A simple, do-it-yourself method to evaluate bond strength

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Introduction

A direct-bonding bracket exhibiting the best features is useless if just one is missing: an acceptable bond strength. As a result, over a hundred articles related to its testing were published till 1997 only in the American J. of Orthodontics and Dentofac Orthop. Current debonding methods [1] include all the known types of force application *(Figure 1).*

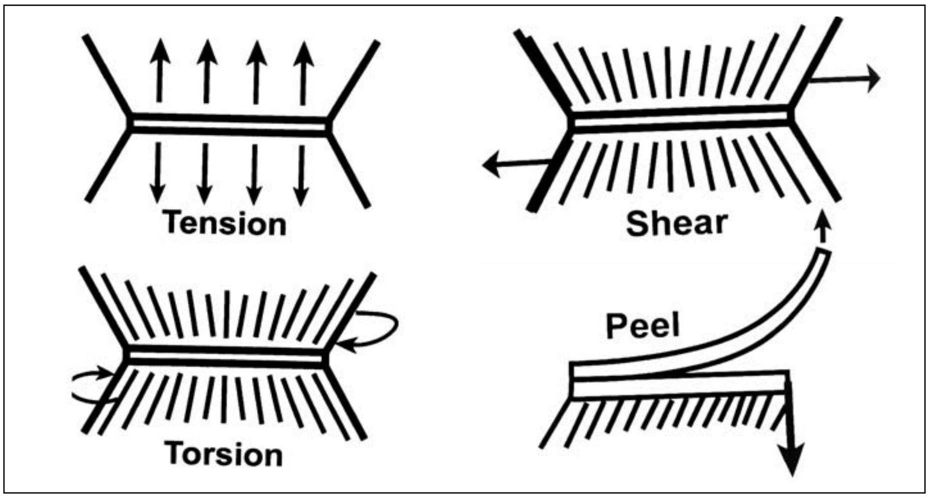


Figure 1. Debonding methods

Evolving from tensile testing, current studies claim the use of shear. Because of an unavoidable inherent bonding moment, it is impossible, however, to apply a pure shear load to a bracket [1] due to an „unavoidable inherent bending moment“. To reflect this phenomenon, the term shear-peel should be used instead [1]. Still, many older studies use the term shear bond strength [2-6] when, in fact, testing shear-peel bond strength: others use simply the term peel [7]. „*Whether in bracket removal the base is cut off with a sharp-beaked instrument or the bracket wings are squeezed together, this cause the base to peel from the adhesive*“ [8].

As Artun and Bergland [9] have shown, the amount of adhesive remaining over a substrate after debonding is highly suggestive. Between their Adhesive Remnant Index (ARI) and peeling there is a close relationship, many studies reporting both of them. Actually, even the ARI concept was used to evaluate the peeling action exerted with a Weingart plier [9].

As the brackets with mesh pads are more and more replaced with the less expensive ones exhibiting bases with dents, grooves or even rough surfaces, testing bonding strength becomes critical. Performed by specialized labs and involving trained technicians and acrylic-mounted bovine teeth, this evaluation uses universal testing instruments that are valued at prices exceeding $30,000.

Peeling is the least energy-consuming debonding method: if the substrate is soft or thin (mesh on a foil), its radius of curvature approaches zero. The contact zone degenerates into a very small area, generating an almost infinitely high local stress even for small loads. As a result, peeling is the choice debonding method.

Materials and Method

The principle of the method starts from the idea that if the adhesive and one of the substrates (a porous/retentive surface) remain the same, the use of the same force should allow the evaluation of the other substrate, the bracket's pad. If the latter adheres well, it will remove most of the adhesive from the substrate. If not, the adhesive will be left behind and the pad will come out clean: both situations are at the base of the ARI system.

Attempts to find already made, easy to acquire substrates that could provide always a standard surface, failed. Stainless steel 100 mesh-laminated sheets are acceptable, but difficult to get. After testing etched marble and glass, we tried ceramic tiles used for floors. These exhibit both a glazed, smooth surface, as well as a rough one which has built in indentations to retain the adhesive. While perhaps adequate as a mechanical interlocking surface, the rough side does not lend itself to the test due to its purposely made, uneven profile. The glazed side, however, if properly treated with hydrofluoric acid, leads to a porous surface that may simulate the etched enamel. Instead of the pliers used in office, an adjustable clamp or a common C-pincer, *Figure 2*, were used.

