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A new orthodontic bonding adhesive.

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INTRODUCTION

The period with bands on all teeth is long gone and the bonding of orthodontic attachements is here to stay, Turner, 1996. Bonding orthodontic brackets have for a number of years been obtained by using a composite resin material. Either a chemical cure or a light-cure material, , Sargison, McCabe and Gordon, 1995. In the last couple of years glass-ionomer cements have also been used with good success, though mostly for cementing of orthodontic bands, Örtendahl and Thilander, 1998.
The use of composite resins have not been completely free from problems. A number of dentists have experienced allergic problems due to the bonding resins Hensten-Pettersen, 1991. A common problem has also been the moisture sensitivity and the taste of the adhesives.

For almost 20 years cyanoacrylate glues have been widely used within the industry as well as in medicine, Eastman and Robicsek, 1998. A number of studies have reported from longterm use of cyanoacrylate material inside the human body, Gosaina et.al., 1998; Cheng and Saing, 1997. In 1991 a commercial ethylcyanoacrylate material was tested as an orthodontic adhesive for bonding of brackets, Kahl et.al., 1993. It was compared to a traditional composite resin and the ethylcyanoacrylate material was found to reach significantly higher tensile forces than the composite. After 50, 100 and 150 days in a saline solution no decrease in tensile forces could be registered.
The cyanoacrylate adhesive used in the present study (Smart Bond®) is delivered as a gel adhesive. The material has after preliminary clinical tests been found to reach an acceptable shearforce strength after 2-3 minutes but do not to reach it´s maximum shearforce until after 24 hours according to manufacturers instructions. The setting is initiated by pressure and water. The surface of the etched enamel should therefore be completely covered with water just prior to the bonding of an orthodontic bracket.

The **aim** of this report was to study and compare a cyanoacrylate bonding material with established composite bonding materials regarding shear bond strength, debonding properties and ARI index.

MATERIALS AND METHODS.

Prior to the analysis of the cyanoacrylate adhesive (Smart Bond®) a methodevaluation using Rely-a-Bond® was performed. Rely-a-Bond® was compared to the following composite resins in order to analyse if it was a suitable material to be used together with booth metal and polycarbonate brackets. Rely-a-Bond® was also choosen as it is widely used. The other tested bonding materials were Cure-on-touch®, Polar Light®, Phase II®, Quasar®, Monolock®, Advantage® and Light Bond®. Table 1.

Bondingmaterials

Material	**Name**	**Manufacturer**	**Setting**
composite	Cure-on-touch®	Sci-Pharm Inc, Pomona, Cal.	Light-cure
	Polar Light®	Gestenco International AB, Göteborg, Sweden	Light-cure
	Light Bond®	Reliance Orthodontic Products Inc. Itasca, Ill	Light-cure
	Advantage®	Ortho-Organizers Inc, San Marcos, Cal.	Chemical
	Rely-a-Bond®	Reliance Orthodontic Products Inc. Itasca, Ill	Chemical
	Phase II®	Reliance Orthodontic Products Inc. Itasca, Ill	Chemical
	Monolok®	Rocky Mountain Orthod Inc. Denver, Co	Chemical
	Quasar®	Rocky Mountain Orthod Inc. Denver, Co	Chemical
ethyl-cyanoacrylate	Smart Bond®	Gestenco International AB, Göteborg, Sweden	Chemical

Table 1
Adhesives and manufacturers. With the light-cure adhesives, primers were used for 30 sec on the base of the polycarbonate brackets prior to applying the adhesive.

Sound extracted premolars were after extraction stored in 4 C0 in water. The extracted teeth were embedded in plaster in a mould with the buccal surface of the tooth visible above the plaster. The enamel surfaces on the extracted teeth were etched following the manufacturers recommendation for the composite resin (Rely-a-Bond®). Polycarbonate brackets (Image®) were bonded using an orientation device to secure that the brackets were identically bonded on the buccal surfaces. The chemical cure materials were allowed to set for 24 hours in 100% humidity in 35 degrees and the light-cure materials were light-cured for 60 sec using a VCL 400 Demetron® device before the shearbond testing was performed. They were thereafter stored under the same conditions.

After the initial tests Rely-a-Bond® was found to be a representative composite material and was used in comparison to the new ethyl-cyanoacrylate. Rely-a-Bond® reached well above the 7 MPa level which is regarded as a minimum limit for a bonding material used clinically, (Rezk-Lega and Øgaard, 1991), Figure 1.

