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MICRO & MACRO RETENTION' IN FPD- AN INTRICATE REVIEW

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ABSTRACT

One important element affecting the long-term viability of fixed partial dentures (FPDs) is retention. It can be broadly divided into two categories: micro retention, which depends on surface treatments and adhesive bonding, and macro retention, which depends on mechanical design elements. A correct taper (6°–12°), a sufficient crown height (≥4 mm in molars, ≥3 mm in anteriors), and the addition of auxiliary retentive structures like grooves and boxes are all necessary for macro retention. Modern minimally invasive preparation methods seek to maintain tooth structure while improving retention. Optimizing bonding at the material contact is the main goal of micro retention. Airborne-particle abrasion (50 µm Al_2O_3), tribochemical silica coating (CoJet technology), and functional monomers like 10-MDP are recent inventions that improve the chemical adhesion between zirconia and resin cements. Research has indicated that the combination of mechanical retention and sophisticated adhesive procedures enhances lifespan and clinical results.The most recent advancements in macro and micro retention tactics are highlighted in this analysis, with a focus on how they might improve FPD success. The best retention, durability, and patient satisfaction are guaranteed by combining precision preparation methods with cutting-edge adhesive bonding techniques.

Keywords: Fixed Partial Dentures, Macro Retention, Micro Retention, Adhesive Bonding, 10-MDP, Tribochemical Coating, Grooves, ZirconiaMicro Retention in Fixed Partial Dentures (FPDs)

1. INTRODUCTION

The small-scale mechanical interlocking or adhesive bonding mechanisms that improve the adhesion of coatings, cement, or restorative materials to the prepared tooth structure or prosthetic framework are referred to as micro retention in Fixed Partial Dentures (FPDs). In fixed prosthodontics, it is crucial to obtaining good adhesion, durability, and resistance to dislodgment. [1-3]

Micro Retention in Fixed Partial Dentures (FPDs)

A number of strategies that improve the bonding of prosthetic materials to the prepared tooth structure or framework are used to achieve micro retention in Fixed Partial Dentures (FPDs). These methods use chemical adhesion, mechanical interlocking, or a mix of the two. The many forms of micro retention in FPDs are explained in depth here, with pertinent references included. [1-6]

1. Surface Roughness & Micro-Mechanical Retention

Micro-mechanical retention is achieved by creating surface irregularities that allow luting agents or adhesives to flow into the microscopic gaps and form a strong bond after polymerization or setting. [7,8]

Methods to Achieve Micro-Mechanical Retention

Airborne Particle Abrasion (Sandblasting): Uses alumina particles (50–110 µm) to roughen metal, zirconia, or ceramic surfaces. This increases the surface energy and improves the mechanical interlocking of resin-based cements.

Acid Etching: Hydrofluoric acid (HF) is used for etching glass ceramics (e.g., lithium disilicate) to create microporosities for resin cement penetration.

Laser Treatment: Lasers such as Er:YAG and Nd:YAG create micro-textures on ceramic and metal surfaces, enhancing mechanical interlocking.

Electrochemical Etching: Used for non-etchable ceramics like zirconia, providing nano-roughness for improved bonding.

2. Adhesive Bonding (Chemical Retention)

Chemical retention occurs when specific chemical groups in the adhesive or luting agent react with the functional groups on the prosthetic material. [9,10]

Methods to Achieve Chemical Retention

Silane Coupling Agents: Used for silica-based ceramics (e.g., feldspathic, lithium disilicate) to promote bonding with resin cements.

Metal Primers: Contain functional monomers such as 10-MDP (10-methacryloyloxydecyl dihydrogen phosphate) that chemically bond to oxide ceramics (e.g., zirconia) and base metal alloys.

Phosphate-Based Adhesives: These adhesives chemically interact with metallic and oxide ceramic surfaces, improving cement retention.

