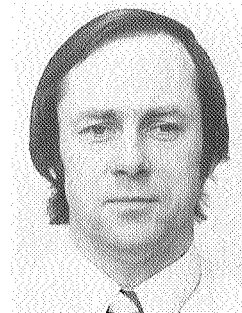


Near-alpha titanium — a potentially new orthodontic archwire material

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Abstract:

High tensile stainless steels and Elgiloy (a) have been until recently the dominant orthodontic archwire materials. The introduction of Nitinol (b) and T.M.A. (c) has extended the choice. In the present work a new wire near-alpha titanium has been studied. Its tensile properties have been found to be similar to gold, whilst its elastic deflection (springback) is comparable to high tensile stainless steel. It has been shaped into representative Edgewise and Begg archwires to which tipback bends were added, and in so doing has brought "Variable Modulus Orthodontics" much closer to practical reality.

Keywords: orthodontic wire, titanium, Young's modulus

INTRODUCTION

For many years austenitic stainless steel and cobalt-chrome-nickel (Elgiloy) (a) have been the dominant wire materials for the fabrication of orthodontic archwires. This has been due to their excellent combinations of corrosion resistance, stiffness, resilience, formability and cost. Both materials have similar moduli of elasticity and comparable yield strengths (proof strengths) and tensile strengths. With such a restricted choice of materials, wire selection for archwires depended upon size alone to achieve the desired forces. Fine wires (0.3 mm, 0.35 mm) were used for starting wires whilst heavier gauges (0.4 x 0.55 mm) were employed for finishing operations. Fine wires, however, present problems in that they are easily distorted.

In an attempt to overcome this problem two other alloy wires have been marketed under the names "Nitinol" (b) and T.M.A. (c) (Beta-Titanium). Both of these alloys have much lower values of Young's modulus, yield strength and tensile strength than either stainless steel or Elgiloy (Elgiloy and True chrome). Because of this they have opened up the possibility of "Variable Modulus Orthodontics" (Goldberg and Burstone 1979) in which the desired forces can be achieved via a combination of wire size and materials, not merely by size alone.

In the present work the mechanical properties and surface finish of a potentially new orthodontic wire have been examined. A comparison is then made with already existing wire materials.

MATERIALS and METHODS

The new alloy wire is titanium based and contains 5.5-6.75% Al, 3.5-4.5% V, 0.03% max Fe, 0.0125% max H. In equilibrium at room temperature it possesses the close packed hexagonal (CPH) alpha structure. However, due to the sluggishness of the transformation from the high temperature body centred cubic (BCC) beta phase and this latter's retention at room temperature, it is usually described as a near-alpha alloy. It was produced and processed to wire 2.6 mm diameter by I.M.I. Titanium (U.K.) and is known commercially as IMI318. It was then cold reduced (by A. J. Wilcock, Whittlesea, Australia) to 0.5 mm diameter, solution heat treated at 850-880 degrees Celsius, straightened by axially stressing at 450-470 degrees (C) in argon†, cut to 0.6 metre lengths and finally age hardened at 470 degrees (C) for 8 hours in argon. Some of these lengths were centreless ground to 0.45 mm, 0.40 mm and 0.35 mm diameters whilst other lengths were pickled using hydrofluoric acid (6%) and nitric acid (30%).

Specimens from each process route have been tensile tested in an Instron 1134 tensile testing machine at a cross-head speed of 0.5 mm/minute. Young's modulus, yield strength,

tensile strength and ductility were measured. The surfaces of both pickled wire and centreless ground wire were examined in a JEOL JSM35 scanning electron microscope.

RESULTS

1. Tensile Tests

The results obtained from the different samples on tensile testing are given in Table 1. It is evident that the centreless ground wires are significantly stronger and more ductile than the pickled wires.

2. Scanning Electron Microscopy

The surfaces of the pickled and centreless ground 0.45 mm diameter wire samples are shown in Figure 1. These show that the pickled wire is far rougher than the centreless ground wire, a feature which is evident to the touch and is an easy way of distinguishing the two types apart. Another feature is the cracks which are present in the centreless ground wire. Relatively few of these were observed in the 0.40 mm diameter wire and none in the 0.35 mm diameter. In addition they were much smaller in the 0.40 mm wire. Their effect on the mechanical properties and corrosion resistance is undoubtedly detrimental.

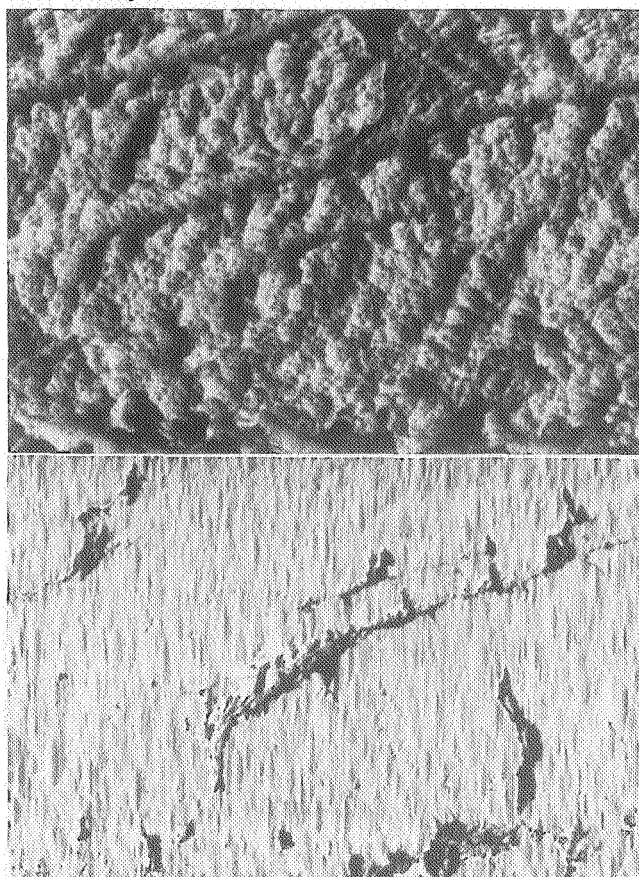


Figure 1. Scanning Electron Microscope photographs of the surfaces of (a) the pickled wire, and (b) the centreless ground wire. Magnification X150.

