Resin-Bonded Bridges in vitro and in vivo

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SUMMARY 12

In this thesis in vitro and in vivo studies on the clinical application of resin-bonded bridges are described and discussed.

The development of different types of resin-bonded bridges is described in chapter 1. The bridges are often made by bonding a cast metal retainer fitted with an artificial tooth to the acid-etched enamel of the abutment teeth. The cast metal retainers were originally perforated to obtain macro-mechanical retention of the composite resin to the metal. The first clinical results of resin-bonded bridges with perforated retainers showed that fractures occurred in the resin-to-metal bonding causing the bridges to become detached. This bonding had to be improved to increase the overall bond strength of resin-bonded bridges. Many studies have since been carried out on new resin-to-metal retention systems. One of these systems, electrolytic etching of the metal retainer surface, effectively creates micro-mechanical retention for resin. The bond strength values of resin to an etched metal surface should be higher than to an etched enamel surface. Disadvantages of this technique are the complex procedure itself and the restriction of its application to non-precious alloys. In 1983 an opaque resin bonding system (Opaker-Verbund-System or O.V.S.) was marketed to increase the retention of resin veneers to castings. This system is based on tin-electroplating a metal surface after sandblasting and can be applied to precious as well as non-precious alloys.

The few clinical results of resin-bonded bridges which have been published, generally deal with anterior bridges only.

Several designs have been proposed for posterior bridges but information on their indication and prognosis is scarce.

The aims of the present investigations were:

a) To describe and compare different resin to metal retention systems.

b) To test in vitro, the tin-electroplating system as a bonding system for the retention of resin-bonded bridges.

c) To compare in vitro, six retention systems for resin-bonded bridges.

d) To test the clinical behaviour of resin-bonded bridges with perforated or tin-electroplated retainers in the anterior and posterior regions of the mouth.

In chapter 2 bridge design and general procedures employed for resin-bonded bridges are discussed. Guidelines for: the indication of resin-bonded bridges, the preparation of the abutment teeth, the fabrication of the bridges in the dental laboratory and the bonding of the resin-bonded bridges used are described.

A review of retention systems for composite resins to the cast metal retainers of resin-bonded bridges is presented in chapter 3. These include macro-mechanical retention with perforations or retentive casting patterns; micro-mechanical retention created by sandblasting, electrolytical etching, electrolytical tin-plating and silane coating. Furthermore, earlier bond strength studies were reviewed and discussed in the light of the very wide range of values reported. No conclusions about the most suitable retention system for resin-bonded bridges can be drawn from the available in vitro studies.

The bond strength data of composite restorative material to metal surfaces treated with the O.V.S. tin-electroplating system are presented in chapter 4. These bond strength values have been compared with those of composite bonded to perforated or electrolytically etched surfaces. The bond strength of composite to O.V.S. tin-electroplated surfaces was found to be about 10 MPa, twice that measured on perforated surfaces and not significantly different from those on electrolytically etched surfaces. The conclusion of this pilot study was that tin-electroplating the retainers of a resin-bonded bridge might be a suitable retention system.

In chapter 5 the O.V.S. tin-electroplating system was tested in vitro by measuring the tensile bond strength of Comspan bonded bridge resin for the variables: electroplating voltage, type of alloy, the use of the opaque resin layer and some standardized clinically relevant factors.
Tin-electroplating only resulted in a significant improvement in the bond strength of Comspan to metal, if the procedure was performed at 9V or "6+9V". Under these conditions not only the mean bond strength of Comspan but, more importantly, the lowest values measured, were at least twice those recorded for sandblasted surfaces. No significant differences were seen in the effect of tin-plating on three different types of alloys. Tin-electroplating was considered to be a reproducable method of increasing resin-to-metal bond strength. The application of the opaque O.V.S. resin to tin-plated surfaces did not seem to affect the bond strength value of Comspan to the metal.
Saliva contamination on tin-plated retainers resulted in about a 50% decrease in the bond strength and cleaning methods appeared to be ineffective. Mechanical damage of a tin-plated surface, which can occur during a try-in of bridges, also resulted in a decrease of the bond strength. Advantages of using the opaque O.V.S. resin appeared to be the protection provided against damaging the brittle tin-coating and the greater cleaning efficacy after saliva contamination. A disadvantage of the use of the opaque O.V.S. resin was the decrease in the bonding capacity with time. Therefore, it was decided that tin-electroplating should be performed only after the bridge had been tried in the mouth. Since Comspan bonded bridge resin appeared to mask satisfactory the incisal greying of the abutments caused by the

metal retainers, the O.V.S. opaque resin was omitted in the clinical study.

Information on the bonding mechanism of the O.V.S. tin-electroplating system for resin-to-metal bonding was obtained with the use of a scanning electron microscope (S.E.M.). This is described in chapter 6.
The effects of the variables current voltage and number of strokes of the tin applicator on the micromorphology were investigated. An optimal micro-retention pattern of tin oxide particles bonded to the metal was found by using the tin-applicator five times at a current of 9 Volts. The thickness of the tin coating was estimated to be 1-3 microns. A fracture surface of a specimen selected from a bond strength study showed a mixed fracture pattern. Tin-electroplated metal surface appears to have a micro-retention area for resin in the same range as that found for acid-etched enamel.
It was difficult to compare the bond strength values measured for resin to tin-plated metal with bond strength values published for other systems, due to difficulties in interpretation and to the great variation between the different studies. Therefore, the bond strength of Comspan to six retention systems was compared in the next chapter.

