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Bonded Orthodontic Retainers: Clinical Survival, Adhesion and Material Aspects

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Summary

The debonding of bonded orthodontic retainers is one of the most frequently reported failure type in orthodontics as a consequence of multiple reasons. This thesis was conducted in an attempt to identify some of the possible factors causing the failure of bonded orthodontic retainers.

The objectives of the retrospective clinical study in **Chapter 2** were to evaluate the clinical survival rate of flexible, braided, rectangular bonded stainless steel lingual retainers, and to investigate the influence of gender, age of the patient, and operator experience on survival after orthodontic treatment at the Department of Orthodontics, University of Groningen, between the years 2002 and 2006. The study group comprised of 277 patients (162 females: median age 14.8 years and 115 males: median age 15.3 years). Data concerning, failures, gender, age of the patient, and operator experience were retrieved from the patient files that were updated by chart entries every 6 months or when failure was reported by the patient. The maximum follow-up period was 41.7 months. All 277 patients received flexible, braided, bonded mandibular canine-to-canine retainers. A failure was recorded when there was debonding, fracture, or both, occurring in one arch. Eighteen failures were observed in the maxilla. Only first failures were used for statistical analysis. Ninety-nine debonding (35.7%), two fractures (0.7%), and four debonding and fracture (1.4%) events were observed. No significant effect ($P > 0.05$) of gender (females: 41%, males: 32%) or patient age (<16 years: 37%, ≥ 16 years 38.7%) was observed. The failure rate did not differ due to operator experience (n = 15; less experienced: 38.0%; moderately experienced: 28.9%, professional: 46.7%; $P > 0.05$). Kaplan- Meier survival curves showed a 63% success rate for the bonded lingual retainers over a 41.7 month period.

In **Chapter 3** the bond strength of a stainless steel orthodontic wire was compared versus various fibre-reinforced-composites (FRC) used as orthodontic retainers on enamel, analyze the failure types after debonding and to investigate the influence of different application procedures of stainless steel wires on bond strength. Caries-free, intact human mandibular incisors (N=80, n=10 per group) were selected and randomly distributed into 8 groups. After etching with 37% H_3PO_4 for 30 seconds, rinsing and drying, bonding agent (Stick Resin) was applied, light polymerized and one of the following FRC materials were applied on the flowable composite (Stick Flow) using standard molds: Group 1: Angelus Fibrex Ribbon; Group 2: DentaPreg Splint; Group 3: everStick Ortho and Group 4: Ribbond. In Group 5, Quad Cat Wire

was applied in the same manner as in FRC groups. In Group 6, after bonding agent (Stick Resin), Quad Cat Wire was placed directly on the tooth surface and covered with Stick Flow composite. In Group 7, after bonding agent (Heliobond) was applied, Quad Cat Wire was placed directly on the tooth surface and covered with Tetric Flow composite. In Group 8, after applying bonding agent (Heliobond), Tetric Flow composite was applied, not polymerized and Quad Cat Wire was placed and covered with Tetric Flow again. Specimens were thermocycled for 6000 cycles between 5-55°C and loaded in a universal testing machine under shear stress (crosshead speed: 1 mm/min) until debonding occurred. The failure sites were examined under an optical light microscope. Significant differences were found between the groups ($p = 0.0011$). Bond strength results did not significantly differ neither between the FRC groups (Groups 1-4) (6.1±2.5 to 8.4±3.7 MPa) ($p > 0.05$) or the wire groups (Groups 5-8) (10.6±3.8 to 14±6.7 MPa) ($p > 0.05$). Failure types varied within the FRC groups, but mainly composite was found left adhered on the enamel surface at varying degrees. In the stainless steel wire groups, when the retainer was applied onto the bonding agent and then covered with flowable resin, partially attached composite on the enamel was often found after debonding. When the wires were embedded in the flowable composite, the Heliobond group (Group 8) showed more adhesive failures between the enamel and the composite compared to Group 5, where bonding agent was Stick Resin. Regardless of their application mode, stainless steel orthodontic bonded retainers delivered higher bond strengths than those of fiber retainers. The differences were statistically significant compared to those of Angelus Fibrex Ribbon and DentaPreg Splint.

The aim of **Chapter 4** was to analyze the fatigue resistance, debonding force, and failure type of fiber-reinforced composite, polyethylene ribbon-reinforced, and braided stainless steel wire lingual retainers in vitro. Roots of human mandibular central incisors were covered with silicone, mimicking the periodontal ligament, and embedded in polymethylmethacrylate. The specimens (N = 50), with two teeth each, were randomly divided into five groups (n = 10/ group) according to the retainer materials: (1) Interlig (E-glass), (2) everStick Ortho (E-glass), (3) DentaPreg Splint (S2-glass), (4) Ribbond (polyethylene), and (5) Quad Cat wire (stainless steel). After the recommended adhesive procedures, the retainers were bonded to the teeth by using flowable composite resin (Tetric Flow). The teeth were subjected to 1,000,000 cyclic loads (8 Hz, 3 - 100 N, 45° angle, under 37 ± 3°C water) at their incisoproximal contact, and

debonding forces were measured with a universal testing machine (1 mm/min crosshead speed). Failure sites were examined under a stereomicroscope (×40 magnification). All the specimens survived the cyclic loading. Their mean debonding forces were not significantly different ($p > 0.05$). The DentaPreg Splint group (80%) showed the highest incidence of complete adhesive debonding, followed by the Interlig group (60%). The everStick Ortho group (80%) presented predominantly partial adhesive debonding. The Quad Cat wire group (50%) presented partial overlying composite detachment. Cyclic loading did not cause debonding. The retainers presented similar debonding forces but different failure types. Braided stainless steel wire retainers presented the most repairable failure type.

