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Restorative Dentistry in Horses

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Introduction

Restorative dentistry is the dental discipline concerned with the treatment, repair, and conservation of teeth broken down by trauma or decay. The goals of restorative dentistry include returning the diseased tooth to its original shape and function, preventing breakdown of the remaining tooth structure, protecting the pulp from thermal, mechanical, and bacterial insult, and creating an aesthetic tooth appearance.

Throughout recorded equine dental history, exodontia has been the primary treatment option for diseased teeth; however, the goal of dentistry is to preserve functional dentition in order to promote the general health, longevity, and productivity of the horse. Although equine veterinarians have practiced restorative dentistry for over 120 years, the introduction of less technique sensitive dental materials over the last 20 years has stimulated renewed interest in direct placement restorations.

While there are numerous anecdotal reports of restorative successes in equine patients, the peer reviewed literature is limited to only a few case reports. All of which should be viewed as biased according to the standards of evidence based medicine. Therefore, until the application of restorative materials in equine hypsodontic teeth have been scientifically evaluated, each practitioner must make treatment decisions based on his/her personal experiences and understanding of restorative principles.

Treatment Planning

Regardless of the disease etiology, the restoration of a tooth includes two equally important procedures: (1) **cavity preparation** and (2) **selection and application of the restorative materials**. Early diagnosis of a cavity, before the structural integrity of the tooth is compromised, facilitates for a favorable outcome. Treatment planning for any restoration must include radiographic evaluation of the affected tooth and its surrounding tissues. Radiographic evaluation of the diseased tooth includes evaluation of the pulp, the specific location of the lesion, and the depth and extent of the lesion. Radiographic findings consistent with pulp disease would indicate root canal therapy before tooth restoration. The location of the lesion on each specific tooth determines the forces that will be applied to the restoration. Restorations on the occlusal surface of a tooth must be designed to withstand compressive loading and wear; whereas, restorations on the proximal, vestibular and lingual aspects of the clinical crown might experience tension or bending stresses. *Regardless of the present location of the lesion, all restorations have the potential for eventual occlusal wear due to hypsodontic tooth eruption; therefore, the strength and wear resistance of restorative materials must be considered during* *material selection.* The depth and extent of the lesion must be evaluated to determine the dental tissues involved in the lesion as well as the proper size and shape of the cavity preparation. Consideration of these factors will determine the required properties of the restorative materials needed to fill the cavity.

Cavity Preparation

Cavity preparation is the surgical operation involving the debridement of decayed or diseased dental tissues in order to shape the tooth to receive and retain the restorative material. The procedure is usually performed in the standing sedated horse, and local anesthesia should be provided if the lesion extends into the dentin. Instrumentation includes excavators and a high-speed water-cooled dental drill and burs. Regardless of the location of lesion, the operator must adhere to the following principles:

1. The cavity must be prepared so that all diseased and damaged dental tissues are removed without weakening the tooth's structure.
2. The cavity is extended to prevent further decay or damage to the restoration.
    a. Removal of any unsupported or undermined dentin and enamel.
    b. The walls of the cavity are oriented perpendicular to the tooth surface.
3. The cavity is configured to facilitate filling, retention, and finishing of the restorative material.
    a. Dentinal undercutting for mechanically retained materials.
    b. Marginal beveling to increase the enamel surface bonding area.

Direct Placement Restorative Materials

The ideal restorative material would allow for conservative cavity preparation, be easy to apply, bond to the substrate (dental tissues), have the similar strength, thermal, and wear characteristic to the tooth, and be the same color as the tooth. No material has all of these ideal characteristics; therefore, a material, or combination of materials, must be selected based on its specific advantages in a specific situation. Three basic groups of restorative materials are used in veterinary dentistry: Amalgam, Glass Ionomers, and Resin Composites. Amalgam has lost popularity in both human and veterinary dentistry, and will not be discussed.

The following is a general discussion of clinical properties and applications of the different categories of dental restorative materials. While the materials within each category are similar, each product has unique properties, handling characteristics, and an application protocol. To optimize the clinical properties of any material, the manufacturer's instructions for storage, mixing, and application must be followed exactly.

Types of Bonding

To select and apply the appropriate restorative materials, practitioners must be familiar with the bonding mechanism of each material.

1. **Mechanical Retention**: Nonadhesive bonding where the dental material infiltrates the surface irregularities of the dental tissue and cures to interlock with the dental tissue. **All restorative materials exhibit mechanical bonding.**
    A. **Macromechanical Retention –** involves instrumented undercuts (retention grooves) in the dental tissues (usually dentin).
    B. **Micromechanical Retention –** involves surface preparation (acid etching) and the use of bonding agents that microscopically interlock in the enamel porosities, dentinal tubules, and other microscopic surface irregularities. The bonding mechanism with **resin composite systems**.
2. **Chemical Bonding – Glass ionomer** forms a chemical crystal bond between the carboxyl groups in the polyacid of the cement and the calcium ions of the apatite crystals in the enamel and dentin.