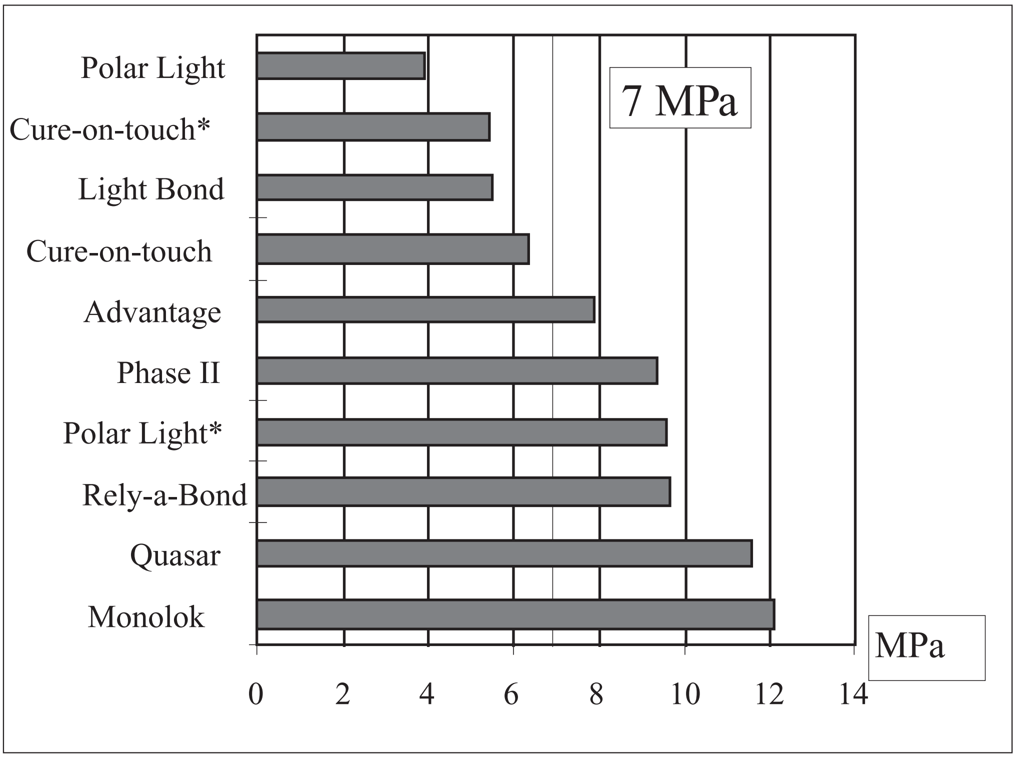

Figure 1
Shearforce strength for 8 adhesives. For two of them a primer was used.

For the comparison between Smart Bond® and Rely-a-Bond® the following brackets were used: Edgeway®, Omniarch®, Discovery®, Silcon®, Image®, Forestadent®, Elan® and Spirit®. Table 2.

Brackets

Material	**Name**	**Manufacturer**	**Retentionarea /others**
Stainless steel,	Omniarch®	GAC International Inc, Central Islip, NY	
	Edgeway®	Ortho-Organizers Inc, San Marcos, Cal.	
	Discovery®	Dentaurum GmbH, Pforzheim, Germany	
Polycarbonate	Image®	Gestenco International AB, Göteborg, Sweden	x
	Élan®	GAC International Inc, Central Islip, NY	Metal insert
	Aesthetic line®	Forestadent, Bernhard Förster GmbH, Pforzheim, Germany	
	Spirit®	Ormco, Glendora, CA	Metal insert
	Silcon®	American Orthodontics, Sheboygan, Wi	x

Table 2
Brackets, materials and manufacturers. Extensive basesurface enlargement marked with (x).

Sound extracted premolars were after extraction stored in 4 C0 in water. The extracted teeth were embedded in plaster in a mould with the buccal surface of the tooth visible above the plaster. The visible enamel was inspected using light microscopy to avoid including test samples with enamel fractures as a result from the extraction. The enamel surfaces on the extracted teeth were etched for 10 sec for the ones to be used together with the cyanoacrylate (Smart Bond®, CA) material and following the manufacturers recommendation for the composite resin (Rely-a-Bond®).
The brackets were bonded using an orientation device to assure that the brackets were identically bonded on the buccal surfaces. The composite resin was allowed to set for 24 hours before the shearbond testing and the teeth were stored for 24 hours in 100% humidity in 35 degrees. Excess material was removed immediately.
As the setting for the CA material is initiated by pressure and water the surface of the etched enamel was completely covered with water just prior to the bonding of an orthodontic bracket. A slight pressure was applied using a probe for 1-2 sec. Excess material was removed immediately. The CA was allowed to set for 24 hours before the shearbond testing and the teeth were stored for 24 hours in 100% humidity in 35 degrees. The blooming of the rest of the excess material was not removed.

Due to the effect from the CA material on the polycarbonate bracketbase surface, brackets with very pronounced retention areas or undercuts has to be pretreated with water. Otherwise the CA can be left unreacted in the undercuts, leading to a deterioration in the bracketbase surface. The brackets which was pretreated with water is indicated in table 2.