3. Microporous Structures

Microporous structures in dental materials enhance cement penetration, leading to better micro-mechanical and chemical adhesion. [11,12]

Methods to Achieve Microporosity

Tribochemical Coating (CoJet/Silicoating): Applies silica particles via air abrasion, creating a silica-rich surface that improves resin bonding through silanization.

Porous Zirconia Formation: Hydrothermal aging or selective infiltration etching (SIE) generates micropores on zirconia, increasing its bond strength with resin cements.

Lithium Disilicate Heat Treatment: Controlled crystallization modifies the microstructure, improving cement retention.

Clinical Implications of Micro Retention in FPDs

Improved Longevity: Enhanced micro retention reduces the risk of debonding.

Better Marginal Adaptation: Proper adhesion prevents microleakage and secondary caries.

Enhanced Aesthetic Stability: Reliable bonding ensures long-term retention of translucent ceramic restorations.

Macro Retention in Fixed Partial Dentures (FPDs)

Large-scale mechanical design elements that improve the prosthesis's retention to the prepared abutment teeth are referred to as macro retention in Fixed Partial Dentures (FPDs). In contrast to micro retention, which depends on bonding methods and surface treatments, macro retention is accomplished by the preparation's geometric design and the restoration's overall structural shape.

Types of Macro Retention in FPDs

Macro retention in FPDs is classified into the following types:

Tapered Preparation Retention; Grooves and Boxes for Additional Retention; Parallel-Walled Preparation Retention; Secondary Retentive Features (Pins, Slots, and Holes); Luting Agent Retention (Passive Macro Retention).

Each of these types contributes to the stability and longevity of FPDs. Below is a detailed explanation of each type along with suitable references.

1. Tapered Preparation Retention

The retention of an FPD largely depends on the degree of taper of the abutment tooth preparation. A minimal taper provides greater surface contact between the tooth and restoration, increasing resistance to dislodgment.

How to Achieve Tapered Retention: [13]

Ideal taper: 3° to 6° per wall, achieving a total occlusal convergence (TOC) of 6° to 12°. Excessive taper (>20°) leads to reduced retention and an increased risk of failure. Proper angulation can be achieved using diamond burs with guiding grooves.

2. Grooves and Boxes for Additional Retention

Grooves and boxes enhance resistance form by limiting the path of displacement. They are particularly useful in short clinical crowns or over-tapered preparations.

How to Achieve Grooves and Boxes:

Proximal grooves: Placed on mesial and distal surfaces to restrict lateral displacement.

Axial grooves: Created on the buccal or lingual surfaces for additional stability.

Boxes: Used in cases with extensive tooth structure loss to enhance stability.

Grooves should be parallel or slightly convergent (≤ 6°) for maximum retention. [14]

3. Parallel-Walled Preparation Retention

Retention is maximized when the axial walls of the abutment preparation are nearly parallel. Parallelism increases the frictional contact between the cemented restoration and the tooth.

How to Achieve Parallel-Walled Retention:

Minimal axial wall taper (near 0°) can be achieved using precision-guided burs. Suitable for tall abutments with sufficient surface area to enhance adhesion. Requires optimal cementation technique since minor misfit may compromise seating. [1,2]

4. Secondary Retentive Features (Pins, Slots, and Holes)

Additional mechanical retention is provided by features like pins, slots, and holes, which are useful in cases with reduced crown height or insufficient primary retention.

How to Achieve Secondary Retention:

Pins: Placed within the dentin to reinforce retention in extensively damaged teeth.

Slots: Placed in axial walls to increase resistance against lateral dislodgment.

Holes: Created in the preparation to provide direct mechanical retention, especially in core buildups. [3,15]

5. Luting Agent Retention (Passive Macro Retention)

While cementation is primarily a chemical process, luting agents contribute to passive macro retention by filling gaps and increasing frictional resistance. Retentive strength varies based on the type of cement used.

How to Achieve Cement-Based Macro Retention:

Conventional cements (Zinc phosphate, Glass Ionomer): Work mainly by mechanical interlocking within the rough surfaces of the preparation.