Bases and Liners

Cavity preparations, in which less than 2 mm of dentin remains between the pulpar wall and the pulp (indirect pulp exposure), require the application of a pulp protecting material. Cavity liners and bases are used to protect the pulp.

Cavity liners are nonirritating materials which are placed in a thin layer to protect the pulp and decrease dentinal sensitivity. They provide no thermal or mechanical protection and are *inadequate as a sole protective medium*. Calcium hydroxide (**CaOH**) is the most popular liner. CaOH is supplied as a powder or as commercially prepared pastes. The powder can be applied directly into a pulp canal or mixed into a paste with water, saline, or anesthetics. The strong alkalinity (pH 12.5 when mixed with saline) of CaOH is bactericidal, neutralizes acids, and induces reparative dentin formation. CaOH will dissolve if contaminated with oral fluids and must be covered by an insoluble restorative material.

Cavity bases are used in deep cavities to provide structural support for the final restoration and chemical and thermal protection of the pulp. Dental cements are typically used as bases. Glass Ionomer (**GI**) cement is currently the most popular base material.

Glass Ionomer Cements

Glass ionomer (**GI**) cements are a group of materials which *chemically bond* to dentin and enamel. Bonding to cementum has not been investigated. GIs are formulated for many dental applications (see Classifications of GI Cements), but in veterinary medicine GIs are primarily used as bases and liners under composite restorations to protect the pulp, to minimize thermal conduction, and to augment marginal sealing. This application is commonly referred to as the "sandwich technique." GIs are relatively biocompatible with pulp. The chemical bonding of GIs allows for conservative cavity preparation and placement into moist fields, and GIs have shown clinical success when placed in incompletely debrided cavities (Atraumatic Restorative Treatment). The unique property of GIs is the release of high levels of fluoride ions over the life of the restoration which is known to strengthen enamel, decrease dentin sensitivity, and provide an antibacterial and cariostatic effect to the surrounding tissues. Since GIs have poor mechanical properties (hardness, fracture strength, and wear resistance), they are inappropriate for most equine restorative applications. GIs are technique sensitive during preparation and placement and must be mixed and applied exactly according to the manufacturer's specifications for handling and working time. To improve the mechanical properties and handling characteristic, resins and other admixes are being added to GIs; however, most of these products lack clinical validation.

Classifications of Glass Ionomer Cements

Type I:	Luting cements used to bond crowns and orthodontic appliances.
Type II:	Restorative materials.
Type III:	Bases and liners used under composite materials.
Type IV:	Admixes, Light-curing bases and liners.

The Basic Technique for Glass Ionomer Restoration

1) The tooth and cavity preparation are cleaned with non-fluoride, flour pumice.
2) If the manufacturer recommends or if increased bonding strength is required, condition the cavity with polyacrylic acid. (see Acid Etch Technique) *Evidence-based dentistry protocols support this step.*
3) Mix, or activate (encapsulated GI), exactly according to the manufacturer's instruction. Remove one level scoop of powder and place it on a mixing pad. Divide the powder into three to four aliquots. Dispense the liquid next to the first aliquot and rapidly mix with a mixing spatula. Continue by drawing each aliquot into the liquid until the material is thoroughly mixed. The typical mixing time is approximately 30 seconds; however, mixing on a chilled surface extends the working time. The prepared material should have a uniform, tacky, glossy liquid consistency.
4) Apply the GI to the restoration with a plastic instrument or a compule syringe. In vertical restorations a mylar strip is usually required to hold the material in place. The initial setting time for GIs is approximately 4 minutes, during which time the material can be manipulated; however, overworking the material should be avoided.
5) The GI must be protected from contamination and drying during the initial setting period (about 20 minutes) by covering the restoration surface with a varnish or unfilled resin.
6) After the initial set, the restoration surface is contoured with a diamond finishing bur on a high-speed water-cooled handpiece, and then finished with finishing stones and discs on a low-speed hand piece.
7) Due to the prolonged curing time of GIs (months), the restoration surface and marginal tissues are sealed by re-etching and applying a bonding agent. This technique is referred to as "*rebonding*."

Resin Composites

Dental composites are the most commonly used restorative materials in veterinary dentistry. A composite is a solid material formed from multiphased materials that have been combined to produce properties superior to the individual constituents. They are easy to apply, provide acceptable strength and wear resistance, and are aesthetically pleasing. Modern composite bonding systems to dentin and enamel require limited cavity preparation and greatly reduce marginal leakage. Bonding to cementum has not been investigated.