As testing device a Lloyd® testing machine for dynamic loading was used. The brackets were analysed with respect to shearforce strength, ARI index and analysis of adverse debonding effects using light microscopy. Students - t-test was used for the force analysis as the differences was pronounced. For the ARI analysis Wilcoxon signed rank test was used.

RESULTS

The results from the methodevaluation tests indicate that Rely-a-Bond® works well for the bonding of both metal and polycarbonate brackets. The widely agreed limit of 7 MPa shearforce strength was well passed.
The results when comparing CA and CR is presented in Figure 2

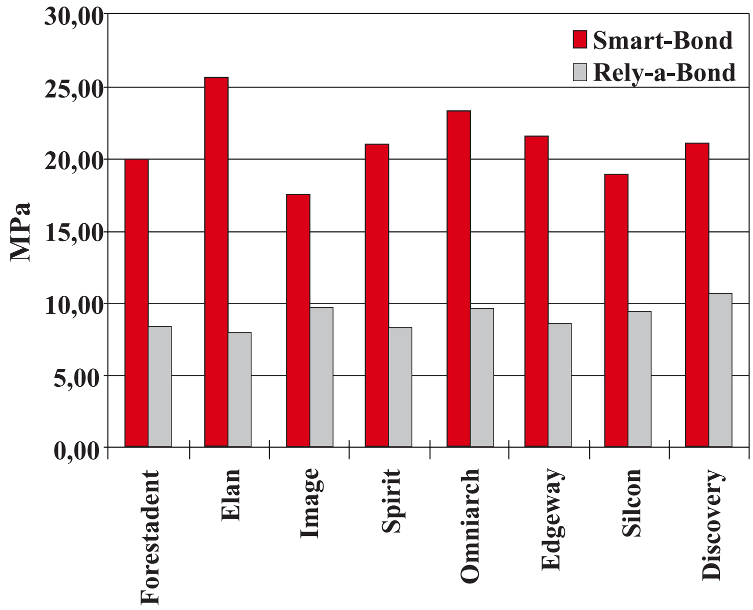

Figure 2
Shearforce strength results per square mm.

The shearforce strength level for CA together with the tested brackets were significantly higher ($p<0.001$) than for CR. The shearforces for CR for the different brackets did not differ significantly. The shearforce strength for the CA material was 60 - 300% stronger than for CR. For a bracket with pronounced retention areas such as Image® and Silcon® the CA material is only 60% stronger than the CR material, though the base was pretreated with water. The Élan bracket has an almost completely smooth base

surface and therefore reaches the highest values as gaps between the bonded surfaces decrease the shearforce strength.
The ARI index was used and the enamel under the bracket after debonding was analysed using the light microscope.

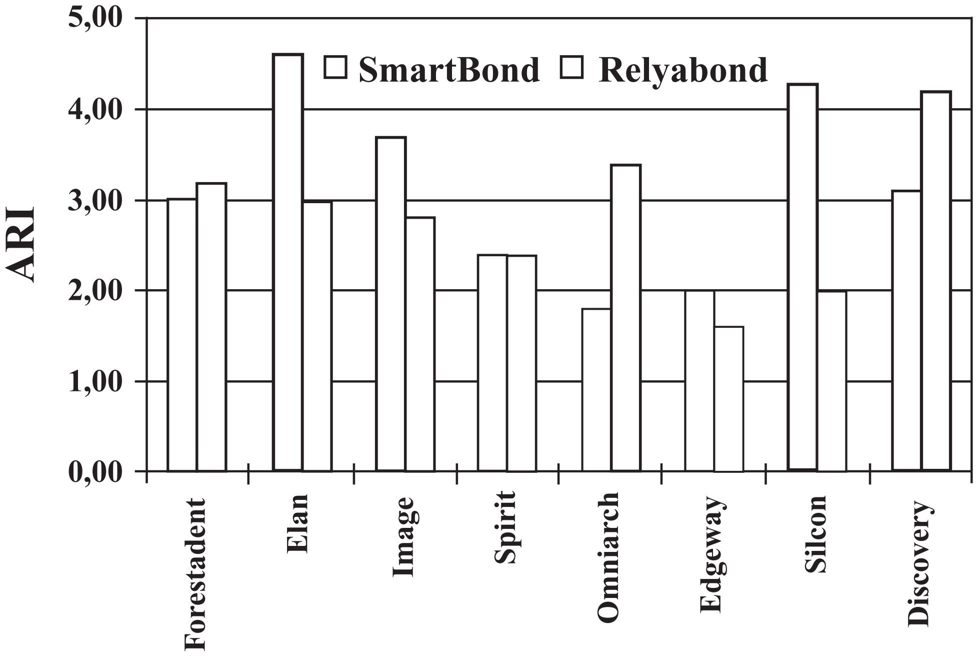

Figure 3
ARI index results. 1= 0% remaining on the tooth; 2 = <9% remaining on the tooth; 3 = 10-90% remaining on the tooth; 4 = >90% remaining on the tooth; 5 = 100% remaining on the tooth.

