A Slide Rule for Archwire Selection

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In orthodontic tooth movement tissue reorganizations actually carry the tooth to a more desirable relationship. The strategy is to apply to a tooth a controlled force of sufficient magnitude, duration and distance to initiate the appropriate tissue reorganization.

Force is generally applied through the medium of preloaded wire springs or archwires of various configurations. A number of popular techniques employ a progression of archwires sequentially applied to maintain constancy of force through the range of application. One of the many factors influencing rational choice of techniques in arch components is the relative flexural rigidity of the available orthodontic wires. Heretofore, however, comparative flexural rigidity of the common orthodontic wires has been available only in relatively unusable tabular form (Table 1).

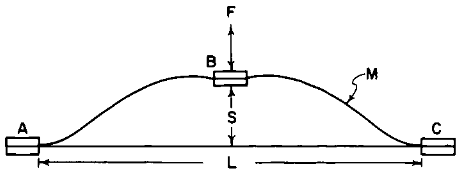
The purpose of this paper is to develop the mathematical basis for the comparison of relative flexural rigidity of the popular orthodontic wires and to describe a slide rule which can be utilized by busy clinicians as a simple reference tool for comparing the flexural rigidities of the orthodontic wires commonly available.

Flexural rigidity is a term recently introduced to the orthodontic profession. It refers to the ability of an archwire to resist elastic deformation. This property is dependent upon molecular constitution, configuration of the wire, its length and cross-sectional area and design. Figure 1 diagrammatically illustrates an orthodontic wire of length "L" ligated to brackets "A" and "C", displaced by a load "F" to engage in bracket "B" which lies a distance "S" from the plane of brackets "A" and

TABLE 1

RELATIVE FLEXURAL RIGIDITY OF STAINLESS STEEL WIRE

Diameter	.008	.010	.012	.014	.016	.018	.020	.022	.021x .025	.022x .028
.008	1.000	0.410	0.197	0.107	0.063	0.039	0.026	0.017	0.007	0.005
.010	2.441	1.000	0.480	0.260	0.152	0.095	0.062	0.042	0.018	0.012
.012	5.063	2.074	1.000	0.540	0.316	0.198	0.130	0.089	0.037	0.025
.014	9.379	3.841	1.852	1.000	0.586	0.366	0.240	0.164	0.069	0.047
.016	16.000	6.554	3.160	1.705	1.000	0.624	0.410	0.280	0.117	0.080
.018	25.629	10.500	5.063	2.733	1.602	1.000	0.656	0.448	0.188	0.128
.020	39.063	16.000	7.716	4.164	2.441	1.524	1.000	0.683	0.287	0.195
.022	57.191	23.426	11.300	6.100	3.574	2.231	1.464	1.000	0.419	0.285
.021x .025	136.185	55.781	26.901	14.520	8.512	5.314	3.486	2.381	1.000	0.679
.022x .028	200.441	82.100	39.593	20.400	12.528	7.821	5.131	3.505	1.472	1.000



A,B,C, = Orthodontic brackets
F = Amount of loading
L = Length of wire
M = Modulus of rigidity of material
S = Amount of flexure

Fig. 1

"C". The modulus of rigidity of the wire is represented by the symbol "M".

The load "F" divided by the distance "S" gives the load deflection rate (LDR)[1]:

$$LDR = F/S$$

The load deflection rate for round wire can be expressed mathematically as:

$$LDR = \frac{3\pi \cdot Md^4}{4 \quad L^3}$$

where d = diameter of the wire. The load deflection rate for rectangular wire can be expressed mathematically as:

$$LDR = \frac{4 \cdot M \cdot a^3 \cdot b}{L^3}$$

where a = dimension of wire in direction of flexure and b = dimension of wire transverse to flexure.

The load deflection rates of two wires may be expressed as a ratio to show their relative flexural rigidity:

$$LDR1/LDR2 = RFR$$

And the relative flexural rigidity may be presented in terms of the mathematical expressions for load deflection rates. Thus the relative flexural rigidity of two round wires may be expressed:

$$RFR = \frac{M_1 d_1^4 L_2^3}{M_2 d_2^4 L_1^3}$$

The relative flexural rigidity of two rectangular wires may be expressed mathematically as:

$$RFR = \frac{M_1 a_1^3 b_1 L_2^3}{M_2 a_2^3 b_2 L_1^3}$$

Finally the relative flexural rigidity of a round wire and a rectangular wire may be expressed mathematically as:

$$RFR = \frac{1.7 M_1 a_1^3 b_1 L_2^3}{M_2 d_2^4 \quad L_1^3}$$

It should be clear that whenever one or more of the factors—length, diameter, modulus of rigidity, etc., for both wires are equal they can be removed from the mathematical expression. Thus for two round wires of the same length and diameter, one of steel and one of gold, the

$$RFR = \frac{M_1}{M_2}$$

Since the modulus of rigidity of steel is twice the modulus of rigidity of gold to a first approximation:

$$RFR = \frac{M\ steel}{M\ gold} = 2$$

$$= \frac{M\ steel}{M\ steel} = 1$$

$$= \frac{M\ gold}{M\ gold} = 1$$

$$= \frac{M\ gold}{M\ steel} = 0.5$$

The relative flexural rigidity thus becomes a simple ratio between two numbers which can be assigned to the wires being compared. Such a simple ratio can be solved by a slide rule since the logarithm of relative flexural rigidity (RFR) is equal to the logarithm of the rigidity of one wire (W1) minus the logarithm of the rigidity of the other

