

A Laboratory Evaluation of Adhesively Crimped Surgical Ball Hooks

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## **Abstract**

Surgical stabilizing arch wires are usually placed before orthognathic surgery. They allow immediate postoperative stabilization of the new occlusion. Attachments are usually placed on these wires to facilitate both maxillomandibular fixation and postsurgical use of intermaxillary elastics. Crimpable ball-hooks are often used as attachments. However, these hooks have a tendency to loosen when placed using crimping pliers alone.

The application of excessive crimping force will cause gabling of the archwire and the introduction of unwanted active forces..

The aim of this study was to examine the effect of the addition of sandblasting and/or dental adhesive on the stability of the crimpable hook when positioned and crimped onto the archwire.

Eighty-nine crimpable ball-hooks were divided into six test groups. Each hook was treated according to the criteria of the relevant test group and then crimped to the archwire. The force required to dislodge each hook from the archwire was then measured.

The results demonstrated that sandblasting caused a significant increase in the force required to dislodge the crimped hook. The addition of either Panavia 21 or 4-META Superbond adhesives also resulted in a significant increase in the required dislodging force.

The force required to dislodge the hook was increased by a factor of 10 where sandblasting + Panavia 21 were applied. The same increase was observed where 4-META Superbond was applied, without sandblasting. However, it was concluded that the use of Panavia 21, together with an intraoral sandblasting machine, would be more appropriate in the clinical setting, primarily due to the ease of use associated with Panavia 21.

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<b><u>Contents</u></b>	<b><u>Page</u></b>
Abstract	2
Acknowledgements	4
Contents	5
1 Literature Review	6
1.1 History of Adhesive Dentistry	6
1.2 History and Development of Resin Materials	9
1.3 History and Development of Direct Orthodontic Bonding	12
1.4 History and Development of Adhesives in Restorative Dentistry	19
1.5 Adhesives used for Metal to Metal Bond	21
1.5(i) Panavia	21
1.5(ii) 4 - META Superbond	26
1.5(iii) Geristore	28
1.5(iv) Mirage ABC System	29
1.6 History and Development of Sandblasting	29
1.7 History and Use of Crimpable Hooks in Orthognathic Surgery	33
2 Aim	36
3 Method and Materials	36
4 Results	39
5 Discussion	44
6 Conclusion	45
7 Bibliography	46
Appendix (i) Tables and Figures	53
Appendix (ii) Manufacturers	54

## **1. Literature Review**

### **1.1 History of Adhesive Dentistry**

The history of adhesive dentistry began with Michael Buoncore's paper in 1954 (Buoncore, 1955). He successfully altered the tooth surface by chemical treatment with 85% phosphoric acid. Liquid acrylic resin was placed on the prepared surface and allowed to set. The average duration of adhesion was 1020 hours and removal required considerable force, applied with a sharp instrument. The author speculated that the mode of action was primarily due to a great increase in surface area ( physical bond ), or possibly the presence on the enamel surface of an adsorbed layer of highly polar phosphate groups ( chemical bond).

This debate becomes a recurrent theme in subsequent literature i.e. physical bond or chemical bond. The authors concluded that the main application of the discovery would be as a pit and fissure sealant. They did not consider the possibility of use in orthodontic therapy.

Adhesion may be defined as the molecular attraction exerted between the surfaces of bodies in contact or the attraction between molecules at an interface. The molecular attractive forces involved in adhesion may be divided into two classes, physical and

chemical. Physical forces, including Van der Waal forces, are related to the existence of dipoles, induced dipoles and the non dispersion polar effect which results from the random motion of electrons, atoms or ions. Hydrogen bonding is also considered to be a special type of physical bond, a dipole-dipole bond.

Chemical forces produce much stronger bonds and result in the formation of covalent, ionic or metallic bonds. In chemical bonds there is usually a sharing of electrons, this does not occur in physical bonds. For adhesion to work, especially for the development of physical bonds, the two surfaces need to be in very close contact  $1-2\text{\AA}$ , and subsequently to maintain this molecular distance.

There are various factors in attaining and maintaining adhesion. If anatomically smooth surfaces could be produced, strong adhesive forces would exist. Usually there are voids between surfaces which prevent contact between surfaces and result in failure to achieve maximum adhesion. It is almost impossible to produce anatomically smooth surfaces. Therefore one way to produce close contact is to use fluid adhesives which will flow into the irregularities of the surface.

The phenomenon of wetting is associated with the existence of a small or zero contact angle. The stronger the attraction, the smaller will be the wetting angle.

The smaller the contact angle, the better an adhesive is able to fill the irregularities in the surface of the void. It is important that the adhesive has the right viscosity. Fluid adhesives are preferred as they penetrate voids more quickly and efficiently.

The thickness of the adhesive layer can also have a profound effect on bond strength

(Jost - Brinkman, 1992). There may be too many voids or cracks in thicker layers or it may be that thick layers become more deformed than thin layers and therefore fracture earlier. Thin layers have less scope to fracture laterally and are more likely, once adhesion is achieved, to fracture cohesively. Cohesion can be defined as molecular attraction due to the same physical forces involved in adhesion, except that these forces exist between like- molecules rather than unlike-molecules.

Most adhesives undergo shrinkage which induces internal stress. In a thicker layer, the sum of the internal stress may be greater, leading to early fracture.

The extent to which monomers react to form polymer during the polymerization reaction ( degree of conversion ) also affects the mechanical properties of the resin (Ferracane, 1986).

The ideal requirements for an adhesive dental material were recognized early on by Buoncore (1963).

1. Lasting bond to enamel and dentin,
2. Polymerize rapidly near body temperature, with minimal shrinkage.
3. Minimal expansion or water absorption.
4. Resistant to masticatory forces.
5. Similar co-efficient of thermal expansion as tooth structure.
6. Biocompatible to pulp and tissues.
7. Resistant to degradation.

Buoncore was discussing the requirements for adhesives to be used as restorative materials. Where the adhesive is to be used for orthodontic bonding, the requirement



that the bond be reversible, with no lasting damage to enamel, should be added to the above list.

## **1.2 History and Development of Resin Materials.**

Self-curing acrylics were first introduced in 1947. The first restorative material was called Kapon. However this material proved to be unpopular, because it failed to bond to tooth structure, had considerable polymerization shrinkage, poor color stability and caused pulpal irritation (Langeland *et al.*, 1966; Macchi and Craig, 1969; Nelsen *et al.*, 1952; Phillips and Swartz, 1966; Smith and Schoonover, 1953; Stanford, 1971).

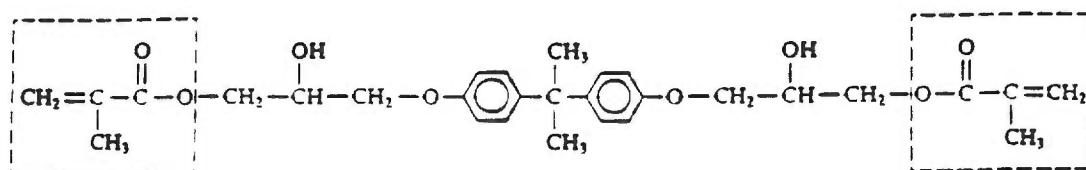
In order to reduce shrinkage, powdered polymer was mixed with the monomer and to avoid the use of external heat, the amount of catalyst was increased in the monomer. The catalyst used was benzoyl peroxide. This produced free radicals and led to a rapid polymerization of the monomer.

An accelerator was also added which brought about the decomposition of the peroxide at room temperature. Because peroxide decomposes in light, it is usually added to the ground up polymer phase. If it were added to monomer it would also tend to polymerize it. The amine is usually carried in the monomer phase since it will not induce polymerization of the monomer. Even though these early acrylic resins were catalyzed at room temperature, they gave out unacceptable heat i.e. exothermic reaction. Discoloration caused by benzoyl peroxide and amines and recurrent decay caused by high levels of polymerization shrinkage, were severe clinical shortcomings.

While acrylic could bond extremely well to glass, it did not perform well in the aqueous oral environment.

Because of their high coefficient of thermal expansion, compared to tooth structure, acrylics expand or contract approximately seven times as much. As a result, these materials had a limited place in restorative dentistry.