After seizing the bracket, these were gently tilted on a side until debonding took place. After debonding, the trace left on the tile was examined to quantify the adhesive left behind using the following values as listed in the Modified Adhesive Remnant Index (MARI) [10] and graphically shown in the MARI legend:

Figure 2. Debonding tools for peeling

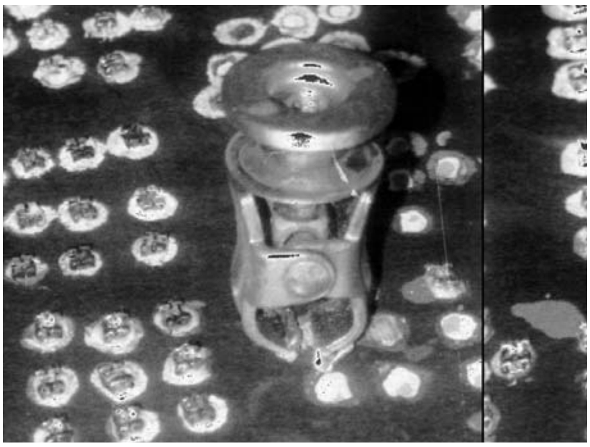


Figure 3. Tile with bonded brackets

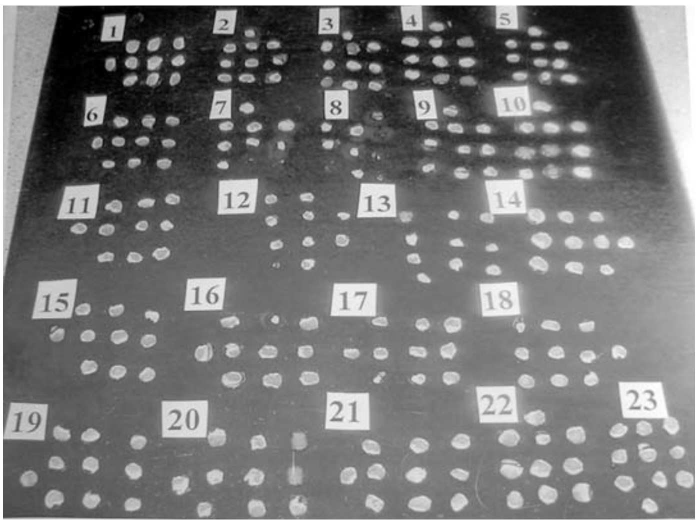


Figure 4.
Tile after debonding

Figure 5. MARI values for new brackets

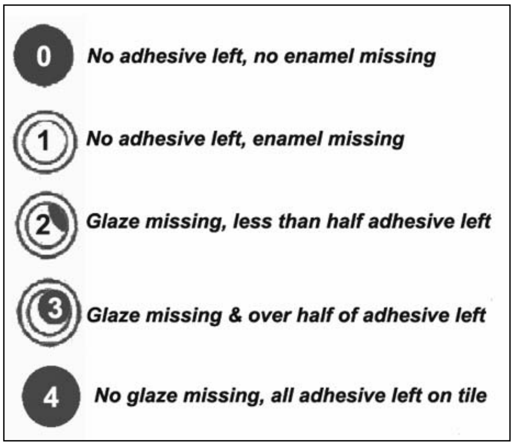
Nr.	Brand	Line	Marks on tile	Rating	Observations
1	GAC	AccuArch	10x 1	10	Micro-Loc derts
2	Ormco	Mini Diamond	9x 1 1x 2	11	100 mesh
3	Orec	Aardvark	8x 1 2x 4	16	100 mesh
4	Ortho Organizers	Edgeway	5x 1 2x 2 3x 4	21	Cast grooves
5	Ortho Organizers	Elite Mini Twin MTN	10x 1	10	Microetched 100 mesh
6	Rocky Mountain	Taurus	9x 1 1x 2	11	100 mesh
7	Ortho Organizers	Elite Medium	8x 1 2x 0	10*	MIM grooves
8	Pyramid Orthod.	Prestige	5x 1 1x 2 4x 0	11.5*	Coined protrusions
9	Unitek	Miniature Twins	8x 1 2x 2	12	Protrusions
10	Unitek	Dynalock	7x 1 3x 4	19	Machined grooves
11	Dentaurum	Ultratrim	10x 1	10	100 mesh
12	Rocky Mountain	Taurus	9x 1 1x 2	11	Lok-Mesh (100)
13	Dentaurum	Rematitan	9x 1 1x 3	12	Laser structured protrusions
14	Forestadent	Mini Mono	10x 1	10	100 mesh
15	GAC	Super Mesh	10x 1	10	2-3 x 100 mesh
16	"A"-Co.	Standard Twins	9x 1 1x 2	11	100 mesh
17	Amer. Orthodontics	Master Series	9x 1 1x 2	11	100 mesh
18	"A"-Company	Min Twin	10x 1	10	100 mesh
19	GAC	Microarch	10x 1	10	Micro-Loc derts
20	Unitek	Twin Torque	7x 1 1x 2 2x 4	17	100 mesh
21	Amer. Orthodontics	Triple Action	10x 1	10	80 mesh
22	Ormco	Diamond	9x 1 1x 2	11	100 mesh
23	Rocky Mountain	Mini Taurus	10x 1	10	100 mesh

1. All the adhesive is removed from the substrate
2. Less than half of it has remained on the substrate
3. More than half of it has remained on the substrate
4. All the adhesive has remained on the substrate

Results

Typical views of the tile surface before and after the debonding of the brackets are shown in *Figures 3 and 4.*

In some instances, the adhesive was left entirely on the tile; in others, the bond was as good as to remove chuncks of the etched glazing. Marking the sites left after the debonding of series of ten from several brands according to MARI, the values obtained in the table shown in *Figure 5* were obtained.



MARI legend

