A simple, do-it-yourself method to evaluate slot width tolerance

Claude G. Matasa
Chicago, USA

Introduction

The tolerance with which bracket's slot widths are manufactured is of outmost importance for modern orthodontics. Many years ago, Thurow [1] and recently Kusy [2] have shown that as wires decrease in size relative to bracket slot size, the friction is low but the control is poor. A contrasting "engagement index" improves the control, but may lead to binding.

Balancing friction versus control

Whereas wires can be easily measured, the width of the slot's bottom is not. Manufacturers of orthodontic appliances generally do not state their tolerances [3]. Moreover, according to F. Sernetz, Dentaurum's Chief Engineer [4], related norms do not exist. As the measurement of a tiny empty space is plagued by errors, an accurate relationship is seldom achieved, despite of its great importance [5]. While some have measured slot width with vernier calipers [6], most researches use various microscopes [7]. Interestingly, even using a sophisticated Zeiss Axioscope with a traveling stage, Meling and al. [8, 9] have complained both about accuracy and time consumption.

Testing the effect of recycling

As improper bracket electro-polishing may generate an undesirable enlargement of the slot width, several studies focused on the difference between new and recycled brackets. Thus, using a microscope, Buchman [10] didn't find a difference between the brackets recycled by Ortho-Cycle Co. and the new ones. Hixson et al. [11] did not measure the tolerance but calculated it from converging graphic plots of the data for clockwise and counterclockwise torsion only to find out that recycling does not lead to statistically significant changes in tolerance through to successive recycles. Using Deltronic gauge pins, a study founded by the Orthodontic Manufacturers Association [12] found differences as high as .0187" for new brackets that supposed to have a .018" nominal slot, along with clinically insignificant changes after recycling.

Materials and method

In a previous research, Professor Dr. Mitchell W. Haller Jr. (MWH) Penn State at Harrisburg (a forensic expert called in the case Dr. Donald M. Fox against TPOrthodontics [13]), was asked to use again the same highly sophisticated non-contact optical apparatus to measure slot widths with a nominal accuracy of +.00015" (+.004 mm), and to compare identical brackets before and reconditioning by using Ortho-Cycle's adhesive dissolution process [14]. Such an apparatus (Smart Scope® by Optical Gaging Products, Rochester, NY) costs today US$ 38,995: see the "Flash", *Figure 1.*

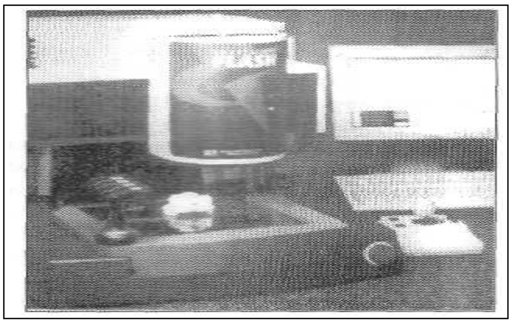

Figure 1. The "Flash" by Optical Gaging Corp.

After the tests, MWH arrived to the conclusion that the slot's *"dimensional changes from recycling were extremely small compared with the variability observed in new brackets"* [14].

Subsequently, starting from the practice of checking brackets by moving laterally a gage (0.022 or 0.018") inserted into their slots and rejecting those where this “play” shows an angle, we have devised a method allowing the measurement of the width by using simple tools and geometry. A common, portable vise and an adjustable clamp, *Figure 2* were used to hold tight various new and recycled brackets having a slot width of .022”. In each of these was inserted a 14 inches long stainless steel wire “straight length”, .021 x .025”, Ref. STSS2125 (G & H, Greenwood, IN). For all measurements, a common caliper was used (721B-6/150 by L.S. Starrett Co., Athol, MA).

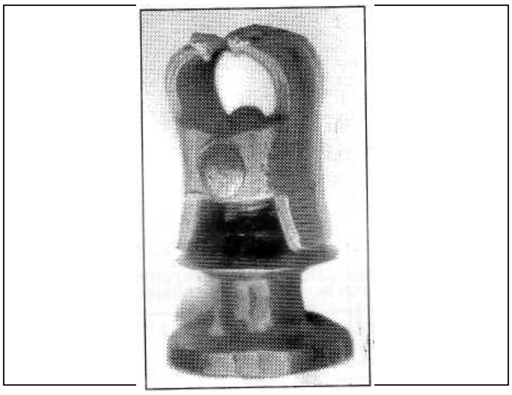

Figure 2. Adjustable clamp

Two types of tests were performed: one on new brackets from several brands, and the other on new and recycled (the same as these used by MWH, i.e. Ormco Diamond® laterals). Each of the brackets was first tightly secured in the adjustable clamp that was in turn tightened in the vise. In each bracket, the same long, straight wire was ligated in such a way that its long length (12.5”) almost touched the graph paper and the graduated liner placed on it, *Figure 3.*