In **Chapter 5,** in a prospective clinical trial the survival of multi-stranded stainless steel lingual retainers (SSR) bonded using different resin composite types was evaluated. Between April 2011 and March 2013, a total of 75 patients (40 women, 35 men; mean age: 16.3 years old) received full arch orthodontic treatment after which SSRs (Multi-strand 1 x 3 high performance wire, 0.022” x 0.016”, PG Supply Inc.) (N=150) were bonded in the maxilla and/or mandible on all 6 anterior teeth. After etching enamel surfaces with 35% H_3PO_4, adhesive resin was applied (Clearfil SE Bond) and photo-polymerized for 20 s. SSRs were bonded using one of the following resin composites: a) Hybrid (Clearfil AP-X, Kuraray Noritake) (H1), b) Hybrid (Light Cure Retainer, Reliance Orthodontic Products Inc.) (H2), c) Flowable (Clearfil Majesty Flow, Kuraray) (FL). At baseline and thereafter at 1, 2, 3, 6, 12 and 24 months, SSRs were checked upon macroscopically for partial or complete debonding or fracture. SSRs were scored as failed if any operative intervention was indicated for repair, partial or total replacement. SSRs were observed for a minimum of 6, and maximum 43 months (mean: 19.5 months). At the final control (24 months), 10 patients could not be followed up (H1: 12, H2: 4, FL: 4) due to drop out. In total, in 150 SSRs, 28 failures were observed (n=19 in the maxilla, n=9 in the mandible). The majority of the failures were observed with FL (n=12), followed by H1 (n=8) and H2 (n=8) being not statistically significant (maxilla: $p=0.133$; mandible: $p=0.551$). Overall, 3 fractures of the SSR were observed all of which were in the maxilla. Overall, cumulative survival rate was 81.3% up to 43 months (Kaplan-Meier). Location of the SSRs did not show significant difference (maxilla: 74.7%, and mandible: 88%) ($p>0.05$). No significant difference was observed between gender type (female: 78.8%; male: 81.3%) ($p=0.059$). Although microhybrid flowable resulted in slightly more frequent incidence of failures, the

type of composite, the location and the gender did not significantly affect the clinical survival of multi-stranded stainless steel bonded lingual retainers in the studied sample.

In **Chapter 6** the objective was to evaluate the anterior tooth movement without and with bonded fixed orthodontic retainers under incremental loading conditions. Six extracted mandibular anterior human teeth were embedded in acrylic resin in True Form I Arch type and 3D reconstruction of Digital Volume Tomography (DVT) images (0.4 mm^3 voxels) were obtained. The anatomy of each tooth was segmented and digitally reconstructed using 3D visualization software for medical images (AMIRA, FEI SVG). The digital models of the teeth were repositioned to form an arch with constant curvature using a CAD software (Rhinoceros) and a base holder was designed fitting the shape of the roots. The clearance between the roots and their slot in the holder was kept constant at 0.3 mm to replicate the periodontal ligament thickness. The holder and the teeth were then manufactured by 3D printing (Objet Eden 260VS, Stratasys) using a resin material for dental applications (E=2-3 GPa). The 3D-printed teeth models were then positioned in the holder and the root compartments were filled with silicone. The procedure was repeated to obtain three identical arch models. Each model was tested for tooth mobility by applying force increasing from 5 to 30 N with 5 N increments applied perpendicular on the lingual tooth surface on the incisal one third (crosshead speed: 0.1 mm/s). The teeth on each model were first tested without retainer (control) and subsequently with the bonded retainers (braided bonded retainer wire; Multi-strand 1x3 high performance wire, 0.022” x 0.016”). Tooth displacement was measured in terms of complicance (F/Δ movement) (N/mm) using custom-built optoelectronic motion tracking device (OPTIS) (accuracy: 5 μm; sampling rate: 200 Hz). The position of the object was detected through three LEDs positioned in a fixed triangular shape on a metal support (Triangular Target Frame). The measurements were repeated for three times for each tooth. The use of retainer showed a significant effect on tooth mobility compared to non-bonded teeth (control) ($p<0.0001$). The amount of displacement on the tooth basis was also significantly different ($p=0.0381$) being the most for tooth no. 42 (without: 0.024±0.01; with: 0.012±0.002) ($p=0.0018$).