



3M™ APC™ Flash-Free Adhesive

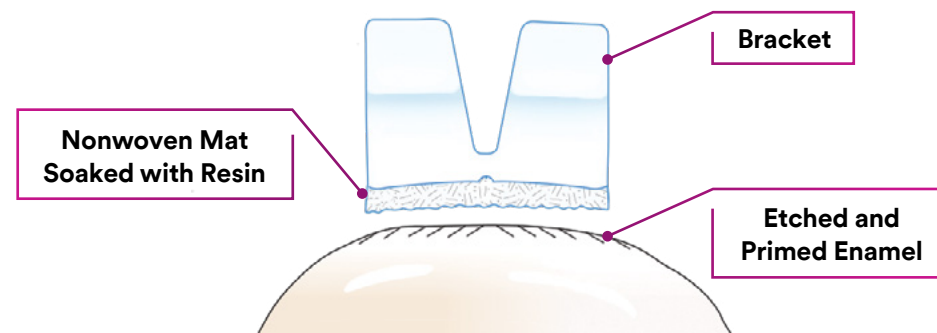
by Dr David K. Cinader, Mathazin Aung, Rachel Ugai and Alan Conley

Orthodontic adhesives, including previous APC Flash-Free Adhesives, have traditionally been highly-filled pastes descended from dental restoratives. Orthodontists usually consider removal of excess adhesive flash after appliance seating an inherent part of their bonding procedure. If not removed, exposed adhesive flash could discolour or stain. Further, flash removal is a time-consuming and stressful task for many orthodontists as their careful positioning of appliances on teeth, as well as the bond integrity, could be compromised by bumping the appliance. Furthermore, any reduction in the time that the patient spends in cheek retractors enhances comfort.

We recognised flash removal as a persistent pain point and developed a new class of APC adhesive that would not require this step by means of a compressible material and a lightly-filled resin formula.

A 3M Solution

APC Flash-Free Adhesive is an effective composition of a compressible nonwoven mat (a 3M core technology), soaked with a relatively low viscosity adhesive resin (another 3M core technology). When an APC Flash-Free adhesive coated appliance is seated in place on a tooth, the compressible mat lets the resin seep out to fill the space between the appliance bonding base and the tooth. The surface tension of the low viscosity resin allows it to wet the tooth surface well and form a fillet around the bonding base, instead of forming the irregular clumps of adhesive flash typically produced by paste adhesives. The fillet is typically smooth and similar to a meniscus seen at the interface of a liquid and laboratory glassware. In this application, the size of the fillet is constrained by the precise amount of resin determined for each type of tooth. As a result, APC Flash-Free appliances offer a bonding procedure with no need for the flash removal step so that orthodontists can focus on appliance positioning.



Dr David K. Cinader received a B.S. Degree in Chemical Engineering from Michigan Tech University in 1994 and a PhD in Chemical Engineering in 1999 from Northwestern University.

He joined 3M Unitek Research and Development in September 1999 and has been involved in orthodontic bonding development including 3M™ Transbond™ Plus Self-Etching Primer, 3M™ APC™ II, 3M™ APC™ PLUS and 3M™ Transbond™ Supreme Low Viscosity Adhesives.



Mathazin Aung received a B.S. in Physics with Minor in Mathematics from University of Arizona in 2004. She worked in 3M Unitek Manufacturing from 2005-2006 and joined R&D in 2006. She was involved in

product development of 3M™ Clarity™ SL Brackets and 3M™ Ortholux™ Luminous Curing Lights before joining the APC Flash-Free Adhesive project in 2009.



Rachel Ugai received a B.S. Degree in Chemistry from University of California, Irvine in 2002. She joined the 3M Unitek Research and Development in 2007 and has been involved in many experiments in the

laboratory. In 2011, she took part in APC Flash-Free Adhesive development team as an Advanced Technical Service Engineer.



