ETRUSCAN GOLD DENTAL APPLIANCES

EVIDENCE FOR EARLY "PARTING" OF GOLD IN ITALY THROUGH THE STUDY OF ANCIENT PONTICS

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ABSTRACT: By 630 BCE Etruscan metallurgists in central Italy had begun to apply their impressive goldworking skills in the production of dental bridges (pontics). The achievement of this technological development began with the fabrication of a hollow gold tooth mounted on a thin band of gold. The band served to anchor this dental appliance to the healthy teeth adjacent to the gap filled by the gold tooth. The original use of these Etruscan appliances was to provide a decorative replacement for one or more maxillary incisors that had been deliberately removed in a cultural process known as dental ablation (or tooth evulsion). Soon after 630 BCE the Etruscan technology for making these replacements shifted to using natural human teeth, often those that had been deliberately removed, or carved ivory examples. These "false" or replacement teeth were mounted in a gold band where they were held in place by various methods. The more common means was to drill and rivet the replacement in place using gold pins. Less commonly a part of the band was formed into a rectangular bezel into which the false or replacement tooth could be set like a jewel.

The purity of the gold used in the fashioning of these appliances has been a question for some time. Gold commonly appears naturally alloyed with silver (electrum), always with less than 2% copper. The process of "parting" these metals is believed to have developed in the area of Lydia in Turkey ca. 560 BCE. An earlier date for a similar development in gold refining in Etruria is suggested. Possible impacts of such a development on Etruscan "dentistry" are noted.

INTRODUCTION

The variations in shapes and the decorative functions of Etruscan gold "dental" appliances (also called pontics, or dental bridges) are now extremely well known (Becker 1992, 1994, 1999a, 2002; also 1997). The available data base, however, lacks specific studies of the elemental composition of these appliances except for one example. The proportions of gold (Au), silver (Ag), copper (Cu) and various trace elements in these appliances may reveal a great deal regarding developments in Etruscan metallurgical abilities. In particular, the ability to separate silver from gold, a natural pairing called electrum, is a skill believed to have developed in the Old World about 560 BCE. The earliest known Etruscan dental appliance is securely dated at ca. 630 BCE, but at present its composition remains to be evaluated.

Electrum is the name for all natural alloys of gold, in nuggets and other forms, as well as any human made blends of gold and silver. "Almost all gold occurs naturally containing some silver ... typically ... between about 5% and 40% by weight" (Ramage and Craddock 2000b: 11). Silver can comprise as much as 45% of natural electrum, but levels below 20% are so rare that Vaûte (1995) suggests that all such alloys must be intentionally generated. Almost certainly any
gold occurring with less than 5% silver or other metals has been purified, and most gold over 800 fine (800 parts per 1000) has been processed to achieve that high percentage of gold. Copper is the only other metal found in natural gold above trace levels, but rarely in amounts greater than 1% or 2%. Thus gold alloys with copper levels above 2% are almost certainly human products. The total weight of the platinum group elements (PGE) in natural gold alloys is far less than 1% by weight (Ramage and Craddock 2000b: 13; for details see Craddock 2000c: 238-244).

Some 2000 years ago Pliny noted the ease with which gold can be worked (see Humphrey et al 1998: 207-208; Craddock 2000c: 233), but the Etruscans had already been masters of the art for over 600 years! Gold is the most malleable of the eight precious metals. Pure gold (24 carat) is 999 fine or 99.9% gold. Gold at 22 carat (916 fine) has 91.6% purity, and proportionally decreases to 12 carat or 50% gold (500 fine). Gold can be rolled and drawn into thin wire, or hammered into a foil 0.08 micrometers thick (3.33x10^-6 inch). Gold leaf used for gilding is extremely thin beaten gold foil, measuring between 0.00008 and 0.00010mm thick (Craddock 2000a: 32, 51 n.39; from Untracht 1982: 662). Craddock defines gold leaf as any gold sheets so thin that they cannot support their own weight. More significantly, Craddock (2000a: 32, 51 n.42) observes that it is possible to produce leaf from gold alloy that contains small amount of copper and "appreciable quantities of silver," perhaps as much as 50%. This suggests that gold leaf can be produced from natural electrum. I suspect that 93% or higher pure gold may be more effectively beaten into useful gold foils for gilding than is electrum.

The melting point of pure gold is 1,063°C, but drops to 1,000°C with only 5% copper. An 80/20 gold to copper alloy will melt at 870°C. (Pingel 1995: 395). Specific details regarding the electrochemistry and other aspects of gold are provided by Möller (1995). Copper generally is added to harden gold and also provides the advantage of reducing the melting range, but also copper reduces tarnish resistance. A 70/30 (Au/Cu) ratio alloy has the greatest hardness; silver levels have relatively little impact on hardness (see Table 1). Of use in understanding the variations in strength of various alloys are the Copper-Gold Phase Diagrams provided by O'Brien (1989: 253, fig. 12-6) or by Pingel (1995; also Martinelli and Spinella 1981). Both platinum and palladium can be added to gold alloys to counter tarnish problems, retard grain growth and increase hardness. Various modes by which concentrations of copper might vary in ancient gold alloys are discussed by Ontalba et al. (1998: 856).

### TABLE 1.

<table>
<thead>
<tr>
<th>Gold Casting</th>
<th>VHN*</th>
<th>Au</th>
<th>Pd</th>
<th>Ag</th>
<th>Cu [±]</th>
<th>Used for:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type I</td>
<td>59-90</td>
<td>83.0</td>
<td>-</td>
<td>11.5</td>
<td>5.5</td>
<td>Small inlays, low stress</td>
</tr>
<tr>
<td>Type II</td>
<td>90-120</td>
<td>77.0</td>
<td>1.0</td>
<td>13.0</td>
<td>9.0</td>
<td>Most inlays, single crown</td>
</tr>
<tr>
<td>Type III (Hard)</td>
<td>120-150</td>
<td>74.0</td>
<td>4.0</td>
<td>12.0</td>
<td>10.0</td>
<td>Most crowns &amp; bridges</td>
</tr>
<tr>
<td>Type IV (Extra hard)</td>
<td>(achieved by adding 2.0 to 7.0 Pt)</td>
<td>150 minimum</td>
<td>Partial dentures</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Quenched 150 minimum
Hardened 220 minimum