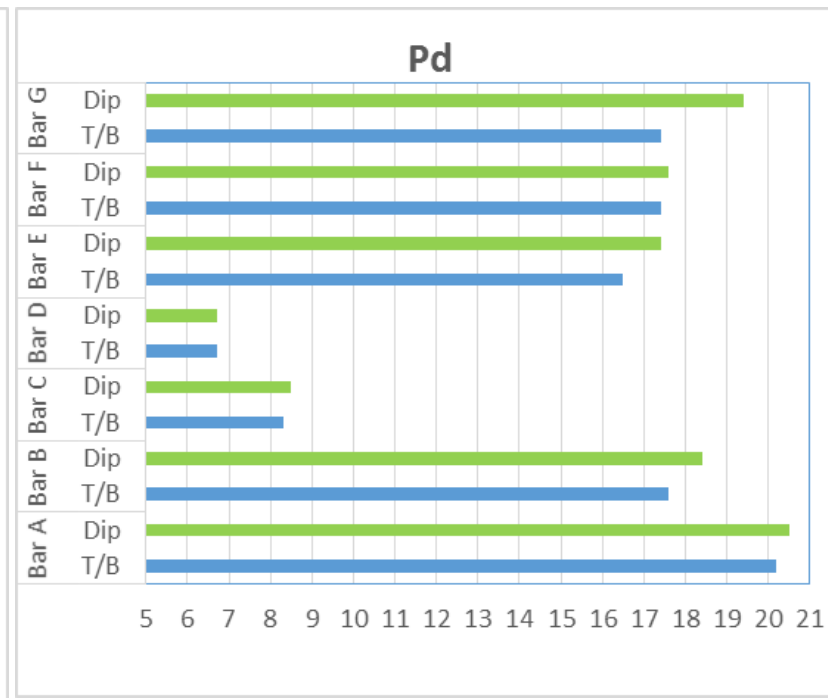
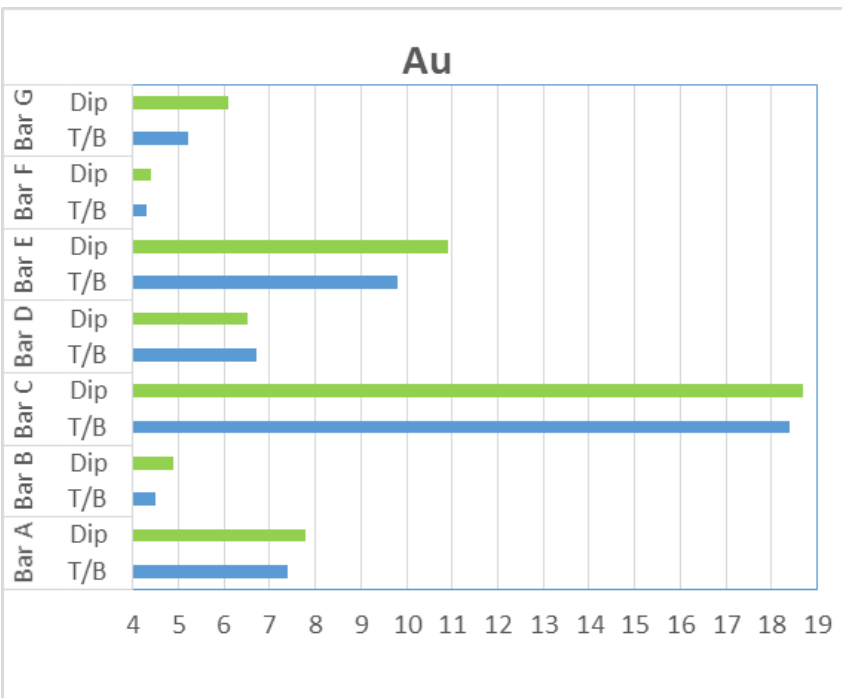
- Dip Sampling . A quartz tube of 6mm diameter is used to extract ~50mm length of molten metal (any non-metallic layer is excluded from the test portion). The portion is flattened to facility further acid extraction.
- Drilling Sampling. Three drilling portion minimum are taken from opposite corners of the top and bottom sides. Drills from different bar sides are analysed separately.

Au			Pd			Cu		
Top (%)	Bot (%)	Dif (%)	Top (%)	Bot (%)	Dif (%)	Top (%)	Bot (%)	Dif (%)
32.89	32.13	2.3	3.3	3.21	2.8	42.2	41.6	1.5
7.09	7.63	7.3	19.54	20.77	6.1	34.7	36.2	4.2
4.48	4.48	0.0	4.91	4.92	0.2	14.3	14.3	0.0
46.73	47.09	0.8	17.55	17.62	0.4	35.8	35.7	0.4
18.54	18.27	1.5	8.28	8.31	0.4	58.1	58.3	0.3
4.03	4.64	14.1	16.1	18.6	14.4	49.6	44.2	11.5
4.68	4.92	5.0	13	13.1	0.8	43.2	42.6	1.4



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Sampling Dental Bars: Comparison dip vs top/bottom



Dip sampling Top/bottom

Au is ~5% higher in the dip trial
 Pd is ~3.5% higher in the dip trial
 Cu is 2% higher in the dip trial