In 1962, Bowen introduced the first practical monomer for use with composite resin (Bowen, 1962, 1963). It was the reaction product of bisphenol A and glycidylmethacrylate.



**Fig 1.** BisGMA ( Addition product of BisPhenol A and glycidylmethacrylate)

Composite restorative materials consist of an organic and an inorganic portion, as compared to the self-curing acrylics in which the liquid and powder ingredients are essentially organic.

The base monomer (bisphenol A and glycidylmethacrylate) with a solvent to reduce viscosity, was combined with a variety of inorganic fillers to produce

polymerizable resin mixtures. The inorganic fillers are numerous. They are either tiny glass beads, powdered glass, lithium or aluminum nitrates and calcium phosphate. One of the first of these materials was called Adaptic.

The use of very hard, large quartz particles was associated with unacceptable surface roughness. Newer composite materials, such as Concise and Nuva-Fil, have finer particles and are more easily polished. The filler particles are treated with coupling agents such as silanes to coat them with an organic film to chemically bond to the surface of the filler particle.

The paste-paste composite resins employ a peroxide-amine, catalyst accelerator system. The Bowen monomer has two methacrylate groups. Under the influence of free radicals, produced by the peroxide catalyst-amine accelerator, the double bonds of the methacrylate residues open up. The residues from different molecules then combine to produce long chains consisting of many monomer units. The end product is cross-linked, unlike the acrylic resin which had only linear polymerization.

It is important to remember that with either self-curing acrylics or composite type restorative materials the polymerization process does not produce a new reaction product. The solid inorganic fillers in the resin are simply encapsulated by the polymerizing resin matrix which bonds to the surface of the silane-treated filler particles.

### **1.3 History and Development of Direct Orthodontic Bonding.**

Newman is credited as being one of the first pioneers in the development of orthodontic bonding materials ( Newman, 1965). He used epoxy-type adhesives to bond plastic laminates with brackets to anterior teeth. Cueto and Buoncore directly bonded metal brackets to enamel surfaces of teeth at the Eastman Dental Center . They used the same type of acrylic resin previously used by Buoncore for the sealing of pits and fissures ( Cueto, 1965; Cueto and Buoncore, 1967).

Direct bonding of brackets to enamel did not really start until the mid to late 1970's and was limited to the upper and lower six anterior teeth. Adhesives available at the time required absolute dryness and posterior application was consequently more difficult due to poor isolation technique (Dietz and Giannelly, 1975). The other major delay in using already well established adhesive systems was the lack of development of a proper mesh pad at the back of the metal bracket. Metal bracket- base construction was quite primitive, with holes drilled at the back to provide retention.

The first commercially available orthodontic adhesive was developed by Newman ( Newman, 1965). The OIS system utilized methyl- methacrylate as the adhesive material. Bonding was limited to the use of polycarbonate plastic brackets to maxillary anterior teeth.

The cure time of 15 minutes for this resin was a major clinical drawback. Eventually the cure time was reduced to 5 minutes. Newman published later articles, towards the end of the 1960's, describing successful use of acrylic resin adhesive.

Miura, Nakagawa and Masuhara used an adhesive system containing methyl-methacrylate, polymethyl methacrylate and a tin-n-lutyl base derivative as catalyst. A silane was applied after washing off the enamel previously etched with 66% phosphoric acid. This was quite successful for bonding plastic brackets. However, it was not successful for metal brackets (Miura, Nakagawa and Masuhara, 1971).

Silverman, Cohen, Giannelly and Dietz (1972) described the direct bonding of plastic and metal brackets. These were held by physically locking the adhesive into perforations in the bracket backing.

In the early 1970's, modified versions of Bowen's resin ( diacrylate resin ) bisphenol A glycidyl dimethacrylate (Bis GMA) began to be used in the clinical setting during the introduction of metal brackets with metal pads welded to bracket bases. This was a more versatile material, combining the setting versatility of acrylic resin with the strength and stability of composite resin. Bowen's resin has been called numerous names epoxy, epoxy-type, acrylated epoxy dimethacrylate and epoxy acrylic. Curing is carried out either chemically, with tertiary amine-benzoyl peroxide as well as with the composite resins, or with ultraviolet light of the 364-367Nm wavelength, which was later replaced by visible light.

Cross - linked diacrylates are more stable than the linear- linked acrylics. Inorganic filler content can vary from 60-80% weight. The material must have sufficient viscosity to wet the enamel surface and the bracket base, yet cannot be of such a low viscosity that the bracket will move once placed in the correct position on the tooth. There was quite extensive experimentation with this concept in the variety of commercially

available products which began to flood the market at this time. The only major disadvantage is that diacrylates do not bond to plastic brackets. However acrylic resins could be used instead.

Sealants began to be used for two major purposes at this time, (1) to facilitate wetting of the enamel or attachment surface or (2) as a coupling agent to provide chemical union between the surfaces and the adhesive. Reynolds (1975) concluded that filled diacrylate resins with gauze backed metal attachments were the most suitable materials for bonding as they were characterized by minimal setting time and adequate working time. This material satisfies a minimum of 50 kg/cm<sup>2</sup> tensile bond strength and gave the highest bond strength for metal brackets (Buzzitta *et al.*, 1982).

Gorelick (1979) concluded from his national survey in 1979 that bonding was preferred by 93% of respondents (2000 replied from 7000 questionnaires) and that 57% had been bonding for 3 or more years.

It is not surprising that Zachrisson used Concise, a heavily filled diacrylate resin, for the first prospective assessment of direct bonding in a large sample of 46 children with a total of 705 attachments bonded directly (Zachrisson, 1977).

He found that the failure rate was less than 10% for anterior teeth with lower second premolars and molars having the highest failure rate of 24.2% and 29.5% respectively. He concluded that bonding as a routine clinical procedure was here to stay. Since then bonding for anterior teeth has become almost universal with some practitioners bonding all teeth except for upper first molars. Failure rates for steel mesh

backed brackets, directly bonded with highly filled diacrylate resin, can be as low as 1-4% (Zacchrisson, 1977). There have been no reported allergic reactions, unlike the acrylic no - mix systems (Hutchinson, 1994; Sohoel *et al.*, 1994). Bond failures at the enamel adhesive interface are caused by inadequate technique (moisture, movement). Failures at the adhesive bracket interface are more likely caused by a weak adhesive.

In the last 15 years, successful bonding of metal brackets to enamel has become very consistent and a routine procedure, with low de - bond failures of < 4% (Zachrisson, 1978). Most of the routine bonding problems have been solved, with the correct use of adhesive resins. The bond strength of Concise at 24 hours post- bonding has always been considered the gold standard. However, it is now possible, using light cured adhesives (e.g. Transbond), to achieve the same bond strength after a 40 second light cure and to insert arch wires immediately (Wang *et al.*, 1992).

However, the iatrogenic problems associated with acid - etching i.e. the irreversible loss of enamel caused by the bonding procedure with the tendency for these teeth to be more prone to white spots and early decalcification around brackets, has led to a reevaluation of the acid - etch - resin bonding system (Kusy, 1995) and a critical evaluation of the cost of these higher bond strengths (Graber, 1995).

Kusy (1995) has recently argued that stronger bonds may not necessarily be better and that the simplicity of a non - etch glass ionomer system, with less iatrogenic problems, may be the future of bonding. At the moment, the bond strengths of glass ionomer are low compared to diacrylate resin, with no comprehensive prospective clinical trial similar to Zachrisson available for comparison (Wiltshire, 1994).

Newman (1995), in his latest study of 150 cases bonded with glass ionomer, reports 96.8% success rate. However, the trial only covered the first 8 months of clinical treatment.

The concentration of phosphoric acid has reduced significantly from 85%, used by Buoncore, to 35%-50%. Some investigators now recommend using a concentration of 5% for 1 minute (Barkmeier *et al.*, 1987). Bryant *et al.* (1987) recommended a 30 second application of 15% phosphoric acid. These lower concentrations of phosphoric acid still give adequate bond strength and allow far less iatrogenic damage to enamel, together with easier clean up at debond.

