METHODS OF TESTING THE MECHANICAL PROPERTIES OF ORTHODONTIC WIRES

A report submitted in partial fulfilment of the requirements for the degree of Master of Dental Surgery

BY

KATHERINE RUTH ALLEN B.D.S.

Department of Dentistry

Faculty of Dentistry

The University of Adelaide

South Australia

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NOMENCLATURE

Unless otherwise stated the symbols have the following meaning:

A	area in mm squared
at	alpha-titanium
a	length or distance
b	breadth
bt	beta-titanium
d	diameter
d	the length of the diagonal of a square in micrometers
D	length of the diagonal in millimetres
DPN	Diamond Pyramidal Hardness Number
E	elastic modulus (or Young's modulus)
ep	electropolished
ep 25	electropolished for 25 seconds
F	measured load
fn	frequency of vibration
GPa	Giga Pascal
h	height
HV	Vickers hardness number
Hz	hertz (cycles per second)
I	moment of inertia
I	second moment of area
l	distance
m	mass
m	metres
nt	nickel-titanium
P	applied load
ps	pulse straightened
rpm	revolutions per minute
se nt	superelastic nickel-titanium
SEM	scanning electron microscope
ss	stainless steel
ssp	stainless steel premium
sspp	stainless steel premium plus
sspp ps	stainless steel premium plus, pulse straightened
sss	stainless steel supreme
sssp	stainless steel special plus

TEM	transmission electron microscope
TMA	titanium molybdenum alloy
TTR	transition temperature range
v	velocity
y	extension
YS	yield strength

σ	stress
ε	strain
ε	maximum flexibility
ρ	density
μm	micrometre
μs	microsecond

Dimensions

018 ≡ 0.018" (0.45mm)

Note: Some orthodontic wires are supplied in imperial units but all scientific studies should use metric.

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SUMMARY

In orthodontics a light, continuous force is thought to be most desirable as it results in maximum tooth movement and minimum patient discomfort and damage to the supporting tissues. With an increasingly large selection of wires on the market, selecting the most appropriate archwire for a given clinical situation is difficult. Choice may be based on the feel of the wire, clinical impression or from standard mechanical test data.

Of these, the modulus of elasticity is of primary importance since it determines the stiffness of an archwire, which in turn governs the force delivered by an appliance. The elastic modulus of a material has been thought to be a constant value for a particular material. It was therefore surprising, to find such a wide range of elastic modulus values quoted in the literature.

The principal aim of this study was to evaluate available experimental techniques for the determination of Young's modulus. Tensile, bend, resonance and speed of sound tests were performed. Elastic modulus values were calculated from the data acquired, allowing the different testing methods to be compared.

Emphasis was placed on stainless steel wires as fundamental questions remain, despite their long history of use. In addition some of the newer archwires such as nickel-titanium, alpha-titanium and beta-titanium were tested.

It has been proposed that stiffness appeared to be affected when a wire was electropolished. For this reason, wires were tested in the as-received condition and after electropolishing, to ascertain whether elastic modulus was affected.

Elastic modulus values both in the as-received state and after electropolishing were lower than the textbook quoted values, and were difficult to reproduce. Electropolishing did not appear to have a consistent effect on elastic modulus.

It was proposed that these heavily drawn wires exhibited anisotropic behaviour and that this may account for the low elastic modulus values. Wires were annealed to reduce the anisotropic behaviour prior to testing. This had a varied effect on elastic modulus with values for some wires increasing while others decreased.

A wire's surface may be more heavily cold worked than the central region. Wire specimens were embedded in Bakelite and polished to allow the maximum wire diameter to be microhardness tested. Microhardness tests did not detect differences between the surface layer and inner core. If a surface difference is present it is very small.

The surface appearance of wires was also assessed in the SEM, in the as-received state and after electropolishing. As-received wires showed a very elongated grain structure giving a fibrous appearance typical of a heavily cold worked structure. The striations were removed with electropolishing, leaving a smooth surface (apart from occasional deep gouges).

To enable any textural differences between the wire surface and inner core to be assessed, wires were deliberately maltreated to the point of fracture. Fractured surfaces were then assessed in the SEM.

It is important to remember that it is the microstructure and in turn the chemical composition and thermomechanical processing during manufacture, that determines the mechanical properties of wires. For these reasons, assessment of the microstructure in the TEM was attempted. Specimen preparation proved difficult and no suitable foils were produced. Ability to assess the microstructure would improve our understanding of these materials and assist with the development of more advanced materials.

SIGNED STATEMENT

This report contains no material which has been accepted for the award of any other degree or diploma in any university. To the best of my knowledge and belief, it contains no material previously published or written by another person, except where due reference is made in the text of the report.

KATHERINE R. ALLEN

I give consent to this copy of my thesis, when deposited in the University Library, being available for photocopying and loan.

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