Resin-based cements: Provide both mechanical and chemical bonding, especially when used with adhesive primers (e.g., 10-MDP for zirconia). Hybrid luting agents (RMGI, self-adhesive resins): Offer moderate retention for less retentive preparations. [16]

Macro retention is crucial for the success of FPDs, as it ensures:

*Increased longevity by preventing displacement.

* Improved stability under occlusal forces.

* Optimized cement performance by providing adequate surface contact.

*Enhanced resistance form, reducing the risk of failure in high-stress areas.

Ideal Type of Retention for the Success of Fixed Partial Dentures (FPDs)

Achieving the ideal balance between macro retention (geometric features) and micro retention (surface treatments and adhesive bonding) is essential for the success of Fixed Partial Dentures (FPDs). Although both are important, studies indicate that the best long-term results are obtained when adhesive micro retention and macro-mechanical retention are combined.

1. Ideal Macro Retention for FPDs

Primary Retention Factors: Tapered preparation (6°–12° total occlusal convergence - TOC). Adequate crown height (≥4 mm for molars, ≥3 mm for anterior teeth). Grooves and boxes to enhance resistance form. [13,14]

2. Ideal Micro Retention for FPDs

Primary Retention Factors: Surface treatments (airborne-particle abrasion, acid etching, laser treatment, silanization). Adhesive luting agents (resin-based cements with MDP primers) [5,6]

The Best Retention Approach for FPDs - Combination of Macro & Micro Retention achieves best Clinical Success. Ideal TOC (6°–12°) + axial grooves enhance mechanical retention. Adhesive bonding with resin cements further improves long-term retention.

Retention in Zirconia Restorations

Fixed partial dentures (FPDs) made of zirconia have become more and more popular because of their great strength, biocompatibility, and beauty. However, zirconia's inert surface and absence of silica component make bonding difficult. As a result, retention is mostly reliant on certain micro retention strategies and macro retention characteristics.

Macro Retention for Zirconia FPDs

Ideal Tooth Preparation for Zirconia Retention. Taper: 6°–10° Total Occlusal Convergence (TOC). Minimum axial wall height: ≥4 mm (posterior teeth), ≥3 mm (anterior teeth). Grooves/boxes: Added on proximal and lingual surfaces for better resistance [13]

Micro Retention for Zirconia FPDs

Since zirconia lacks silica, traditional hydrofluoric acid etching does not work. Instead, other techniques are required:

Airborne-Particle Abrasion (Sandblasting). Uses Al_2O_3 (Aluminum Oxide) particles (50 µm–110 µm) at 2–3 bar pressure. Creates micro-roughness, enhancing mechanical retention. [7]

Adhesive Bonding with 10-MDP Primers

10-MDP (10-methacryloyloxydecyl dihydrogen phosphate) chemically bonds with zirconia. Used in resin-based luting cements like Panavia V5, RelyX Ultimate. [10]

Tribochemical Silica Coating (CoJet System)

CoJet Sand (30 µm silica-modified alumina) creates a silica-rich layer. Silanization (using Silane Primer) then chemically bonds to resin cement. [6]

Best Retention Strategy for Zirconia FPDs

For long-term success:

*Retention: 6°–10° taper + axial grooves for mechanical retention

*Micro Retention: Sandblasting (50 µm Al_2O_3 at 2 bar); 10-MDP primer (Panavia V5, RelyX Ultimate); Alternative: CoJet + silane for maximum adhesion

Step-by-Step Clinical Procedures for Retention in Zirconia FPDs

It takes both macro retention (preparation design) and micro retention (surface treatments and bonding procedures) to achieve long-term success with zirconia Fixed Partial Dentures (FPDs). A thorough clinical procedure for each technique is provided below.

1. Macro Retention: Ideal Tooth Preparation for Zirconia FPDs

Step 1: Evaluate Occlusal Clearance

*Ensure 1.5–2.0 mm occlusal clearance for adequate zirconia thickness.