All commercial dental composites use free radical initiators to start an addition polymerization reaction. These free radicals are activated either chemically, or by an external energy source (e.g. a curing light), or by a combination of the two mechanisms.

Light Activated Resins (light-cured) are packaged as a single paste in a light-proof container (e.g. syringe or compule). The advantages of light activated resins are an unlimited working time for material placement and a short, "on demand" set time (usually 30 to 60 seconds). While some new materials are available with curing depths up to 4 mm, the curing depth for light activated resins is accepted to be approximately 2 mm. Therefore, deep restorations must be applied using a layering technique (incremental buildup). The curing light should be held within 1 mm of the restoration to optimize light exposure; however, light activated resins are also initiated by visible light and must be protected from sunlight, surgical lamps, and room lights during application.

Chemically Activated Resins (self-cured, auto-cured) are packaged as two paste systems. Upon mixing, polymerization begins, and the composite sets into a solid within 3 to 5 minutes. Heat will increase both the rate and degree of polymerization. Chemically activated resins are usually used for large bulk fill restorations or restoration with limited light access.

Dual-Cure Resins are chemically activated resins in which a light activation system has been added to each paste and are indicated in restorations where light cannot penetrate the entire depth of the restoration. Light activation attains the initial set of the restoration, and the chemical activator completes the polymerization.

Whether the composite is light or chemically activated, the polymerization reaction continues for at least 24 hours before the resin is completely cured. An unfilled resin coating (dentin bonding agent) should be applied to protect the restoration from air and oral fluids during this curing period (Rebonding Technique).

Historically, the most significant problem with dental composites has been shrinkage of the material during polymerization. This shrinkage creates a gap between the restoration and the cavity wall which creates an imperfect seal allowing for oral contamination and bacterial penetration and is referred to as *marginal leakage*. In order to reduce this volumetric change, high levels of filler particles are added to the composite material. Increased filler loading increases the restoration hardness, fracture strength, and wear resistance and reduces thermal expansion and contraction. While filler loading minimizes marginal leakage and improves the mechanical properties of the restoration, it also results in a viscous material with poor handling characteristics.

Numerous composite materials are manufactured in an attempt to maximize the physical, mechanical, and handling properties required for different restorative applications.

Dental composites are commonly classified by the filler particle size. Those most relevant to equine dentistry are listed:

Hybrid Composites: These composites have a high filler content, and contain various sizes of particles ranging from 0.04 to 4um. They are currently **the preferred restoration material in human and veterinary dentistry** because of their wide range of uses, their superior clinical properties, wear resistance, and acceptable polishability. They are used in both stress bearing and aesthetic restorations.

Microhybrid Composites were developed to offer a composite for both high stress as well as aesthetic restorations. This is the **most popular category** of composites because of its versatility.

Flowable Composites: This subcategory of hybrid composites consists of low viscosity (syringeable) composites with reduced filler content which flow and adapt intimately to the cavity walls, and the use of flowable composites as a "filled-adhesive" is an accepted practice in human dentistry. In this application, a flowable composite layer is placed between the bonding agent and a stiffer structural composite to ensure thorough wetting of the adhesive and act as a stress absorbing layer. Negatively, the reduced filler content produces a composite that lack strength and wear resistance; therefore; flowable composites are only recommended in low stress restorations and restorations with poor accessibility. *The restoration of equine teeth with flowable composites has become a common practice because of the material's handling characteristics; however, this application must be questioned due to the poor mechanical properties of the material.*

Nanofilled Composites: The nano-particle size (0.005-0.01um) allows for increased filler loading which improves strength and wear resistance, minimizes shrinkage, and provides superior polishability. Nanocomposites have rapidly gained popularity in both human and veterinary dentistry because of their clinical properties and aesthetics. *Recent clinical trials comparing the clinical performance of nanofilled, microhybrid, hybrid, and packable resin composite restorations in load bearing applications on human molars have shown no statistically significant difference between the composite materials.*

Core (Buildup) Composites are high strength composites designed for placement under prosthodontic crown restorations where significant tooth structure has been lost. Filler particle sizes vary from micro to macro, and polishability is poor. Anecdotal success in equine restorations of incisor fractures and extensive decay has been reported.

Dentin-Enamel Adhesives (Bonding Agents)

Resin composite materials will ***not*** bond to dental tissues; therefore, composite restorations require an adhesive application between the tooth and the restoration to which the composite can copolymerize. The adhesive used in dental applications is a *dentin bonding agent*. The two most commonly used bonding systems are "Etch and Rinse" (5^{th} generation) and "No Rinse" (6^{th} Generation) systems.