It is known that incorporation of fluoride into the enamel structure in fluorapatite [ $\text{Ca}_5(\text{PO}_4)_3\text{F}$ ] can result in the remineralization of small decalcified or carious lesions, as well as rendering the enamel less susceptible to acid destruction by bacteria (Melberg and Mallow, 1984). The magnitude of the fluoride release on a daily basis over a prolonged period of time and not the initial fluoride content of the resin, is the key factor in determining remineralization (Forsten, 1976; Phillips, 1988). Wiltshire *et al.*, (1995) recently reported a new composite resin FluorEver (Macrochem, Mass.) which continued to release fluoride up to 85 weeks.

It would appear that Buoncore's ideal requirements for an adhesive dental material to bond to enamel as outlined earlier, have been achieved. Further research will minimize the potential iatrogenic effects of acid - etch bonding to enamel, while providing an adequate bond strength for the duration of treatment.

Attention has now focused on bonding to porcelain, non-precious metals or gold



(Wood, 1986). This has become of greater importance as adult patients account for a larger portion of orthodontic patients than in the past. Bonded attachments have been shown to cause less periodontal tissue damage than bands (Boyd, 1992; Zachrisson, 1985). Wood (1986) found that, when the gold surface was roughened with a green stone, the bond strength was significantly higher using a highly filled diacrylate as opposed to an adhesive with smooth surface bonding. He also found that, regardless of the resin or priming agent used, roughening of the porcelain surface provides significantly higher bond strengths. Furthermore, porcelain bond strengths obtained chemically with silane coupling agents compared favorably with the mechanical retention obtained by acid etching of enamel.

Roughening of smooth surfaces with green stones has led to the development of sandblasters recently approved by the FDA for intra-oral use. SEM studies indicate that the micro-mechanical retention of metals can be increased 30% using this technique (Eldris *et al.*, 1992; Sorenson *et al.*, 1991).

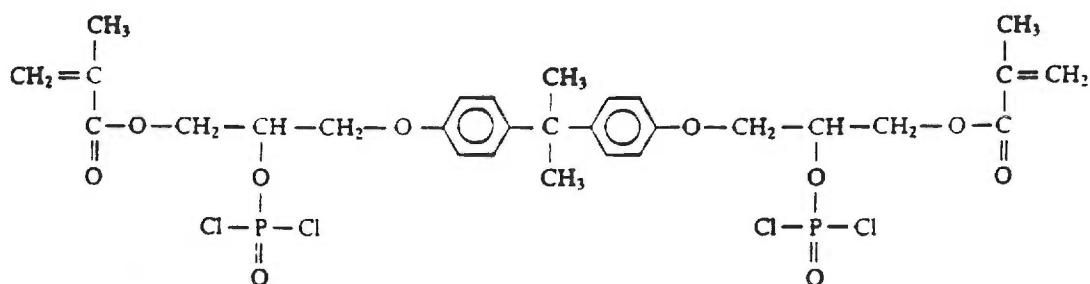
In addition to the use of direct bonding with a heavily filled diacrylate such as Concise, the Micro-Etcher has proved to be capable of providing reliable bond strength in vivo over a full period of orthodontic treatment (Zachrisson 1993). It is used for bonding to amalgam, gold and porcelain.

Up until the last 5 years, either diacrylate or acrylic resins have been the major groups of adhesives used in orthodontics. However, recently two completely new adhesives (Panavia and Superbond), originally developed for use in restorative dentistry (White, 1993), have been used in the bonding of metal brackets to both non-precious and precious metal surfaces such as gold. They are believed to bond

chemically to metal. Super - Bond C& B is activated by combining 4-metacryloxyethyl trimellitate and tributylborane monomers and then adding the polymer powder to the activated liquid (Yamashita, 1982, 1986; Yamashita and Yamani, 1982a, 1982b, 1986; Yamashita, Kondo and Fujito, 1984; Yamashita *et al.*, 1984).

The polarity of the 4-META molecule is believed to be the key to its bonding mechanism. It is thought that the oxygen or hydroxyl groups in the metal layer are activated to form hydrogen bonds with the 4- META molecule.

Panavia EX, a filled BisGMA resin, differs from other adhesives in that the monomer contains a phosphate ester group MDP [ 10 methacryloyloxydecyl dihydrogen phosphate], (Matsura, 1987; Omura, 1982, 1983; Takeyama *et al.*, 1978; Thompson *et al.*, 1985; Wada, 1986a, 1986b; Yamani, 1986; Yamauchi, 1980). The bonding mechanism is not understood, but involves both mechanical and chemical retention. MDP bonds chemically to oxides of nickel, chromium and cobalt and to oxides of tin formed by tin plating. Panavia requires an anaerobic environment for complete setting, therefore the bond margins should be covered with a gel such as Oxyguard.

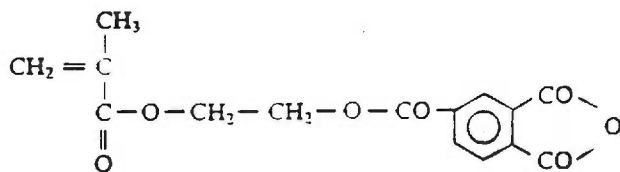


**Fig 2.** Phosphate ester of BisGMA

Zachrisson and Buyukyilmaz (1993) have shown that sandblasted + Superbond C & B have a mean MPa of 14.7 to gold compared to sandblasted + Concise (MPa of 4.8). This compares, in the same study, with Concise to etched enamel mean MPa of 16.6. Clearly this adhesive is better than Concise for bonding to amalgam, however the bond strength achieved is not as good as for Concise to enamel.

#### 1.4 History and Development of Adhesives in Restorative Dentistry.

Tanaka *et al.* (1981) described an opaque resin containing 4 methacryloxyethyl trimellitate anhydride (4-META) which provided good adhesion between thermo-setting acrylic resin and nickel-chromium alloy castings without use of mechanical retention. They found that with this new resin, the bond strength was greater than 200kg/cm<sup>2</sup> after immersion in water for one day at 37°C as compared to less than 80kg/cm<sup>2</sup> for a conventional resin specimen.



**Fig 3.** Structure of 4- META

Combined pretreatment of the casting surface with either grinding or etching and oxidation resulted in improvement of adhesive stability.

This resin has found widespread use in clinical cementation of adhesive fixed partial dentures (AFPD) and recently has been used for post-orthodontic fixed retention (Deguchi and Amari, 1987).

It is important to remember that the original Rochette bridge relied solely on macromechanical retention provided by the countersunk perforations in the framework (Rochette, 1973). The Maryland bridge described by Livaditis and Thompson (1981) used a microetched surface to achieve retention.

The electrolytic etching of the alloys used was technique sensitive and time consuming. There has been reasonable success with these adhesive bridges (Olin, 1991; Yu X-Y and Xu J-N, 1987).

Creugers (1988) maintained that the bond strength of a composite resin to an alloy is dependent on

- 1] Surface treatment of the alloy.
- 2] The luting resin cement.
- 3] The type of alloy.

He argued that an optimum bond strength would result from an ideal combination of three factors. In the hope of finding an optimum resin - metal bonding system, he evaluated four resin metal bonding systems for tensile bond strengths. The systems tested were:

- [i] Silicoating (Micropont)

[ii]	Sandblasting	(Panavia X)
[iii]	Electroplating	(Panavia X)
[iv]	Etching	(Clearfil F)

Highest bond strength values were found for silicoated and sandblasted CoCr samples. Lower bond strength values were found for etched NiCr samples.

### **1.5 Adhesives used for Metal to Metal Bond**

1. Panavia 10 MDP ( Kuraray Co., Kayama, Japan ).
2. Superbond 4-META ( Sun Medical Co. Ltd., Kyoto, Japan ).
3. Geristore / Tenure ( Den Mat, Santa Maria, USA ).
4. ABC Milage Bond System ( Chameleon, Kansas City, USA ).

#### **1.5(I) Panavia**

Panavia Ex is a dimethacrylate resin incorporating phosphate ester groups which bonds well to etched enamel and has shown very high bond strengths (up to 40 MPa ) to sandblasted nickel -chromium alloy ( Albers, 1991; Aquilino, 1991; Diaz - Arnold *et al.*, 1989, 1993, 1996; Kohli *et al.*, 1990; Watanabe *et al.*, 1988).