Alan F. Conley is a Packaging Engineer for 3M Unitek, having joined the company in 2007. He received his B.S. and M.S. in Packaging from Michigan State University, where he also researched the dynamics of package distribution systems.

Specially designed nonwoven mat

The term “nonwoven” generally applies to fabric-like materials made of long, entangled fibers. Nonwovens differ from woven or knit fabrics in that they are randomly arranged much like a bowl of noodles. Examples of 3M brand products range from Filtrete™ filters and Thinsulate™ insulators to Nomad™ doormats and Scotch-Brite™ abrasive pads. Depending on the needs of each application, material properties are typically tailored through selection of fiber composition and processing technique. For APC Flash-Free, the nonwoven material needs to provide a degree of compressibility in the direction (z) of seating the appliance in order to accommodate a range of tooth contours, yet not expand in the direction (x-y) as flash around the bonding base. Additionally, its thickness and loft need to provide similar adhesive bond line thickness to paste adhesives so that orthodontic treatment outcomes will be unaffected.

The required nonwoven material was developed internally within 3M and is a web of micron-sized polypropylene fibers, shown close-up in Figure 1. The web is made with 3M’s expertise in web processing so that the fibers are entangled enough so as not to unravel as small pieces of mats are cut and applied to the appliances while still providing the necessary thickness and loft.

APC Flash-Free Adhesive mats are precisely cut from the web to fit and align with the shape of each appliance’s bonding base. Figure 2A-B shows a mat as assembled on a bonding base. When attached to the appliance, the defined mat configuration helps ensure that the resin reaches the edges of the bonding base, creating a well-formed fillet.

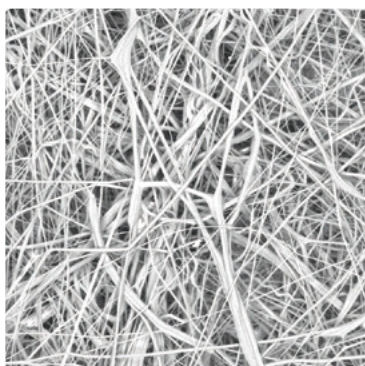


Figure 1:
The nonwoven fabric used in APC Flash-Free Adhesive consists of randomly oriented, entangled fibers.

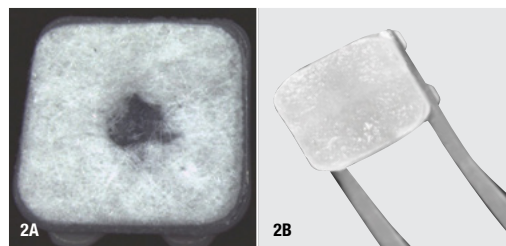


Figure 2A-B:
The size and shape of the nonwoven mat is custom designed for each bonding base. The mat is attached to the bracket with a small amount of cured resin.

An innovative resin design

The resin used in APC Flash-Free adhesive is renowned among orthodontic adhesives. It is of a much lower viscosity and has a surface tension designed to wet the enamel and form the filleted edge. Additionally, the resin amount is critical to creating a well-formed fillet. Multiple in-vitro studies were conducted with doctors to define an acceptable fillet and define the resin loading for each bracket. The results can be seen in Figure 3A-E, in which well-formed fillets are

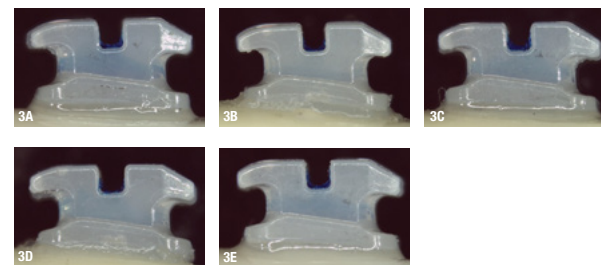


Figure 3A-E:
Images of brackets bonded with APC Flash-Free Adhesive (3A, C, E) vs. a typical paste adhesive (3B, D).