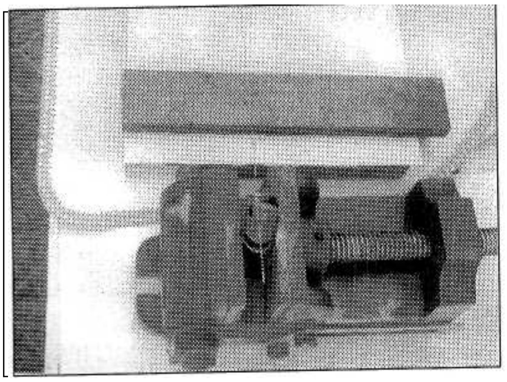

Figure 3. Arrangement vise-clamp-wire and graduated liner

Special care was taken to insert wires in such a way that the geometry of the arrangement was respected (insertion of the wire at the same length and at a 900 angle against the liner).

Moving laterally, the wire’s shorter end, while held at the slot bottom of various brackets, generates the movement another of the other, longer end. To avoid any plastic deformation of the wire, only slight forces were applied. The maximum displacement of the other end on the ruler, marked with Δ_2, can be used to calculate the slot’s “play”, Δ_1.

Form *Figure 4* t can be seen that the two triangles form during the wire movement, DCC’ and DEF, are isosceles and the angle generated by the movement is small (well under 5°). Having the same shape while being different in size, the following relationship ensues between edges:

$$\mathbf{DC / CC' = DE / \Delta_2}$$

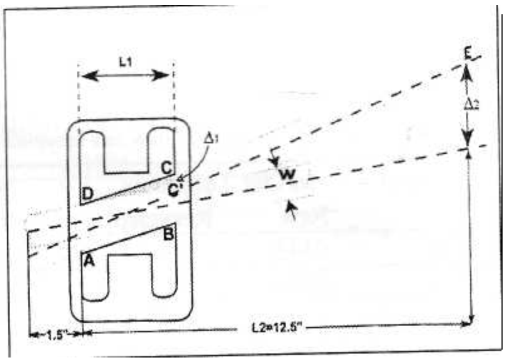

Figure 4. Geometric representation of the arrangement in Figure 3

In words, the line CC’ or Δ_1, or the “play”, i.e. the difference in width between the widths of the wire and the slot, can be obtained by dividing the product between the length of the line DE (the 12.5” portion of the wire) and the slot length DC (measured with the caliper) by the maximum course of the wire’s longer end, Δ_2.

To find the real width of the slot, the width of the wire (selected to be .0210” throughout its length) has to be added with the “play”: $\mathbf{w = a + \Delta_1}$.

To achieve comparable results, we followed the technique employed by MWH, i.e. we have used in a first experiment only brand new brackets. To identify them after recycling, these new brackets had their mesh base marked with a tungsten carbide vibrating tip.

Results

MWH's results [14] obtained with the Smart Scope® apparatus are presented for comparison purposes in *Table 1.*

To apply the above-presented "geometric method" to similar attachments, we had to limit only to the middle two columns, i.e. these showing the width found at the bottom of the .022" Ormco Diamond® upper laterals, measured before and after recycling. The values obtained are shown in *Table 2.*

MWH found values both above and under .022", their standard deviation representing 1% form the mean value. Calculating the differences between the new and recycled values for each individual bracket, their sample standard deviation is equal to .000226". As the width values for the new brackets obtained in the same way has a standard deviation of .000806, the implication is that the variation within new brackets as measured by standard deviation is about 3.5 larger than that between the same brackets, new and then recycled.

Testing several new upper laterals from 4 brands, .022" slot width, we obtained Table 3. Using these values, we have performed an analysis of variance (ANOVA) to test the null hypothesis that the four groups of brackets were drawn from populations having the same mean values of the width. As the high F-value (37.15) obtained is highly significant (the critical value of F at .01 rejection level is 4.5), the four types of brackets exhibit significantly different mean slot widths.

