Chapter 8

Summary
Since previous investigations revealed that most clinical failures in adhesively luted ceramic restorations initiate from the cementation or internal surfaces, the study presented in Chapter II evaluated the effect of three different surface conditioning methods on the bond strength of a Bis-GMA based luting cement to glass ceramics, glass infiltrated alumina, glass infiltrated ZrO₂, reinforced alumina. The three conditioning methods assessed were: (1) HF acid etching, (2) Air-borne particle abrasion, (3) Tribochemical silica coating. All specimens were tested for shear bond strength at dry and long-term thermocycled (6000 times) conditions. It was hypothesized in this study that amphoteric alumina in the ceramic matrix could form strong enough chemical adhesion bonds, covalent bridges, through its surface hydroxyl groups with hydrolysed silanol groups of the silane: -Al-O-Si-. The results indicated that bond strengths of the Bis-GMA based composite luting cement tested on the dental ceramics after surface conditioning techniques varied in accordance with the ceramic types. HF acid gel was effective mostly on the ceramics having glassy matrix in their structures. The findings confirmed that the use of HF acid appeared to be the method of choice for bonding the Bis-GMA resin composite luting cement to those ceramics having glassy matrix in their structures. Conditioning the ceramic surfaces with air-particle abrasion followed by silanization provided higher bond strengths for high-alumina ceramics and the values increased more significantly after silica coating followed by silanization. Thermocycling decreased the bond strength values significantly after all surface conditioning methods tested and the least favourable results were obtained with ZrO₂ and glass infiltrated ZrO₂ reinforced alumina.

Experimental and clinical reports provide evidence of significant differences in the survival of metal posts. The separation of core materials from titanium posts has been identified as one of the clinical problems related to post-core restorations. To withstand functional loads, the bond between the core material and the post should be strong and durable. In order to study the interaction between conditioned titanium posts and cores, in Chapter III, 6 brands of core materials with different compositions (microfilled, hybrid, compomer, resin-modified glass ionomer) were applied to titanium posts that were previously conditioned and coated with either of the two types of light-polymerized opaquers (methacrylate, bismethacrylate). Five conditioning methods based on silica coating followed by silanization and acrylization namely, Silicoater Classical, Silicoater MD, Rocatec, Kevloc and Siloc were used. The resistance of the various core materials adapted to differently conditioned titanium posts were evaluated using a torque test that is quite an aggressive method compared to previous test methods existing in the
literature. When compared with the non-conditioned control group, the results indicated that the resistance to torsional forces for the core materials on titanium posts increased with the use of chemical surface conditioning techniques and varied in accordance with the opaquer type. Type of core material also significantly influenced the resistance after long term thermocycling. Resistance against torque forces was the greatest with Siloc and then, in descending order, with Silicoater Classical, Silicoater MD, Rocatec, and Kevloc surface conditioning systems. The resistance of core materials based on silica coating and silanization or silica coating and acrylization varied in accordance with the opaquer used. Methacrylate opaquer demonstrated higher resistance values than bismethacrylate opaquer. Monomethacrylates are linear polymers with high flexibility but providing better adhesion and on the other hand, polymerization is more difficult to be obtained by light curing. However, dimethacrylates are highly cross-linked with increased brittleness. Hybrid composites and compomers used as core materials demonstrated higher torque resistance compared with microfilled composites or resin-modified glass ionomer.

With the increased demand for adult orthodontics, the orthodontists are often faced with the problem of luting brackets to metal-ceramic fixed-partial-dentures. Recently, more aesthetic and relatively invisible brackets, satisfying patient desires gained popularity in orthodontics. Unfortunately lack of durable bonding between the brackets and ceramic restorations is still a major problem in adult orthodontics. Bonding concepts in orthodontics are somewhat different than in the other restorative applications in operative dentistry. Since bonding in orthodontics is semi-permanent in nature, bond strength should be high enough to resist debonding during the whole course of treatment but also low enough so that damage to the existing tooth or restoration would not occur during debonding. In the study presented in Chapter IV, the effect of five different surface conditioning methods, namely (1) Phosphoric acid (H₃PO₄) + primer + bonding agent, (2) HF acid gel + primer + bonding agent, (3) chair side tribochemical silica coating (4) Air-borne particle abrasion with alumina + silane, (5) Air-borne particle abrasion with alumina + silane + bonding agent were tested for the shear bond strength of polycarbonate brackets to glazed feldspathic ceramic surfaces using light-polymerized resin-based cement. Since the orthodontic treatment duration is shorter than conventional restorative procedures, bond tests were performed after only 1000 cycles. The results indicated that bond strengths of the polycarbonate brackets luted with resin composite cement tested on the dental ceramics after surface conditioning techniques varied in accordance with the conditioning methods.
Air-borne particle abrasion with aluminium trioxide or silica coating followed by silanization demonstrated the most favourable bond strengths. The satisfactory bond strengths obtained after air-particle abrasion either with silica or alumina together with silanization could eliminate the need for acid etching, primer and/or bonding agent applications. After debonding, the fracture sites of the ceramic specimens and the bracket bases were further examined under scanning electron microscopy to evaluate the changes on the surface. The failure modes were classified according to modified Adhesive Remnant Index (ARI) system. While in the phosphoric acid etched group, the brackets failed mainly at the ceramic/resin interface with all of the luting cement remaining on the bracket base, in the HF acid treated group, predominantly less than half of the composite was left on the ceramic surface after debonding. In both air-borne particle abraded groups, more than half of the luting cement was left adhered to the ceramic surface and the bracket base. On the contrary, in the silica coated group, luting cement was mainly debonded from the bracket base being left adhered to the ceramic surfaces with distinct impression of bracket mesh. The type of failures observed after debonding indicated that the critical parameter was the strength of the adhesive joints of the luting cement to both the bracket and the ceramic. Bond strengths of the polycarbonate brackets luted with resin composite cement tested on the dental ceramics after surface conditioning techniques varied in accordance with the conditioning methods. The use of HF acid would still be appropriate for orthodontic reasons with sufficient bond strength and favourable failure modes after debonding if the critical aspect was accepted to use this chemical agent intraorally.