The "**Etch and Rinse**" **(ER)** category is divided into two or three step systems in which the first step is *always* the etching (conditioning) the tooth surface (Step 1). In the Two Step ER system (One Bottle System) a primer and adhesive resin overlayer are applied in a single application

(Step 2). In the Three Step ER system, the primer and adhesive resin overlayer are applied separately (Steps 2 and 3). Within the "Etch and Rinse" category of bonding agents, the Two Step (One Bottle) system is the most popular. While both the Two and Three Step ER systems produce acceptable bonding strengths to both enamel and dentin, the 3 Step ER system has superior bonding to dentin.

The "**No Rinse**" (**NR**) (self-etch, self-priming) category is divided into one or two step systems. In the One Step NR system the conditioner, primer, and adhesive resin overlayer are all applied together from a single bottle. In the Two Step NR system the combined conditioner and primer components (first bottle) are applied followed by the application of the adhesive resin overlayer (second bottle). *The "No Rinse" bonding systems have failed to produce clinically acceptable bonding strength when compared to the "Etch and Rinse" systems.*

The Acid-Etch Technique

35% phosphoric acid is the "gold standard" etchant, although other acids (e.g. polyacrylic acid) and varying acid concentrations are available. Etchants are available in liquid and gel forms, with the gel being the most popular because it is easier to dispense and because it retains its placement during vertical applications.

The etching procedure includes the following steps:

1. The preparation is isolated to prevent contamination from blood or oral fluids.
2. The tooth and cavity preparation are cleaned with non-fluoride, flour pumice to remove the organic pellicle, plaque, food, and other oral fluids. The pumice is mixed with water into a thick paste and applied with a prophy cup on a low-speed handpiece. Fluoride polishing paste is contraindicated because it interferes with the etching reaction.
3. The cleaned area is rinsed and gently air dried.
4. The etchant is applied to the preparation for appropriate contact time, and then thoroughly rinsed off with water. The standard contact time for dentin is 10-15 seconds and for enamel is 30-40 seconds. The etching time for coronal cementum has not been established; however, the author allows 20-30 seconds contact time for cementum. Over etching should be avoided since a contact time over 120 seconds leaves insoluble calcium precipitates on the surface of enamel.
5. The etched surface is dried according to the adhesive material instructions. Most enamel bonding systems require a dry etch surface, and properly conditioned enamel has a chalky-white or frosty appearance. If this appearance is not achieved, the surface should be re-etched. Most dentin bonding systems require a moist surface with a glistening appearance. Drying the dentin desiccates and collapses the collagen fibrils, which prevents proper bonding.
6. The conditioned tooth is protected from contamination until the restoration material is applied. In the sedated horse this often necessitates that an assistant cover the prepared tooth with sterile gauze while the operator prepares the restorative material.

The Basic Technique for a Composite Restoration

1. The cavity or endodontic access is prepared (Cavity Preparation).

2. In deep cavity preparations and endodontic access restorations a liner and/or base material (e.g. Calcium Hydroxide, Glass Ionomer, or Reinforced Zinc Oxide-Eugenol Cement) may be applied.
3. The walls of the cavity are conditioned (Acid Etch Technique).
4. A bonding agent is applied to all etched surfaces with a disposable brush and light cured. Most manufacturers suggest two applications of the bonding agent.
5. The resin composite is applied into the cavity and shaped with a plastic instrument. Chemical cure composites are typically applied in bulk, while light-curing and dual-curing composites are applied and cured in 2 mm increments to allow for proper curing of composite and to minimize the shrinkage of the restoration. (Incremental Buildup).
6. The cavity is filled to the coronal margin, or slightly overfilled.
7. The restoration surface is contoured with a diamond finishing bur on a high-speed water-cooled handpiece, and then finished with finishing stones and discs on a low-speed hand piece.
8. The restoration surface and marginal tissues are sealed by re-etching and applying two coats of bonding agent. (Rebonding)

Case Follow-Up

Long-term clinical trials to determine the performance of restorations in equine teeth are lacking, and treatment success must be determined on each patient through follow-up examinations. The author recommends evaluating the restoration at 3, 6, and 12 months postoperatively. Annual radiographic evaluation is recommended.

Summary

While restorative dentistry in equine patients was practiced during the last decade of the 19th century, this dental discipline received minimal attention until the first decade of the 21st century. The resurgence of veterinary dental care in the 1990s stimulated practitioners to investigate the tooth preserving dental disciplines (endodontics, orthodontic, periodontics, and restorative dentistry). Accepted dental procedures and material applications have been extrapolated from human and small animal veterinary dentistry for use in the equine patient and anecdotal reports of success support the continuation of these practices. However, treatment failures and the inappropriate selection and application of dental materials demonstrates the need for scientific investigation and formal training in advanced dental procedures instead of the current widespread state of experimentation on equine patients. With continued case reporting by practitioners and clinical research by universities, our restorative treatment decisions in equine patients will become evidence-based.

References Available Upon Request