AN INVESTIGATION INTO PHYSICAL AND MICROSTRUCTURAL PROPERTIES OF ORTHODONTIC WIRES AND CHANGES INCIDENT TO BENDING.

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

by

S.L. WHITTLE
B.D.S. (Adel)

Department of Dentistry,
Faculty of Dentistry,
The University of Adelaide,
South Australia.

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ABBREVIATION	DEFINITION
ADSL	Australian Dental Standards Laboratory
AISI	American Iron and Steel Institute
AJW	A.J. Wilcock Scientific and Engineering Equipment
ASTM	American Society for Testing Materials
bcc	Body centred cubic
CAD	Computer Aided Design
CEMMSA	Centre for Electron Microscopy and Microstructural Analysis, The University of Adelaide.
E	Young's modulus of elasticity
fcc	Face centred cubic
kg	Kilograms
kV	Kilovolts
µA	Microamperes
µm	Micrometres
mm	Millimetres
MPa	Megapascals
N	Newtons
nA	Nanoamperes
Pa	Pascals
PDL	Periodontal ligament
SEM	Scanning Electron Microscope

SUMMARY

Anecdotal accounts of an unacceptable breakage rate of high tensile stainless steel orthodontic wires have been received by their manufacturer, A.J. Wilcock of Whittlesea, Victoria. It would seem that these allegations are directly related to problems in the successful clinical manipulation of the wire with orthodontic pliers. It was decided to investigate some of the bending characteristics of the high tensile 0.016 inch (0.4064 millimetre) 'premium plus' grade Wilcock[1] wire to identify any cause for a higher than expected breakage rate.

Those physical properties considered important in the behaviour of orthodontic wires are: stiffness, strength, springback, formability, joinability, biocompatibility and stability, and friction. These physical properties have been thoroughly investigated, and form the basis for Industrial Standards in a number of countries. However, an examination of the literature concerning stainless steel orthodontic wire reveals disagreement as to which tests best describe the requirements of such fine wires for clinical orthodontic purposes.

Tensile testing of aged wire specimens has indicated that strength may change over time. Results from this investigation found that ultimate tensile strength for aged specimens was up to ten per cent greater than the ultimate tensile strength determined from the same batches of wire by the Australian Dental Standards Laboratory in 1985. Thus the ageing of wire may increase

[1] A.J. Wilcock Scientific and Engineering Equipment, Whittlesea, Victoria, Australia.

its strength, although, differences in the subtleties of testing technique cannot be eliminated as a cause of these differences.

The structure of fine, high tensile orthodontic wires is considered to contribute significantly to their behaviour but has received very little attention in the available literature. This is particularly evident in the inability to calculate Young's modulus accurately (ie: a numerical expression of a materials' relative rigidity). 'As-received' wire was used to produce specimens that simulated clinical manipulation by bending. These were then prepared by longitudinal grinding and polishing and subsequent etching. The internal diameter of these specimens was viewed by Scanning Electron Microscopy to investigate the microstructure in and around the bent region.

Different pliers were used to place bends of varying degrees in a series of wire specimens, and the microstructural features were compared across the diameter of straight and bent portions of the wire. When compared with stainless steel tipped pliers, unmodified tungsten carbide tipped pliers showed a more severe deformation on the concave, internal region of the bend. Modified tungsten carbide tipped pliers however, showed little if any damage to this same region of the wire

No breakages were found during specimen preparation when using a standard clinical bending technique. Therefore, in order to study fracture behaviour, forces inconsistent with those used during normal clinical manipulation were deliberately used to fracture some wire specimens. This was best achieved by bending the wire very quickly with a snapping motion. Scanning Electron Microscopy suggests the wire has a lamellar structure, and that specimen failure is consistent with the 'peeling' seen clinically when faulty manipulation causes unwanted fractures. 'Fast' fractures of this type seem to originate on the convex, external surface of the bend. A comparison was made between this type of fracture pattern and those seen in some specimens collected in the clinical situation, where the initial failure point was also found on the external, convex surface of the bend.

It is suggested that to avoid fractures in high tensile stainless steel wires, two factors in manipulation are critical. Firstly, bends should be made slowly with the fingers. Secondly, unmodified tungsten carbide tipped pliers should be used with caution, or, the edges of the square beaks modified by smoothing with a cratex type wheel.

Force levels at different points along an arch-wire were measured as a function of the various types of 'canine hooks' employed in the Begg technique, and, according to the amount of anchorage bend placed in the wire. Results suggest that different types of 'canine hooks' have negligible effect on anterior force values, but, consistent with beam theory, forces exhibited in the premolar region are about ten times greater than in the incisal region. These results suggest that caution should be exercised when attaching premolars to an arch-wire designed for anterior intrusion as a part of the Begg technique. This same caution should be exercised if molar tipping is undesirable.

SIGNED STATEMENT

This report contains no material that has been accepted for the award of any other degree or diploma in any other university or tertiary institution. 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.

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Samuel L. Whittle.

Fifteenth day of December 1995.

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