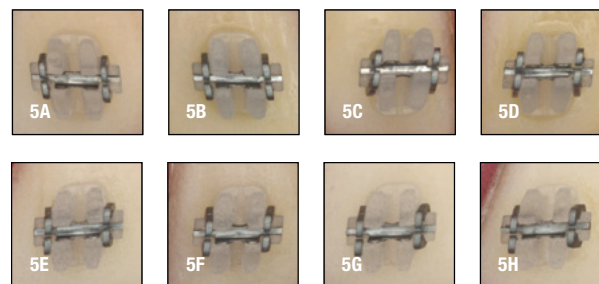
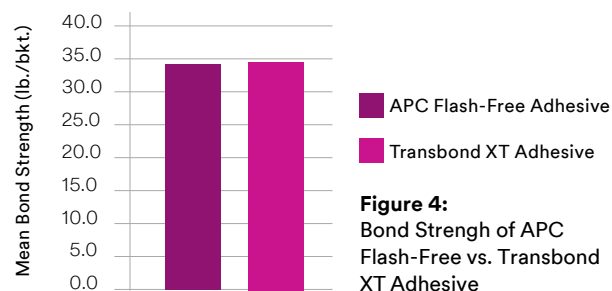


Figure 5A-H:
Bonded samples exposed to curry broth for 240 minutes at 40°C

Figure 5A-D:
APC Flash-Free Adhesive

Figure 5E-H:
APC II Adhesive

contrasted to irregular edges obtained when bonding paste adhesives.

The most important job of an adhesive is to provide a reliable bond. In adhesive joint design, well-formed fillets such as seen in Figures 3A, C and E are instrumental in distributing stress and contributing to a reliable bond. One indicator of the bond reliability of an orthodontic adhesive is the bond strength measured in laboratory tests. In Figure 4, the bond strength of APC Flash-Free adhesive is plotted alongside that of well-received 3M™ Transbond™ XT Adhesive. It can be seen that APC Flash-Free adhesive compares favorably. Further evidence of APC Flash-Free adhesive’s reliability is recounted in the discussion of customer evaluations.

Naturally, with any bonding system one is concerned with discolouration/ staining of the bonding material. Extrinsic staining occurs mainly as a result of materials dissolved in the water that an adhesive may absorb while in use. APC Flash-Free Adhesive has been formulated with very hydrophobic monomers to minimise the amount of material that will be absorbed during treatment. Its performance in resisting the staining effects of common foods and beverages is shown in Figure 5A-H. It is observed that APC Flash-Free adhesive performs as well as 3M™ APC™ II Adhesive, which is generally considered to be a very stain-resistant adhesive.

An Integrated Delivery System



Figure 6:
APC Flash-Free Adhesive Coated Brackets are held in place by structures that grip the occlusal and gingival edges of the bonding base.

Delivering a precoated bracket to the customer is a unique challenge. A new package was designed which minimally contacts the adhesive to ensure that the correct amount of resin remains on the bracket. It is shown in Figure 6 and consists of tapered bars which touch the bracket bases on the occlusal and gingival edges only.

The package was designed to retain the same ease of use that customers have come to expect from the 3M™ APC™ Adhesive System blister. Brackets may be gripped in the same manner in which users are accustomed and pulled in a direction perpendicular to the blister bottom. Alternatively, a gentle rocking motion in the mesial-distal directions can be employed to ease removal (Figure 7A-C).

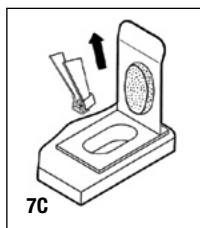
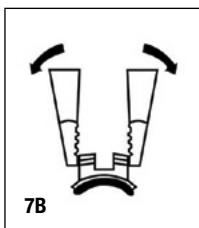
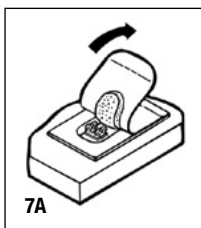


Figure 7A-C:
Suggested method for bracket removal. Open lid with peeling motion. Grasp bracket tie-wings and gently rock side to side. Remove from blister by lifting.