Atta *et al.* (1990) used three different adhesives: Panavia Ex, Superbond C & B and ABC Cement to bond to a beryllium free, nickel -chromium alloy.

After 6 months immersion in water or through thermocycling (500 cycles) between 50°C and 600°C, the specimens were tested for both shear and tensile strengths. The highest values of tensile and shear strength were found with Panavia Ex material

( 40 MPa ) and the values showed no significant change after thermal cycling.

The samples were sandblasted with 50 micron aluminum oxide particles. Panavia Ex usually failed partially cohesively, partially adhesively, when tested in tension and shear.

The authors concluded that, since the electron micrographs showed a rough, pitted surface with no macro or micro retentive elements, the bond between the sandblasted surface and the adhesive cement must be attributed to the ability of the adhesive cement to wet the metal surface and form chemical bonds. The phosphoric ester group, incorporated within Panavia Ex, must be responsible for the strength of its bond with the metal.

Kern and Thompson ( 1993) also investigated the bond strength of Panavia Ex to non- precious metals using sandblasted surfaces and found similar bond strengths.

Ishijima *et al.* (1992) investigated the bond strength of three different composite resin systems, Silicoater, Panavia Ex and Superbond C & B. They found that thermal cycling caused a reduction in the bond strength for all combinations of the adhesive systems and alloys. The Silicoater system recorded the greatest bond strength with all the alloys. The 4-META and Panavia Ex adhesive systems exhibited similar bond strengths to most metals, but 4 - META demonstrated greater strength with specific metals.

The original choice of alloy determined the final bond strength after thermal cycling. After 7 days in saline at 37°C, the mean bond strength for Panavia to Herador alloy

was 12.9lbs. After 1500 thermal cycles (50°C and 550°C), the bond strength was 8.8 MPa.

However, when Panavia bonded to another alloy, Vitallium, the original bond strength was 30.6MPa ( after 7 days in saline at 37°C). The bond strength was 30.8MPa after 1500 cycles (50°C and 550°C). The increased chromium content in Vitallium, compared to Herador, may be responsible for the different bond strengths. Salonga and Matsumura (1994) investigated the bonding durability of an adhesive resin ( 4 - META/MMA TBB opaque resin ) joined to the nickel- chromium alloys with different chromium content. Pure chromium and nickel metals were examined in vitro by shear testing before and after thermal cycling. They reported that the bond strength of all groups deteriorated after thermal cycling and the rate of decrease inversely followed chromium content. They recommended the use of a high chromium content alloy when a fixed partial denture made of nickel chromium is cemented with a 4-META/MMA - TBB resin.

These studies of cobalt- chrome adhesives are important as common nickel- chromium - beryllium alloys, used for resin -bonded fixed partial dentures, have possible health hazards due to leaching of nickel and chromium ( Moffa *et al.*, 1977).

Kern and Thompson (1994) sandblasted CoCr alloy ( Wiron 99) with 110 micron Al<sub>2</sub>O<sub>3</sub> at 0.25 MPa pressure and investigated six different bonding systems.

Medium term water storage at a constant temperature or thermal cycling are the conditions used most often to simulate aging of bonds. In this study medium term

water storage was combined with thermal cycling at regular intervals to test the medium term durability of the bonding methods used. The phosphate containing composite ( Panavia Ex ) resulted in an initial bond strength of 47.5MPa to a final bond strength of 53.7 MPa after 150 days at 37°C with 500 thermal cycles. This bond strength was statistically higher than the bond strength of the conventional BisGMA composite which contains no adhesive monomer. The phosphate ester is reported to bond directly to metal oxides (Wada, 1986).

However, Kern (1993) reports that sandblasting dental alloys results in a significant increase in alumina in the surface composition and MDP - containing composite exhibited a high and durable bond strength to glass- infiltrated alumina ceramic.

The authors concluded that only SMD (Silicoater ) and Panavia Ex fails completely within the resins and had durable bond strengths of over 50MPa and can therefore be recommended for use with CoCr alloy.

In the last 2 years, the Kuraray Co. Ltd has produced a new Panavia paste / paste system called Panavia 21. ( Fig 4 )

It has a dual metered syringe dispensing unit that delivers measured amounts of catalyst and paste. This system greatly simplifies mixing and handling of the material. The new Oxyguard has a lower viscosity than the original Oxyguard and also contains a polymerization accelerator to ensure more effective setting of the margins. The chemical composition of the original Panavia 21 is similar to the original Panavia.

It has a variety of clinical applications:



### 1.5(ii) 4 - META Superbond (Fig 5)

4 - Methacryloxyethyl trimellitate anhydride (4 - META ) is a resin monomer which contains hydrophilic and hydrophobic groups. 4 - META is a component (5% by weight ) of an adhesive resin which contains methyl methacrylate MMA/polymethylmethacrylate (PMMA ) initiated by Tri - N - Butyl Base (TBB).

The adhesive resin bonds strongly to etched enamel (14 MPa ) and weakly to unetched enamel (Yamida *et al.*, 1988). It can also bond (17MPa) to dentin treated with a solution of 3% ferric chloride in 10% citric acid. This solution removes the smear layer, allowing mechanical interlocking of the resin.

Acrylic resin containing 4 -META bonds to dental alloys, especially non precious ones. Oxidation of the surface increases adhesion, indicating that the resin bonds more strongly to the metal oxide than to the metal itself (Yamashita, 1982).

Unfortunately, the adhesion of 4 - META resin to chemically oxidized alloy has proved to be not as water- resistant as Panavia, resulting in clinical failure (Atta *et al.*, 1990; Tanaka *et al.*, 1986).

Most studies show that sandblasting of non precious alloys with 50 micron alumina particles does enhance adhesion to the resin. Sandblasting roughens the alloy surface, removes debris and improves wetting of the adhesive. Bonding to cobalt chromium has produced a bond strength of over 21MPa ( Tanaka, 1981). Similar results have been reported for nickel chromium alloy ( Boyer, 1992).



Fig 5. 4 - META Superbond

4 - META does not bond as strongly to precious gold alloys as to non precious alloys. However, sandblasting and tin plating of Type IV gold alloys improves adhesion to the resin to acceptable levels (McCaughey, 1993; Watanabe, 1988). 4 - META resin bonds more strongly to sandblasted Ni -Cr -Be than to sandblasted gold alloy because more oxides are present on the surface.

4 - META/MMA - TBB resin bonds strongly (20MPa) to dental porcelain primed with silane coating agent and ferric chloride. The silane coupling agent bonds to the SiO<sub>2</sub> component and 4 - META bonds to the Al<sub>2</sub>O<sub>3</sub> component of porcelain (Matsumara et al 1987).

4 - META/MMA - TBB resin is used for cementation of sandblasted or tin plated resin - bonded prostheses. It can also be used for cementation of posts in endodontically treated teeth and for conventional crowns, fixed partial dentures and inlays (Farah, 1988; Shintani *et al.*, 1985). The resin has also been used to seal cavity margins of alloys and it inhibits microleakage (Uarga *et al.*, 1986; Shimizu *et al.*, 1986).

### **1.5(iii) Geristore**

The Geristore/Tenure system is composed of a blend of 72% glass ionomer, 28% hydrophilic Bis-GMA composite resin in a two paste formulation (Clin. Res. Assoc.,

1992) and an adhesive based on an oxylate bonding system containing NTG- GMA and PMDM. NTG -GMA is N -Toly- glycine glycidyl methacrylate in acetone. PMDM is the reaction product of pyromellitic dianhydride and hydroxyl methacrylate ( Barkmeier and Cooley, 1989). The shear bond strengths are high (18MPa) when bonding sandblasted nickel - chromium alloy to enamel, even after thermal cycling ( Penugonda *et al.*, 1992).

#### **1.5(iv) Mirage ABC System**

This system consists of three component solutions A,B and C: A is the resin adhesive activator which is based on NTG -GMA; B is the adhesive resin containing PMGDM (pyromellitic glycerol dimethacrylate) and C is the metal adhesive activator and is a solution of dimethyl - p- toluidine. Bond strengths of 16.8 MPa to non precious alloys are claimed by the manufacturer ( Mirage Product Information).