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(a) Rocky Mountain Orthodontics, Denver, Colorado

(b) Unitek Corporation, Monrovia, California

(c) American Orthodontic Corporation, Glendora, California

†A process developed by A.J. Wilcock, Scientific and Engineering Equipment.

DISCUSSION

The reason for the higher strength and greater ductility of the centreless ground wires is unclear. Two possible reasons are: (a) surface grinding removes an oxygen embrittled layer from the surface, and (b) the formation of a compressive stress state in the surface layer. The latter does not seem to be able to explain the increase in ductility, but whatever the case this factor requires further investigation.

The possible potential of this near-alpha titanium alloy wire is best seen by comparison with wire materials already in use. This comparison is made using the tensile data in Table 2.

It is evident that the near-alpha titanium wire is very similar in its tensile properties to gold in that it has comparable proof strength and Young's Modulus. This, combined with the corrosion resistance of titanium alloys in the oral environment make it an excellent substitute for gold. In addition, it will be considerably cheaper than gold. Its importance to the clinician is that it occupies the gap between the lower modulus alloys Nitinol and beta-titanium and the high strength, high modulus stainless steel and Elgiloy. Thus, low forces combined with a low load deflection rate can be obtained with this alloy in relatively large gauges. This reduces the inherent tendency of archwires manufactured from fine gauge wire to deform in the mouth. For example, 0.016" (0.4 mm) near-alpha titanium wire is equivalent to 0.013" (0.34 mm) stainless steel, and 0.016" x 0.022" near-alpha titanium is equivalent to 0.016" x 0.018" stainless steel.

In terms of elastic deflection or springback (using the ratio: tensile strength to Young's modulus from Table 2) near-alpha titanium is similar to high tensile stainless steel at 1.39×10^{-2} . Hence, the clinician can activate the archwire more

with this new alloy without permanent deformation with the same force levels as he can with these stainless steel wires.

As an indication of its formability the new wire has been shaped into representative Edgewise and Begg arch wires to which tipback bends were added. However, some 0.45 mm diameter samples of both pickled and centreless ground wires were not easily formed into loops without breaking. This is probably due to the poor surface finish of the pickled wire or the surface cracks in the centreless ground wire as 0.40 mm diameter wire was bent into loops without encountering any problems. It is clear, therefore, that the surface finish plays an important role in the formability of this wire and that attainment of a good surface finish is a necessary step in the production sequence. Centreless grinding can achieve such a surface finish. It is evident also that the centreless grinding operation must be taken to the point where only the occasional small crack is present in order to achieve this situation.

CONCLUSIONS

This near-alpha titanium alloy possesses some mechanical characteristics such that it occupies a position previously held by gold. The low forces combined with a low load deflection rate which can be achieved by its use make it a very useful addition to the range of orthodontic archwire materials. This, together with its elastic deflection, being similar to that of stainless steel and its formability indicate a wire which can be used by the clinician with confidence and will bring variable modulus orthodontics much closer to practical reality.

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REFERENCES

- BURSTONE, C.J. and GOLDBERG, A.J. (1980)
Beta-titanium: A new orthodontic alloy.
Amer.J.Orthod. 77: 121-132
- Elgiloy and True Chrome.
Advertising literature by Rocky Mountain Orthodontics, Denver, Colorado.
- GOLDBERG, J. and BURSTONE, C.J. (1979)
An evaluation of beta titanium alloys for use in orthodontic appliances.
J. Dent Res. 58: 593-599.
- KUSY, B.P. and GREENBERG, A.R. (1982)
Comparison of the elastic properties of nickel-titanium and beta-titanium archwires.
Amer.J.Orthod. 82: 199-205
- HAZEL, R.J. Unpublished data.

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Table 1: Tensile Test Results.

Sample	0.2% Proof Stress (MPa)	Tensile Strength (MPa)	Elongation %	Young's Modulus (GPa)
1. 0.45 mm dia. Pickled (5 samples)	1093 ± 18*	1139 ± 25	1.8 ± 0.6 (2.6)	86.0 ± 2.7
2. 0.45 mm dia. Centreless Ground (3 Samples)	1180 ± 8	1252 ± 10	2.6 ± 0.6 (3.2)	90.1 ± 1.3
3. 0.40 mm dia. Centreless Ground (2 samples)	1177	1251	4.2 (4.6)	87.1
4. 0.35 mm dia. Centreless Ground (2 samples)	1160	1244	3.9 (4.0)	95.3

* Mean ± standard Deviation

N.B. Only two samples were available in the smaller diameters.

The values of elongation in brackets are the maximum values obtained.

Table 2. A comparison of the tensile data of orthodontic archwires.

	Gold ⁽¹⁾	Stainless Steel ⁽⁵⁾	Elgiloy ⁽²⁾	Nitinol ⁽¹⁾	Beta-Ti ⁽¹⁾	Near-alpha-Beta-Ti
Proof Stress (MPa)	344-1100	1900-3000	2131	—	1169	1180
Tensile Strength (MPa)	—	2200-3300	2338	1650	—	1252
Young's Modulus (GPa)	103	158-199	196-206	33	64.6	90.1