A study into application of fiber technology for endo posts
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Introduction

This thesis contains a study about an alternative for the well-established concept of using metal posts as eventual reinforcement of endodontically treated teeth. Since its recent introduction in the dental profession$^{1-2}$, a new model, based on fiber reinforced resin systems has shown to be an interesting substitute. Although the gradual switch over from metals to composite materials has already for about three decades shown its value in various fields of restorative dentistry and thus the concept sound familiar, a short fundamental reflection dedicated to the characterization of composite material is appropriate.

Development in application of materials to restore teeth went, on a mini scale, almost parallel with the evolution of mankind (stone, bronze and polymer age). The first dental restorations were made by cementation of (precious) stones, subsequently for a long time metals were considered as the best sustaining or replacement for lost tooth structure and because of growing demand for esthetics, nowadays ceramic and polymer-based materials are widely employed.

Also in analogy with general materials application, it took a long time before resin-based materials were accepted as indeed very useful alternative for metals. It is a fact that the mechanical properties of most polymers (plastics) are inferior to those of metal alloys, but by constructing resin-based composites, materials can be designed with characteristics that eventually meet the requirements far better than the metals do.

A composite is any material that is composed of hard, pebble-like filler particles, surrounded by a hard matrix of a second material, which binds the filler particles together (see fig. 1).
Fig. 1. Schematic representation of a particle reinforced composite.

The filler particles can be any coarseness varying from large rocks to (sub-) microscopically fine powder. The matrix material generally starts out as a paste or liquid and begins to harden when mixed with the filler particles. Before it hardens, it can be pressed into a mold, or stuffed into a hole. A well-known example of a composite material is concrete. In dentistry, the most common types of composites involve various types of finely ground glass powder fillers mixed into a matrix, which is usually a form of an acrylic called BIS-GMA. The glass particles are mixed with the acrylic and then, when the dentist is ready to place the restoration in the tooth a catalyst is mixed into the paste and this causes the acrylic to harden around the glass particles. In the case of light cured composites, the photo-initiator is already mixed into the paste, but does not become active until irradiated with high intensity light.

The fact that the glass particles do not have to react with the matrix allows the manufacturer a great deal of freedom in the process of manufacturing the glass powder. They can flux the glass with materials that give it characteristics like better wear, workability and esthetic qualities than they could achieve if they were constrained by the need to manufacture the glass according to solubility specifications. Special formulations allow for particles
of differing size for different restorative situations. The particles may have different shapes, which allow for an attachment between adjacent particles thus strengthening the material. The manufacturer may adjust the particle size and shape to allow for differing consistencies without compromising strength or wear characteristics. They can also vary the qualities of the acrylic matrix independently of the filler particles.

Most dental restorative materials are designed to perform mechanically isotropic. In case of prefabricated posts, longitudinal strength is believed to be of greater importance than transverse strength and therefore the composite is better off with longitudinally directed, fibrous filler particles (see Fig. 2). From several materials like glass or carbon, fibers can be made that carry extreme properties in longitudinal direction and thus can serve very well in e.g. reinforcing the tensile strength of the composite.

Fig. 2. Schematic representation of fiber reinforced composites.

Composites are used because overall properties of the composites are superior to those of the individual components. For example: polymer-ceramic composites have a greater modulus than the polymer component, but aren't as brittle as ceramics. Composites are also found in nature. Wood, natural composite containing cellulose fibers, is one of the most common
materials used in the construction industry. Tooth enamel, dentin and bone as well are composites.

For many years, the concept for restoring damaged teeth was based on employing materials, as strong and as stiff as possible. Metals best fulfilled this goal. However, since the introduction of composite materials, a new approach in thinking about optimal reconstruction is at our disposal. Indeed, resin-based composites are weaker, less stiff or less wear resistant when compared to metal alloys, but their mechanical properties match those of tooth structure better in many ways. Main advantage of matching mechanical characteristics is that stress distribution in the restored tooth remains without high stress concentrations. Avoiding stress concentrations is particularly of interest for restoration of endodontically treated teeth, where all effort has to be done to avoid root fracture.

Recently fiber-reinforced resin posts have been introduced for treatment of endodontically treated teeth\(^1\-2\). Similarly to the substitution of metal alloys by resin-based composites in restoring cavities, fiber reinforced resin-based composite posts require profound understanding of how this new designed material and technique has to be employed to restore the weakened root satisfactorily. Unfortunately, also with this new concept, developed as alternative and possibly a substitute for the well established cast post and cores or prefabricated metal posts techniques, it was accepted with great sepsis. It has to be emphasized that removal of a large amounts of sound dentin to shape the root canal for posts weakens the tooth. Posts are mainly meant for retention and work less successful as reinforcement against premature root fracture \(^4\-6\). Cast post and core technique is only successful, if the system remains within the elastic limits of dentin \(^7\-8\). This enunciation has been undervalued in daily practice. Not maximally strong posts are required but posts that prevent stressing the root beyond its elastic limits. Within this reasoning it is not important if fiber posts are weaker than Gold, Titanium or Stainless Steel posts as long as they provide sufficient retention. Thanks to their composite nature they can be designed to match the
mechanical properties of the host material optimally. It is not a goal of this investigation to criticize the cast post and core technique. Millions of cast post and core are well doing their job, but for sure many a dentist experienced the frustration of the extraction as the only remedy left after a root fracture following an endodontic treatment and restoration with cast post and core.