### **1.6 History and Development of Sandblasting**

Sandblasting or air abrasion, microetching with either 25, 50 or 110 micron aluminum oxide particles, is a simple, inexpensive and effective method of removing investment and has become popular in dental laboratories (O'Connor *et al.*, 1990; Kern and Thompson, 1995). It may also be used as part of the surface preparation of bonding alloys before steam cleaning, degassing and application of opaque porcelain (Rosenstiel *et al.*, 1988). It is also used as a treatment for the fitting surfaces

of adhesive bridges, cast from non precious alloys, when they are cemented with adhesive luting resins such as Panavia ( Clin. Res. Assoc., 1990). The surface should be sandblasted and then, if possible, immediately covered with resin ( Scott *et al.*, 1993).

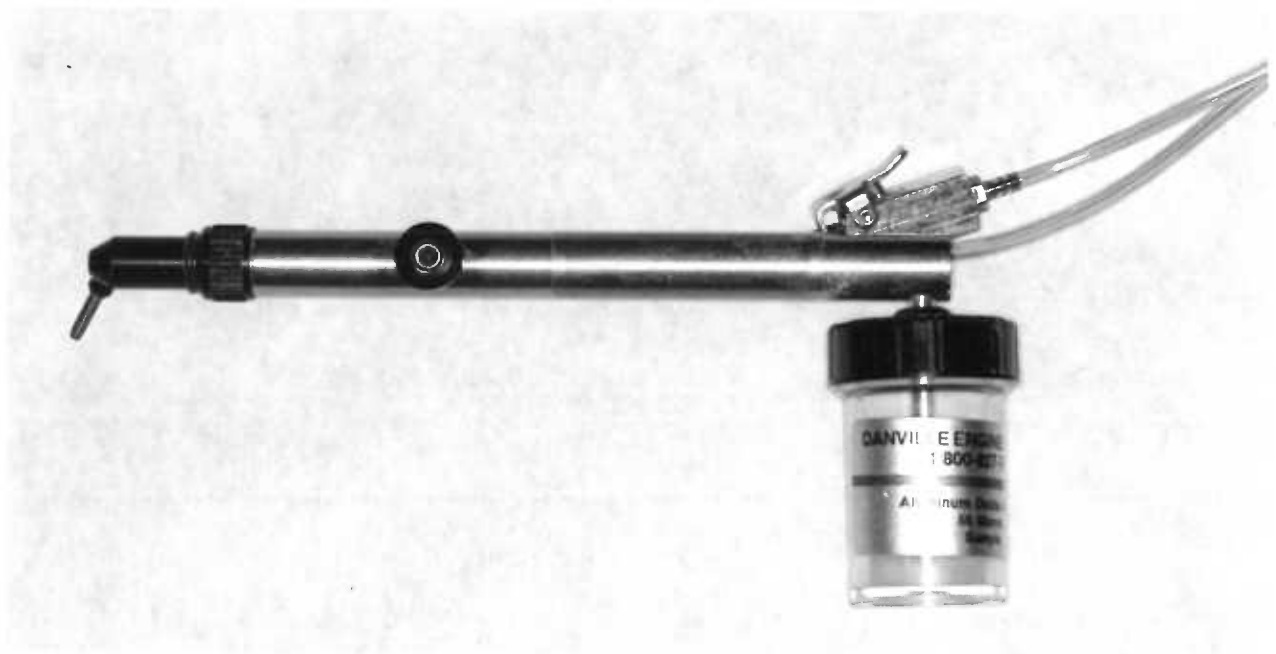
Sandblasting the fitting surface of conventional crowns has been shown to increase the cementation strengths with zinc phosphate cement. It has been shown that if the freshly sandblasted surface is not to be cemented immediately with Panavia, storage in distilled water causes the least reduction in bond strengths ( Aboush, 1992).

Until recently, the only sandblasters available have been for laboratory use. However, several units are now available for intra - oral use. One of these is the Micro-Etcher, a modified airbrush requiring an air pressure of 60-100 PSI, which should be available from a dental unit. This sandblaster has now been approved by the FDA as an intra-oral mechanical device. Protective goggles must be used for patient , operator and assistant together with wide bore high volume aspiration. A damp piece of gauze should cover the patient's nose.

The Danville model ( **Fig 6** ) includes a contra-angle nozzle, control buttons and rear - mounted abrasive jars that contain either a fine 50 micron white or a coarser 90 micron tin aluminum oxide powder ( Note: Only 50 micron powder has been given FDA approval for intraoral use). The tubing is connected to a compressed air source in the operatory and operates at about 7Kg/cm<sup>2</sup> optimum pressure.

Specific orthodontic applications include removal of composite from base brackets before rebonding (Newman *et al.*, 1994, 1995), increasing the retentiveness of

stainless steel bands and bonding to porcelain (Millet *et al.*, 1995). Intraoral sandblasting is messy, however it only takes about 3 seconds. Any laboratory sandblasting should be carried out inside a dust cabinet.



**Fig 6. Microetcher ( Danville Model )**

Fox, McCabe and Buckley (1994) examined, in vitro, the effect of sandblasting on the bond strength and survival time of first molar orthodontic bands. Survival time was assessed after simulated mechanical fatigue in a ball - milling machine. The effect of sandblasting on the failure rate of 320 first molar bands cemented in 107 patients was examined in a clinical trial.

In vitro sandblasting increased strength by 27% and produced a three fold increase in the median survival time relative to the untreated sample in the ball mill experiment. In vivo, sandblasting resulted in more cement remaining on the band rather than on the tooth enamel following band removal. It also reduced the clinical failure rate by 20%.

There is no standardization of test procedures for the measurement of bond strengths (Fox, McCabe and Buckley, 1994), making a valid comparison between reported bond strengths more difficult. The literature can only be read with a view to observing certain trends. Reported results of experimentation can be used to confirm one's clinical impression.

Rueggeberg (1991), in a review article, states " There are myriad variables that must be considered in the testing of materials adhesive to tooth structure. With adhesion research being performed in a non - standardized manner, it becomes impossible for results to be compared among different research groups."

From this brief review, it would seem that sandblasting non - precious alloy, such as stainless steel, together with the addition of either Panavia or Superbond should increase the bond strength of crimpable hooks applied to archwires.

## **1.7 History and Use of Crimpable Hooks in Orthognathic Surgery**

Surgical stabilizing arch wires are usually placed at least one week before surgery. The arch wires stabilize the new occlusion immediately post - operatively, usually via an interdental splint.

They have the following characteristics:

- 1] They should fully engage the slot ( as large as the rectangular arch wire that is compatible with patient comfort, usually 17/25 in an 18-slot appliance or 19/25 or 21/25 both in a 22-slot appliance).
- 2] They should allow for attachments on the arch wires and soldered brass spurs are the preferred attachments to the wire itself (Profitt, 1991).
- 3] In addition to allowing the splint to be tied in at surgery, it also allows post surgical use of elastics.

Profitt (1991) criticizes the placement of crimpable hooks directly to the archwire.

- 1] Crimping alone may not hold the hook in the correct position with subsequent sliding while dento-alveolar segments are being manipulated.
- 2] The act of crimping alone may distort the arch wire and introduce unwanted active forces into the archwire.