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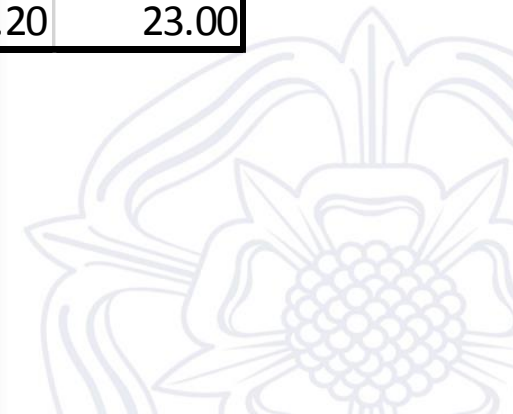
Assaying Dental Bars

Analytical techniques

- Cupellation Au: Au content above 10%
- ICP-OES – Pd, Pt , Au (<10%)
- Potentiometric with H₂SO₄/HNO₃ or XRF- Ag (>1%)

Comparison between two Analytical Techniques for Au (%)										
Cupellation	31.81	47.93	18.52	24.77	21.88	23.09	23.54	24.18	20.46	23.09
ICP-OES	31.97	46.91	18.40	24.04	22.06	22.22	21.89	24.07	20.20	23.00

Other PM contents for material studied above <10%



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Case Study



Bottom



Middle



Top



Original Chemical composition		
	BAR I	BAR II
Ag (%)	10.7	4.8
Au (%)	12.8	7.9
Pd (%)	30.9	23.7
Pt (%)	0.76	0.39

BAR DIMENSIONS
~2.5Kg
160mm*65mm*35mm



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Case Study

BAR I: Precious metal contents (%) in each section and compared with original

	Ag			Au			Pd		
	Top	Bot	Aver	Top	Bot	Aver	Top	Bot	Ave
Part A	2.7	16.8	9.7	5.52	15.4	10.5	21.6	34.9	28.3
Part B	3.5	16.1	9.8	5.78	15.6	10.7	21.4	34.5	28.0
Part C	2.2	15.0	8.6	5.22	15.6	10.4	21.5	35.3	28.4
Avg ABC	9.4			10.6			28.2		
Avg original	10.7			12.8			30.9		

There is a clear differences in all PM contents between top and bottom sides

Bottom side shown generally higher content on PM

BAR II: Precious metal contents (%) in each section and compared with original

	Ag			Au			Pd		
	Top	Bot	Aver	Top	Bot	Aver	Top	Bot	Ave
Part A	7.6	22.9	15.2	5.5	15.4	9.8	21.6	34.9	25.1
Part B	6.4	18.4	12.4	5.8	15.6	9.0	21.4	34.5	24.8
Part C	7.8	15.7	11.8	5.2	15.6	9.0	21.5	35.3	24.6
Avg ABC	13.1			9.3			24.8		
Avg original	4.8			7.9			23.7		

There is not clear content trend between original and section comparison



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BAR I and II PM contents (%) after being re-melted with 50% Cu

	Ag		Au		Pd		Pt	
	Top	Bot	Top	Bot	Top	Bot	Top	Bot
BAR I	7.71	6.00	7.99	6.98	21.2	18.4	0.41	0.48
BAR I (avg)	6.86		7.49		19.80		0.45	
BAR II	6.29	5.63	4.87	4.73	16.0	15.5	0.27	0.27
BAR II (avg)	5.96		4.80		15.75		0.27	

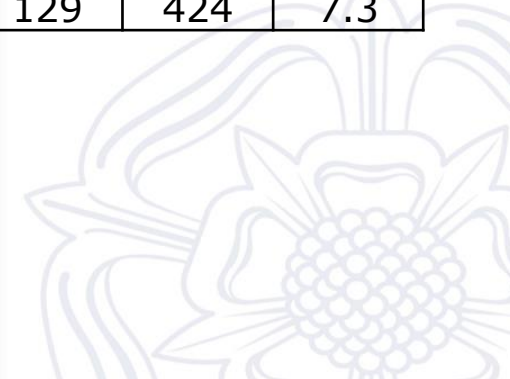
Addition of Cu improves homogeneity significantly but does not solved completely due to variation in chemical composition of dental scrap

BAR I Total PM weight in gr

	Weight	Ag	Au	Pd	Pt
Original as sold	2084.5	223	267	644	9.6
Avg ABC	2052.0	192	216	509	6.6
Bar with 50% Cu	3010.8	207	226	596	13.5

BAR II Total PM weight in gr

	Weight	Ag	Au	Pd	Pt
Original as sold	1833.2	87.3	177	434	7.1
Avg ABC	1804.0	237	171	477	6.0
Bar with 50% Cu	2693.7	161	129	424	7.3



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Conclusions

- To achieve a Homogenous dental bar is challenging as there is significant difference in nature from dental scrap melt to another
- Physical separation of metal likely after melting
- Dip sampling seems to produce slightly higher results than average between top/bottom sampling
- Acid extraction follow by ICP-OES analysed seems to give lower result to fire assay
- Addition of Cu/ CuO helps significantly to produce an homogenous material





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Thank you very much

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