Ease of removal from the package must be balanced against surviving the rigors of shipping through a global supply chain. To this end, a comprehensive test was conducted to ensure that the bracket would not come loose during exposure to prolonged harsh vibration and multiple sharp shocks.

Ease of use extends to the manner in which the product fits into the orthodontic practice. The original APC Adhesive System was designed to provide a dedicated “inventory to chairside” solution. The APC Adhesive Inventory Dispensing System (IDS) includes a back-up storage unit, stackable dispensing drawers, and set-up trays. The outside of the APC Flash-Free Adhesive blister package is identical to that of APC PLUS adhesive packaging so that it fits into the existing IDS components, providing both new and existing users the convenience of the APC system (Figure 8).

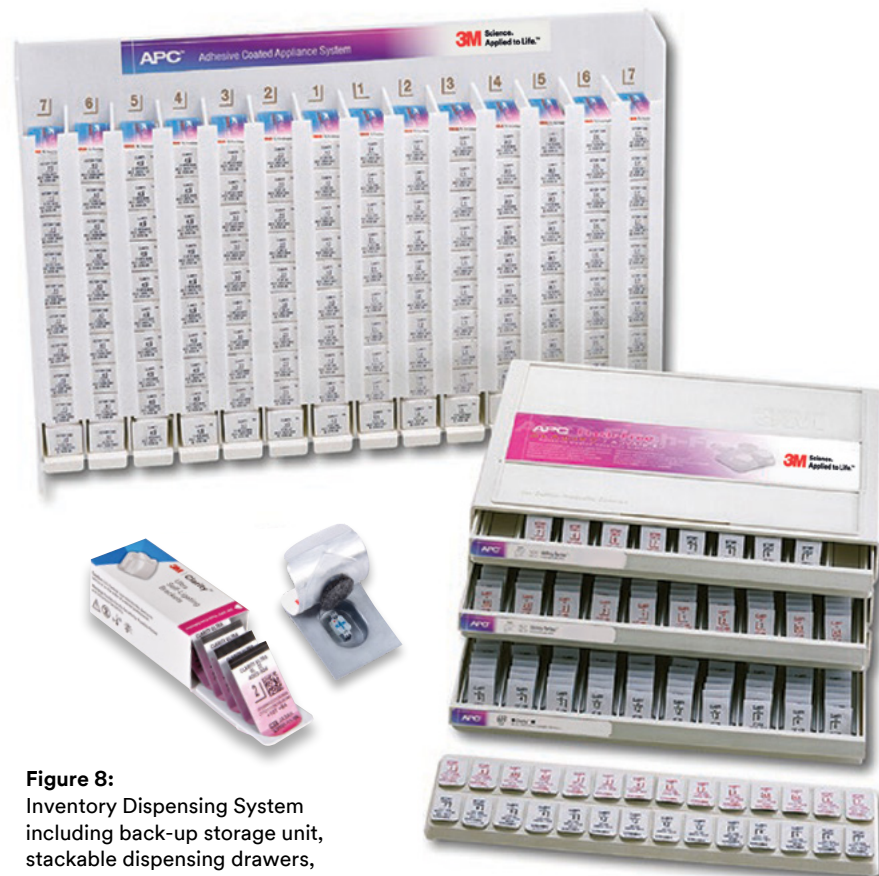


Figure 8:
Inventory Dispensing System including back-up storage unit, stackable dispensing drawers, and set-up trays.

Conclusion

The APC Flash-Free adhesive coated appliance system combines multiple 3M core technologies to create an innovative bonding system. The resin, nonwoven mat, and unique package come together to deliver an easy to use solution with no flash to clean up.



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To learn more about APC Flash-Free,
visit 3M.com.au/APCFF or
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