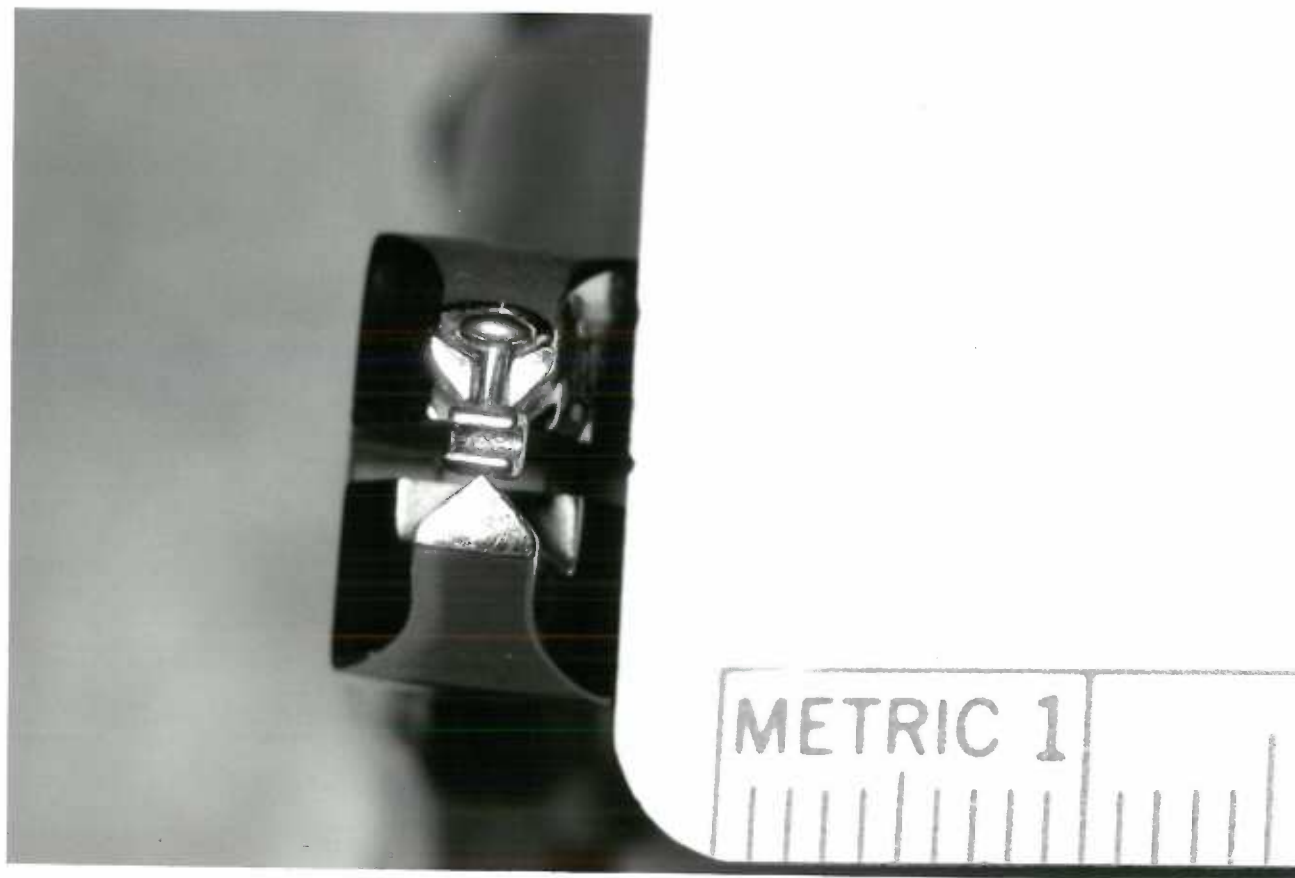


It is important to allow the stabilizing wire to become passive before surgery.

Crimpable hooks ( **Fig 7** ) allow the placement of hooks on rectangular archwire quickly and with minimum patient discomfort. They can be placed with the archwire in situ, thereby reducing chair time in comparison with the conventional method of soldering brass wire to the archwire. They are usually placed and crimped with a special crimping pliers. If placed properly, they can resist sliding forces of up to 10 N (Evans and Jones, 1991). Unfortunately, this is often achieved with the side effect of kinking the wire.

Despite this, they have achieved widespread popularity and have been used both in routine orthodontics and as surgical hooks for maxillo-mandibular fixation.

However, some surgeons distrust crimpable hooks as they can, on occasion, become loose with possible serious consequences, especially during surgery (Evans and Jones, 1991).



**Fig 7. Crimpable Ball-Hook**

## 2     Aim

The aim of this study is to use crimpable hooks in a conventional manner with the addition of sandblasting the stainless steel rectangular wire, while also using adhesive resin to increase the bond strength. It is hoped that gabling of the wire will be prevented by using light crimpable pressure.

## 3     Method and Materials

The same operator carried out all procedures.

6 groups were tested as follows ( *Table 1* )

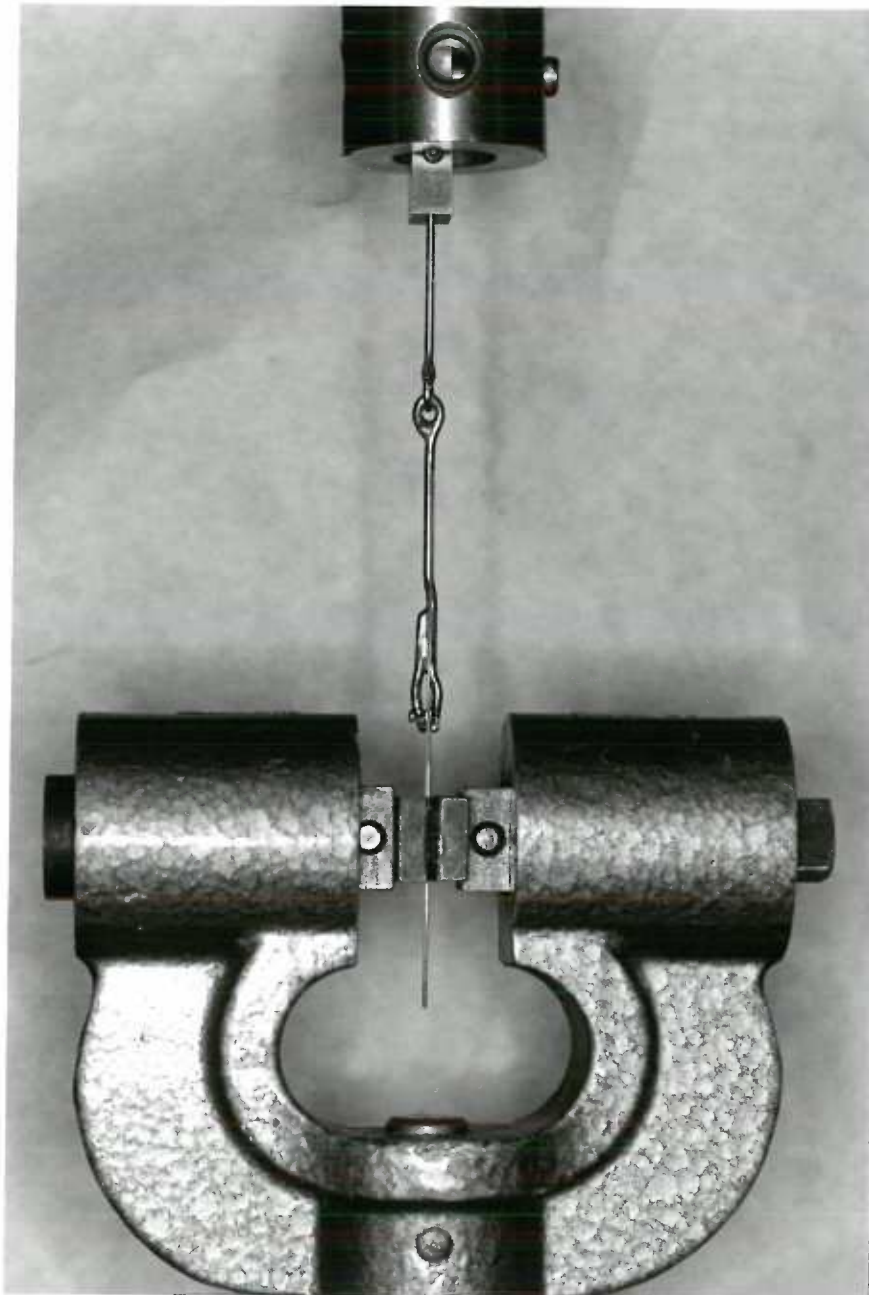
	<u>Control</u>	<u>Panavia</u>	<u>4 - META</u>
<u>Crimp</u>	Group 1	Group 2	Group 3
<u>Crimp + Sandblasting</u>	Group 4	Group 5	Group 6