Two macro-, two micro- and two combined micro/chemical retention systems were tested and compared in chapter 7. Temperature cycling in water and submaximal load cycling were included in the test. The retention systems: network (16.9 MPa), tinplating (13.4 MPa) and silane coating (13.5 MPa) resulted in significantly higher mean bond strength values for Comspan^{R} resin compared to the other treatments. After temperature cycling the lowest bond strength values measured decreased for all treatments except for perforation. Perforation (5.5 MPa) and sandblasting (6.6 MPa) showed relatively low, but reproducible bond strength values. The results of electrolytical etching (6.3 MPa) were disappointingly low and variable.

In chapter 8 the bonding mechanisms of the six retention systems studied in chapter 7 were examined using S.E.M. observations of fractured specimens.
Observation of a perforated specimen showed that the back-scatter mode (BE) increased the contrast between resin and metal. A sandblasted specimen showed small parts of resin left on the rough surface illustrating the micro-mechanical retention of the surface. The macro-mechanical retention of a cast network pattern appeared to have been increased by sandblasting. The acid-etched Ni-Cr alloy surface showed an irregular, grit like surface under the light microscope (40x), but under the S.E.M. the surface appeared almost without undercuts. The disappointingly low bond strength values measured in chapter 7 were thus explained.
The fracture surface of a tin-electroplated specimen showed mainly cohesive fractures of the resin immediately above the tin coating. Fractures in the tin coating and between tin and metal also were observed. Both adhesive and cohesive fractures occurred in the resin as well as in the tin coating.
The silane coated specimen indicated the greatest surface area with cohesive resin fractures, indicatory for the greatest bond strength. In this study the silane coating could of course not be identified, due to its molecular dimensions. The surfaces appeared to be identical to sandblasted surfaces. This result suggests there has to be a chemical component in the silicoater bonding system.

It was concluded from these studies that a network casting pattern, tin-plating and silane coating were suitable systems for clinical testing on the retainers of resin-bonded bridges. On the basis of a cost-benefit analysis the O.V.S. tin-electroplating systems was choosen for the clinical study. Clinical experience with resin-bonded bridges with perforated retainers was already available to serve as a reference for this study. A retrospective study to evaluate the clinical results of resin-bonded bridges with perforated retainers is presented in chapter 9.

After a mean observation period of 3,5 years 10 (15.6%) of the 64 resin-bonded bridges had become detached. A detachment percentage of 14% was found in the anterior region of the mouth. The detachment percentage in the posterior region was higher (21.5%), but not significantly different from the anterior region. The location of the detachment found clinically was in agreement with the location found in in vitro bond strength tests. The resin to metal bond appeared to be the weakest link of the bonding system. Cohesive fractures of the resin were seen in the perforations. The detachment percentage found in this study was comparable with the best results which have been published in the literature. These clinical results suggest that the criteria for indication, patient selection and treatment procedures had been well chosen.

With the results of the patients fitted with resin-bonded bridges with perforated retainers as a control a prospective study was started to test the non-perforated design clinically. After an observation period ranging from 12 to 40 months, mean observation period 21.8 months, 7 (4.6%) of the 152 resin-bonded bridges with tin-electroplated retainers had become detached. Of the 84 resin-bonded bridges in the anterior region of the mouth 7 (8.2%) had become detached, whilst none of the 68 resin-bonded bridges in the posterior region had become detached. Resin pontics had fractured in bridges replacing upper premolars (5), upper incisors (2) and a lower molar (1).
A total of nine retainers had become detached. The location of the fracture as a percentage of the retainer surface was 26% on the resin-enamel bond and 74% on the resin-metal bond. The results were not significantly affected by the variables: location of the arch (upper or lower) number of pontics (one or two), type of resin-bonded bridge resin (Comspan^{R} or Panavia^{R}) and operator (author or students). In 4 cases an unexpectedly heavy loading on the bridges was the major cause of detachment. The detached bridges showed predominantly that the resin had fractured from the metal re-

tainer. The weak link in the bonding of metal to enamel appeared to be the resin-to-metal bond, even after tin-electroplating. Clinical studies of resin-bonded bridges with electrolytically etched retainers also showed that the resin-to-metal bond was the weak link.

In a comparison of the results of resin-bonded bridges with perforated and tin-electroplated retainers the latter had a much lower failure rate. Even in the posterior region of the mouth all resin-bonded bridges with tin-electroplated retainers offered resistance to masticatory forces during the entire evaluation period. This is the first time such a favourable result has been published on posterior resin-bonded bridges. The design of the bridges, the preparation of the abutment teeth and the bonding procedures used, all of which were carried out according to a protocol will have contributed to this result.

In conclusion, resin-bonded bridges with perforated retainers are very suitable for immediate and temporary replacements of anterior teeth. For long term replacement of anterior teeth and for replacement of posterior teeth non-perforated, tin-electroplated retainers are more suitable.