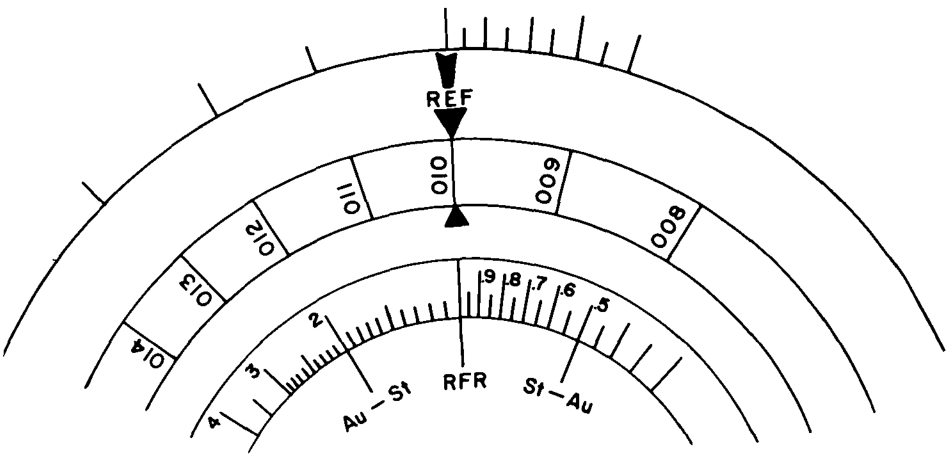


Fig. 2

wire (W2). We simply subtract the logarithmic distance of W1 and W2 to get a logarithmic distance for the relative flexural rigidity. These distances on a slide rule are labeled with their antilogarithms and are consequently read directly. Furthermore it is not necessary to have scales from W1 and W2 since there are a limited number of wires. The position of a wire of a given size is all that needs to be plotted.

Inasmuch as the modulus of rigidity of the various alloys used in orthodontic wires can be expressed as fractions or multiples of 18-8 stainless steel, these differences of physical characteristics can also be plotted on the slide rule and can be expressed directly in relative flexural rigidity values. The inclusion of these relationships on the slide rule can greatly facilitate a comparison, not only between wires of the same alloy, but also between wires of different physical and chemical constitution.

The slide rule was designed circularly for simplicity and convenience as illustrated in Figure 2. It may be used in comparing the flexural rigidity of two wires of the same dimension. In Figure 2 the guide is placed over the position of a round wire of 0.010 or 10 mils. The arrow pointer marked RFR for relative flexural rigidity is placed at the same point. Reading to the left on the inner scale from gold to steel discloses that if the 10 mil wire under question was gold, a steel wire of similar diameter would have twice the flexural rigidity. On the other hand, if the 10 mil wire under question had been steel, gold wire of the same diameter would have had one half the flexural rigidity of steel.

The slide rule may be used to find a wire of the same physical and chemical constitution of a different diameter that would, for example, give twice the flexural rigidity. In this instance keep the pointer, or the indicator, at 0.010 and move the reference pointer to 2 on the flexural rigidity scale and read directly above to find 0.012 or 12 mil wire (Figure 3). To select a wire with approximately four times the flexural rigidity go to four on the flexural rigidity scale and read a wire somewhere between 14 and 15 mils. Again, place the flexural rigidity pointer at 14 mils and find that it has 3.7 times the flexural rigidity of 10 mil wire (Figure 4).

As a reference tool this slide rule makes it possible to select a progression of orthodontic wires by relative flexural rigidity rather than by fabricated diameters. This should aid students in de-

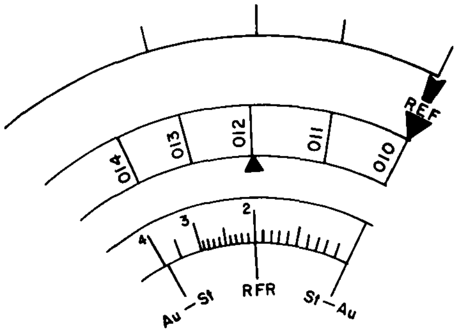


Fig. 3

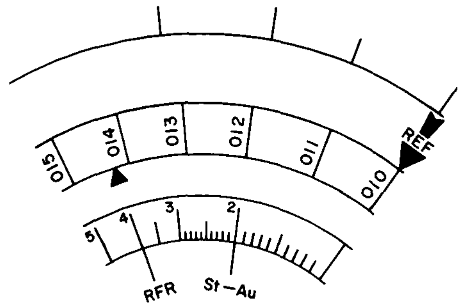


Fig. 4

veloping a clinical sense as to the sequence of archwires which will induce the optimum tissue response. It will assist the busy clinician in arriving at a rational choice of arch components. And finally it should stimulate the fabricators of orthodontic supplies either to provide the profession with a similar slide rule or to draw their wire in diameters which will provide a smooth stepwise progression in relative flexural rigidity.

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REFERENCE

1. Burstone, C. J., Baldwin, J. J. and Lawless, D. T. Application of Continuous Forces to Orthodontics. *Angle Orthodont.* 31:1-14, 1961.