Discussion

In contrast with the non-contact, optical methods measuring the slot's width only at its extremities, the "geometric" method measures the actual "play" as encountered in real cases. Even so, the agreement between the data obtained with the help of sophisticated optical instruments and our

Table 1. MWH's measurements of new and recycled brackets

Number	In/Out Thickness		Slot Width (Bottom)		Slot Width (Top)	
	New	Recycled	New	Recycled	New	Recycled
1	.0332	.0329	.0235	.0239	.0235	.0239
2	.0333	.0332	.0228	.0226	.0243	.0242
3	.0261	.0258	.0223	.0224	.0237	.0242
4.	0503	.0501	.0238	.0236	.0246	.0246
5	.0328	.0325	.0216	.0217	.0240	.0241
6	.0363	.0362	.0216	.0216	.0228	.0230
7.	0523	.0519	.0210	.0209	.0260	.0260
8	.0307	.0303	.0235	.0233	.0235	.0233
9	.0344	.0345	.0219	.0222	.0232	.0233
10	.0354	.0355	.0222	.0223	.0234	.0237
11	.0347	.0344	.0220	.0222	.0230	.0231
12	.0299	.0293	.0225	.0224	.0225	.0231
13	.0283	.0281	.0232	.0237	.0259	.0263
14	.0509*	.0508*	.0229	.0226	.0241	.0248
15	.0528	.0528	.0216	.0218	.0231	.0233
16	.0533	.0529	.0231	.0233	.0235	.0239
17	.0541	.0544	.0220	.0222	.0245	.0244
18	.0367	.0366	.0217	.0218	.0240	.0241
19	.0362	.0359	.0213	.0214	.0228	.0232
20	.0352	.0350	.0229	.0226	.0240	.0244
Mean	**.038845**	**.038655**	**.02237**	**.02245**	**.02382**	**.02405**
S.D.	**.0094403**	**.0095037**	**.00080662**	**.0080582**	**.00095053**	**.00090349**
± Δ	**.0006334 (0.67%)**		**-0.00008 (1%)**		**-0.00002704 (2.9%)**	

Table 2. Slot width measurements of new and recycled brackets

Nr.	ORMCO Diamond		3M UNITEK Dynalock		A.M. ORTH. Triple Action		R.MOUNTAIN Minitaurus		G.A.C. Micro-Arch		"A"CO. Minitwin	
	New	**Recycl.**	**New**	**Recycl.**	**New**	**Recycl.**	**New**	**Recycl.**	**New**	**Recycl.**	**New**	**Recycl.**
1	.02110	.02166	.02357	.02390	.02230	.02245	.0236	.02405	.02257	.02284	.02110	.02198
2	.02157	.02193	.02269	.02334	.02192	.02222	.02300	.02333	.02266	.02292	.02162	.02180
3	.02202	.02279	.02292	.02348	.02169	.02184	.02307	.02340	.02267	.02292	.02166	.02180
4	.02268	.02302	.02288	.02308	.02223	.02238	.02341	.02425	.02258	.02310	.02158	.02194
5	.02239	.02274	.02274	.02309	.02185	.02195	.02402	.02453	.02276	.02324	.02165	.02201
6	.02242	.02304	.02328	.02364	.02184	.02195	.02221	.02301	.02268	.02297	.02166	.02201
7	.02189	.02215	.02260	.02291	.02192	.02227	.02216	.02272	.02269	.02291	.02162	.02202
8	.02149	.02188	.02314	.02334	.02230	.02275	.02389	.02429	.02277	.02323	.02163	.02172
9	.02154	.02198	.02297	.02327	.02161	.02184	.02283	.02366	.02262	.02310	.02158	.02209
10	.02204	.02230	.02317	.02355	.02238	.02260	.02277	.02321	.02238	.02298	.02159	.02187
Mean	**.02192**	**.02235**	**.02299**	**.02336**	**.022004**	**.022225**	**.023010**	**.023645**	**.022638**	**.023021**	**.021569**	**.021924**
Diff.M	**.00043**		**.00037**		**.0000221**		**.00055**		**.00038**		**.00036**	
S.D.	**.00049**	**.00051**	**.00030**	**.00029**	**.00028**	**.00032**	**.00064**	**.00061**	**.00011**	**.00014**	**.00017**	**.00012**
Diff S.D.	**.00002**		**-.00001**		**.00004**		**-.0003**		**.00003**		**-.00005**	
S.D./ Mean	**2.2%**	**2.2%**	**1.3%**	**1.2%**	**1.27%**	**1.4%**	**2.7%**	**2.6%0.**	**48%**	**0.6%**	**0.8%**	**0.5%**