**Table 1**     *Test groups*

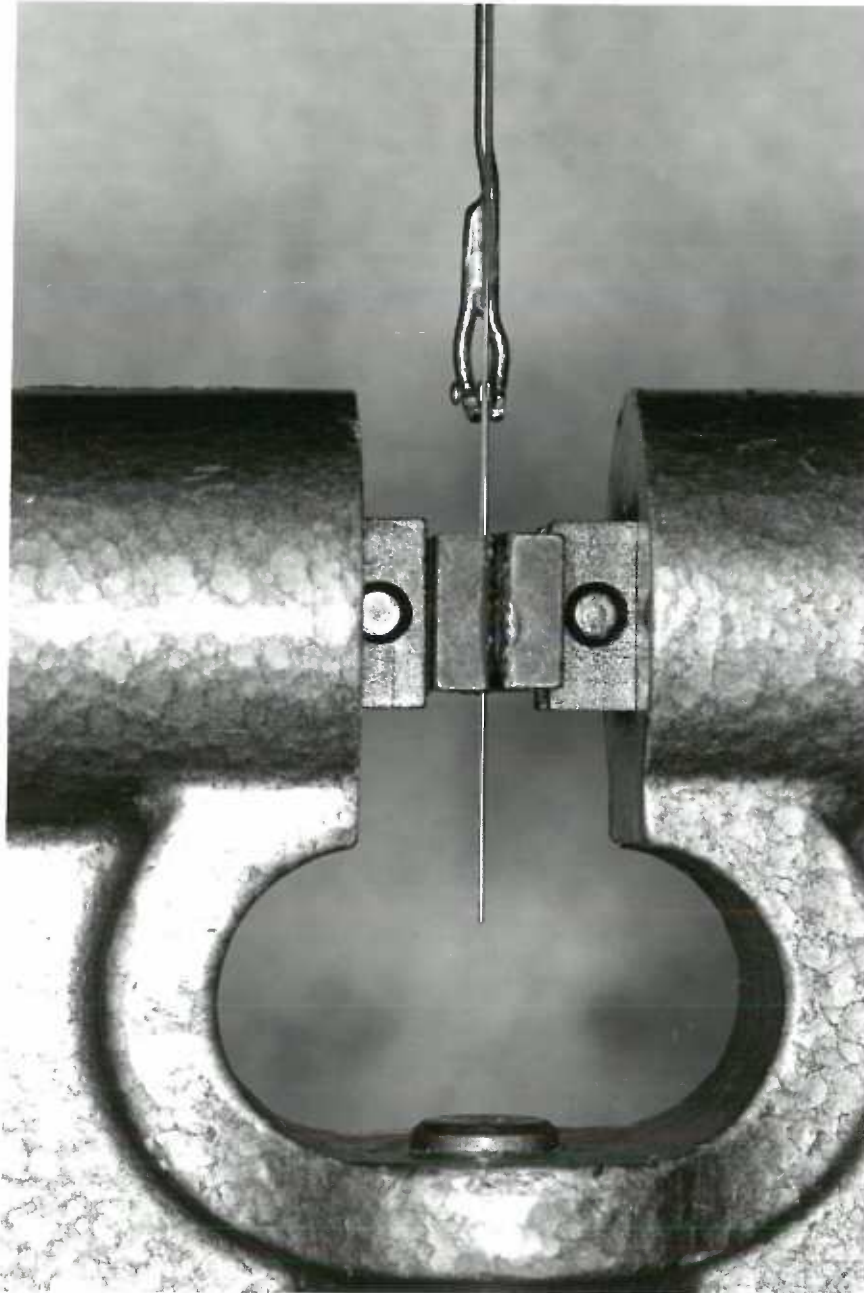
... In 5 groups ( Groups 1,2,3,5,6) 15 hooks were attached to a 4 cm length of .019 x .025 inch stainless steel wire .

... In the remaining group ( Group 4 ) 14 hooks were attached to a 4 cm length of .019 x .025 inch stainless steel wire.

The hooks were lightly crimped and any wire showing any evidence of gabling was rejected.



**Fig. 8      Crimpable Hook + Stainless Steel Wire Loaded in Customized Jig  
of Instron Machine.**



**Fig. 9** Crimpable Hook + Stainless Steel Wire Loaded in Customized Jig of Instron Machine (Close - up view ).

The groups where adhesive was used ( Groups 2,3,5 &6) were tested one week after the application of adhesive.

The hooks were then loaded in a vertical direction via a customized jig to the cross heads of an Instron machine. ( **Fig 8 and Fig 9** )

Groups 2,3,5 and 6 were run at a speed of .05in/min, with a full scale deflection of 20lbs.

Groups 1 and 4 were run at a speed of .05in/min with a full scale deflection of 2lbs.

#### **4      Results**

The force required to dislodge each hook is recorded in (**Table 2**).

The mean force required to dislodge the hooks is shown in ( **Table 3** ) and ( **Fig 10** ).

Analysis of the data using a two way ANOVA ( **Table 4** ) demonstrates that the forces required to dislodge the hooks subjected to crimping alone differed from those required where the hooks had been sandblasted prior to crimping. The difference was significant at  $P < .0001$ .

The adhesive factor was also found to be significant and follow up Scheffe Tests indicate that Control, Panavia and 4 - META all differ from each other at  $P < .0001$  ( **Table 5i and 5ii** ) .

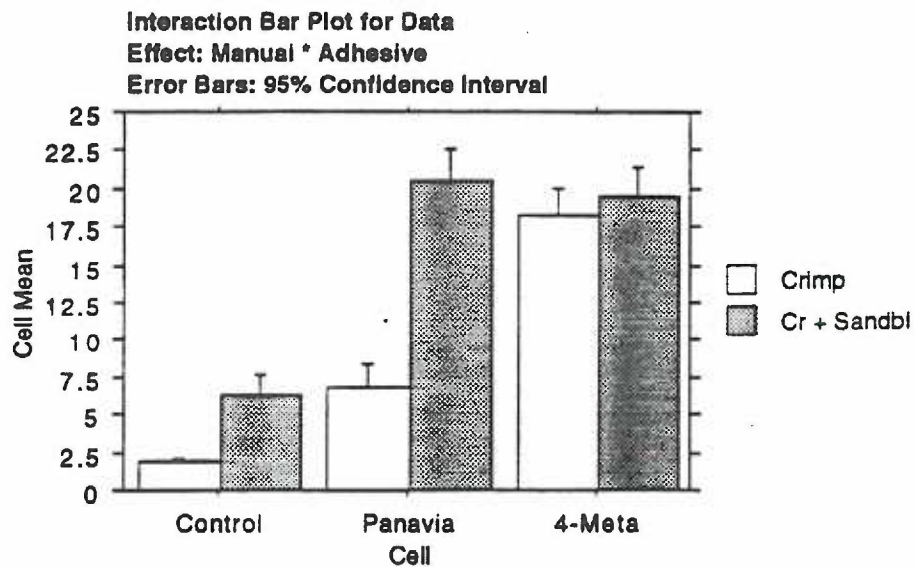
In ( **Fig 11** ) the two lines are not parallel, indicating that the crimping plus sandblasting groups always produce a higher bond strength than the crimping- alone groups. However, where the adhesive used is 4 - META, this difference is small.