For Elan® and Silcon® almost no CA material was left on the enamel indicating a high degree of adhesive fracture between the enamel and the material. Only for Omniarch® and Discovery®, (both metal brackets) the CA material showed significant lower ARI index than the CR material.
The ARI index also indicate that there should be no risk for debonding damage to the enamel as no values reached ARI =5. The CA material reacts very similar to the CR material during the debonding procedure. After the registration of the shearforce strength all enamel surfaces on all test samples were analyzed using a light microscope. No signs of enamel fractures or other damages to the enamel with both the CA and the CR materials could be observed.

DISCUSSION

The cyanoacrylate adhesive is widely used as a super glue in industry for automakers, circuit- boardmakers and light-aircraftmakers. In medicine it has also been used for fracture fixation (Perry and Youngson, 1995; Kim, 1997), skin suturation (de Blanco, 1994), cardiac surgery (Eastman and Robicsek, 1998), guided tissue regeneration (Echeverría and Manzanares, 1995) and circumcision of children (Cheng and Saing, 1997).

As the polymerisation starts because of precense of water(moisture) and pressure the clinical procedure differ in relation to the traditionell one when bonding a bracket as well as how the patient and the orthodontist experience the material. Initial clinical experience indicate that the CA material does not work well together with polycarbonate brackets with pronounced retentionsurfaces unless the surface is pretreated with water. The excess material will be instantly polymerized and turns into a white acrylic powder around the bracket called blooming.

It is also very important that the surfaces to be bonded is as close to each other as possible. The material can not build up spaces and gaps why a bracket base with deep mesh or undercuts can decrease the shearforce strength.

Relating the results to a widely used bonding adhesive simplifies the interpretation of the results.

As far as the literature indicate there is no reports of allergy when using the material in the present formula and no signs of biocompatability problems. However, reports of toxic eczema among fingernail sculpture artists have been found, (Guin et.al., 1998). As these artists mostly use a number of materials it is most likely that the problems reported are due to metacrylate substances, (Kanerva et.al., 1996). Due to the wet environment and the small amount of adhesive used during the bonding procedure (20grams/year/orthodontist), vapour from the unpolymerized material is immediately polymerized when it get in contact with water. The well known vapour from a CA material can not be experienced by the orthodontist or the patient. The water also takes care of the taste. Exceptional situations can however occur when taste or smell can be experienced. The patient will not feel any taste or smell and no reports of allergy or other odontological adverse effects have been reported.

The cyanoacrylate polymerizes completely in contact with moisture. No rest monomer can react later in the process why no water is absorbed by the material. This is probably the reason why no discoloration of the adhesive during treatment can be seen.
No fractures in the enamel were observed after debonding which is in line with the clinical experience of the Dental Faculty of Malmö (personal communication) who has used Smart Bond. They have no experience of debonding problems. This is also in agreement with the author who has used it on a large number of patients with no signs of adverse debonding effects.
The shearforce strength level for CA together with the tested brackets were significantly higher than for CR which corresponds well with results from (Kahl et.al., 1993). For a bracket with pronounced retention areas such as Image® and Silcon® the CA material is only slightly stronger than the CR material, though the base was pretreated with water. The Élan® bracket has an almost completely smooth base surface and therefore reached the highest values as gaps between the bonded surfaces decrease the shearforce strength. The pretreatment of the base with water is only necessary when using a polycarbonate bracket.
The ARI index was used and the enamel under the bracket after debonding was analysed using the light microscope.

For Elan® and Silcon® almost no CA material was left on the enamel indicating a high degree of adhesive fracture between the enamel and the material. Only for Omniarch® and Discovery®, (both metal brackets) the CA material showed significant lower ARI index than the CR material.
The ARI index also indicate that there should be no risk for debonding due to high ARI values and the CA material reacted very similar to the CR material during the debonding procedure. No signs of enamel fractures or other damages to the enamel with both the CA and the CR materials could be found.

CONCLUSION

- Significantly higher shearforce strength values was registered for the CA material (Smart Bond®) than for the CR material (Rely-a-Bond®)
- Pretreatment with water of pronounced retentionsurfaces on polycarbonate brackets resulted in adequate shearforce strength.
- The CA material reacted similar to the CR material regarding adhesive remnants on the enamel indicating a large number of fractures that occured within the CA material and not on the enamel.
- No signs of damage to the enamel such as fractures or infractions could be observed after debonding.

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