The pads with both mesh and Microloc® bases (GAC) performed better than the ones relying on dents, protrusions and grooves. As variations may have occurred between tests, it is fair to consider that the bases summing a MARI score of 12 or less showed an acceptable retention. It was surprising to see that Unitek's Twin Torque brackets rated low: the reason may well reside in the tack welding points used to join the mesh to the bases mesh, a fact consistent with research done by Maijer and Smith [11]. Another observation is that the bases exhibiting protrusions adhered better than those having grooves or dents: GAC's Microloc® bases may be an exception. Micro-etched and multiple mesh bases showed also better bonding, confirming previous research [12].

Surprisingly, a larger mesh size base (American Orthodontics, #21) gave as good results as the fine mesh preferred today, confirming previous studies [13-17]. Bases with smaller surfaces (mini) presented a performance similar to those having a medium size, confirming previous research stating that bond strength is independent of nominal area and mesh size of the bases [18].

In a separate experiment, a hundred each, new (upper tiles) and recycled (lower tiles) „A“-Co Standard Edgewise laterals were tested the same way, as shown in *Figure 6.*

The sites were recorded using the MARI score as shown in *Figure 7*. In contrast with the previous tests, in the present one, a new category (noted with a purple circle) has appeared: indeed, three new brackets detached from their bases (these were not „fire-tested“ like the recycled ones). The unexpected, highly desirable low MARI average (1.15 vs. 1.4) exhibited by the recycled brackets may well be due to their cleanliness and the increased mesh roughness caused by wear and treatments.

Discussion

Knowing the bond strength of the many various bases sold today is economically important, as the price of some attachments can be as high as five times that of others that may have identical properties. Unfortunately, the measurement of bond strength is costly, difficult and inaccurate. While attempts were made in the past to replace the traditional acrylic embedded bovine teeth with other substrates [19], a literature search shows that the method was not adopted by subsequent studies. The concept, however, is sound as long as the adhesion is based upon mechanical interlocking and not on chemical affinity.