Table 3. Slot width measurements of new brackets

Nr.	"A" CO Minitwin	GAC Micro-Arch	ORMCO Diamond	3M/UNITEK Dynalock
1	.0222	.02269	.02196	.02305
2	.0223.02245	.02202.02305		
3	.0223	.02236	.02163	.02260
4	.0221	.02232	.02163	.02272
5	.0222	.02250		.02280
6	.0221	.02236		.02272
7	.0222	.02245		.02288
8	.0225	.02245		.02272
9	.0227	.02236		.02264
10	.0222	.02245		.02264
Mean	**.02228**	**.022439**	**.02181**	**.022782**
S.D.	**.00018738**	**.0001054**	**.0002092**	**.0001628**

simple, geometry-based method, was surprising. Indeed, it showed that to measure slot widths and their variation, tools that are a hundred times less expensive could be accurately used. The results confirmed that the actual width found in the new brackets tested released as having a .022" varies from brand to brand, both in the individual and the mean values.

The difference found between identical new brackets was 3.6 times larger than that found between the new and the recycled ones. From the clinical point of view, the difference found between new brackets released by known manufacturers may be insignificant, but so are also these between the same attachments, new and recycled in a proper way.

Conclusion

Slot widths vary from brand to brand, and even within samples of the same type. A limited variation as that between new brackets or between new and properly recycled brackets is normal and probably insignificant form the clinical point of view. However, as newer and cheaper brackets are continuously launched on the market, testing their slot tolerance may save the time and effort which otherwise will be spend in correcting inefficient movements. To accurately measure slot widths, a simple, do-it-yourself arrangement can substitute highly expensive instruments, allowing a quick and accurate way to find brackets the slots of which were either poorly manufactured or recycled.

References

1. Thurow R.C. Edgewise orthodontics, ed. 2, St. Louis, 1966, C.V. Mosby.

2. Kusy R.P. Vistas from the top of a new century. *Am J. Orthod. Dentofac. Orthop.,* 2000, **117**: 589-591.

3. Meling T.R., Ødegaard J., Meling E.O. On mechanical properties of square and rectangular stainless steel wires tested in torsion. *Am J. Orthod. Dentofac. Orthop.,* 1997, **111**: 31.

4. Sernetz F. Qualität und Normung orthodontischer Produkte aus der Sicht des Herstellers. *Kieferorthopädische Mitteilungen,* 1993, **7**: 13-26.

5. Kusy R.P., Whitley J.Q. Assessment of second-order clearances between orthodontic archwires and bracket slots via the critical contact angle for binding. *Angle Orthod,* 1999, **69**: 71-80.

6. Ghosh J., Nanda R.S., Manville G., Duncanson M.G. Jr., Currier. Ceramic bracket design: an analysis using the finite element method. *Am J. Orthod. Dentofac. Orthop.,* 1995, **108**: 575-582.

7. Oliver R.G., Pal A.D. Distirtion of edgewise orthodontic brackets. *Am J. Orthod. Dentofac. Orthop.,* 1989, **96**: 65-71.

8. Meling T., Ødegaard J., Meling E.O. A theoretical evaluation of the influence of variation in brackets slot height and wire rounding on the amount of torsional play between bracket and wire. *Kieferorthopädische Mitteilungen,* 1993, **7**: 41-48.

9. Meling T., Ødegaard J., Meling E.O. Cross-sectional stability of square and rectangular wires. *Kieferorthopädische Mitteilungen,* 1994, **8**: 41-54.

10. Buchman D.J.L. Effects of recycling on metallic direct-bond orthodontic brackets. *Am J. Orthod. Dentofac. Orthop.,* 1980, **77**: 654-668.

11. Hixson M.E., Brantley W.A., Pincsak J.J., Conover J.P: Changes in brackets slot tolerance following recycling of direct-bond metallic orthodontic appliances. *Am J. Orthod. Dentofac. Orthop.,* 1982, **8**: 447-454.

12. Fisher T. An *in vitro* comparative study of new and recycled orthodontic brackets. Master Thesis, U. of Iowa, 1995.

13. Fox vs. T.P. Orthodontics, Case 3: 97CV181, Richmond, VA.

14. Haller M.W. Jr.: Personal communication in “Are reconditioned attachments worse than the new ones”. *The Orthod. Materials Insider,* 1998, **11**(1): 2-4.

Correspondence to: Claude G. Matasa, DCE, DSc., Adj. Professor, U. of Illinois, Chicago, USA, President, Ortho-Cycle Co., 2026 Scott St., Hollywood, FL 33020, e-mail: Matasa@aol.com