It is a common opinion among several researchers that a well-performed cast post and core can work for years and that the 3–7% failure rate may be due to mistakes in designing and realizing them. In contrast to this experience, eventual failure with Carbon Fiber posts is reported to be attributed to coming loose of the construction but not to catastrophic root fracture. In our own practice experience was gathered since 1994. In some cases, the prosthetic restorations could be re-bonded, in other cases it was possible to save at least the full crown coverage and of course also in some cases a new prosthetic procedure was necessary, but no root fractures were observed.

The clinical advantages of the technique when compared with cast post and cores are evident: less costs (direct technique), less time-consuming (one-visit work), no temporary posts required. A disadvantage was the demanding bonding procedure. Sometimes the posts de-bonde, especially during the removal of temporary crowns. In case of full-ceramic crowns or veneering, masking the black color faces difficulties and in some cases they were visible through prosthetic provision.

The satisfactory clinical success rate was the main reason to start an investigation into some aspects of Carbon Fiber posts with special attention to their weakest point: bonding. One of the first options in order to avoid debonding failures was to simplify the clinical procedure to evaluate if the "one bottle" systems, which reduce the "dentist skill factor" in obtaining proper bonding when compared with the conventional "three steps" procedure, usually indicated for bonding fiber posts. Bonding to the substrate of narrow root canals (roughly 1.5mm of diameter and 10mm of
depth) is much more difficult that to a normal Class I cavity. Initially everybody considered and treated this preparation as a conventional restorative cavity.

Notwithstanding the type of bonding (three steps or one-bottle materials), it turned out to be extremely difficult to obtain proper hybridization (infiltration of the bonding into the acid-etched substrate) of the root canal at the apical third when compared to the medium and coronal third of the root canal preparation. Initially the anatomy was taken responsible for that as getting closer to the apex, the number and disposition of tubules were progressively less favorable for bonding. As a matter of fact, bonding proved to be less reliable in the apical third. The whole clinical bonding procedure, including solely acid-etching with ortho-phosphoric acid was reconsidered. It turned out that the placement of the acid to the end of the preparation was relatively easy, but this held not for its removal. By using a plastic syringe with endo needles instead of a water/air syringe, the problem of removal seemed to be solved as could be illustrated with SEM. Yet the problem of unreliable bonding at the apical third persisted. Subsequently the available types of bonding “carriers” like differently sized and shaped brushes, cotton pellets, micro-brushes etc. were tested on their efficacy to carry the adhesive solution within the whole preparation, including the apical third. This time optical microscopy was helpful to observe the efficacy of ultra thin micro-brushes and SEM observations confirmed the efficacy of this clinical procedure.

One of the addressed problems of employing Carbon Fiber Posts was the masking of the black color. In particular when the anatomy of the tooth was markedly convex, urging to bring the post towards the vestibular portion of the abutment, it could happen that the appearance of the abutment was almost black. In case of planning the final restoration being a ceramic-metal crown this is irrelevant, but when the final restoration will be a full-ceramic crown, the aesthetic performances may be negatively influenced. Only when the thickness of the ceramic restoration was 1.5 mm or more, the black color could easily be masked. Nowadays, while the carbon fiber posts are
gradually being replaced by quartz fiber post, this problem seems to be overcome.

Another problem related to achieving good bonding at the deeper areas of the preparation regarded the distance between the polymerization source and the apical third of the post preparation.

One of the proposals in order to solve this problem was to take advantage of the properties of a new type of post. A modification of the chemistry of the epoxy resin of the post allowed the production of translucent posts. This new type of post not only permitted better curing light transmission, but also contributed further to improved aesthetic features. Thanks to this way of light conductance, the curing of the adhesives was supposed that might be improved.

To bypass the problem of the difficulty to proper cure the resin at the apical third, a new adhesive system has been developed in which both adhesive resin and luting cement are self-curing. In particular, in the adhesive resin, an innovative idea has been finalized, by which the catalyst is sprayed on the top of an especially designed microbrush. An original package was also developed in order to allow a very easy, fast and safe polymerization reaction.

In summary, the introduction and evolution so far of fiber posts in combination with advanced insertion instruments has led to a dental post system that dependably can be bonded over a almost the entire preparation in the endodontically treated root. The experimental part of this thesis describes an evidence-based procedure of employing fiber-posts optimally with respect to ease of handling for the clinician and reliable clinical results.

References

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