Adhesion of resins to processed composites has been difficult to achieve. Aggressive oral environment and enzymatic changes all provoke discoloration, degradation, microleakage, wear, ditching at the margins, delamination or simply fracture being often experienced in clinical conditions, that may require replacement of the restoration. We hypothesized that if the right conditioning method could be found then a new layer of composite could be applied to the already polymerized one in an attempt to prolong the service life of restorations suffering from small deficiencies. Therefore the objective of the study presented in Chapter V was to evaluate the effect of three surface conditioning methods 1) HF acid gel (9.5 %) etching, 2) Air-borne particle abrasion (50 µm Al₂O₃), (3) Silica coating (30 µm SiOₓ, CoJet®-Sand) on the shear bond strength of a low-viscous diacrylate veneering particulate filler resin-composite (PFC) to 5 PFC substrates. The bond strengths were evaluated at both dry and thermocycled (6,000 cycles) conditions. Bond strengths of low-viscous diacrylate veneering resin to PFC substrates tested,
increased with the use of silica coating and silanization and varied in accordance with the PFC types. HF acid gel appeared to dissolve the filler particles but resulted in the least favourable bond strengths when compared with other methods tested. Air-borne particle abrasion with silica particles increased the bond strengths regardless of the PFC type. When compared to dry testing conditions, bond strengths decreased after thermocycling in all HF acid gel treated substrates but no significant change was noted after air-particle abrasion or silica coating followed by silanization.

Complete or partial cusp fracture of posterior teeth associated with amalgam restorations is a common problem in dental practice. In an attempt to find a reliable method to restore the fractured surfaces without drilling and removing the sound amalgam restorations, in the study presented in Chapter VI, the effect of different surface conditioning methods on the shear bond strength of a hybrid resin composite to fresh amalgam were evaluated. Amalgams were conditioned using one of the following conditioning methods: (1) Alloy primer + opaquer, (2) Air-borne particle abrasion (50 µm Al₂O₃) + alloy primer + opaquer, (3) Silica coating (30 µm SiOₓ) + silanization + opaquer, (4) Opaquer + pre-impregnated continuous bidirectional E-glass fibre sheets, (5) Silica coating + silanization + fibre sheets, (6) Silica coating + silanization + opaquer + fibre sheet application. Non-conditioned amalgam surfaces were considered as control group (7). The mean surface roughness depth (Rz) was measured from the control group and air-abraded amalgam surfaces. All specimens were tested at dry and thermocycled (6,000 cycles) conditions. The results revealed that combination of silica coating and silanization with addition of glass fiber sheets at the adhesive interface could be considered as an alternative method to improve adhesion of resin composite to amalgam. Bond strengths of the resin composite to amalgam substrates varied in accordance with the surface conditioning techniques. Conditioning the amalgam surface with air-borne particle abrasion prior to bonding resin composite provided higher bond strengths compared to the non-conditioned control group or alloy primer treated groups in dry conditions. The use of optional E-glass fibers was tried for the first time in this study in combination with silica coating and silanization. The addition of optional resin-impregnated bidirectional E-glass fiber sheets at the adhesive interface increased the bond strengths significantly and therefore can be considered as an alternative method to improve attachment of resin composite to amalgam. Thermocycling decreased the bond strength values significantly after all surface conditioning methods tested.
In Chapter VII the methodological aspects of the experiments conducted in Chapters II-IV are evaluated and the results obtained after thermocycling in relation to the recommended ISO standard are discussed. The efficacy of various adhesion methods and some hazardous aspects related to the use of hydrofluoric acid are critically evaluated and the future research ideas that are planned on surface analysis are mentioned. Furthermore in this chapter, recent data obtained by the author after the completion of this thesis using airborne particle abrasion, silica coating together with silanization are mentioned and the ongoing research, further investigation on the working mechanisms and durability of these methods are discussed. Finally the results of this thesis were extrapolated to clinical situations. The results of this thesis seem to be more in favour of chemical conditioning methods for various substrates. Using these methods in clinical practice may prolong the service life of dental restorations in a cheaper way, avoid the total replacement of the existing restorations and preserve the tooth structure in a non-traumatic way.