**Table 2. Summary of Force Required to Dislodge Crimpable Hooks**

<b>Hook #</b>	<b>Group 1 Control Crimp only</b>	<b>Group 2 Crimp + Panavia</b>	<b>Group 3 Crimp + 4 - META</b>	<b>Group 4 Control Crimp + S/B only</b>	<b>Group 5 Crimp + S/B + Panavia</b>	<b>Group 6 Crimp + S/B + 4 - META</b>
1	2.25lbs	7.8lbs	13.9lbs	5.6lbs	16.7lbs	16.5lbs
2	1.45lbs	6.2lbs	14.8lbs	8lbs	15.2lbs	17.5lbs
3	2.15lbs	9.7lbs	20lbs	5.4lbs	16lbs	19.6lbs
4	2.4lbs	6.7lbs	15.7lbs	4.7lbs	20.5lbs	20.4lbs
5	2.25lbs	5.6lbs	13.7lbs	5lbs	17.3lbs	16.2lbs
6	1.75lbs	4.1lbs	17.6lbs	4.3lbs	23lbs	15.2lbs
7	2lbs	6.6lbs	18.4lbs	7.7lbs	25.8lbs	26lbs
8	1.85lbs	11.8lbs	20.3lbs	10lbs	26.5lbs	13.2lbs
9	1.4lbs	4.3lbs	17lbs	9.42lbs	19.1lbs	23.3lbs
10	2.2lbs	7.7lbs	17.1lbs	5.2lbs	22.8lbs	20.7lbs
11	1.45lbs	5.8lbs	21.3lbs	4.1lbs	19.5lbs	24.6lbs
12	1.35lbs	3.8lbs	24.3lbs	9.4lbs	25.3lbs	23.2lbs
13	2lbs	5lbs	22.3lbs	6.4lbs	23.3lbs	23.7lbs
14	1.35lbs	4.2lbs	21.2lbs	9.4lbs	17.7lbs	20.3lbs
15	1.8lbs	12.7lbs	15.4lbs		19.5lbs	16.8lbs

**Table 3.****Mean Force Required to Dislodge Hooks****Means Table for Data**  
**Effect: Manual \* Adhesive**

	Count	Mean	Std. Dev.	Std. Err.
Crimp, Control	15	1.843	.370	.095
Crimp, Panavia	15	6.760	2.752	.710
Crimp, 4-Meta	15	18.200	3.248	.839
Cr + Sandbl, Control	14	6.314	2.201	.588
Cr + Sandbl, Panavia	15	20.547	3.696	.954
Cr + Sandbl, 4-Meta	15	19.387	3.418	.882

**Fig 10.****Bar Graph of Mean Forces Required to Dislodge Hook**



**Table 4. 2 Way Anova for Data**

**ANOVA Table for Data**

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Manual	1	934.081	934.081	115.123	<.0001
Adhesive	2	3277.483	1638.742	201.971	<.0001
Manual * Adhesive	2	639.765	319.883	39.425	<.0001
Residual	83	673.442	8.114		

**Table 5i. Scheffe Test: Crimp / Crimp + Sandblasting**

**Scheffe for Data**

**Effect: Manual**

**Significance Level: 5 %**

	Mean Diff.	Crit. Diff	P-Value	
Crimp, Cr + Sandbl	-6.688	1.201	<.0001	S

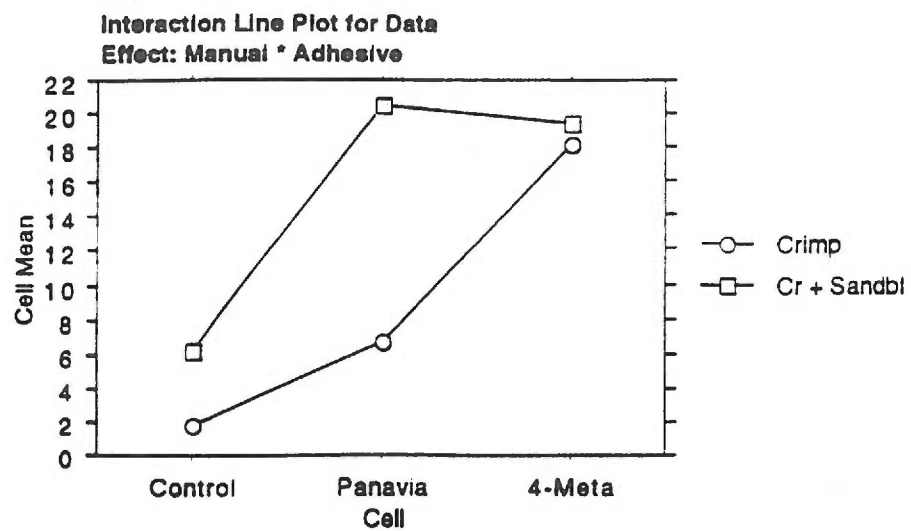
**Table 5ii. Scheffe Test: Panavia / 4 META**

**Scheffe for Data**

**Effect: Adhesive**

**Significance Level: 5 %**

	Mean Diff.	Crit. Diff	P-Value	
Control, Panavia	-9.652	1.849	<.0001	S
Control, 4-Meta	-14.792	1.849	<.0001	S
Panavia, 4-Meta	-5.140	1.833	<.0001	S



**Fig.11**      Interaction Line Plot for Data

## 5 Discussion

The results show that using either: [i] Panavia + sandblasting + crimp or  
[ii] 4 - META + crimp  
can increase the force required to dislodge the hooks by a factor of 10.

Historically, both Panavia and 4-META have proved to be difficult materials to manipulate, requiring strict adherence to manufacturer's instructions. With the introduction of Panavia 21 in a metered dispensing system, the application of the material for orthodontic purposes has been greatly enhanced. The working and setting times are adequate and should find application in other areas, e.g. bonding to gold and amalgam and porcelain. 4 - META has also shown a dramatic reduction in bond strength with thermal cycling and therefore is not a material of choice to use with construction of surgical archwires. It still remains an interesting material whose full potential will not be realized until it is introduced in a metered system. The reduction of bond strength may not be a major problem as arch wires only remain in situ for a maximum of 3 months.

The next logical step, besides a clinical trial, would be to repeat this experiment but with thermal cycling of the materials. Theoretically, 4 - META bond strength should decrease, whereas Panavia should stay at the same level. It may also be possible to use this technique with modified crimpable bases to bond spring attachments directly to the archwire.

A bond strength of 20lbs is adequate for surgical wire manipulation. It is recommended that this procedure be carried out extraorally, at chairside with surgical wires. It

should be possible, with experience, to use this technique with surgical wire in situ, as an excessive force is no longer required to crimp these hooks.

The most useful clinical technique is that involving the Panavia adhesive system and microetching. It is a much easier system to manipulate, simply requiring the rotation of the dispensing syringe until it clicks. This dispenses the correct amount of Panavia 21 catalyst and Universal paste with a working time of 4 minutes, allowing sufficient time to crimp one arch wire, when working with a chairside assistant.

4 - META is not as "user - friendly", requiring more stages and greater manipulation of the material. Working time is only 2.5min.

## **6 Conclusion**

- 1] The addition of Panavia 21 + sandblasting increases the force required to dislodge hooks by a factor of 10.
- 2] Inadvertent gabbling or slippage of hooks is eliminated, as excessive force is no longer required to crimp the hooks.
- 3] The material is more hygienic and avoids cross infection problems encountered with the use of a single soldering machine in a busy office. Consequently, effective cross- infection protective zoning can be achieved.
- 4] Construction time of surgical wire is greatly reduced.

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**Appendix (i)****Tables and Figures**

Table 1	Test Groups	p36
Table 2	Summary of Force Required to Dislodge Crimpable Hooks	p40
Table 3	Mean Force Required to Dislodge Hooks	p41
Table 4	2 Way Anova for Data	p42
Table 5i	Scheffe Test: Crimp/ Crimp + Sandblasting	p42
Table 5ii	Scheffe Test: Panavia/ 4 - META	p42
Fig.1	BisGMA	p10
Fig.2	Phosphate Ester of BisGMA	p18
Fig.3	Structure of 4 - META	p19
Fig.4	[Photo] Panavia 21	p25
Fig.5	[Photo] 4 -META Superbond	p27
Fig.6	[Photo] Microetcher (Danville Model)	p31
Fig.7	[Photo ] Crimpable Hook	p35
Fig.8	[Photo ] Crimpable Hook + Stainless Steel Wire Loaded in Customized Jig of Instron Machine	p37
Fig.9	[Photo ] Crimpable Hook + Stainless Steel Wire Loaded in Customized Jig of Instron Machine (Close up view).	p38
Fig.10	[Graph] Bar graph of mean force required to dislodge hooks	p41
Fig.11	[Graph ] Interaction Line Plot for Data	p43

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- \*\* Parkell, 155 Schmitt Blvd., Farmingdale, NY 11735, USA. [4-METASUPERBOND]
- \*\*\*\* TP Orthodontics, La Porte, Indiana, USA. [CRIMPABLE HOOKS]