*Check clearance in both centric and eccentric movements.

Step 2: Achieve Proper Taper (6°–10° TOC)

*Use a tapered diamond bur with a 3°–5° inclination per wall.

*Maintain an even axial wall height of: ≥4 mm in molars; ≥3 mm in premolars/anterior teeth.

Step 3: Add Grooves and Boxes (If Needed)

*If the crown height is <3 mm, add proximal grooves or lingual boxes for extra retention.

*Ensure grooves are parallel or slightly convergent (≤6°) to the occlusal plane.

Step 4: Finish the Preparation

*Use fine-grit diamond burs to smooth axial walls.

*Chamfer or modified shoulder margin (0.5–1 mm width) for optimal zirconia adaptation. [13]

2. Micro Retention: Surface Treatment for Zirconia; Option A: Airborne-Particle Abrasion (Sandblasting)- Best for conventional and resin cement bonding.

Step 1: Prepare the Internal Zirconia Surface

Use Al_2O_3 (aluminum oxide) 50–110 µm particles. Maintain pressure of 2–3 bar (30–45 psi) at a distance of 10 mm. Spray for 10–15 seconds to create micro-roughness. Rinse with water and dry with oil-free air. [7]

Option B: Adhesive Bonding with 10-MDP Primer. Best for resin-based cements (Panavia V5, RelyX Ultimate)

Step 1: Apply 10-MDP Primer

After sandblasting, apply a thin layer of 10-MDP primer (e.g., Z-Prime Plus, Monobond Plus) to the zirconia surface. Leave for 60 seconds, then air dry (DO NOT rinse).

Step 2: Cement with Resin-Based Luting Agent

Apply resin cement (e.g., Panavia V5, RelyX Ultimate) inside the zirconia crown. Seat the restoration with finger pressure. Remove excess cement and light cure for 20 seconds per surface (or self-cure per manufacturer instructions). [10]

Option C: Tribochemical Silica Coating (CoJet System) + Silanization. Best for maximum bonding strength

Step 1: Apply CoJet Silica Coating

Use 30 µm silica-modified alumina particles (CoJet Sand) for sandblasting. Apply for 10–15 seconds at 2 bar pressure. Rinse with water and air dry.

Step 2: Apply Silane Coupling Agent

Apply silane primer (Monobond S, RelyX Ceramic Primer) for 60 seconds. Air dry gently.

Step 3: Cement with Resin-Based Luting Agent

Use resin cement (e.g., Panavia V5, RelyX Ultimate) and proceed with light curing/self-curing. [6]

Best Protocol for Zirconia FPDs

*For traditional cementation (Zinc Phosphate, Glass Ionomer):

Use Macro Retention (6°–10° taper + grooves). Perform Airborne-Particle Abrasion (50 µm Al_2O_3 at 2 bar)

* For stronger bonding with resin-based cements: Sandblast + 10-MDP Primer + Resin Cement (Panavia V5, RelyX Ultimate)

For highest bond strength: CoJet Sandblasting + Silane + Resin Cement

2. CONCLUSION

Both macro and micro retention are essential to the durability and stability of the prosthesis, and their combination is what makes Fixed Partial Dentures (FPDs) successful. Mechanical stability and resistance to dislodging forces are provided by macro retention, which is accomplished by appropriate tooth preparation with an ideal taper (6°–12°), sufficient axial wall height, and auxiliary features like grooves and boxes. In order to improve retention while maintaining tooth structure, conservative preparation procedures have advanced.

Conversely, micro retention improves bonding at the contact between materials. Airborne-particle abrasion, tribochemical silica coating, and functional monomers like 10-MDP are examples of modern adhesive techniques that have greatly increased the bonding efficiency between resin cements and restorative materials. Since traditional acid etching is inefficient for zirconia-based FPDs, these methods are especially crucial.

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