Aside from the fact that the bovine teeth enamel is weaker than the human one, it is unlikely that any bracket base will evenly match the profile of the tooth to which it should be attached. In such tests, as a result of the variance in adhesive thickness, the related bond strength is affected, as shown both by Matasa [16] and

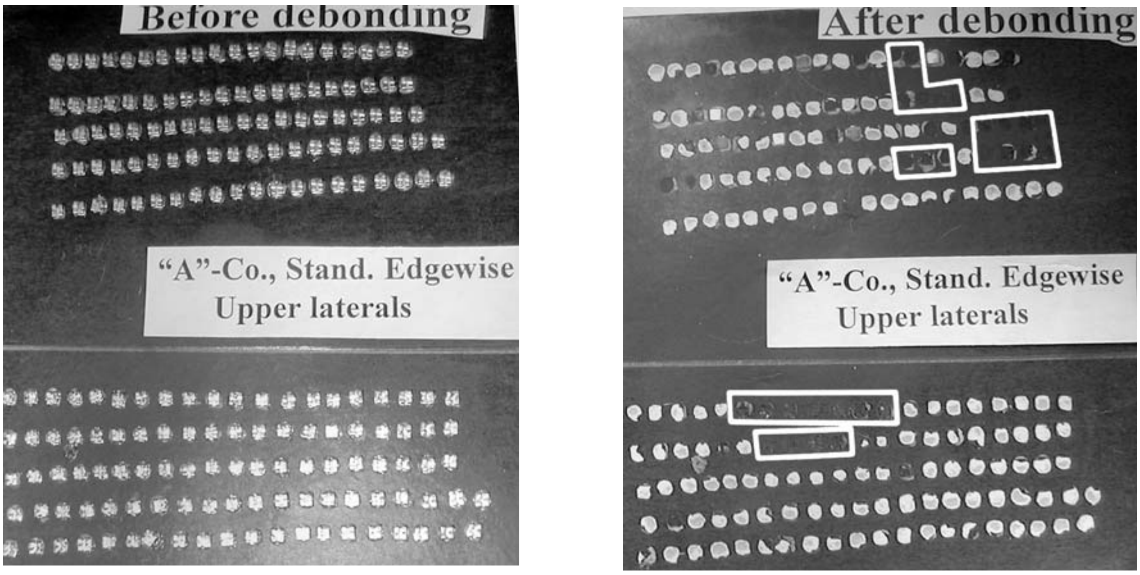


Figure 6. Tiles with new vs. OC-recycled brackets, before and after debonding

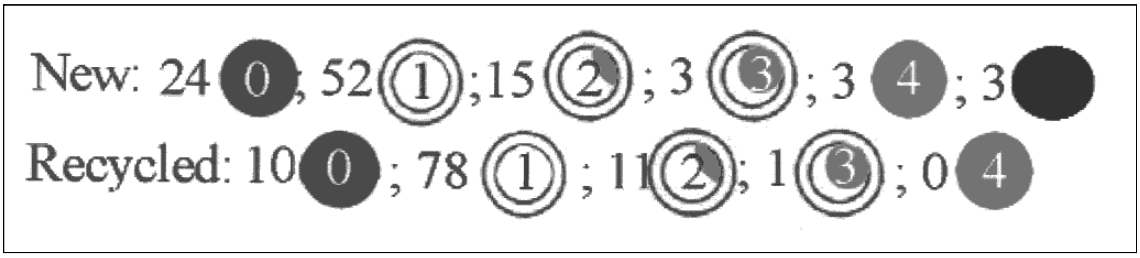


Figure 7. MARI score new vs. recycled

Evans [17]. In contrast, in the bracket base-tile case, the distance between the base and substrate is even throughout the experiment, as is also the adhesive.

Conclusion

In the present research no attempts were made to determine debonding forces: by comparing brands, however, the practitioner can select these that exhibit bonding strengths equal to that of a brand he is familiar with but may be more expensive or miss other desirable features.

The method proposed relies upon a more reliable substrate than teeth. By using a uniform, heat-activated polymerization, it allows a departure from the individual (and often uneven) bonding. Indeed, chemical and photochemical polymerization of the adhesive may well vary from teeth to teeth due to differences in the part ratios (concentration), timing, exposure, etc.

Instead of testing bonding bases, as explored in this study, the method can be used also to test adhesives, of course using the same brackets.

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